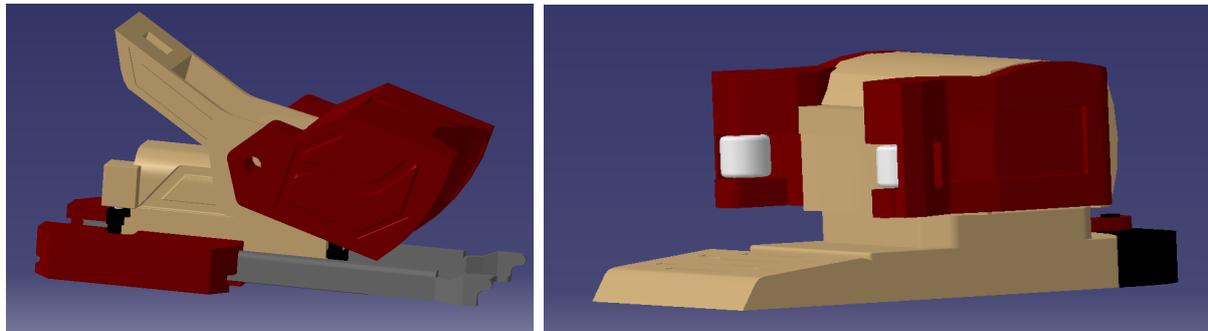
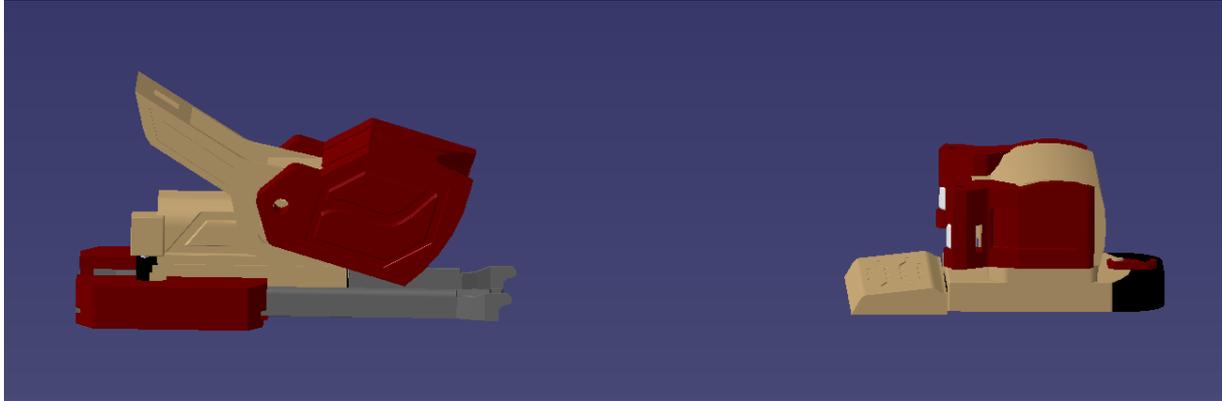
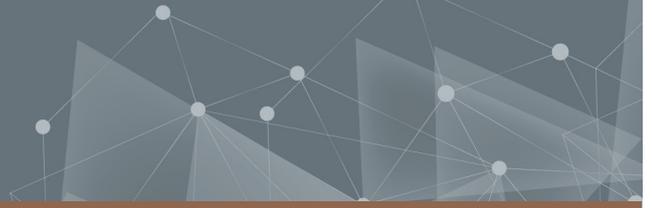




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Designing a modular binding system for alpine skiing

Master's thesis in Product Development

JOHANNA STENINGER

DEPARTMENT OF PHYSICS

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2025

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MASTER'S THESIS 2025

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Master's Thesis in Product Development
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Cover: Digital mockup in Catia showing a modular alpine binding system

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Abstract

The master's thesis, "Designing a modular binding system for alpine skiing" explores the development of a versatile ski binding system that allows skiers to exchange binding parts depending on user preferences. The thesis contains various work procedures and processes related to the project. The research concerns the collection and interpretation of information obtained through patent research, market research, interviews, brainstorming, and the narrowing down of ideas, and a conceptualization phase to be able to design a digital model of a modular alpine binding system for skiing.

The project stems from Alpine skiing being a popular sport that can be performed in various ways. The skier can ski downhill in the ski resorts, off-piste, and tour up the mountain (ski-touring). Within these styles of skiing, there are also different levels of skiing depending on skill, some extreme examples are alpine race skiing, park skiing, and freeriding. Nowadays many skiers are very versatile and ski in many different ways, hence bindings that also enable ski-touring have been available on the market for some time. In recent years the ski-touring aspect of skiing has grown increasingly popular. The options on the market are either expensive or a trade-off compared to a specified binding for a specific purpose dedicated to skiing downhill in the resorts, skiing off-piste, or solely dedicated to ski-touring. The interest in a modular binding system has therefore grown, a modular binding can provide a dedicated binding for either choice of skiing as the binding parts could be exchanged to best meet the demands placed on it for different types of skiing without compromising the performance of the binding.

Provided the methodology used in the study, existing solutions and gaps in the market could be analyzed, and a digital model of a modular alpine binding system was developed using CATIA software (Computer-Aided-Design). The concept was iteratively refined and evaluated through prototyping, assembly, and testing of 3D-printed components, to ensure its feasibility.

The findings of this study indicate that the modular binding system offers increased versatility with attachable and detachable binding parts, making it possible for users to use a single platform for multiple types of binding systems to accommodate their various needs. However, challenges remain in material selection to achieve a balance between weight, durability, and performance, as well as real-world testing of the prototype to ensure safety standards and reliability. The study concludes that the proof of concept is feasible and has the potential to transition into a commercial product. The modular binding system could offer skiers greater flexibility while maintaining high performance and safety, however further work is needed regarding refinements of technical aspects, real-world testing of functionality and performance, and exploration of the product scalability. The research provides a solid foundation for future development of the modular binding system that can bridge the market gaps without compromising the performance of the modular binding system.

Keywords: Modular, design, alpine-skiing, binding-system, ski-touring, off-piste,

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List of Abbreviations

The following list contains the descriptions of some of the words used in the report. The abbreviations include general concepts used in the technical development field, but also specific terms used in skiing terminology. The list is presented in alphabetical order:

AFD	Anti-friction device
ASTM	American Society for Testing and Materials
CATIA/CAD	Computer Aided Three-Dimensional Interactive Application (Computer-aided design, CAD, in short)
DIN	Deutsches Institut für Normung (Industry adopted scale for release force)
GDPR	General Data Protection Regulation
ISO	International Organization for Standardization (worldwide federation of national standards bodies)
KJ	Kawakita Jiro (structured analysis method)
POW	Protect Our Winters (environmental organization)
TÜV	Technischer Überwachungs-Verein (Technical monitoring associations)
3D-printing	Rapid prototyping

Skiing terminology

Alpine binding	Binding system specified for alpine downhill skiing
Backcountry skiing	Off-piste skiing, in unmarked or non-patrolled areas outside or inside ski resort areas
Elastic travel	Distance that the binding can move before releasing ski boot
GripWalk	Standard of "Alpine ski boots with improved walking soles" compatible with certain ski bindings
Hybrid binding	Binding system which accommodates both alpine skiing and ski-touring
Park skiing	Skiing in park areas within the resort with jumps and obstacles where the skier can perform tricks
Resort skiing	Skiing in resort area with groomed slopes, lifts and other facilities
Stack height	Height distance from ski boot sole to the ski
Ski-touring	Skiing that involves uphill travel in backcountry terrain
Tech-binding	Lightweight binding system specified for ski-touring

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1

Introduction

This chapter contains a presentation of the company and the background of the thesis, as well as the project objectives and research questions. It also explains the project scope and provides an overview of the report.

1.1 Background

Norse is a Swedish ski manufacturer that targets different types of skiers. They believe in choosing the right dimensions, models, and sizes depending on the skier's experience and capabilities rather than differentiating between genders while simultaneously keeping the environment in mind and developing skis with as little impact on nature as possible. Norse Skis is based in the south of Gothenburg, Sweden, and produces all its products in democratic countries in Europe, collaborating with one of the best ski factories in the world, located in Poland.

Norse Skis only works with the best and has partnered up with Tyrolia Alpine bindings, Atomic and Marker hybrid bindings as well as ATK touring bindings. Hence the idea of developing a new hybrid binding came to the surface.

In an ever-developing alpine industry where new products are launched every year, the interest and expectations of alpine skiing equipment have also increased. Skiers want to be able to ski on the piste, and off-piste and simultaneously have the freedom to go ski-touring. A lot of demands are also expected of the products. Currently, people often have different types of skis, with different bindings or with hybrid-bindings depending on how they want to ride. The different types of bindings have different abilities. A hybrid binding is always a compromise of different requirements, such as lightweight, strength, durability, cost, and performance. These requirements are difficult to combine as different properties are more important depending on how you ski and where you ski. For example, traditional bindings developed for touring aren't strong and stable enough to go downhill due to the different forces that apply when skiing downhill versus touring up the mountain. An often occurring problem is that parts of the binding break or malfunction as the main purpose is to provide the ability for the skier to tour and walk up the mountain, but if the skier wants to ski hard downhill or often goes downhill the risk of crucial parts breaking is quite high as the applied forces on the parts increase.

Newly developed hybrid bindings are based on quick-changing systems of the toe

part of the binding, providing a touring toe for touring and a more stable and durable toe part for downhill skiing. These bindings were developed to better accommodate different types and styles of skiing. They are more durable as the skier can switch the toe part depending on the usage. Switching binding parts depending on the area of usage requires the development of the assembly between the binding parts and the base plate of the skis. The development of a modular binding solves issues such as different needs of the binding's performance during different usage, easier to switch bindings between different pairs of skis, easier to store and package during traveling, and is considered to be more cost-beneficial and sustainable in the long run as a consumer don't have to buy multiple bindings.

The development of such a product requires knowledge of the sport, the different types of skiers, ways of riding as well as the conditions in which the modular binding system is going to be used. The binding system must therefore be able to tolerate applied forces during different types of riding and be able to withstand different kinds of weather. The development of such a product requires planning to meet the requirements and needs of the skiers. This report contains the challenges and solutions that follow with the planning and development of this type of product.

1.2 Purpose

Norse Skis wants to develop a binding, that enables the skier to choose binding parts depending on usage, to open up the possibility of upgrading the chosen binding easily and mitigate the total cost for the customer who decides to upgrade. By providing a modular binding system on a platform with exchangeable parts, Norse could target different categories of skiing (ski-touring, off-piste skiing, piste skiing, etc) for versatile skiers as well as more specialized skiers, and thus target a wider group of customers on the market.

1.3 Objectives

The objective of the project is to develop a CAD-model (Computer-Aided Design (CAD) model) and a functional prototype of a modular binding system, that is highly versatile and solves different requirements that the majority of skiers today expect of their bindings, enabling the consumer to switch binding parts depending on if they want to use alpine parts or tech parts while also being able to switch between different types of skis.

1.4 Limitations

The project's main focus is to develop a concept and create a CAD model and a physical prototype with 3D printed parts to demonstrate the modular alpine binding and its functionality. This requires knowledge about the current offerings of similar bindings on the market today as well as the customer needs and demands of such a product. The initial design phase can be initiated with the customer's needs and demands as a foundation for the project. In the initial design phase ideas will be conceptualized, and translated into digital models, using CAD software. The most promising concept(s) will thereafter be 3D-printed to demonstrate the prototype and its function.

Since the primary focus of the project is to develop a functional model of a modular binding system, cost analysis, and manufacturability studies are not included. A cost analysis and an analysis of the manufacturing processes and the supply chain will not be covered due to the narrow time frame. The requirement specification of the product will be based on information gathered from in-depth interviews, and already existing specifications of alpine bindings to reduce extra workload, however, this requirement specification will be modified as a customer needs research will be conducted to obtain information regarding how a user of a modular alpine binding system would use such a product.

The project focuses on making conscious choices of materials regarding the prototype with a focus on repairable and recyclable parts. The study does not include the aspects of production and supply chain, as this is not within the project scope. Furthermore, the prototype and functional model will not be physically tested in a real environment and conditions as this is not within the scope, due to the limited capabilities and time frame for such extensive testing.

This master's thesis project is based on 30 credits, which in turn indicates the project's estimated workload and its academic value. The work of the master thesis project will be carried out during the autumn semester 2024, and provide a clear time frame of the project's duration and deadlines. During the project, facilities are provided via Chalmers University of Technology, based in Gothenburg, Sweden.

1.5 Aims & Research Questions

The aim of the master thesis project is to:

- Conduct research related to modular binding systems by obtaining information about current offerings on the market and competitors. This should be done for technical aspects.
- Identify the customers and users.
- Obtain information and understand the needs and requirements of the customers.
- Develop a CAD model and a functional prototype of a modular alpine binding system with exchangeable parts.

These aims are set due to the importance of conducting research correlated to a modular alpine binding system by gathering as much information as possible for the development phase of the actual prototype. To develop a prototype, knowledge about current offerings on the market and competitors is necessary to obtain knowledge of potential pitfalls and mistakes of the product and the market. By identifying the customers and users, the most essential requirements and needs for the product can be illustrated as the product is designed for the customer, and thus crucial to understand.

Provided the information gathered from current offerings on the market as well as customer needs and requirements, the creation of a CAD model, and a functional prototype that meets the demands and needs of such a product is more likely. By creating a digital and physical prototype the function of the product can be illustrated and also further developed as the creation of such is an iterated process.

To fulfill the goals of the thesis, the following research questions will be explored:

- Which properties are of higher value for the customer regarding this kind of product?
- Are there similar solutions on the market? In which way do they solve modularity?
- In which environment do the users use the product? In what way are they using it?
- How can the product be designed to be modular and allow for the assembly of exchangeable parts?

2

Motivational factors and key principles

This chapter analyses the societal, ethical, and ecological aspects of the project. It presents the motivational factors of the project and key principles that guide the practical implementations throughout the study.

2.1 Societal aspects

Two million Swedes go alpine skiing annually [1], requiring practitioners to own or rent equipment. The level of experience between these skiers differs, and therefore the primary societal aspect is the safety of the skiers. Current alpine bindings are constructed to keep the rider as safe as possible when riding, allowing the binding to release the skier's boot, because of large forces, to reduce the risk of injuries. Typically, the toe part releases the boot sideways, as a result of a large twisting force. The heel part releases the boot upwards if there is a large forward force in the boot [2]. Therefore, it is crucial when developing a modular alpine binding system to mitigate the risk of injuries for the rider in various terrains and conditions.

By designing a modular alpine binding system that enables the skier to exchange parts the economical threshold will be smaller. It will allow a wider range of users as well as less experienced skiers to upgrade their equipment. This is because it is possible to change alpine binding parts to technical binding parts and also to change binding parts between different pairs of skis, without having to buy a completely new binding system. Providing this solution will allow less experienced skiers to not only upgrade their gear, but also to develop their skiing as they will have access to other types of skiing and terrain that will challenge them in a new way. The possibility of exchanging alpine binding parts for tech binding parts allows the skier to access more of the mountains and go ski-touring in places where there might not be any ski resorts and lifts.

The alpine sports industry contributes a lot to the local economies, especially those located in the mountain regions. Many villages around ski resorts rely on tourism and the population in these villages drops significantly off-season. The skiing season depends on the conditions and in Sweden, the ski resorts usually operate between November and May [3]. By developing a modular binding system the opportunity to go skiing will not be restricted to the season of the ski resort, but rather the

conditions, so if there is enough snow before and after this season it's still possible to go ski-touring. This can lead to a positive impact on the local economies as people can extend their stay and thus the tourist season is also extended. The ability for skiers to exchange binding parts can also lead to less experienced skiers hiring ski instructors and guides to develop their skills in different terrains and to learn more about safety. This will in turn allow local businesses to grow and expand their customer targets as they can educate instructors and guides and develop new services and offerings like individual lessons, group lessons, guided tours, renting of equipment etc. By opening up the ability for local economies and businesses to expand their market, work opportunities for local people can increase.

2.2 Ethical aspects

This study requires collecting personal data as a means of being able to understand the customer's needs and requirements, from an ethical perspective it's therefore important that the data collected from interviews and surveys protect the privacy and confidentiality of the participants. All information and data collected will be done with the participant's consent following Chalmers University's guidelines for handling personal data [4] in accordance with the GDPR (General Data Protection Regulation).

The study aims to develop a modular alpine binding system, and similar technologies already exist on the market. Since the study aims to develop sports equipment to fixate but also release the ski boot in the event of excessive pressure, the risk of misusing the product to harm is interpreted as low. Most injuries in alpine sports concerning ski bindings are usually related to the human factor and incorrectly adjusted ski bindings [5].

The realization of a modular alpine binding system can make ski bindings more affordable for users with different economic means, as hybrid bindings and technical bindings can be expensive depending on how technical they are and which group of customers the product is targeting. A modular system consisting of a base plate and exchangeable parts opens the possibility of mounting the same kind of plate on different pairs of skis allowing the customer to move the binding parts between skis. It also allows skiers with only one pair of skis to upgrade and exchange alpine bindings for tech bindings. These features should allow for scalability in pricing since there is no need for the customer to buy one pair of bindings for each pair of skis nor buy a very costly hybrid or tech binding that can't meet the demands of a pure alpine binding or a pure tech binding as its multipurpose and thereby a trade-off on different attributes depending on the way of riding [6]. The development of a modular binding system can also become a luxury product but it's the company's interest to target a wide range of customers within the alpine industry that makes it easier for beginners and not as experienced skiers to develop their skills and upgrade their gear while simultaneously strengthening the company's competitive advantage on the market. Most companies on the market target high-end customers and focus

on advanced to highly advanced skiers which provides a gap in the market for Norse to also be able to target the beginners and the intermediate skiers.

The development of a modular binding system requires international safety standards for ski equipment in case of any prototype testing in a real environment, such as DIN, ISO and ASTM. It is important to ensure that the binding system is developed according to these standards to ensure the safety of use and the testing of the product. It is also important to inform any participant during any test in real environments and conditions about the risks of testing a new binding system as well as inform the participant that it is okay to choose not to participate at any time. However, the study means to develop a prototype, and the realization of testing in the real environment and conditions is not within the scope of the project.

2.3 Ecological aspects

The ecological aspects of developing and producing a modular alpine binding system consider the environmental impact regarding the development and production of such a system. From an ecological perspective, it's important to consider what materials are used in a binding system, is it possible to recycle and are the materials environmentally friendly? Can the environment and people working within the production be exposed to hazardous materials?

From a sustainable perspective, a modular system can be easier to repair as parts can be exchanged as long as the ski and the base plate have not been damaged. Since the ski base plate will be mounted directly on the ski it's difficult to exchange as damage can occur on the skis which can lead to moisture entering the ski core and the ski breaking or losing its properties. A modular alpine binding system could reduce the total amount of waste as users can replace parts instead of the entire system. Furthermore, the design of the modular binding system can be developed to mitigate and reduce emissions and thereby the carbon footprint. This can be accomplished by choosing conscious and recyclable materials, as well as designing for repair, extending the life cycle of the product over time.

A highly discussed worldwide issue is global warming, there is an established organization POW (Protect Our Winters) [7] that promotes and informs about different kinds of actions in order to preserve and protect the winter season. They promote commute travelling, by train or busses to ski destinations instead of driving a car or taking a flight, they also promote the reuse of equipment and buying gear second-hand as this can aid in the matter of reducing the overall carbon footprint for ski enthusiasts. Developing a modular alpine binding system can have a positive contribution to skiing activities as more people have access to different kinds of skiing, and a bigger area of the mountain is thereby accessible. However, allowing people to go off-piste and experience more of the mountain could potentially lead to consequences for the environment. Animals that habitat the unexploited areas of the mountains can be disturbed [8], and ski resorts might exploit bigger areas deforesting parts of

the mountain to create open areas for skiing. This is an issue mainly concerning ski resorts that dedicate their tourism to the alpine skiers that ride on the piste. The interpretation for ski-touring however is that the environment will not fall to harm regarding deforestation as skiers riding off-piste enjoys the natural obstacles of nature as it's a part of the culture. Ski resorts build ski lifts that allow direct access to the piste, but for the enthusiast, the off-piste is usually not too far from the lifts unless the rider goes ski-touring in unexploited areas. It's a system that in many cases works in symbiosis.

Increased skiing activities and global warming also take their toll on the amount of natural snow that resorts receive during the season, causing the resorts to produce artificial snow which requires large volumes of water [9]. The awareness of global warming for companies worldwide forces companies to take action, Kläppen ski resort in Sweden works actively to reduce its carbon footprint [10] and has taken measures to be fossil-free by 2030. As skiing resorts are dependent on access to snow, the reduction of the contribution to global warming is a prioritized aspect of the industry. Creating a modular alpine binding system that might increase skiing activity is not considered harmful to the environment as skiing, in itself is not bad for the environment and the project aims to make conscious decisions regarding materials used.

The modular alpine binding system itself doesn't harm the environment when in use unless binding parts break and litter nature. The production of the binding system however impacts the environment depending on the supply chain and design of the product, the materials used, and the expected lifecycle of the product. A modular binding system can be designed for easier repair and mending of parts, which can extend the total life cycle for the product. Using recyclable materials and producing the bindings in green energy factories will mitigate the environmental impact of production. It's beneficial for the company to own the factories in which the bindings are produced, or to be close to them to be able to control the supply chain and implement strategies to decrease the carbon footprints and emissions throughout the whole supply chain. This is the case for ATK bindings [11] and the Rossignol group [12]. This project will focus on designing for repair and choosing recyclable materials, all other aspects of the production and supply chain are not within the scope of the project.

3

Theoretical framework

This chapter introduces the theoretical framework of the project. Given the environmental and sustainability considerations discussed in the previous chapter, it is important to ground the study in a framework that supports the study's objectives. The framework assists the research by organizing key concepts and guiding the research methodology. The chosen theories increase the understanding of the study by identifying knowledge gaps and ensuring the relevance of the theoretical approach chosen for the research context.

3.1 Product positioning and maturity of product

To determine the positioning and maturity of the product, a technology S-curve is used. It's a conceptual tool that displays the performance of products within a specific product category over time [13]. The S-curve consists of three phases, the initial phase of slow progress, the rapid growth phase, and the plateau illustrating that the growth slows down. It is a graphical representation of a technology's performance from when it is emerging to when it has reached its maturity and natural technological limit. The S-curve is a proven conceptual tool in product development and can characterize technical changes well, but it is not possible to predict with certainty the future path of the performance curve via the method, as there is no concrete answer to how close or far away the performance limit of a product is.

3.2 SWOT-Analysis

The SWOT analysis was developed in the 1960s at Stanford University by Albert Humphrey [14]. The analytical framework is designed to identify attributes that can influence an organization's development. The analysis categorizes factors into four key dimensions: strengths, weaknesses, opportunities, and threats. A SWOT analysis makes it possible for organizations to address challenges that may arise during operations or projects. Additionally, it offers valuable insights to optimize favorable attributes and simultaneously mitigate the impact of unfavorable ones. The analysis consists of internal and external factors. Internal factors, which an organization can control, include strengths and weaknesses such as products, services, brand associations, and reputation. The external factors, such as opportunities and threats aren't within the organization's control like market trends and competition on the market. The analysis is applicable in many fields, most commonly used by

organizations and companies to enhance their competitive advantage, but it is also applicable at a product level, making it a flexible tool across several areas.

3.3 KJ-analysis

To structure and interpret data the KJ analysis is highly applicable for product development projects. The method originated from the Japanese anthropologist Jiro Kawakita [15]. Large amounts of data are transcribed into notes, and most commonly condensed into a single word. The data are then categorized into different clusters based on similarities, and the different clusters are given a descriptive designation. The application of this form of analysis in product development projects has the advantage that data groupings emerge naturally. This can thus lead to a positive impact regarding the ability to develop user-centered design.

3.4 Requirement specification

The requirement specification is a cornerstone in product development processes, as outlined by Eppinger and Ulrich [13] it is a structured list of criteria that a product must meet to accommodate to customer needs and address the expectations of the stakeholder. The list also align with the goals of a project, as the specifications relate to decision-making under the development process, with the goal that the final design fulfill its intended purpose. Defining the requirements is an iterative process, proportional to the understanding of customer needs and technological constraints that evolve through product development. Analyzing customers and stakeholders inputs through interviews, and surveys lay the foundation to the requirement specification, and later they are translated into quantifiable and measurable requirements that aids in the evaluation and validation of the product. The requirements are divided into two groups, functional requirements that state what the product must do and non-functional requirements that addresses other criteria such as aesthetics and cost. The specification of requirements provide a baseline for evaluating trade-offs in the design process and for the thesis it helps aligning the development processes with the thesis goal by translating needs into actionable design parameters.

4

Design aspects

This chapter contains information on various aspects to consider when developing a modular alpine binding system. It present the key factors of the bindings functionality in regards to safetey and performance.

4.1 Releasing mechanisms

A binding system is designed to retain and release the skier's boot when necessary to mitigate potential injuries. Due to large twisting forces, the alpine binding systems are designed to release the toe of the skier's boot sideways in either direction [16]. The binding heel piece is designed to release the skier's boot upwards due to large forward forces on the boot.

As illustrated in figure 4.1 below, ski bindings must retain the ski boots from unexpected releases caused by loads on the boot sole or ski in several directions while also releasing the boot from the binding when necessary, therefore, standardized test methods have been developed to ensure a bindings functionality regarding these aspects according to ISO 9462 [17].

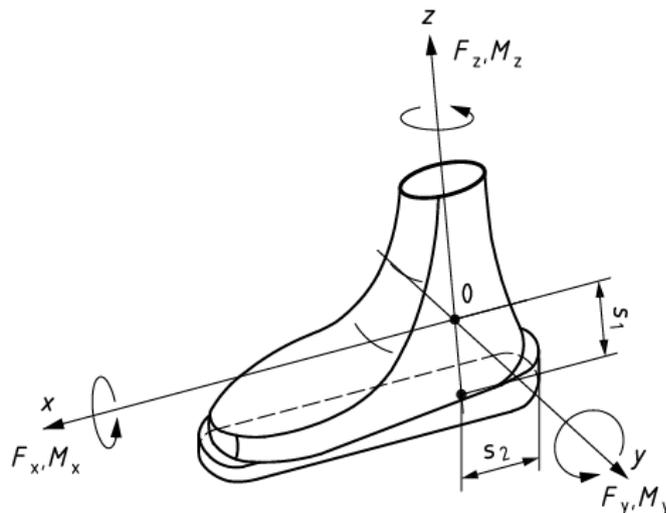


Figure 4.1: Combined loading - ISO 9462:2023(E)

Most touring bindings on the market are designed to allow some release mechanisms of the ski boot, but usually, the toe piece on tech bindings is quite rigid. Though tech

bindings allow the release of the ski boot toe, the releases are inconsistent and not to be compared with alpine binding systems. The heel piece of tech bindings allows the heel of the ski boot to release from the binding. Newer tech bindings on the market offer better consistency in the release mechanism of the toe piece as well, and some solutions like the ST Rotation 14 Binding from Dynafit offer pivoting movement in both the heel and toe, making the binding withstand unexpected releases while also providing a more safe and consistent release mechanism of the skier's boot [18].

4.1.1 Release Value, DIN

DIN (Deutsches Institut für Normung or German Institute for Standardization) is an industry-standard for the release force settings for ski bindings. It determines the tension adjustment of both the toe piece and heel piece of the binding systems, which are set separately. It's the DIN setting that indicates how easily the ski boot will release from the binding in case of twisting or forward forces on the ski boot. There are visual indicators for the DIN setting located on top of the toe piece and the heel piece of the binding system. The DIN settings are adjusted with screws placed on the front and the back of the binding. The proper DIN setting for a user is calculated based on weight, height, level of skiing, age, and ski boot sole length. The DIN settings should be high enough to keep the skier's boot from releasing unexpectedly but low enough to ensure that the ski boot releases from the ski to prevent injuries to the legs.

Since the safety aspect of retaining and releasing a skier's boot are of vital importance regarding the performance and functionality of a binding system, it's important from a design perspective that the alpine binding parts of the system sought to be developed fulfill and solve the functions required to retain and release the ski boot from the ski.

4.2 Elastic travel

One important aspect of the ski bindings is their ability to retain and release the skier's boot from the skis when a predetermined threshold value is passed. The ability is determined by elastic travel [19].

The threshold value is determined according to the DIN settings, as it determines how much force is required to engage the bindings elastic spring, [20]. The elastic spring, when activated, in turn determines the elastic movement of the spring. Thus, the elastic travel determines how much force the binding can absorb before releasing the skier's boot from the binding. It is the amount of distance that the binding can move before releasing the ski boot. For example, the elastic travel of a toe piece in a binding with a value of 45 mm can move 44 mm while still retaining the boot. Elastic travel is common in toe and heel pieces of alpine binding systems. In tech bindings, it is generally only provided in the heel piece, as the toe piece in many tech bindings does not offer much elastic travel at all [19].

To ensure a secure binding, an important aspect of the development of a modular

binding system is to strive for elastic travel in both the heel and toe pieces for all toe and heel pieces. However, less focus is placed on the tech toe as this generally tends to have a relatively rigid construction.

4.3 Boot sole compatibility and ISO standards

Ski boots vary in design and functionality, but it's crucial that the boot soles are compatible with the different binding systems on the market in order to work properly. Therefore, a variety of ski boot norms have been standardized according to ISO (International Organization for Standardization).

The modular alpine binding system to be developed aims to be compatible with GripWalk ski boots, which are made according to the international ISO standard ISO 23223. The ISO 23223 refers to 'alpine ski boots with improved walking soles' [21]. The GripWalk ski boot soles are a result of an innovation by Marker and Dalbello. It solves the problem of walking in bulky boots and provides the skier with a more natural walking motion while providing an improved grip that enables safer walking in snowy and icy areas, [22]. ISO 23223 is compatible with alpine boots (ISO 5355), and touring boots (ISO 9523), and the standard comes into full force on products developed for the season 2022/23 and beyond, [22].

From a design perspective, the modular bindings to be developed must be compatible with the ISO 23223 standard to work for this particular type of boot sole. Therefore, drawings and measurements will be based on the information obtained in the documents of this standard.

4.4 Stack height

The stack height is an important aspect of the bindings, and it refers to how high the binding sits off the ski. The stack height of the heel piece is higher than the toe. The high stack height of the heel piece and the low stack height of the toe piece create an angle of the skier's foot when placed in the binding. The angle obtained is usually called the 'ramp angle', [23]. The more neutral the ramp angle and the lower the stack height, the more natural and intuitive feeling of the binding. A low stack height provides the skier with a better sense of control and transfers power from the skier boot into the skis better on wider skis (all mountain skis) than a high stack height. It makes it easier to initiate turns as the skier has an increased connection with the snow.

The stack height is important to consider, as it is highly relevant to the binding's performance and the perceived sense of security and control it instills in the skier. During the development of the modular alpine binding system, the stack height and the neutral ramp angle will be sought to be as low and neutral as possible.

5

Methodology

In this chapter, the methodology that is to be used in the project is presented. The chapter covers the entirety of the structure and the various processes involved in the project. Included in the chapter are also the different methods of gathering data.

5.1 Market & Competitor Research

A research of the market and competitors will be conducted, with the purpose, of identifying the current offerings on the market, and what strategies can be implemented to avoid mistakes and pitfalls in the development of the product. The research will be conducted by utilizing following methods:

Web-based information search:

Utilization of online resources to identify market trends and competitor offerings.

Patent research:

Examine and identify relevant patents to understand technological aspect in alpine binding systems.

Market offerings:

Utilization of online resources to identify competitor offerings.

Market observations:

Physical observations and evaluations of existing products in retail

Expert interviews:

Discussions with professionals and experts within the industry to gain insight into the market.

5.1.1 The market and trends

To develop a deeper knowledge regarding potential opportunities and pitfalls through the process of developing a modular alpine binding system an analysis of market trends was conducted. The analysis is based on information related to the history of alpine bindings, the different areas of applications including piste, off-piste and skitouring as well as identifying emerging trends within the industry.

5.1.2 Description of different binding systems

In order to understand the current offerings on the market, the different areas of application and use for the different binding systems are required, as it provide a

framework for the development of a similar product. The different areas of application include alpine bindings primarily used for downhill skiing, tech bindings used for backcountry and ski-touring and hybrid bindings combining the features of alpine and tech bindings.

5.1.3 Current offerings

After obtaining information regarding the different alpine binding systems, and their areas of application were identified, information regarding the current market offerings could be obtained. The information were gathered by investigating different offerings within specific areas of application. The current offerings were divided into alpine-, tech- and hybrid- binding systems. Thereafter, the different offerings were further analyzed by comparison. Each market offering was examined for positive and negative attributes which were compiled in a table

The information gathered can aid in the development process as the positive and negative features of the different offers are highlighted. As a consequence, the design and construction of the modular system can be optimized, while pitfalls can be mitigated.

5.1.4 Product positioning and competitive advantage

The technology S curve was used to determine the positioning and maturity of the product that the study aims to develop. The S-curve is a conceptual tool over time, that describes the performance of a specific product category. It consists of three phases, slow progress, the rapid growth phase, and the plateau where the growth slows down. To position the product and determine the maturity of the technology of the product additional research had to be conducted. The focus of the research was the alpine binding system through history, and the evolution of the technology, within three main areas:

1. Historical Development:

- Tracing the first patented alpine binding system
- Obtain information regarding design, functionality, and areas of application over time

2. Evolution of applications:

- Tracing the shifts in the areas of applications due to new technology
- Identify the user's needs and market preferences as the technology shifts

3. Current marketing offers and trends:

- Analyzing current offerings on the market
- Obtain information about market trends and their consequences for the product's positioning and development.

5.1.5 Swot-analysis

After determining the maturity of the technology using the S-curve, a SWOT analysis is implemented. The S-curve provides information on technology over time and the adoption of market trends, however, it does not include aspects that can affect the market success of the binding system. By conducting a SWOT analysis, in-depth information regarding competitive factors, customer perceptions, and product challenges can be identified.

The SWOT analysis is a structured evaluation of a product's strengths and weaknesses, it is performed to acknowledge growth opportunities and identify potential threats in the competitive market. It is most commonly used in a company's or industry's strategic planning process, but a SWOT analysis can also be used for projects and products. In this study, a SWOT analysis will be conducted regarding a product [24]. The strengths and weaknesses of a product are internal factors that the company can control. Strengths are positive attributes of the product that give it an advantage compared to others, it's the reason why customers pick the product over those of the competitors. The weaknesses are the negative aspects of the product, which limit its performance or appeal. The opportunities and threats are the external factors that the company cannot control, such as products from competitors and upcoming market trends.

A SWOT analysis aids in product development and business processes as deeper knowledge can be gained regarding where a product or business will position itself on the market and how to implement strategies to take advantage of the strengths and address the weaknesses. The SWOT analysis identifies key strengths, weaknesses, opportunities, and threats related to the modular binding system, however, it does not account for existing patents that could impact product development. To ensure that the design remains innovative and does not infringe on existing intellectual property, a patent analysis is conducted. The research provides insights into previous solutions, technical constraints, and potential opportunities for further development

5.1.6 Patent Research

To establish a strong foundation for the prototype, research will be conducted on existing patents. By investigating existing patents and products, knowledge can be gathered regarding similar solutions and technologies that competitors have developed. The patent research will be divided into different categories, alpine bindings, tech-bindings, and locking mechanisms to widen the perspectives of possible solutions for a modular alpine binding system, thus providing more results regarding potential technical solutions for the prototype, and the assembly of the binding parts to the base plate. The patent research will be conducted via the website Espacenet, which is a database for patent information.

[25]. To use Espacenet, combinations of keywords and classifications are defined to get results of a wide range and relevance. The most relevant patents are gathered, and within each group, the most interesting solutions and parts that could aid the project in further development are summarized and explained.

5.2 Customer & User Identification

Customer and user identification can be obtained by understanding the market segment, and the stakeholders of the prototype that is to be developed. With the insights from the information about the market segment and the potential customers, as well as the company's current customers and stakeholders, a good foundation is laid for the work.

The primary source of participants in this study include athletes from different segments of alpine skiing, Norse, and other potential users as they have expert knowledge and interact with the solutions and the problems.

5.3 Identifying customer needs & requirements

To identify the customer's needs and requirements qualitative data will be collected. The study will use two different types of data-collecting methods to gather information from relevant sources. Information will be gathered through in-depth interviews and observations.

The interviews will strive to include different kinds of segments within alpine skiing but will be constrained to focus mainly on alpine skiing and ski-touring as these segments are the main users of the product. The method is chosen to provide a wide range of collected data that covers various areas of the different segments within alpine skiing and provides a better understanding of the customer's different needs. The in-depth interviews will be held in person, with the purpose of gathering the primary input for the customer needs data, and last for approximately an hour. The method collects qualitative data in terms of specific information about different customers and their needs and requirements.

The second source of data collection is observations which illustrate the user interaction with the product. Through observations, information that might not be obvious to the user can be obtained. Observations also provide a better understanding of how the product is supposed to be used. The observations will be conducted by letting the participants interact with the product and trying to understand its functions with limited instructions.

The use of mediating tools will be used in the in-depth interviews, in the form of pictures and illustrative descriptions of different scenarios. A physical product will be used in the observations. The mediating tools are used to aid the participant in order to retrieve as reasonable results of the data collected as possible.

5.3.1 KJ Analysis

The method used for analyzing the results of the in-depth interviews is the KJ analysis. The first step relates to gathering the information provided. The data obtained will then be cleaned up to eliminate unnecessary information. The information is then analyzed using the KJ analysis. It is based on brainstorming independently of

other people's assumptions and opinions. This will be carried out in collaboration with two experienced skiers to be able to collect and interpret data to bring out the most important aspects of the participant's responses.

All information and data gathered from the in-depth interviews, and observations combined with the results of the analysis will be used to create a customer needs list which consists of different attributes. The attributes will be ranked relative to each other to gather information whether it is a need or a requirement.

5.4 Customer needs list

The result from the KJ-analysis lay the foundation for the customer needs list. The identified needs and requirements of importance in the study are defined in a list, and thereafter given relative importance rated 1-5. The lowest importance is graded (1) and the highest are graded with (5). The relative importance is assigned according to the results presented in the KJ analysis. The customer needs list in turn provides a foundation on which the requirement specification can be built, which is of relevance for the product development in order for the prototype to align with the goals of the study.

5.5 Requirement specification

A requirement specification contains information about the criteria that the product aims to fulfill together with the requirements and needs of the customer. It also includes quantifiable and measurable requirements for which a product can be evaluated. The requirement specification is established through iterations as it correlates to the knowledge obtained regarding customer needs as well as technological constraints that emerge throughout the development process. In this study, the requirement specification is based on information from customer identification, input from Norse Skis, and existing industry standards.

5.6 Customer personas

The requirement specification defines the functional and technological aspects of the product. Customer personas are used to aid in making design decisions that aligns with user expectations. From the results of the in-depth interviews and the creation of the customer needs list customer personas are created. Customer personas are fictive representations relevant to the targeted customer segment. The customer personas consist of educational background, salaries, level of skiing, etc. The personas provide various perspectives of different attributes that are of importance for the persona. The utilization of customer personas visualizes the typical customer targeted in the project, and based on their different backgrounds needs and requirements are specifically assigned to each persona. By inventing customer personas different kinds of users and their needs and requirements are enhanced and aids in the development of the product.

5.7 The idea generating processes

The idea-generating process will be conducted using different kinds of idea-generation methods. The ideas generated are based on the knowledge gained from research of patents as well as understanding the product and the customer's needs and requirements.

5.7.1 Brainstorming process

A brainstorming session of ideas will be conducted based on the knowledge obtained from the study such as patent search, observations, market research etc. The ideas will be divided into two subgroups, the base plate, and the locking mechanism of the binding parts. From the brainstorming, the ideas are evaluated and unrealistic ideas are discarded.

5.7.2 Black box and Functional tree

A black box and a functional tree will also be implemented to enhance the knowledge and illustrate the different functions of the system. By conducting a black box and a functional tree, greater knowledge can be obtained regarding the different functions of the product that are to be developed. The black box and the functional tree also aid the development process by illustrating how different functions correlate to each other in a system.

5.7.3 Concept evaluation and selection

By creating a morphological matrix with the different solutions generated from the functional tree and brainstorming ideas, more solutions can be generated. Morphological matrices are based on different sub-functions that are integrated and merged which creates new concepts.

The concepts created will be further evaluated in an elimination matrix, where the generated concepts are evaluated in comparison to the demands from the requirement specification. The concepts that are not taken further in the development process are either eliminated or further investigated before deciding whether it has to be eliminated or can proceed in the process. Additionally, a Pugh matrix will be used to evaluate different concepts against each other on how well they meet certain criteria. The lowest-ranked concepts are discarded.

5.8 Concept development

The most prominent ideas and concepts from the idea generation will be further developed using the aid of Computer-Aided Design (CAD) with the CATIA software. The CAD model provides further knowledge, of whether the different parts provide the best suitable solution possible or not for the system. The digital prototype should illustrate the function of the modular alpine binding system. The software used for accomplishing this will be CATIA. After developing the best possible solution for the modular alpine binding system as a functional digital prototype the physical prototype can be developed by using 3D-printing (Rapid prototyping). Through its iterative approach, 3D printing facilitates the transition from a digital mock-up to a physical prototype, while revealing potential issues with measurements, dimensions, and tolerance that need design refinements. This process aids in developing a prototype that can be assembled and prove functionality.

6

Results of methods

This chapter contains the results of the methods implemented in the study to provide a solid foundation for the conceptualization phase. It contains market analysis, describes different binding systems, identifies opportunities and threats correlated with competitive advantage, identifies customers and users, and the results of idea-generating processes.

6.1 Market and competitor research

A research of the market and competitors were conducted to identify current offerings and provide information for strategic decisions regarding the development process to avoid pitfalls and identify success factors. The findings of the research are presented in the following sections.

6.1.1 The market & trends

Alpine downhill skiing was invented in the early 18th century, evolving from military considerations in the Norwegian army [26]. But it wasn't until 1937 that the first self-release binding was patented by Hjalmar Hvam after breaking his leg due to the present binding solutions on the market at that time [27]. In 1939, he refined his self-release binding, featuring a pronged triangular pivoting toe that fit into the notches in the front of the skier's boot. This solution provided a quick release mechanism when angular stress threatened to twist the leg. Since then, a lot of development has been made within the industry of alpine safety bindings. Ski bindings are used within various disciplines of skiing, causing different demands on the binding depending on which discipline is being practiced. The increased interest in skiing and tourism related to skiing has driven the need for reliable and high-performance ski-binding solutions. The different actors on the market today provide various bindings for different needs and demands, pure alpine bindings, hybrid bindings, and ski-touring tech bindings.

The focus of development within the industry is material innovation, safety and performance, and eco-friendly and sustainable solutions [28]. Regarding material innovation, manufacturers and developers strive to enhance the bindings in the areas of performance, durability, and weight reduction. The incorporation of releasing mechanisms in the bindings that respond better to varying skier profiles and skiing conditions, as well as the skier's abilities, are the main focus regarding the devel-

opment of safety and performance of the ski binding, without compromising the performance of the binding and control on the slopes. As the global warming and sustainability aspects become increasingly important in industries worldwide [29] it also affects the alpine ski bindings market, with manufacturers exploring conscious materials and production processes to reduce their environmental impact [28].

Though the existing solutions on the market are many and cover most types of skiing, there is a gap in the market. The hybrid bindings are the best solution for versatile skiers who want to ski-tour up the mountains and ski downhill, though it's a compromise of the binding's performance regarding weight and cost especially. Hybrid bindings are more durable and provide better safety of the release mechanisms than tech bindings but the additional weight is a negative aspect for ski-touring during many hours. Simultaneously the hybrid binding, although it offers more stability and safety than the tech bindings, is not comparable with the performance of a dedicated alpine binding. This is due to the alpine binding being dedicated to maximizing power transfer, rigidity, and stability. Hybrid bindings with their moving parts introduce gaps and flex that compromise the rigidity of the structure. A modular alpine binding system can enable the skier to switch from tech parts for touring and alpine parts for downhill skiing without compromising too much on the rigidity and performance of the binding.

6.1.2 Description of different bindings

To understand the different offerings on the market, it is also important to understand what types of bindings exist, and their function. Currently, there are three different types of alpine ski bindings on the market: alpine bindings, hybrid bindings, and tech bindings. The various types will be further explained and presented below.

6.1.2.1 Alpine bindings

The most common and traditional binding is the alpine binding. This binding is usually made of plastic, metal, or a combination of the materials [30]. The alpine bindings are constructed with downhill skiing in focus, meaning they are designed to ensure safety, and durability, whilst providing the best possible performance for downhill skiing. This is the best binding for transmitting the power from the ski boot to the skis and provides the skier with stability and control, especially at high speeds and in steep terrain.

Alpine ski bindings are directly mounted to the skis with screws. Their function is to lock both the toe and heel of the ski boots, ensuring that the ski is fully attached at all times. Alpine bindings lock in when the user inserts the toe of the ski boot into the toe piece while simultaneously adding pressure to the heel, which will activate the heel piece and lock the ski boot in the binding. A push mechanism on the heel allows the release of the boot when the user takes their skis off. Besides keeping the ski boot fixed in the binding, there are also safety mechanisms that allow for a release of the ski boot in case of a fall. In general, the toe piece releases the boot due to a twisting force (side-to-side), and the heel piece releases the boot upwards due to a large forward force [31].

Alpine bindings are often equipped with an interface on the toe piece, an anti-friction device (AFD). The anti-friction device mitigates the friction between the ski boot sole and the binding, to allow the boot to release from the binding with enough force and reduce the risk of injuries. Furthermore, all ski bindings on the market are equipped with a ski stopper. The purpose of this is to brake the ski when stepping into the binding but also in case of a fall. The ski stopper is activated when the boot is released from the binding and deactivated when pressure is applied from the ski boot to the heel piece of the binding. When deactivated the ski stopper will be aligned with the ski binding not to interfere as the skier is skiing. All alpine bindings have strict certifications and safety standards, primarily in the form of DIN (Deutsches Institut für Normung, or the German Institute for Standardization). DIN determines the rigid standards of the release value for all bindings. It means that if a binding is DIN certified, the DIN release value should be the same for all other bindings with the same value regardless of model or brand.

Some drawbacks of an alpine binding system are that it only allows resort skiing as the bindings do not provide free heel movement for walking, and their construction is bulky and heavy compared to tech bindings.

6.1.2.2 Hybrid bindings & frame bindings

Hybrid bindings and frame bindings are a type of bindings that combines resort and backcountry skiing. The binding offers the user the ability to switch between different modes, alpine or touring [30].

This type of binding is ideal for the user who wants to enjoy both worlds without purchasing separate gear. The downhill performance is not to be compared with alpine bindings as the moving parts will allow for some gap and flex, which in turn will decrease the power transmission from the ski boot to the ski. Their performance downhill however is better than pure tech bindings since their construction is more similar to alpine bindings and therefore more rigid. The touring mode enables free heel movement for going uphill. Either by allowing the whole frame to move, both the toe and heel (frame binding), or pins in the toe piece, which enable free heel movement (hybrid bindings). Hybrid bindings with pin inserts require ski boots compatible with the pin inserts to enable walking mode. The frame binding is locked in a fixed position for downhill mode and works as an alpine binding. For hybrid binding systems with tech inserts, these are usually rotated and hidden as the user converts it to an alpine toe to enable downhill skiing.

Hybrid- and frame bindings function similarly to alpine bindings as they have similar release mechanisms, allowing the ski boot to release from the ski. They are equipped with a ski stopper that works in the same way as on the alpine bindings, but when the skier is in tour mode the ski stopper can be deactivated even though the binding allows for free movement of the heel or binding. Hybrid- and frame bindings also follow safety standards, and some of them are DIN-certified. However, the certifications are not at the same level as those for alpine bindings, making the bindings' release mechanisms less predictable compared to alpine bindings.

Hybrid- and frame bindings are easier to understand and use versus tech bindings but due to the complexity of the construction, they are typically heavier than tech bindings. Since they are not as lightweight as tech bindings, they are thereby not an energy-efficient choice nor do they have the same performance as alpine bindings, making the whole binding a compromise on performance.

6.1.2.3 Tech bindings

Touring bindings also called AT bindings (Alpine touring), or pin-tech, are bindings with low weight [30]. The binding is designed to release the heel so the skier can tour up the mountains, usually with different step modes so the skier can adjust the binding according to the incline of the slope. When the skier goes downhill they will adjust the touring bindings, and lock the toe and the heel of the ski boot with pins, which require specific inserts in the ski boot to be compatible with this particular sort of bindings. Just as alpine bindings and hybrid bindings, tech bindings also have an integrated ski stopper. This can be deactivated in touring mode and activated once the skier wants to ski downhill. Usually, the function is obtained by a lever or mechanism that applies constant pressure on the ski stopper keeping it in a deactivated mode.

Due to their lightweight, they are more energy efficient for ski-touring and long tours in the backcountry. But their performance downhill is less rigid due to the lightweight pin construction. The power transmission at high speed is also lower, compared to alpine bindings, which makes them less stable in steep terrain. Another drawback with ski-touring bindings is that they are more difficult to use since snow and challenging conditions can make it difficult to insert the boot into the binding. The safety margins for tech bindings are usually lower since they do not necessarily follow the safety standards from DIN, even though they usually follow some sort of standard to ensure safety mechanisms.

6.1.3 Current offerings

There are plenty of offerings on the market today from already-established brands, most of whom provide different types of bindings depending on the user's profile and way of skiing. To obtain better knowledge about the technical solutions offered by competitors on the market web research has been conducted which provides technological insight and highlights the pros and cons of the different solutions.

6.1.3.1 CAST FREETOUR 2.0

The only modular binding system on the market today is provided by CAST TOURING (CAST) and comes in two models, "FREETOUR 2.0 Pivot 18" or "FREETOUR 2.0 Pivot 15". The system contains a fixed-mounted heel piece for an alpine binding system provided by LOOK bindings and a baseplate from CAST that enables the user to mount either an alpine or a tech toe piece to the binding. In order to enable the installation of the alpine toe piece, a toe pedestal must previously be mounted on the pivot toe piece. Thereafter the quick attachment and detachment of the different toe-pieces are enabled through guided slots and a loaded spring button at the baseplate. The user simply slides the toe piece into the slots and it is secured by the spring button, which will lock the binding into a fixed position. Once the user wants to switch to another toe-piece, the button is pushed down and the binding part is slid backward and removed from the baseplate.

The binding includes an anti-friction device (AFD), and is compatible with Gripwalk (ISO23223), Alpine (ISO5355), and touring (ISO9523) norms. This means the different AFD options work with boots with corresponding ISO soles. The user can switch the AFD depending on their boot sole. The AFD is replaced by unscrewing two screws and removing the AFD. To mount the new one, the user slides the new AFD into guiding slots and then screws the two screws back. The opportunity for users to customize the binding according to their boot soles makes the binding more versatile than if there was only one setting.

The modular alpine binding system weighs 1340g with alpine parts and weighs 1000g with touring parts. This, according to CAST TOURING, is the lightest hybrid binding on the market. The different models Pivot 18 and Pivot 15 refer to the alpine parts of the system and their release range with Pivot 18 ranging from 8-18, and Pivot 15 ranging from 6-15. The alpine binding system comes in four sizes, 95mm, 105mm, 115mm, and 130mm. The different sizes depend on the width of the skis, on which the bindings are mounted as it determines the brake width of the bindings. The materials used in this binding are machined 7075 Alu, POM/Acetal (a form of thermoplastic), and stainless steel. The elastic travel (toe and heel) is 45mm and 28mm. The elastic travel of the toe and heel in a ski binding refers to the distance a binding can move before the ski boot releases from the binding. The elastic travel of 45 mm respectively 28 mm means that the toe-piece can move 44 mm, and still retain the boot, while the heel piece of 28 mm can move 27 mm [19]. The system also includes climbing risers of 0,8, and 12 degrees, providing three different angles to the walking mode while touring.

The system is compatible with Pivot 18, and Pivot 15, meaning that a user who already has this binding can upgrade their toe piece to be able to tour with the binding as well. The binding system is the only system currently on the market that provides a modular solution, however, the opportunity to switch between alpine and tech bindings is only possible with the toe-piece. The heel piece is directly mounted to the ski. Touring is possible if the user upgrades and buys tech parts such as a touring toe and climbing risers that are mounted to the heel-piece.

The original binding comes with a baseplate that enables the exchange of alpine and tech parts, an alpine pivot toe-piece, a cast touring tech toe-piece, an alpine pivot heel-piece, two different AFDs, and climbing raisers. The customers can also purchase parts separately, making it possible to start with a pure alpine binding, and thereafter upgrade the system to enable ski-touring, making the binding highly versatile and cost-efficient over time as the user doesn't have to purchase multiple bindings.

A complete binding system from CAST that enables high-performance downhill skiing and ski-touring costs 779.95 USD [32]. If the user starts with the alpine binding system the cost is approximately 619.4 USD and includes the Pivot 18 binding [33], toe pedestals from CAST compatible with the look toe piece, and a cast base plate 2.0 [34].

6.1.3.2 ATK RAIDER EVO 13

The ATK RAIDER 13 EVO, is a pure tech binding system for ski-touring. It contains a tech heelpiece, ski brakes, and a tech toe-piece. The binding system is directly mounted to the skis with screws and weighs 370 g. The binding system is constructed in ALU 7075, POM, and stainless steel, with release ranges from 5-13. The binding provides walking modes of 0 mm, +26 mm, and +46.5 mm. The elastic travel provided in the heel is 14 mm (adjusted by a screw), and the toe-piece on this model provides release adjustability of the clamping force in the toe piece. The boot size adjustments are 25 mm and adjusted with a screw in the heel piece, once mounted the binding can only be moved this distance, either forward or backward. The bindings come in six sizes to accommodate different widths of skis with sizes ranging from 86-120mm.

ATK managed to develop a tech binding with an adjustable release value in the toe-piece, instead of a fixed release value as in previous models, making the binding more reliable in case of release of the ski boot. The ATK binding also uses an aluminum snowpack-proof system that prevents snow and ice debris from accumulating under the mobile parts of the toe piece, which otherwise can cause issues for the skier to attach and detach their ski boot in the binding. Another aspect of the ATK RAIDER 13 EVO binding is the so-called EVO brake system, which allows the user to manage the ski brake with one hand, by rotating the head of the heel piece 180 degrees, the ski brake is activated and switched from uphill to downhill mode. During an ascent, the user rotates the head 180 degrees again and applies pressure from the boot heel on the rear plate to lock the ski brake in position. The heel-piece is also constructed to absorb stresses by rotating up to 25 degrees before returning into position, enabling better power transfer from the ski boot, and more control over the skis.

ATK has also invented and patented a CAM Release System, used in this binding, that contributes to easy step-in and enables torsional stiffness. The system is built inside the heel unit and it controls how the pins, which attach the heel of the ski boot, move in case of a release. It is a mechanical structure that positions and moves the pins relative to the ski boots. The system uses spring-loaded cams to control the preload tension on the heel pins, with the function of locking the ski boot during skiing but releasing the boot with a controlled force when necessary.

The heel flaps provide the skier with different settings for the walking modes and use magnets to stay in place while touring or skiing. The different walking modes can be adjusted with only a ski pole as the flaps are magnetic. To insert a ski boot in this binding the user needs to have tour-compatible ski boots with inserts at the toe and heel. The user aligns the pin inserts with the pins of the toe-piece and applies downward pressure on the toe of the boot until the pins snap into the tech inserts. The heel of the ski boot is inserted into the heel-piece by placing it over the pins and applying downward pressure until the pins snap into the heel inserts. These settings are used for downhill skiing. If the skier wants to ski-tour, the user applies downward pressure at a lever in the heel to unlock the heel and rotates the

housing of the heelpiece 180 degrees so the pins are facing the tail of the skis. The skier locks the toe using a lever in the front of the toe-piece that is pushed upward to ensure that the toe-piece does not release in walking mode. During an ascent, the skier can set different walking modes using their pole to adjust the magneto flaps (up or down) mounted to the housing of the heel piece.

ATK RAIDER EVO 13 is an extremely light binding for ski-touring with an upgraded construction to provide better durability, downhill performance, and reliable safety mechanisms, and the cost of this type of solution is 701.95 USD [35].

6.1.3.3 SS/LAB SHIFT 13 MULTINORM

SS/LAB SHIFT 13 MULTINORM from Salomon is a hybrid binding for skiers who enjoy resort and backcountry skiing. It is an alpine binding with integrated tech parts making it a versatile and cost-efficient option for users who want to avoid buying additional setups.

The binding has a DIN range from 6.0-13, and the binding system comes in four sizes ranging from 90-120 mm. It's constructed in Aluminium and carbon-infused PA which makes it light-weight compared to other hybrid bindings on the market, the total weight of the bindings is 1770 g (885 g per each), and it costs 576.52 USD [36]. The elastic travel in the toe-piece is 47 mm, which is impressive since most tech bindings offer none [37]. The heel raisers included in this binding system are 2 and 10 degrees, providing two different angles of the walking mode. The binding accommodates ski boots for alpine models (ISO 5355), touring (ISO 9523) as well as walk to ride (WTR) soles, and GripWalk boots. By accommodating a variety of ski boots and sole types the system is Multi Norm Certified (MCN). Additionally, the Salomon shift binding system has a height adjustment feature in the toe-piece, enabling adjustment of 30 mm. The binding system also provides a 30 mm adjustment range lengthwise to fit a wide range of boot sole lengths. Furthermore, the binding is TÜV-certified (Technischer Überwachungsverein or Technical Inspection Association) meaning that it has been tested for safety and that the release mechanisms of the binding system are reliable and consistent.

In alpine mode the binding works like other bindings, the toe is inserted into the toe-piece, and once pressure is applied to the heel-piece the ski brakes are deactivated, and the clamp in the heel-piece locks the heel of the ski boot.

The toe-piece has integrated pins that are hidden behind a central lever. When pressure is applied to the lever the pins are revealed, and a ski boot with tech inserts can be inserted into the binding. The pins snap together when the user applies a downward force on the toe-piece, locking the toe of the boot. To lock the toe during ski touring, a locking lever located on the front of the toe-piece is raised. The free heel movement required during touring is obtained as the pin inserts are positioned so that the heel of the boot do not interfere with the heel piece. Once the toe-piece is locked, the user raises a brake lever in the heel piece and applies pressure to the heel of their boot, forcing the brake lever down, which will lock and deactivate the brake arms. Additionally, depending on the incline of the ascent, the user can raise a heel riser to adjust the walking position.

To deactivate the touring mode, the user pushes the brake lever back into its original position activating the brake arms. Thereafter, the user pushes the toe-piece lever down to disengage the pins from the tech inserts. To enable alpine mode the user has to apply inward pressure on the wings of the toe-piece, while simultaneously raising the central lever until they snap together. Once these steps are completed, the binding is converted to alpine mode, and the user can step into the binding and activate the locking mechanism required for an alpine binding system.

6.1.3.4 Salomon Strive 14 GripWalk

The alpine binding system Strive 14 Gripwalk from Salomon has a low-centered toe-piece, which provides the skier with better power transfer from the ski boot to the skis. The low-centered profile and low center of gravity also provide the skier with better control and faster response of the skis. The binding system is compatible with all alpine ski boots (ISO5355) or Gripwalk. The total weight of this binding system is 1960g (980g each) and costs 261.68 USD [38]. The binding has a DIN range of 5-14 and comes in four sizes ranging from 90-130 mm. The binding can be adjusted 30 mm lengthwise to accommodate different ski boot sizes. The elastic travel of these bindings is 30 mm and they have an extra wide toe pedal of >60 mm to enhance the lateral power transfer from the skier to the ski. The bindings are lightweight considering they are alpine bindings and consist of fiberglass polyamide. The toe-piece, and the heel-piece of this binding system allow for multidirectional release, in case of a fall the binding can release the ski boot in a variety of directions, enhancing safety. It is also TÜV certified. Additionally, the binding allows for tool-free adjustments for setting the forward pressure and adjusting the binding for different boot sole lengths.

To lock the skier's boot to the binding the ski boot is first inserted in the toe-piece of the binding, then pressure is applied to the heel til the heel clamp clicks and locks the ski boot into place. Simultaneously as the user applies pressure to the heel, the ski brakes will be activated. Once the user wants to detach from the binding, pressure is applied to the heel clamp with a ski pole, and the boot is released.

6.1.3.5 Pros & Cons of analyzed offers on the market

In the figures 6.1 and 6.2 below, a tabular with the pros and cons of the different analyzed offers on the market is presented. The information presented is related to the key features of the different solutions.

Binding	Pros	Cons
Cast Freetour 2.0	Modular system allows switching between alpine and tech toe pieces	Only the toe piece is modular, the heel is fixed to the ski and can't be used for touring
	Compatible with multiple boot sole norms (Gripwalk, Alpine 5355, Touring 9523)	Switching AFDs requires unscrewing
	Versatile with separate AFD options for different boot soles	Heavier compared to pure tech bindings (1340g alpine, 100g touring)
	High elastic travel (45mm in toe, 28mm in heel) provides better power transfer and safety before release	Might require additional purchasing of tech parts to be able to tour, leading to an initial higher cost
	The system can be upgraded gradually, making it cost-efficient over time compared to buying different setups	High initial cost of 779.95 USD for the whole setup with Alpine and tech parts
	Multiple sizes to accommodate different widths of skis	
ATK RAIDER EVO	Very lightweight (370g), making it ideal for ski-touring	Not a modular system, limited performance for downhill skiing
	Durable construction ALU 7075, POM, and stainless steel	Limited elastic travel in heel (14mm) compared to hybrid or alpine bindings, may affect shock absorption and comfort
	Adjustable release value in the toe piece, a significant upgrade over previous tech models with fixed release values	Limited boot size adjustability (25mm), it may not fit all boots without remounting (which can damage the ski)
	Snowpack-proof system prevents debris from affecting performance, making it reliable in challenging conditions	High cost 701.95 USD
	EVO brake system allows for easy transition between uphill and downhill modes	
	CAM Release System enhances easy step-in and torsional stiffness for better control and safety	
	Magnetic heel flaps for easy adjustment of walking modes with a ski pole	

Figure 6.1: Cast Freetour 2.0 & ATK Raider EVO 13

SS/LAB SHIFT 13 MULTINORM	Hybrid binding that supports both alpine and tech setups, providing versatility for both resort and backcountry skiing	Heavier than pure tech bindings (1770g per pair), which may be a drawback for extended tours
	Multi Norm Certified (MCN) accommodates a variety of boot sole types (ISO 5355, ISO 9523, GripWalk, WTR)	Limited climbing riser angles (2° and 10°) compared to other touring-specific bindings
	Elastic travel (47mm) in the toe piece is impressive for a hybrid binding, providing better power transfer and safety	Complex mechanism for switching between alpine and touring modes, which may take some time to master
	TUV certified for safety and consistent release mechanism	Cost 576.52 USD
	Adjustable height of toe piece and heel riser for customization to boot size and ascent angles	
	Tool-free adjustments for easier customization	
Salomon Strive 14 GripWalk	Lightweight for alpine bindings (980g each)	Pure alpine binding, no touring capability, limiting versatility
	Low-profile design improves power transfer and control.	Elastic travel (30mm) in the heel is lower than Salomon Shift hybrid binding, affecting impact absorption in aggressive skiing
	Compatible with GripWalk and all alpine boots (ISO 5355), enhancing versatility for users with different boot setups	Cost 261.68 USD
	Wide toe pedal (60mm) improves lateral power transfer for better control	
	Multi-directional release improves safety during falls	
	Tool-free adjustments allow quick changes in boot sole length	

Figure 6.2: SS/LAB SHIFT 13 MCN & Salomon Strive 14 GripWalk

The offerings were chosen for versatility. Investigating the only modular solution on the market, a tech binding, a hybrid binding, and a pure alpine binding. To summarise the information gathered from the current offerings and the pros and cons CAST FREETOUR 2.0 is for skiers who want versatility, but don't want to compromise on functionality, even though it weighs more than a tech binding. The ATK RAIDER EVO 13 is for the ski-touring enthusiast who engages in longer ski tours and puts value in a lightweight binding. The binding has limited elastic travel, and will not perform as an alpine binding. Furthermore, the binding requires ski boots with tech inserts in toes and heels to be able to use. SS/LAB SHIFT 13 MULTINORM is a highly versatile binding with tech and alpine modes but it is a compromise on different properties, regarding the weight and the efficiency of ski-touring, and downhill performance. It is slightly cheaper than CAST and ATK, making it more affordable and a good choice for the skier who enjoys resort skiing and backcountry skiing. Salomon Strive 14 GripWalk is a pure alpine binding, with a focus on performance and control, which is enabled through the low-centered toe-piece. It's not too expensive but limits the user to resort skiing and easily accessible off-piste skiing near the ski resort.

6.1.4 Product positioning and competitive advantage

A modular alpine binding system is based on technology that already exists on the market today, the challenge lies within the attaching mechanism of the different binding parts to the baseplate of the skis. As mentioned, there are plenty of bindings on the market today that accommodate the needs of different skier profiles and skiing conditions, however, there is always a compromise between different abilities of the binding. Either the touring bindings are super lightweight and not as stable and rigid for downhill skiing, or the hybrid bindings are quite heavy but provide better stability and control for downhill skiing, whilst the alpine bindings don't provide the ability to ski-tour. Many manufacturers provide different offerings to the market and the technology of the bindings is quite mature as many different materials and types of construction have been tested throughout history.

The functional model that the project aims to develop together with NORSE is quite new to the market, though there is one manufacturer who has introduced a modular alpine binding system (CAST), but thus far only provides modularity of the toe-piece of the binding system. There is therefore a gap in the market to introduce a modular alpine binding system of both the toe-piece and the heelpiece of the binding. A modular alpine binding system is therefore a product with low maturity, as it is a new concept of an already existing and mature product. By being a product with low maturity it will be placed early in an s-curve diagram, according to the figure below 6.3. The diagram illustrates that the product belongs at the beginning of a new s-curve, and thus a new segment in the area of development of alpine ski bindings. Whereas the new segment focuses on the development and improvement of traditional alpine ski bindings, new technology adds extra functionalities for the user. A product of this sort may lead to a lot of development in the upcoming years.

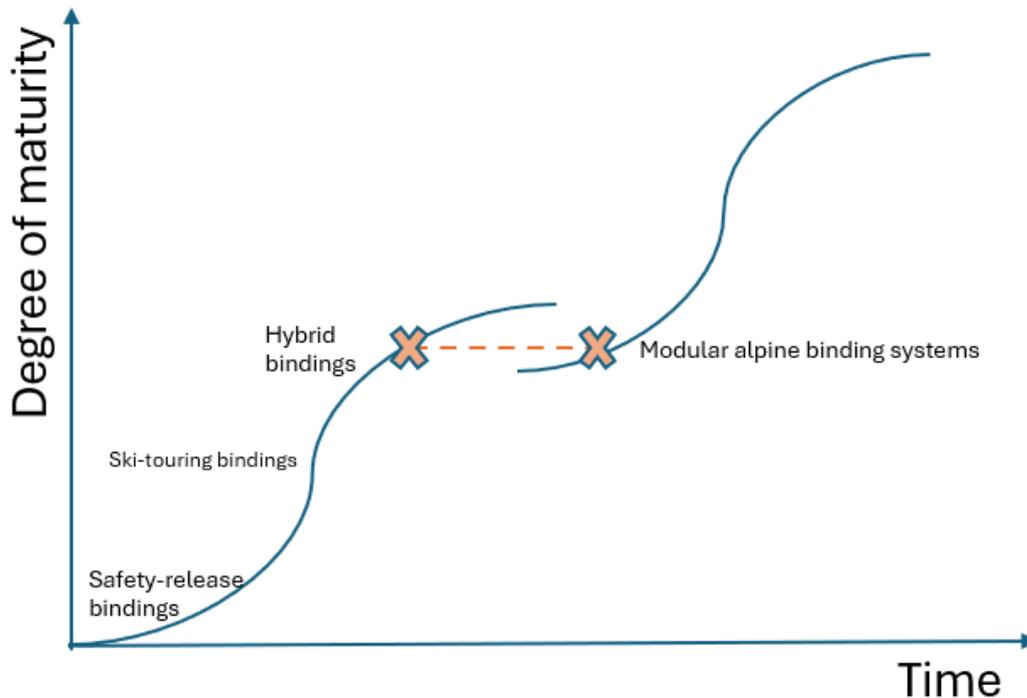


Figure 6.3: S-curve - alpine ski bindings

The first s-curve in the bottom left corner according to figure 6.3 above illustrates the transformation and the development of alpine ski bindings throughout history. The cross located at “hybrid bindings” describes where the segments are positioned today on the development curve. The second cross located at “Modular alpine binding systems” on the s-curve to the right describes the positioning of what the study together with NORSE aims to develop. The segment for a modular alpine binding system belongs to a mature market with a high level of competition but the product that this project and study aim to develop is a step away from already existing solutions on the market, which will lead to new challenges and opportunities.

The challenges of such a product lie in the technical development, as a quick-release system of the attachment and detachment of the product is not as investigated and proven in commercial use. The challenge is to deliver a better product than the existing solutions on the market without compromising on necessary performance in terms of, safety mechanisms, weight, durability, rigidity, and ease of use. Another challenge is to attract customers from the already existing alpine ski binding market, with users who have high demands and needs regarding the equipment. The products on the market today have a high degree of development and the products are optimized in each area to meet the different demands of the user, since this is an unexplored field of innovation there will be challenges regarding the attachment of the different binding parts as gaps and flexion needs to be minimal to be a successful product. Simultaneously the product has the opportunity to solve the

different compromises between alpine and tech-binding parts that currently exist on the market while also allowing for versatility and flexibility, convenience of use, and cost efficiency. By providing a modular alpine binding system the user does not need to buy multiple skis or different binding systems on different skies as the system can easily be swapped on different skis.

The possibility of developing a new product might attract new stakeholders and customers, who in turn can generate publicity and purchases, strengthening Norse as a brand. By entering the market early on, the company has the opportunity to set standards in terms of price and quality on the market. The lifespan of the market itself will also increase as it generates more purchases over a longer period of time, leading to a faster return on investment as a consequence of being an early actor in the market.

6.1.5 SWOT-analysis

After determining the product positioning on the market using the s-curve, information regarding the technology over time and the adaption to market trends has been identified. However, to gain further knowledge and include aspects that can affect the success of the binding system on the market a SWOT analysis was conducted, to identify internal and external factors. The Swot analysis is presented in 6.1.

Table 6.1: SWOT - Analysis of a modular alpine binding system

Strengths	Weaknesses
Flexibility & Versatility Convenience Cost efficiency Innovative Appeal	Complexity & Durability Concerns Weight Higher Initial Costs
Opportunities	Threats
Growing Ski Touring Market Sustainability Trend Partnerships with Ski Manufacturers Expansion into Rental Markets Technological Advancements	Competition from Specialized Products Skepticism from Hardcore Skiers Technological Risks

6.1.5.1 Strengths

The strengths of a modular alpine binding system are that it allows for flexibility and versatility. The system allows users to switch between different types of bindings, both alpine bindings and tech bindings depending on the terrain and activity. This can increase the appeal of the product to a broader audience, catering to the needs of both alpine skiers and ski tourers. By enabling the possibility of switching bindings it reduces the need for multiple skis or dedicated setups, which in turn can save both space and costs for skiers who engage in different disciplines of skiing. Another positive aspect is the convenience that the system offers. The functionality of quick attachment and detachment simplifies the process, users can adapt

to different conditions without the need of extra tools or expert help. It can also save time for backcountry skiers as they otherwise need to switch between different binding modes depending on if they are going uphill och downhill.

Over time the solution is cost-efficient, but initial costs may be high. It is more cost-efficient over time as the users avoid purchasing entirely separate setups of skis and bindings for alpine and touring purposes, making it a long-term cost-effective choice. The threshold of upgrading the setup is lower, and opens up for resort skiers to invest in tour bindings without having to purchase a new set of bindings and mount them to new skis. The final strength is the innovative appeal, since it is cutting-edge technology it might attract skiers who are into new technology and performance of their ski bindings, enhancing the brand's and the product's image as innovative and forward-thinking.

6.1.5.2 Weaknesses

The weaknesses of the system are identified to be complexity and durability concerns, weight, and high initial costs.

The complexity of the modular system may introduce points of failure which might lead to decreased durability over time as the more moving parts, the greater the risk of malfunctions. To ensure that the modular system is secure and stable in different conditions, precision is necessary, which might make manufacturing costs higher and accuracy more difficult to achieve. The weight can also be an issue as added components, to enable the binding's modularity, might result in heavier equipment compared to fixed bindings. This aspect could be a critical factor as backcountry skiers prioritize lightweight gear for energy-efficient touring.

Higher initial costs are another weakness, as the upfront cost of the system is likely higher than traditional fixed bindings. Some skiers, especially beginners or casual skiers, might disregard such a solution due to the initial cost, but the system might be able to compete with the tech bindings on the market as they are already quite expensive. Even though the initial cost might be high for beginners and casual skiers, they don't have to buy the entire setup at once, meaning that the initial total cost of the binding might not be too expensive for this customer segment.

6.1.5.3 Opportunities

An opportunity for this type of solution is the growing ski touring market, the popularity of ski touring and backcountry skiing has grown rapidly [39]. A modular system that allows users to upgrade and be able to switch between alpine and tech bindings could tap into this expanding market, enabling more skiers to explore both worlds without multiple setups and skis. With the growing awareness of sustainability, a system that reduces the need for multiple setups of equipment can appeal to environmentally conscious consumers who strive to minimize their ecological footprints by purchasing fewer products. It is also appealing to consumers who strive

to minimize their carbon footprint by taking public transport to ski resorts and ski destinations as they can travel light.

Partnerships with ski and boot manufacturers could lead to more integrated systems where the modular bindings fit seamlessly with other high-performance gear, enhancing user satisfaction and driving brand loyalty. Expanding into rental markets can obtain a wider target group of customers. If ski rentals adopt the modular system, they can offer clients more options and variety with fewer skis. This can appeal to rentals and customers who want the flexibility of alpine and touring experiences without committing to buying equipment.

Another opportunity is technological advancements as future innovations in materials and quick locking mechanisms could improve the product's performance (lighter, and more durable). This can further differentiate the system from traditional binding systems and strengthen the competitive advantage in the market.

6.1.5.4 Threats

The most evident threat is the competition from specialized products from already established brands that offer dedicated alpine and tech bindings on the market. As they already built their brand and loyalty from customers, they might still be the obvious choice for dedicated skiers who might not trust a modular system to perform at the same level. Already established brands are trying to integrate the alpine and tech binding into the same binding system striving for more durable and lightweight constructions. Therefore, there is the threat of competitors developing their own modular alpine binding system.

A threat to innovations and technologies can also be that high-performance skiers may distrust a modular system, fearing that it compromises safety or performance causing them to resist the technology and stay loyal to competitors providing dedicated binding systems for reliability and precision. Additionally, since the solution is to provide a quick attachment/detachment mechanism, it needs to be fail-proof. This is particularly important for backcountry skiing in difficult, and sometimes life-threatening terrain. Failures in a system put the product at technological risk. If they occur, they could cause serious accidents, product recalls, or damage the brand's reputation.

6.1.6 Patent research

The SWOT analysis provided valuable information on strengths and market opportunities, but to gain knowledge of the competitive landscape it is essential to explore existing patents. This section presents investigated patents and solutions that could be of interest to the study and the development of the different concepts. The patent research provides insights into existing technologies and mechanical solutions in the alpine industry, as well as other mechanical innovations of interest. By conducting patent research insights on current market solutions can be gained.

The information has been gathered through research via web pages such as Espacenet and Google patents. There have been different areas of interest during the patent analysis, and therefore it covers patents of alpine binding parts, tech binding parts as well as different locking mechanisms from innovations within other industries. The patent analysis was divided into three different focus areas. Heel-pieces, toe-pieces, and other interesting patents. Since the project strives to develop a modular binding system that enables both alpine skiing and ski-touring, the analysis was further divided into research regarding tech bindings as well as alpine bindings. The third focus area is related to other interesting patents, and targeted different types of locking mechanisms. The process overview of the patent research are shown in 6.4 below.

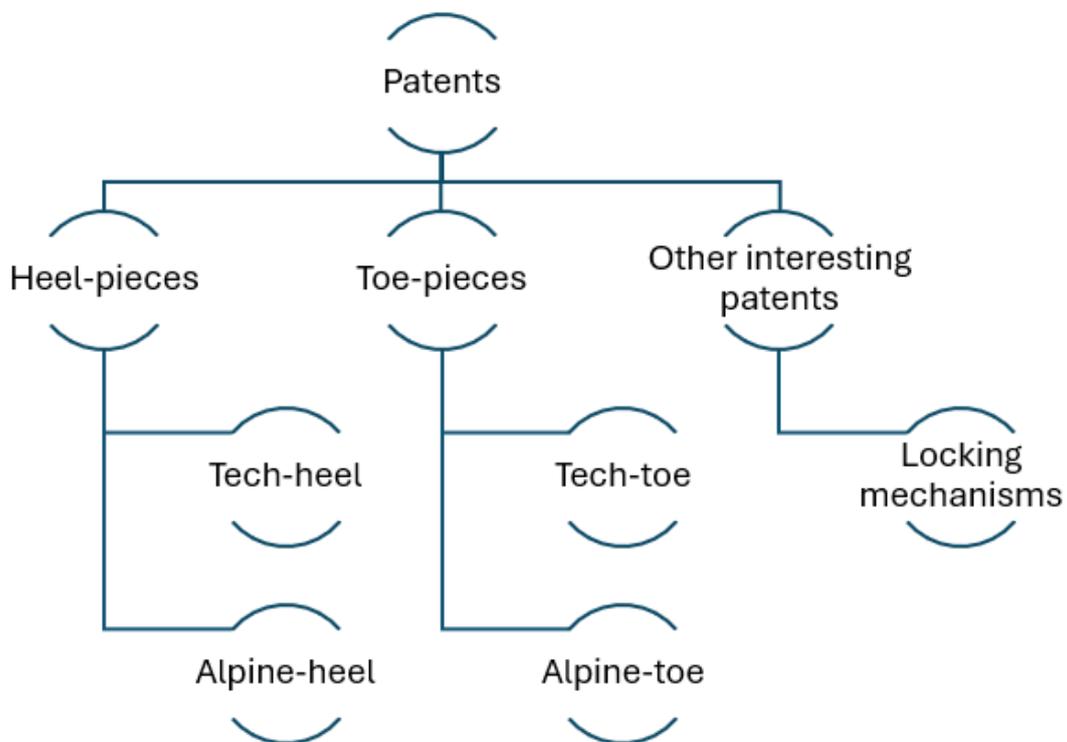


Figure 6.4: Process overview for the patent analysis

From the patent research, ten relevant patents for the thesis were analyzed considering their functionality. Of the patents investigated, six were perceived as more relevant for the development of the modular binding system than the others. The most interesting patents for the thesis are presented in 6.2. The table presents the strengths, and weaknesses of each patent. The full list of patents are presented in appendix, A.3.

Table 6.2: Interesting patents

Patent Name	Strengths	Weaknesses
Heel-pieces		
Atk heel	Lightweight Simple and clean design Tower rotates (Multifunctional)	Pins might not-unhook properly Not as predictable release
Rossignol heel	Pivoting movement allows-for displacement of ski boot Reliable release mechanism	Steep angle of heel tower Heavy
Toe-pieces		
Atk toe	Lightweight Jaws unhook independently	Not as predictable release Risk of snow build-up Sensitive to breakage
Marker toe	Provide elastic-travel Allow smaller displacements-of ski boots Reliable releases Enables walking mode	Heavy Less rigid construction
Other interesting patents		
Burton splitboard	Clamp to fixate binding Allows for snowboarding-and touring Lever secure board-from vertical movement	Binding not fixed,-less rigid construction
Bike pedal lock	Locks shoe to pedal mechanical parts, not-exposed to outer environment Can lock into pedal in multiple ways	Twisting movements for release- High complexity Heavy

Atk heel is a patent of a typical tech-heel, it is lightweight and has a simple and clean design. The heel tower can rotate, which enables the skier to switch between different riding modes, downhill skiing, and walking. The drawbacks of this patent are that the pins might not unhook from the ski boot properly, and thus, do not provide as reliable a release mechanism as Alpine bindings.

Rossignol heel has a pivoting movement in the heel-piece which allows displacement of the ski boot, it has a better ability to chock-absorb and provide a more reliable release mechanism. Since it has a more robust design than a tech-heel it will add weight to the heel and make it heavier. The steep angle of the heel tower can also be a cause of injuries in case of unfortunate falls or bad landings when skiing.

Atk toe is a patent that has a simple design, is lightweight, and has jaws (the profile of which the pin inserts are located on the toe-piece) that can unhook the ski boot independently. Due to the independent unhooking of the jaws, a consequence could be unexpected and less reliable releases of the skier's boot. Since there is no housing around the mechanical parts, the risk of snow build-up is greater and the moving parts are more exposed which can lead to breakage.

Marker toe is a patent that provides elastic travel, therefore it allows for smaller displacement of the ski boot. The releases are more reliable, and the patent is an alpine toe-piece that enables walking mode for ski-touring. The drawbacks of this patent are that the construction is heavier compared to tech-bindings and though it enables walking mode, more moving parts might lead to a less rigid construction.

Burton split board is a patent that enables snowboarding and touring up the mountain by removing the binding and positioning it on attachment features, located at different points of the board. The solution uses a clamp to fixate the binding on the attachment features. Since a split board enables the user to split the board to enable walking mode, the user can also assemble the board into one piece by using levers to secure the board from splitting. The binding is not fixed apart from the locking mechanism of the clamp and can lead to a less rigid construction.

Bike pedal lock is a solution used to lock a bike shoe to the pedal. The patented solution provides a concept that does not expose the mechanical components of the locking mechanism to the outer environment. The user can also attach their shoe to the pedal in multiple ways, clicking the shoe into place by applying forward pressure or by equally distributed pressure straight down on the pedal. The drawback of the solution is that the twisting movement would not be applicable in a binding system for alpine skiing unless the rotating movement can be locked. The number of components leads to higher complexity and also adds to the weight.

The information gathered from patent research increases the knowledge of patented solutions on the market. Simultaneously it shows what properties have a positive impact on the product and its functionality, but also demonstrates negative properties to consider in further development.

6.2 Customer & user identification

The modular alpine binding system to be developed will target a broad range of customers and users. The customers refer to those who purchase the product and the users refer to those who use the product. Table 6.3 below presents the users and stakeholders of interest for the product development. The segmentation was conducted to ensure that the in-depth interviews focused on customers and users relevant to the study.

Table 6.3: Table over the stakeholders and users for the project

Category	Stakeholders
Main stakeholder	<ul style="list-style-type: none">• Chalmers University of Technology• Investors• Norse Skis AB
Lead user	<ul style="list-style-type: none">• Advanced skiers dedicated to:• Ski-touring• Mountaineering• Free-riding• Backcountry guides
Typical user	<ul style="list-style-type: none">• Intermediate to advanced skiers dedicated to:• Resort skiing• Ski-touring• Free-riding
Extreme user	<ul style="list-style-type: none">• Professional skiers dedicated to:• Ski-touring• Mountaineering• Free-riding
Primary user	<ul style="list-style-type: none">• Dedicated backcountry skiers & resort skiers
Secondary user	<ul style="list-style-type: none">• Ski shops• Ski rentals
Tertiary user	<ul style="list-style-type: none">• Users that provide mechanical maintenance

First and foremost, the terminology of the various users has to be explained. Skiing outside of the ski resort boundaries can be divided into three different groups and within these groups, there are different styles of skiing. These groups are free-riding, ski-touring, and mountaineering [40].

Freeriding refers to advanced skiing knowledge and technique. It is fast skiing in all terrains, with challenges such as jumps, moguls, and getting the first run in fresh snow. Freeriders often access their terrain closer to ski resorts, going up with ski lifts or heli-operations. Freeriders usually want wider and longer skis (105-125 under-foot). Freeriders go for shorter trips with avalanche gear in hazardous environments and the focus lies on downhill skiing.

Ski-touring is usually performed in remote terrain and high mountains and practiced in groups due to the risks in high-stakes environments. It requires intermediate skiing knowledge and technique and a great level of fitness as the skiers are exposed for a longer period due to skiing in areas far away from ski resorts. The skis used by this type of skiers are usually lighter and shorter, additionally, it requires skins to ski-tour up the mountain. Ski-touring involves a heavier weight to carry due to avalanche gear, extra clothes, food, and water. Therefore this group of skiers prefers lightweight gear.

Mountaineering requires even more advanced skiing knowledge and technique and usually this group of skiers also have climbing knowledge. They usually tour up the mountains with equivalent equipment as the ski-tourers, additionally, they carry climbing gear and ice axes. The skis preferred for this group of skiers are light but stiffer usually 98-105 under foot. This group of skiers is dedicated to off-piste skiing, and backcountry expeditions and have expert knowledge on movements in hazardous alpine environments.

Resort skiers are a group of skiers who mainly ski within the boundaries of the ski resort, on the piste, where conditions are controlled. Within ski resorts, the skiers have access to facilities and ski lifts.

As illustrated in the table above, the users of an alpine binding system can be divided into three different segments: Lead-, typical- and extreme- users. All segments practice skiing on different levels regarding ski technique and environment. The main stakeholders of this master thesis and development project are Norse Skis AB, Norse Skis' investors, and Chalmers. They have an impact on the project since they invest time and money in the project. The lead users are defined as advanced skiers dedicated to ski touring, mountaineering, freeriding, and backcountry guides. This segment has a high level of skiing technique and utilizes the binding regularly, switching between alpine and tech parts often, in challenging environments. The typical users are intermediate to advanced skiers who are dedicated to resort skiing, ski-touring, and freeriding. This segment utilizes the binding in both the resort and the backcountry and appreciates the flexibility of switching between alpine and tech binding parts depending on weather conditions and preferred way of skiing.

The extreme users are the users with specific and extreme needs that push the limits of the product. The extreme users are defined as professional skiers in ski-touring, mountaineering, and free-riding. This could be a skier that tackles a technical descent in extreme conditions (freezing temperatures, ice-covered slopes, steep and difficult descents) with frequent switches between alpine and tech bindings. Furthermore, the users can be divided into primary-, secondary-, and tertiary users. The primary users for this product are defined as dedicated backcountry skiers and resort skiers. This group of skiers are intermediate and are comfortable in both backcountry environment and the piste. Secondary users are ski shops and ski rentals that sell the product or provide rental services for the product. The tertiary users are the users that provide mechanical maintenance of the product in case it breaks or something is malfunctioning.

The segmentation aids in tailoring the binding system to accommodate different types of users with different skiing preferences while also ensuring that relevant individuals are interviewed. The result of the identified segment ensures that the participants selected for the in-depth interviews align with the targeted market, and enhance the study's relevance.

6.3 Identifying customer needs & requirements

This section presents the results from the collection of qualitative data. The identification of the customer needs and requirements is essential for the development of a modular alpine binding system, to ensure that it aligns with the expectations of the users. The customer preferences, integrations with the products, and potential pitfalls are identified through the analysis.

6.3.1 KJ-method and interpretation of data

The information obtained from the five in-depth interviews was transcribed and all relevant data was collected and interpreted using the KJ method. Post-its and color-coded paper were used to divide the questions from the in-depth interviews into main areas related to the development of a new product. The main areas used in the KJ method were user, environment, cost, competitors, material, shape and ergonomics, attachment, unwanted attributes, problematic areas or issues, value creation, and the modular alpine binding system. All the important and most prominent aspects that could help in the development of a modular alpine binding system that had been mentioned during the interviews were listed on post-its and assigned to relevant areas 6.5. Each area was further analyzed, and the most important aspects indicated in each area were summarized, reducing the range of post-its in each area 6.6. The narrowed range of Post-its through the analysis using the KJ method, forms the building blocks on which the customer needs list will later be built.

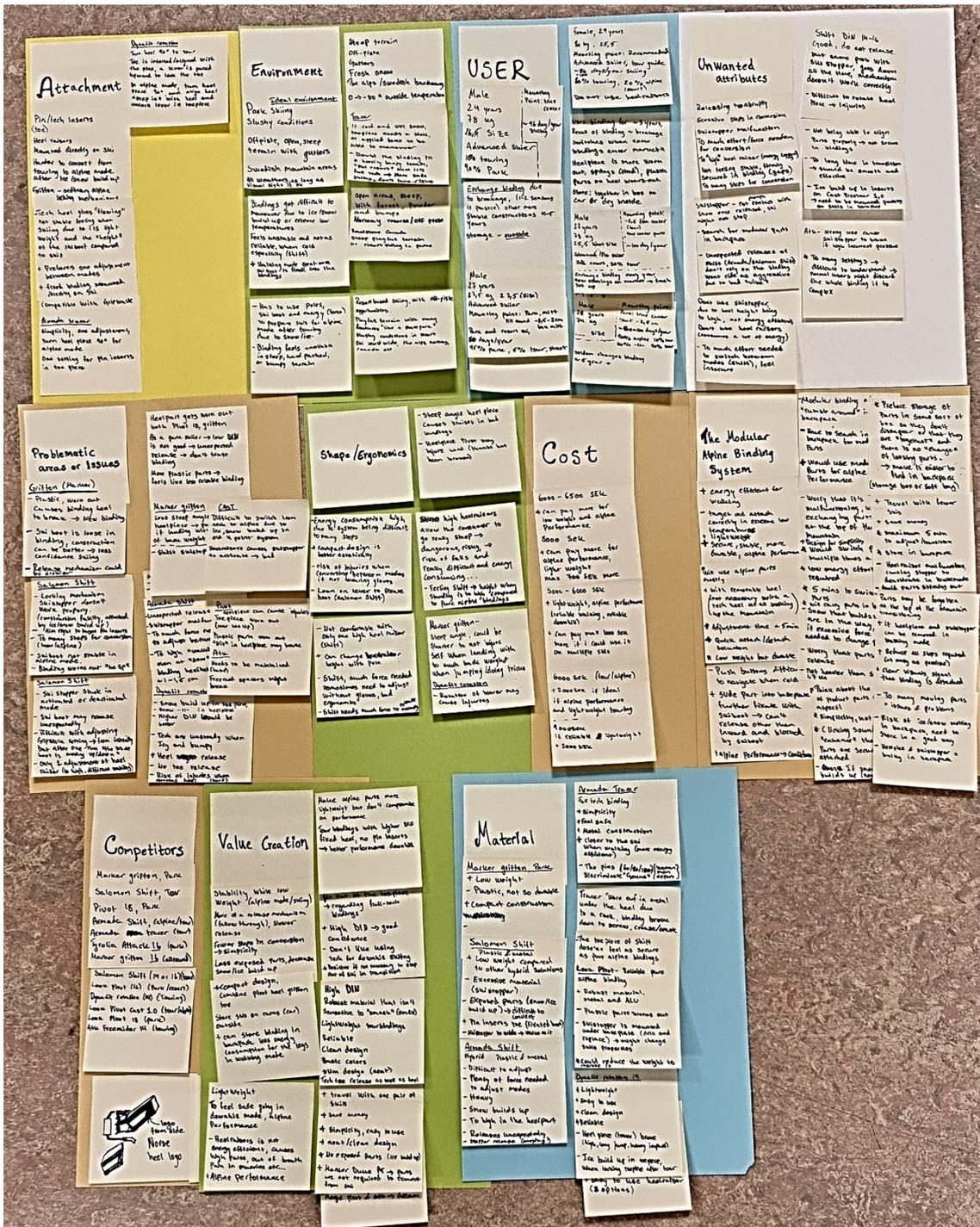


Figure 6.5: KJ-method - first draft

6.4 Customer needs list

The customer needs list (appendix A.1) contains 40 needs and requirements based on the data acquired from the in-depth interviews and the KJ analysis. The needs and requirements were given relative importance from 1-5, with 1 being the least important and 5 being the most important. From the customer needs list, 19 out of 40 needs were graded with the highest importance possible and are therefore demands that the product needs to fulfill in order to satisfy the targeted customers, 6.7.

No	The binding system	Need	Imp.
1	The binding system	should withstand continuous usage (several times per day/week)	
2	The binding system	should enable alpine skiing and ski touring	
4	The binding system	should not be too expensive compared to similar options on the market	
6	The binding system	should automatically release the skier's boot above a certain threshold value	
7	The binding system	should fixate the skier's boot in various conditions and allow applied forces within a certain threshold	
8	The binding system	should allow the user to manually release the skiboot from the binding	
18	The binding system	should enable user to use tech inserts for ski touring and downhill skiing	
19	The binding system	should enable alpine toe piece to allow for elasticity	
20	The binding system	should enable alpine heel piece to allow for elasticity	
22	The binding system	should provide indicators of proper DIN-settings	
23	The binding system	should provide indicators of proper mounting of modular parts	
24	The binding system	should be light weight compared to similar options on the market	
25	The binding system	should contain durable and reliable materials	
26	The binding system	should withstand corrosion	
29	The binding system	should enable easy alignment and attachment of skiboot	
30	The binding system	should enable easy attachment and detachment of modular binding parts	
34	The binding system	should allow for a low-weight binding system in walking mode (detach as many heel parts as possible)	
35	The binding system	should be time efficient (5 min)	
38	The binding system	should provide alpine performance downhill	

Figure 6.7: Customer needs list - highest importance

From the customer needs list it is evident that the customer wants the binding to function like other alpine ski bindings or tech bindings on the market regarding release mechanisms, durability, locking mechanisms of crucial parts for walking and skiing mode, etc. The most important aspects of a modular system despite fulfilling all the requirements expected of ski bindings are that the system should not be too expensive compared to other similar options on the market, provides easy alignment and attachment of ski boots, be lightweight compared to similar solutions, enable easy attachment and detachment of the modular binding parts, reduce as much of the heel piece as possible for touring mode, be time efficient in transition from alpine to tech parts (<5 min) and provide the user with alpine performance for downhill skiing.

There were other needs in the customer needs list that got graded with high importance as well, these were listed separately and will outline the demands, but mainly wishes of the customers. The wishes represents the features customers desire of a product to fulfill to add further value and are presented in figure 6.8 below.

No	The binding system	Need	Imp.
3	The binding system	should accommodate to different boot sole lengths	
5	The binding system	should be functional in temperatures between -40 to 20 degrees	
9	The binding system	should mitigate the risk of snow/ice build up on exposed and sensitive parts	
10	The binding system	should be easy to use with few conversion steps	
11	The binding system	should prevent injuries when managing the different conversion modes	
15	The binding system	should provide functioning locking mechanism for ski brakes and heel raises in walking mode	
16	The binding system	should provide functioning locking mechanisms of ski brakes and heel raises in alpine mode	
21	The binding system	should enable tech heelpiece to allow for elasticity	
27	The binding system	should not be affected functionally by exposure of UV-light	
28	The binding system	should be designed and constructed to mitigate exposed parts (brakeage)	
37	The binding system	should be easy to use and understand	
40	The binding system	should have a low stack height	

Figure 6.8: Customer needs list - wishes

From the separate list of customer needs that were graded lower than the once stated in figure 6.7, there are a few considered to be demands even though they got a lower ranking. These were needs such as accommodating to different boot sole lengths, functional in -40 to 20 degrees, not being affected functionally by UV-light exposure, and allowing elasticity in the tech heel. The other needs stated in the list are considered to be wishes as their functionality might cause pain points for the user but are not regarded as crucial to the overall functionality of the binding system.

From the data collected and analyzed with the KJ method apart from providing a modular binding system that allows for ski touring and alpine skiing. The most prominent wishes regarding such a system were that it offers good alpine performance going downhill, has a compact and neat design, allows for an easy and smooth transition from tech parts to alpine parts, reduces the risk of ice and snow build up in sensitive parts and comes with an additional soft bag or box so that the parts are easily found when stored in backpacks, while also reducing the risk of snow and ice melt in the backpack.

6.5 The complete Requirement specification

After analyzing and interpreting the information and data gathered from the in-depth interviews, the customer's need list and the graded importance of the needs provide the foundation for the requirements specification. The most important needs are converted into demands and the other needs of high importance are converted into wishes. The complete specification of requirements is presented in appendix A.4 and contains information about what criteria the modular binding system aims to fulfill, and has been evaluated and reviewed iteratively throughout the development of the prototype.

6.6 Customer personas

From the customer and user identification, together with the customer needs list, specification of requirement, as well as information obtained from the company, customer personas were created to further aid in the development of the modular alpine binding system. While the requirement specification consists of functional and technical demands of the product, the customer personas aid in aligning design choices for customers actual needs.

The personas created were the amateur skier, the aspirant skier, and the advanced skier. The customer personas contain names, ages, genders, occupations, interests, and levels of income and act as fictional representations to further represent and enhance the different needs and requirements of different users together with quotes and different customer needs of a binding system.

The personas created are presented in A.6. The key properties of a modular binding system from the customer personas are that it is affordable, durable, enables the opportunity to upgrade, provides safety, accommodates different boot sole lengths, does not compromise the performance, and is aesthetically appealing.

6.7 The idea generating process

This section presents the methods and processes implemented to understand, develop, and evaluate concepts of the prototype that the thesis aims to develop. From the information gathered through identifying design aspects, conducting market and competitor research, and customer and user identification, the modular binding system could be analyzed regarding the different functions necessary to meet the customer's expectations. Concepts were generated and evaluated through the use of various matrices.

6.7.1 Function tree

A function tree diagram for a solution that allows a versatile ski binding for alpine skiing and touring has been created, and the solution that enables these functions is a modular alpine binding system. The function of the modular alpine binding system is further broken down into seven sub-functions, the main functions being: enable alpine skiing, enable touring and tech mode, enable modularity for different parts, provide adaptability, ensure safety, enable user preferences, and comfort and usability. The different sub-functions are further broken down into more sub-functions and categorized by numbers as illustrated in figure 6.9 These sub-functions categorized by numbers are further explained in the bullet point list presented in the Appendix A.5.

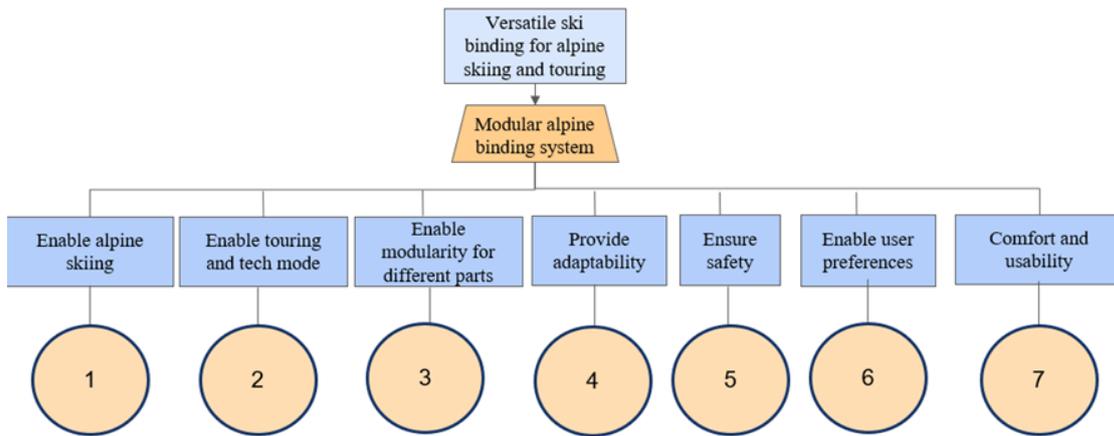


Figure 6.9: Function tree - modular alpine ski binding

6.7.2 Black box

A black box was conducted to understand the different functions of the system further. It describes the inputs of the system, the functions, and the outputs. The inputs concern the skier’s actions, the force applied to the system (energy), and the forces applied from the terrain which also affect the system. The inputs outside the system boundary convert to the outputs which provide a secure binding, released binding, modular configurations of the binding, and power transfer (energy) from the ski boot to the skis. Within the system boundary, the functions are further divided into functions and sub-functions within different areas as illustrated in figure 6.10:

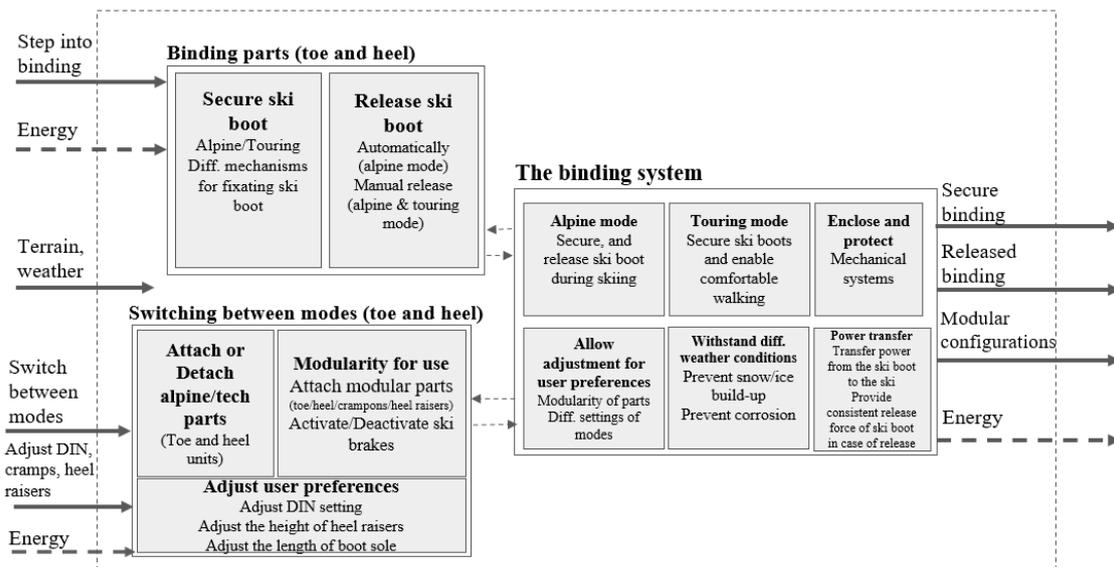


Figure 6.10: Black Box - Modular alpine ski binding system

From the function tree and the black box, the most prominent aspects regarding the functionality of the prototype are that the system is compatible with GripWalk

ski boots, that the system is designed to retain and release the ski boot, enables modularity of toe- and heel pieces, provides adaptability by adjustment for boot compatibility and DIN settings, has few conversion modes and is easy and detach without any additional tools.

6.7.3 Concept Evaluation and Selection

The ideation phase and development of concepts were conducted through brainstorming, sketching ideas of concepts, and generating new concepts in a morphological matrix. The concepts generated in the morphological matrix were further analyzed in an Elimination- and Pugh- matrix. Ideation is an iterative process, conducted multiple times through the development of the modular binding system.

The different concepts were generated by subgroups with support from the functional tree and black box, to divide the various aspects of the binding. The first subgroup considered the attachment and detachment mechanisms of the modular binding parts to the base plate of the skis, the second subgroup regarded the locking mechanism of the system. The first draft of the brainstorming and the different concepts generated in the morphological matrix resulted in 15 solutions, each assigned a name to distinguish them.

The concepts generated in the morphological matrix were further analyzed in an elimination matrix where the concepts were compared to different relevant criteria from the requirement specification.

Concepts are assigned with a '+', '-', or a '?' mark. Once a concept receives a '-' instead of a '+' the idea is eliminated, The question mark is assigned to the concept where there is a knowledge gap. The elimination matrix resulted in eight concepts. Due to existing knowledge gaps, it was difficult to determine whether certain concepts met the various requirements or not, and due to the uncertainties surrounding these, they were not taken further in development. After the elimination phase, solutions similar to other remaining concepts also remain, provided that they are very similar, these can then be combined into new concepts. Some rejected concepts may still be interesting because of sub-functions of interest, if so, they can be merged with the solutions that were similar into new concepts. Hence, the results of the concepts analyzed in the elimination matrix are further evaluated, and similar concepts and discarded solutions with interesting sub-functions are merged before proceeding further with the concept analysis.

After evaluating the concepts in the elimination matrix, the concepts are further analyzed and evaluated in a PUGH matrix. In this matrix generated ideas are evaluated against a reference concept regarding how well they meet the wishes established from the customer needs list. The highest-ranked concepts are further evaluated in an additional PUGH matrix, with the best-ranked concept from the previous draft as a reference. As it is an iterative process, the concepts in the first draft were evaluated against a solution similar to the current offering on the market. In the second iteration, the highest-ranked concept from the first draft is set as a

reference, and the remaining concepts are evaluated against it. The highest-ranked concepts from both iterations are further evaluated and act as the foundation of the concepts that are to be developed. From the elimination matrix, eight concepts remained. The final result after evaluation through iterative implementations of PUGH matrices generated four concepts.

Further development of the other parts of the concept will not include evaluation through matrices because the most prominent part of the solution is the attachment and detachment of the modular binding parts to the base plate of the ski. The other modular parts of the binding will be developed through brainstorming with the information from the patent research, function tree, black box, customer needs list, and the requirement specification as a basis of the development. The concepts generated form a basis for further development, on which they will be evaluated, by creating CAD models and prototypes using 3D printing. After evaluating the CAD models and the 3D printed parts, they are either further developed by merging interesting features or by modifying them into new promising concepts that have a greater opportunity to meet the customer needs and demands.

7

Results of conceptualization process

This chapter contains the result of the methods previously implemented to generate ideas of concepts for the modular alpine binding system, that could be further conceptualized, refined, and developed using CATIA software and 3D-printing. The chapter describes different concepts, the evaluation of these, the final concepts, and the process of 3D printing the modular components.

7.1 Conceptualization of ideas

After generating ideas and using matrices to aid in the idea generating process, the conceptualization phase begins. In the conceptualization phase, different concepts and solutions to the problem were modeled using CATIA software. The original concepts were based on the highest-ranked concepts in the matrices. The concepts were further evaluated in the conceptualization process, and modified as unforeseen issues and new ideas for the solution surfaced during the modeling phase of the project.

To develop a functional modular alpine binding system for ski touring and alpine skiing, the system must be compatible with alpine and ski touring boots. Therefore, a boot sole of ISO 23223 (GripWalk) was modeled using Catia software. The model of the boot sole was then 3D printed to allow testing for the dimensions of the modular binding parts and their compatibility with the ski boot sole.

The main problem to solve in this project is the modular attachment to the base plate of the ski. Initially, conceptualization started with the different solutions for the base plate and its attachment and detachment features. The alpine heel-piece and the alpine toe-piece were modeled with the attachment and detachment features as a foundation for further development. After the first draft of concepts, some were discarded, refined, or new solutions emerged. The discarded concepts were considered too complex to further develop, for example, there were knowledge gaps regarding the feasibility of the construction or mechanical systems.

7.2 Conceptualization of base plate

The conceptualization phase of the base plate initially started with conceptualizing the result obtained from the Pugh matrix. The concepts were then evaluated on design, functionality, and feasibility through the creation of CAD models and 3D-printing of components.

7.2.1 Concept 1 - Cylinder solution

The first solution conceptualized using CAD was a cylinder-shaped solution base plate with grooves. A binding insert (top profile in the figure) is inserted into the cylinder-shaped base plate (at the bottom of the figure). A mounting plate is attached to the bottom of the base plate. A spring and an additional upper plate with grooves are mounted on the mounting plate's axle. The functionality of the concept is that the binding is inserted into the grooves of the base plate and thereafter pushed downward (compressing the spring) and simultaneously rotated into a locking position. The spring will thereafter extend and apply pressure to the binding insert so that it does not rotate back in the grooves.

This concept gathered a high ranking in the Pugh matrix, but after making a digital representation of the solution it was discarded as the complexity of the solution was regarded as too high. The grooves must contain an incline in the 90-degree bend so the binding insert does not slide back into the original vertical groove. Furthermore, the spring must be locked from compression and expansion, which is not conceptualized in the suggested solution. Due to the knowledge gap, the solution was discarded from further development.

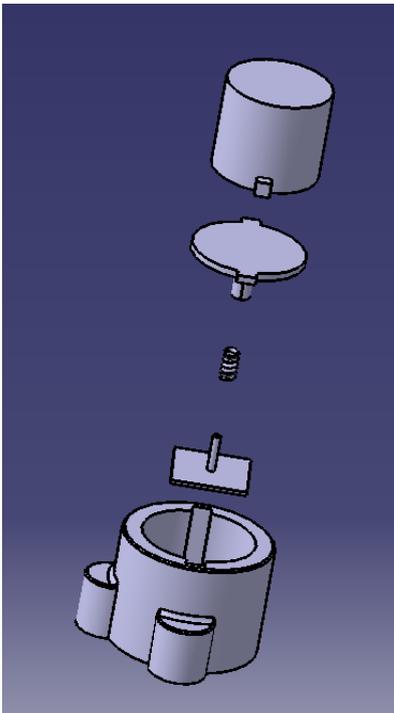


Figure 7.1: Exploded view cylinder solution

7.2.2 Concept 2 - Push button

The Push button concept consists of a base plate with guided slots for the binding insert. The binding insert is pushed into the guided slot forcing down a horizontal inclined pin (located in the front), which is attached with a spring underneath. When the binding insert is fully inserted the spring-loaded push button will expand and return to its original unloaded position. This in turn will lock the binding from gliding in the guided slots because the profile of the backside of the pin is vertical. The pin has a corresponding groove in the binding insert, which will lock its position, the binding insert can not be detached unless the pin is forced downward again. The solution of unlocking and moving the pin downward again can be realized through an extended arm/lever connected to the pin, located either on the side or in front of the base plate.

This concept is similar to the modular toe-piece from CAST, but the spring-loaded pin is positioned at the front of the base plate. This concept was taken further in the process for refinement and further development since similar technologies are used in existing solutions.

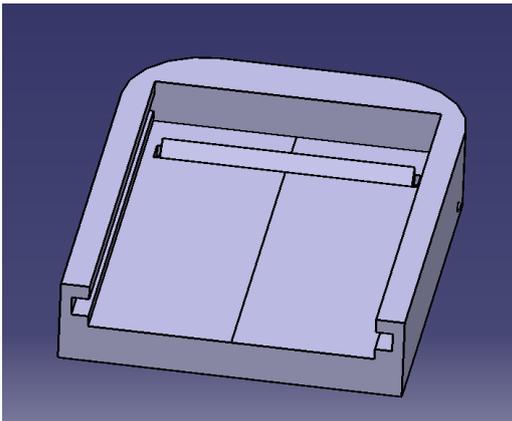


Figure 7.2: Guided slots with inclined push button from above

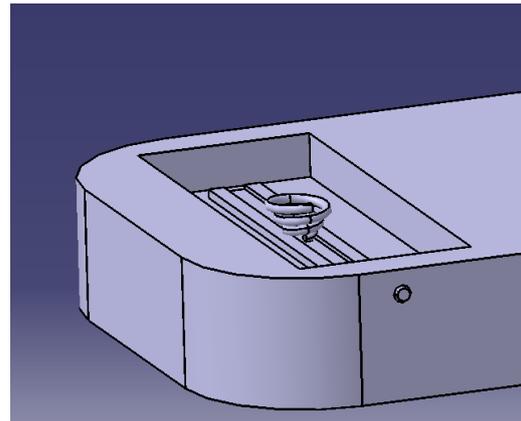


Figure 7.3: Guided slots with inclined push button from beneath

7.2.3 Concept 3 - Pin Solution

The third concept is also based on guided slots, but instead of a spring-loaded pin from underneath the pin is located in the front center of the base plate. The binding insert has a corresponding profile to the guided slots and a square-shaped front containing a hole in which the pin locks the binding. Once pressure is applied to the pin, the spring, to which the pin is connected, will start to compress. Once the hole in the binding insert aligns with the pin, the pin will lock the binding as the spring expands to its original position. To be able to detach the binding insert from the base plate, the spring must be compressed. The insert is detached, either by applying pressure to an extended arm or a lever positioned at the top of the housing or the front of the binding. The concept is a promising solution that, with its rather simple design and simple mechanical system, is considered potentially feasible for the project, and is therefore taken further in development.

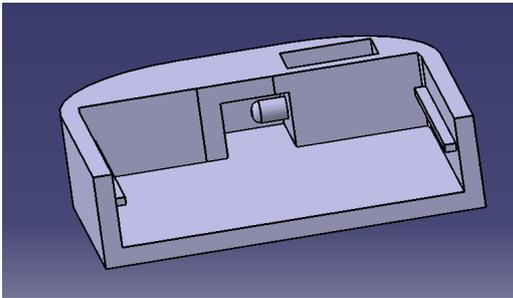


Figure 7.4: Pin solution seen from the side

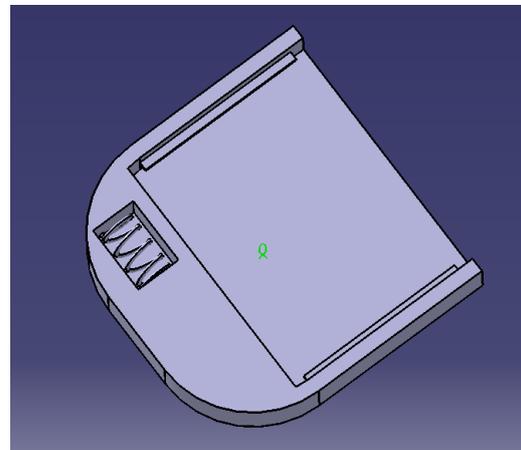


Figure 7.5: Housing of Pin solution seen from above

7.2.4 Concept 4 - Door concept

The fourth concept, which aims to solve the modularity of the binding system, is a partial solution and is not visually integrated into the base plate in the example. The concept is inspired by the mechanisms that enable the closing of doors, and especially the inclined pin that keeps the door shut. The housing consists of a spring and an inclined pin on either side. The main idea is that the housing part of the solution is integrated into the front of the base plate 7.6 The shaft with integrated pockets on either side is in turn integrated with the binding insert. The shaft is inserted into the corresponding hole in the spring housing 7.7. The inclined pins will be pushed into the housing as force is applied to the inclined profile 7.8. When the pockets on the shaft align with the pins, the pins will expand and lock the shaft into position. To detach the shaft, and thereby the binding insert from the pins the user puts a ski pole in the hole at the top of the shaft 7.9 and twists 45 degrees to the right. Thereafter, the user can slide the shaft back through the hole and detach the binding from the base plate. The pockets on the shaft have slightly chamfered profiles which allow twisting as a means of release, as the inclined pins will glide on the profile back into a sufficiently compressed position in the spring housing, allowing the axle to be pushed back.

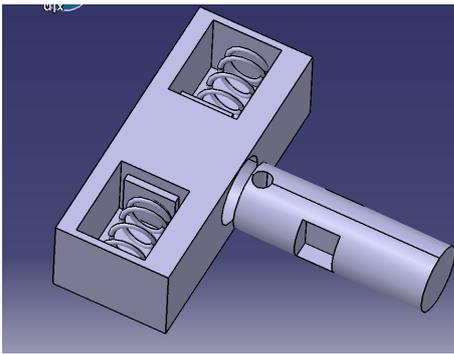


Figure 7.6: Inclined pins on either side in the hole for the shaft

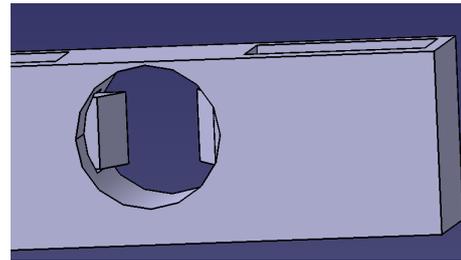


Figure 7.7: View of the shaft and its pockets

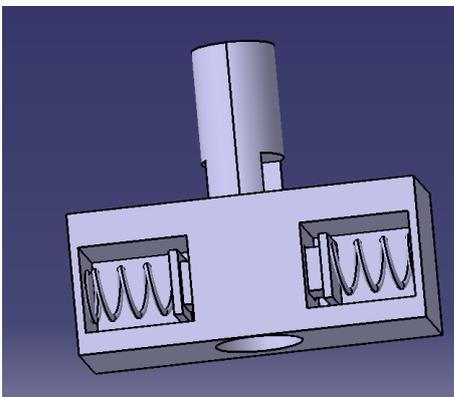


Figure 7.8: Visualization of pins as force is applied from the shaft

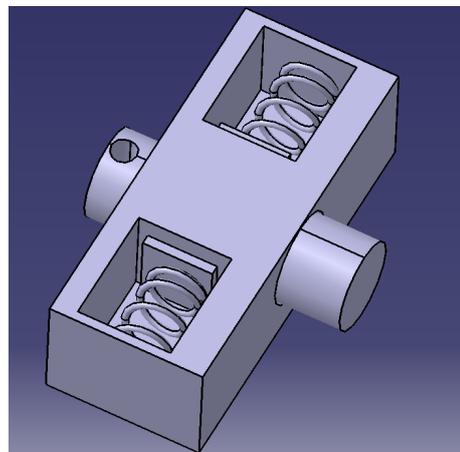


Figure 7.9: Doorpin solution assembled

The concept was a very promising one as the user only required a ski pole to detach the binding insert from the base plate, but as the shaft requires a twisting movement to detach it, it needs to allow for rotation and cannot be fixed to the binding insert. The shaft could be mounted on another shaft to enable rotation, with the consequence that it can rotate freely, thereby making it more difficult for the user to adjust and attach correctly. The rounded hole corresponding to the shaft could contain guided slots, but it will counteract the rotational movement for detaching. Another problematic area identified was that if the shaft was to rotate freely, it needed to be locked in place in front of the base plate to reduce the risk of it rotating and releasing from the binding. Due to the complexity of the design, its integrated parts, and the correlating knowledge gaps, this solution was discarded despite its promising functionality.

7.3 Conceptualization of heel piece

During the conceptualization of the heel-piece, its complexity was more evident than the toe-piece. The heel piece needed to accommodate different ski boot soles to allow boot compatibility, allowing the binding to be adjusted 3 cm to accommodate different boot sole sizes. The most common solution to boot sole compatibility in alpine ski bindings through the years has been either a screw that is screwed into the desired position or a steel lever, both of which are connected to a loaded spring beneath the heel component of the binding and the base plate. The market today also offers simple and user-friendly systems especially used by ski rentals that solve boot compatibility, the binding parts are slid into the base plate, and a lever is used to adjust the binding parts into the desired position. These binding base plates are usually quite long to accommodate boot soles that differ in a wider range than 3 cm.

The solution to solve the boot compatibility problem in this project was decided to be the steel lever mounted on the base plate of the heel binding. The base plate has mounting points to which screws will be screwed to attach it to the skis. The base plate also contains small holes for the steel lever to accommodate different boot sole lengths as the binding is slid forward or backward in the base plate. The base plate is in turn mounted in a “base plate holder” 7.12 before it is mounted and fixed to the skis, the “base plate holder” is developed to mitigate deformations in the ski due to the steel construction of the base plate, but also to provide an alignment with the ski stoppers that is also a component of the heel-piece of the binding. The steel lever is mounted in a body that acts as a housing, referred to as “base plate housing” which includes the lever and its attachment to the loaded spring. The function of the loaded spring is to apply pressure to the lever so that the pins on the lever stay in place in the holes of the base plate. The loaded spring is crucial for the construction, to obtain the desired boot compatibility, ensure a proper fit to retain the skier’s boot, and thereby also ensure the safety of the binding.

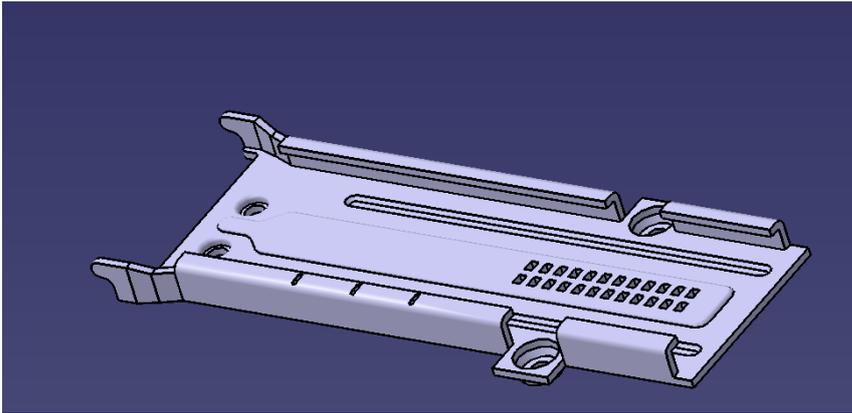


Figure 7.10: Compatability slide

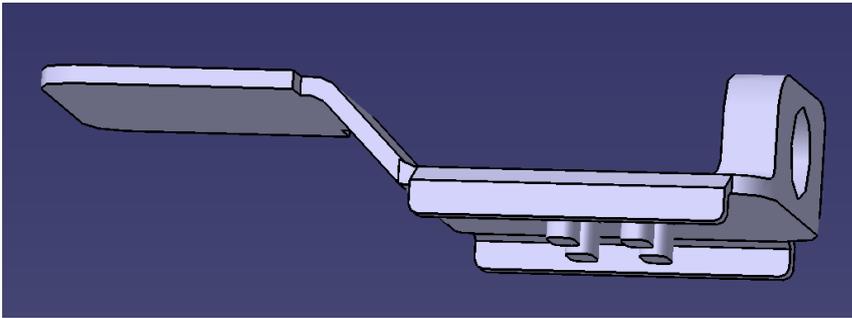


Figure 7.11: Locklever

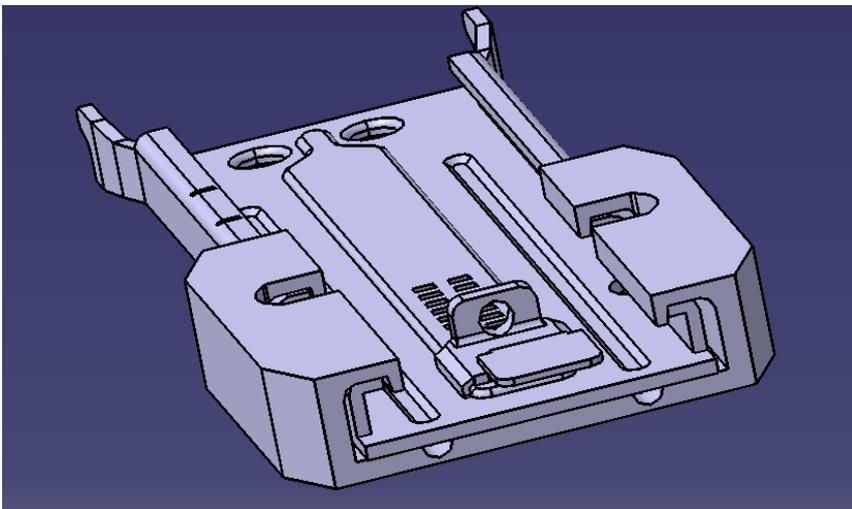


Figure 7.12: Mounted compatability slide and lever

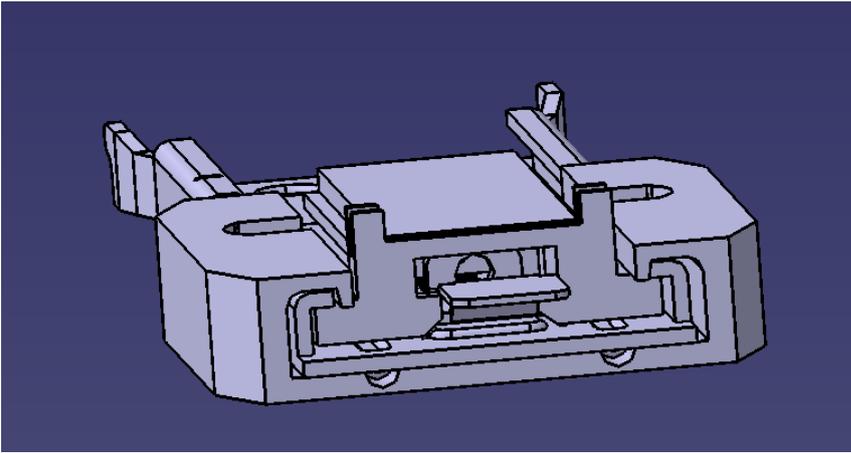


Figure 7.13: Mounted compatibility slide, lever and attachment to modular part

7.3.1 Concept 1 - Push button wedge

One of the biggest issues with a modular alpine binding system is the modular attachment of the binding parts that will retain and release the skier's boot from the binding. Different concepts were developed and discarded as issues and problems emerged during the design and conceptualization phase. One solution for the modular attachment was the construction of a push button with a wedge profile and extended arms mounted within the "base plate housing". As the modular heel-piece is inserted into guided slots, on the sides of the housing, the wedge will be forced down into the housing of the base plate allowing for the modular heel-piece to slide over it, illustrated at the top of 7.14

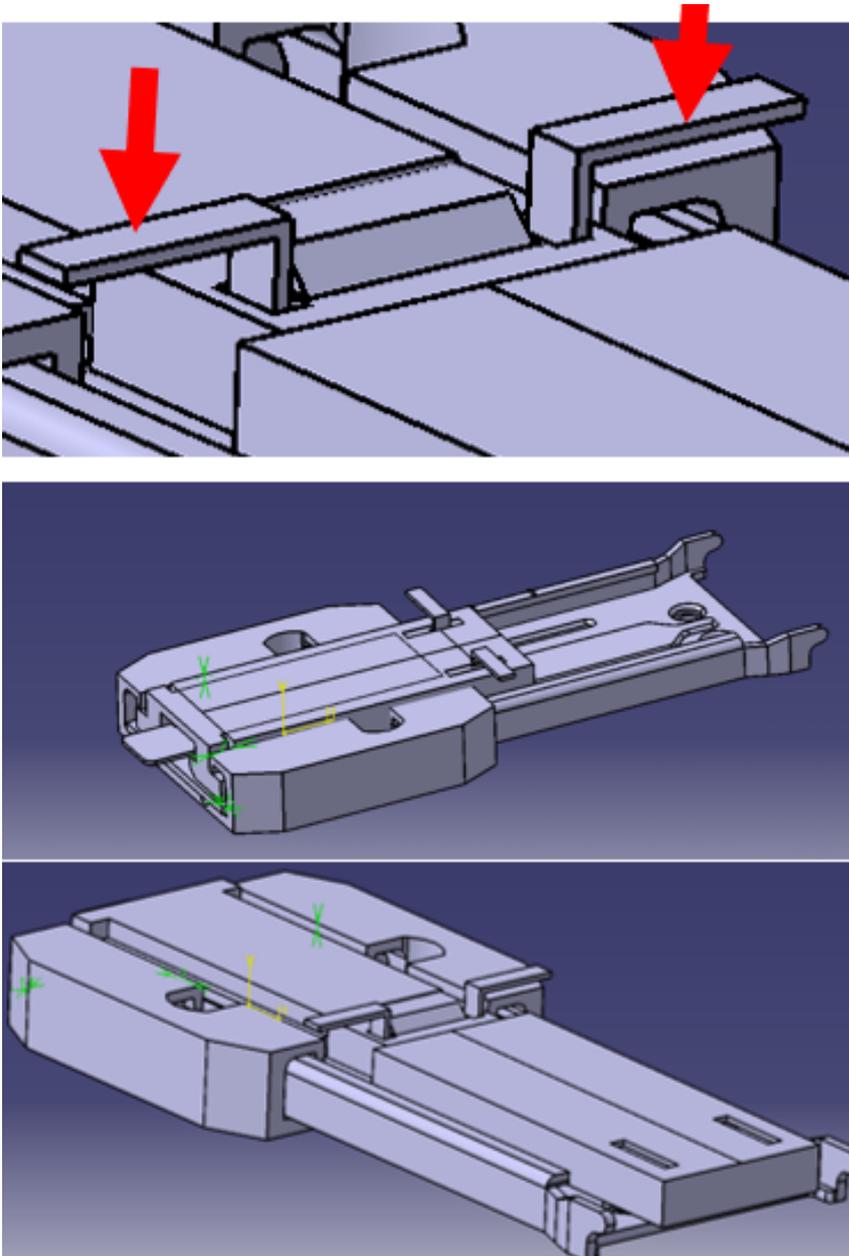


Figure 7.14: Concept 1 - Springloaded wedge with arms

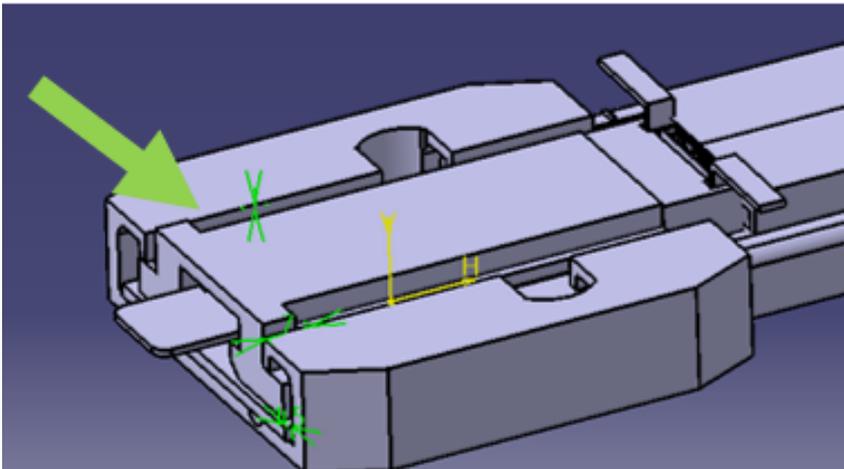


Figure 7.15: Concept 1 - problematic area

Once the whole heel-piece is slid into position on the guided slots the wedge is pushed up into a slot in the heel-piece and thereafter locks the bindings position, second image illustrated in 7.14. There were issues with this concept as the extended arms could not be positioned directly over the housing because the construction of the binding that will release the skier's heel from the boot is equally wide as the modular attachment, and therefore not accessible unless the arms are extended outwards to the side of the binding. Another aspect of this concept is that provided the extended arms and its L-shape the modular heel-piece, which is slid over the L-shaped arms, needs to have integrated slots throughout the whole attachment for the construction to function. The arms could be placed at the furthest end of the binding illustrated by the green arrow in 7.15 however, the housing consists of the boot compatibility lever and therefore there is not enough space for the push button and a loaded spring as the concept is designed and constructed. Because of the complexity of the design, the extended shape of the arms, and the minimal amount of space for design refinement, this concept was discarded.

7.3.2 Concept 2 - Lever concept

Another concept developed was the snap-fit lever concept, illustrated in Figure 7.16. The concept is similar to the previous ones, based on guided slots, in both the base plate housing and the modular heel-piece to be attached to the base plate housing. The modular heel-piece is slid into the slots of the base plate housing. Once positioned, a T-shaped lever is lowered into a T-shaped slot and locks the binding from moving forward and backward. The lever is attached to the modular heel-piece and mounted to an axle with screws, between the lever and the outer sides of the heel-piece there is one torsion spring mounted around the axle on each side of the lever. The torsion spring will be compressed when the lever is lifted from the T-shaped slot, therefore, it will snap back into the snap-fit unless the user applies a load to the lever, similar to a mouse trap. The upper housing of the heel-piece will contain the loaded spring which adjusts the DIN setting of the binding with a screw, at the further end of the house. Therefore, once attached to the base plate, the lever must not cover the screw and hinder the user from adjusting the settings. Since there is a knowledge gap regarding how to design the mounting points and the corresponding chamfered profiles that enable the snap function of the loaded springs, the concept was not taken further into development.

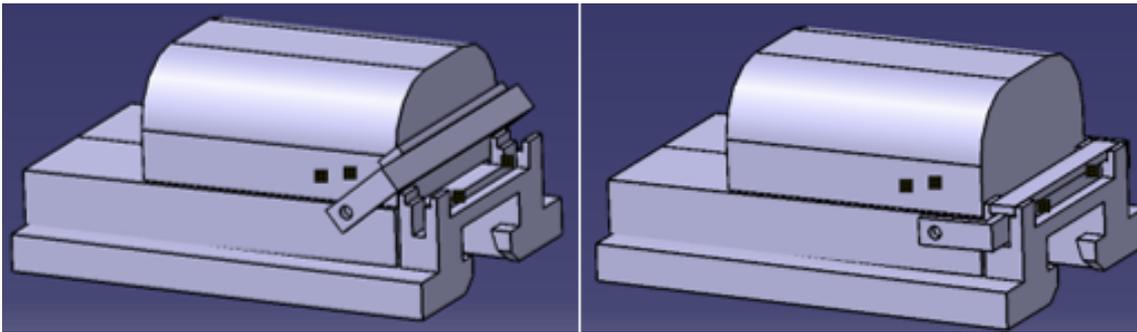


Figure 7.16: Concept 2 - Lever concept

7.3.3 Concept 3 - Pin concept

The Pin concept is based on the same function as the previous. The modular heel-piece is slid into the guided slots of the base plate housing. The housing has a solid wall at the furthest end of its body, preventing the binding from moving further in that direction. The modular heel-piece has a smaller housing, which consists of a loaded spring and a pin. The "stop wall" at the furthest end of the base plate housing is designed with a chamfered profile and a hole corresponding to the dimensions of the pin in the modular heel-piece. The modular heel-piece is slid into the guided slot as illustrated, in 7.17. Once the pin reaches the chamfered profile it will be forced upwards and the loaded spring will be compressed, as illustrated in 7.17, and 7.18. Due to the loaded spring, the pin will snap into the hole in the "Stop wall" and lock the binding from movement. In the figures, illustrating the concept, there is no wall to enclose the spring and the pin. The real concept will enclose all mechanics inside an additional wall. The pin will also be refined with an integrated lever or arm that allows the user to move the pin upward and thereby compress the spring, to detach

the modular heel piece from the base plate housing and remove it from the binding. The wall enclosing the mechanical system of the spring-loaded pin will be attached with small screws to enable easier access for replacing parts if they malfunction or break. The locking mechanism of the pin concept will mainly prevent the user from losing their binding if the binding releases the skier's boot. The boot itself, when in place in the binding, will lock the modular heel piece from moving forward. Safety requires the bindings to release the skier's boots once applied forces reach a threshold value, and thus, the modular attachment needs additional locking mechanisms to prevent binding parts from disappearing in the environment in which they are used.

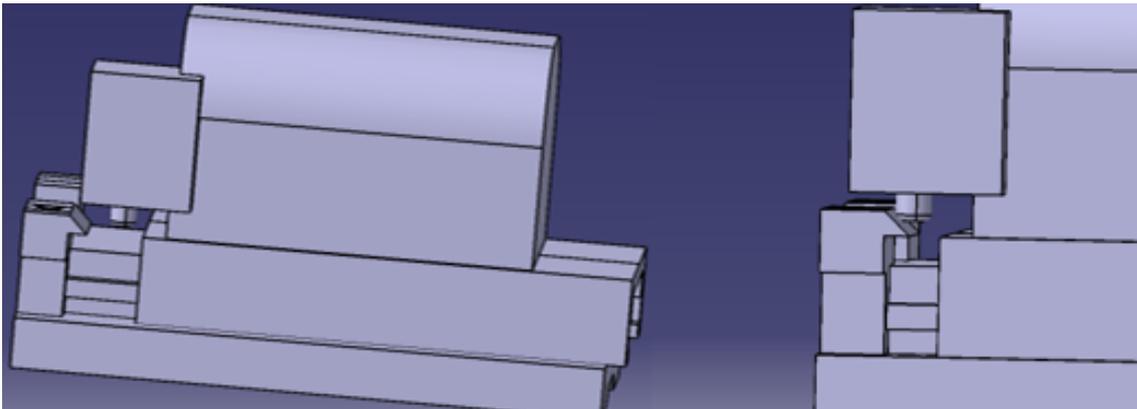


Figure 7.17: Concept 3 - Pin concept

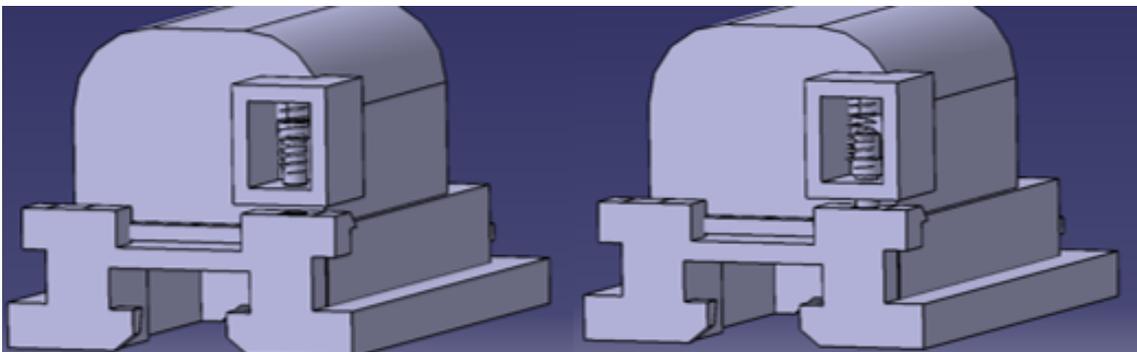


Figure 7.18: Concept 3 - Pin concept

7.4 The final modular alpine heel concept

The final concept is a further development based on the spring-loaded pin to lock the modular heel piece into the base plate housing, Figure 7.19. After developing the modular heel-piece and its attachment and detachment functions, utilizing guided slots, 7.20, for precise alignment, and the loaded spring pin to lock the position of the modular heel-piece. The next step was to design the final concept for the alpine heel-piece. Before conducting this design phase, further knowledge had to be obtained. The patents available only describe the function of different bindings and access to technical drawings is not available. The heel-piece was designed using reverse engineering after acquiring an old heel-piece of an alpine binding and relies on approximate measures using a folding rule.

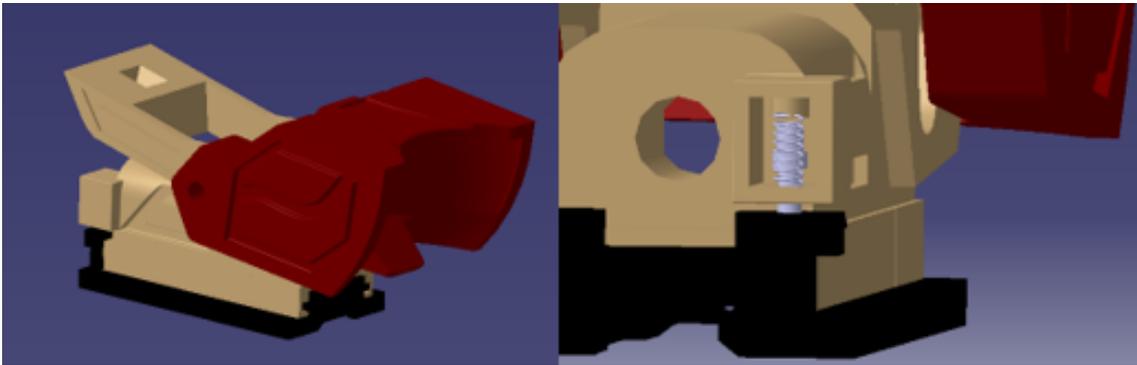


Figure 7.19: Final concept - locking mechanism



Figure 7.20: Final concept - Profile of guided slots, heel-piece

The concept consists of the modular attachment with the housing of the pin and the DIN spring, a heel tower (yellow arrow), and the holder for the heel of the ski boot (orange arrow), Figure 7.21. The heel tower and the holder of the ski boot are mounted on the same axle to the “modular heel piece”. The heel tower is designed to

allow movement upwards and downwards, and slightly forward and backward due to the loaded DIN spring inside the base plate housing. The concept is a design attempt to mimic and function similarly to a real alpine binding system. While it aligns with general principles of existing products on the market limitations such as knowledge gaps, the absence of technical drawings, and reliance on approximate measures have resulted in differences in tolerances, dimensions, and radii of the various integrated parts compared to products on the market.

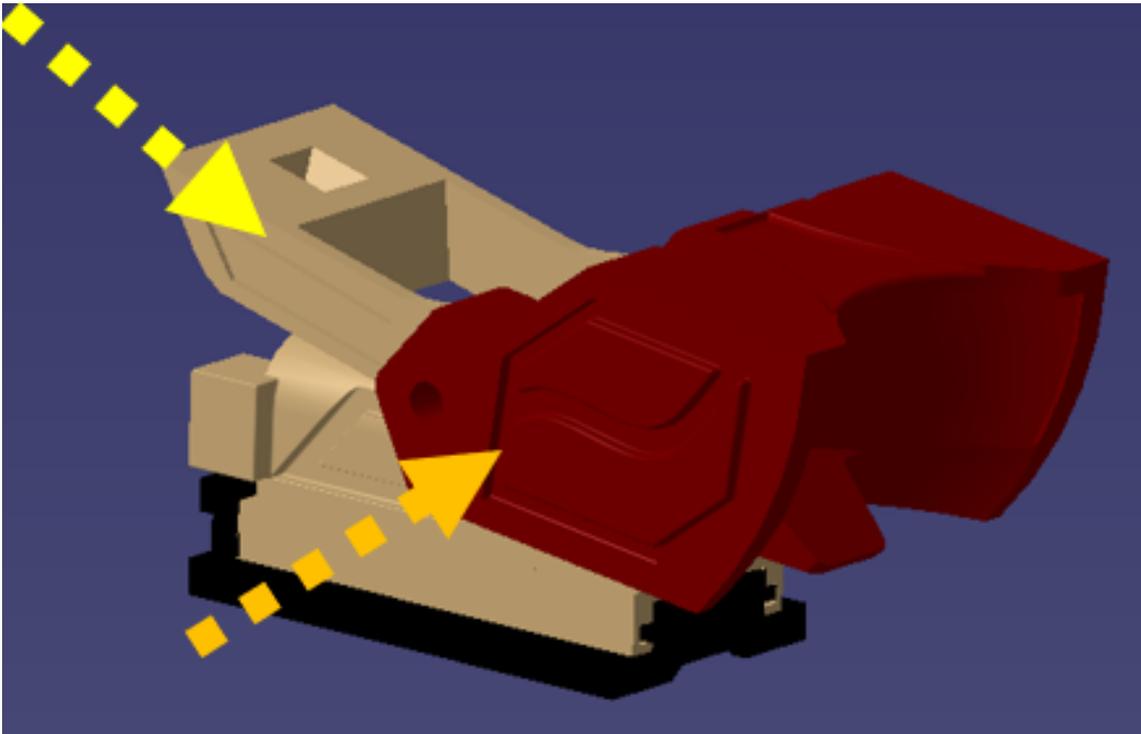


Figure 7.21: Final concept - heel tower and holder of ski boot

Inside the holder, there are chamfered profiles that correspond to the radius of the profile of the heel tower. Inside the housing, the DIN spring is compressed due to an additional smaller housing that retains the spring, an additional component integrated with the heel tower and the holder are mounted on the same axle. The integration and correlation of these different components enable the function: to retain and release the skier's boot within a predetermined threshold value. These different design aspects and components were only attempted, and some were discarded due to knowledge gaps. Hence, they are only explained to illustrate the complexity of the product which can not be seen from the outside unless reverse engineering is performed of an actual product on the market.

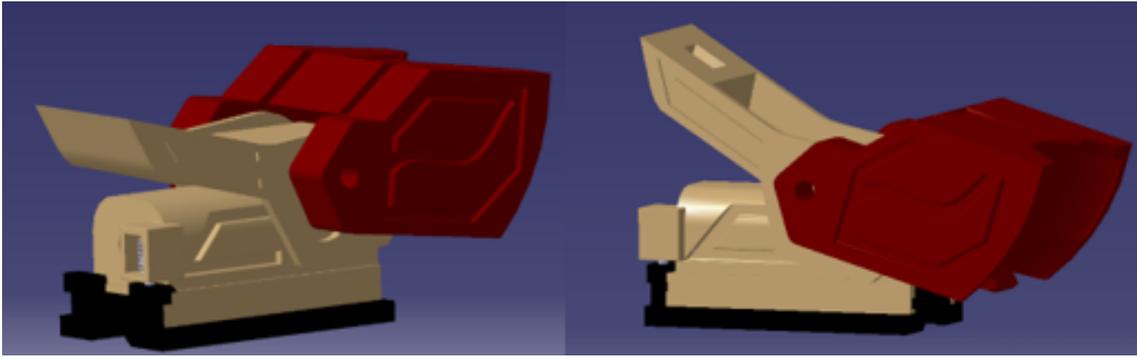


Figure 7.22: Final concept - positioning of heel piece to attach/detach ski boot

As illustrated in the first image of Figure 7.22, the neutral position of the heel tower and the holder allows the skier to step into the binding. When the skier puts pressure on the holder the heel tower will snap into an upward position (second image) as the holder locks the heel of the ski boot into place. When the skier wants to release the ski boot from the binding, pressure is applied using a ski pole, in the pocket on the top of the heel tower, which causes the heel tower and holder to return to the neutral position and release the ski boot. The holder of the ski boot is designed according to ISO23223 and should be compatible with the measurements of these boots. During the entire design phase, the measurements were conducted to correspond to real market offers as much as possible, provided that no technical drawings were available. Only approximate measurements of existing and pre-assembled products could be carried out using a folder rule. This has been conducted to prevent the stack height of the binding system from exceeding current offerings, which has proven to be an important aspect obtained from interviews. The lower stack height enhances control and confidence for the skier while transmitting the power from the ski boot to the skis more efficiently than a higher stack height would. The assembly of the heel-piece mounted to the base plate is illustrated in 7.23.

Another design aspect during this stage has been to implement the company's Norse design language in the binding to increase the competitive advantage through brand identity and recognition. These design aspects are related to recognizable aesthetics that help consumers identify products at first glance, such as mimicking the company's logo on the DIN housing and heel tower, and mixing rougher edges with softer shapes to create an aesthetic appeal. The final concept is a modern solution of a modular binding system with retro aesthetics creating a bridge between the past and present designs of binding systems. It has become a trend among companies to use nostalgia in marketing practices. Nostalgia builds an emotional attachment and influences users' preferences, as past experiences and memories are linked to the current offer.[41]. Furthermore, a retro design signals authenticity and appeals to consumers who value timeless quality as retro designs often appeal to consumers who prefer products that look and feel robust.

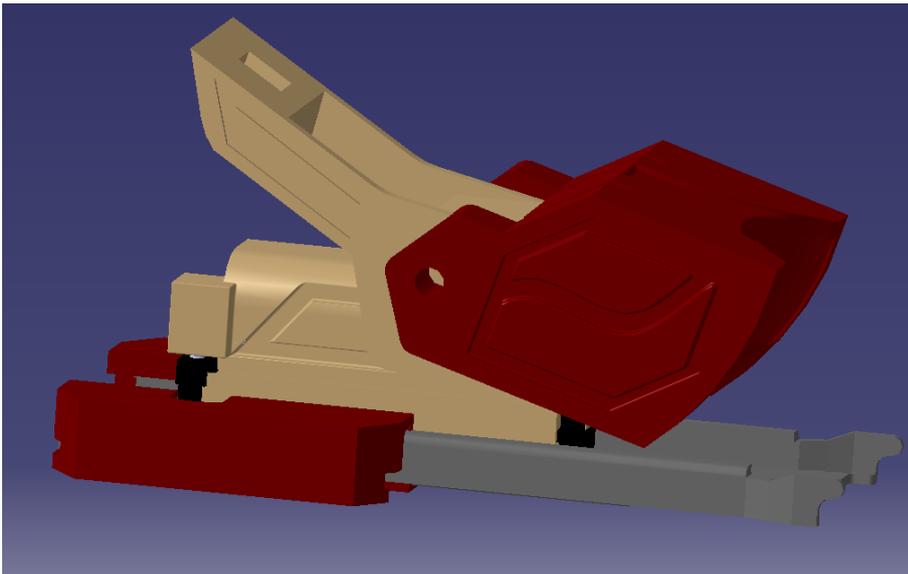


Figure 7.23: Final concept - Full assembly of heel piece

7.5 The final modular alpine toe concept

The final concept for the modular alpine toe is a further development of the concepts initially investigated. It is based on the concept with guided slots, but utilizes another locking mechanism than the heelpiece. It consists of a base plate, mounted on the ski with screws and the modular attachment of the alpine toe. In the modular alpine toe-piece, an AFD (anti-friction device) plate is mounted to the modular attachment with screws from underneath. In the case of binding release, the AFD plate mitigates the friction between the ski boot and the binding, 7.24. The alpine toe piece is designed to be compatible with a grip walk ski boot, thus measures from the ISO23223 have been used as reference during the development of the concept. The toe-piece contains two "toe wings" that keep the toe of the ski boot in place while also allowing for elastic travel. The toe wings are mounted on either side of the toe-piece, on axles to provide movement in the horizontal direction. Additionally, anti-friction rollers are mounted to the toe wings to enable frictionless release of the ski boot from the binding, Figure 7.25.

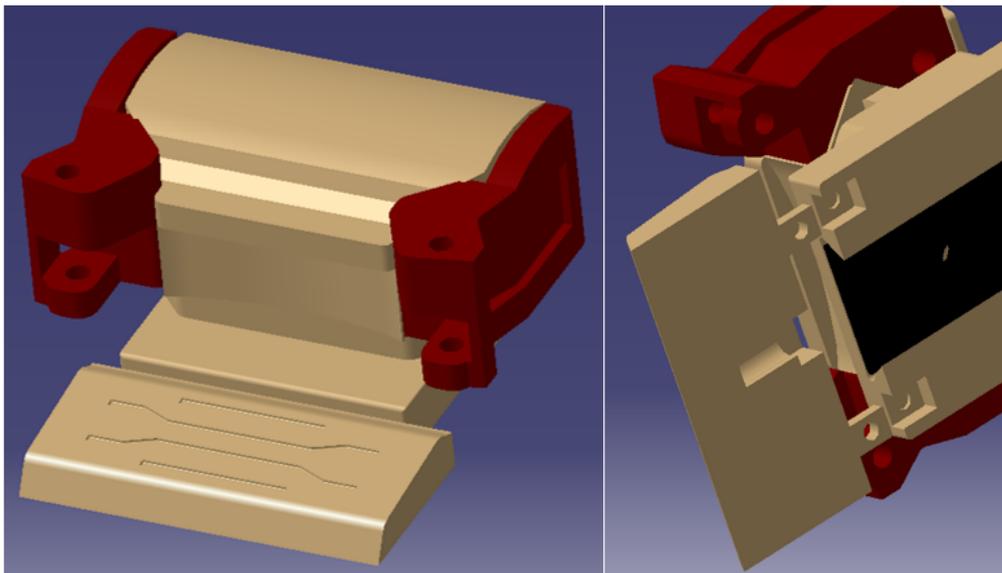


Figure 7.24: Final concept - AFD mounting point

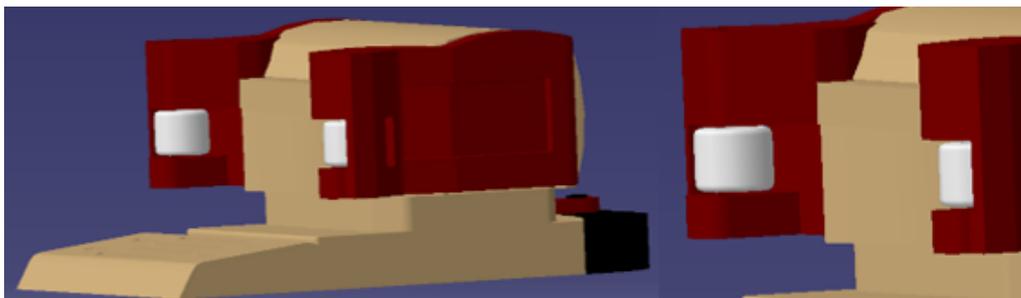


Figure 7.25: Final concept - Anti-friction rollers

The guided slots of the modular alpine toe-piece have been further developed, instead of straight lines and sharp corners, rounded shapes are utilized to reduce the risk of breakage in the material caused by stress 7.26. The base plate of the toe-piece is mounted on the skis, and the modular attachment of the alpine toe is slid into position as the profiles of the different components correspond to each other. The base plate is designed with a "stop profile" corresponding to the curvature of the profile for the modular attachment. The sliding direction of the toe piece is the opposite of the heelpiece, which is evident as the skier skis down the slope, thus applying force to the front of the binding. The attachment of the modular toe to the base plate of the ski is illustrated in 7.27 and 7.28.

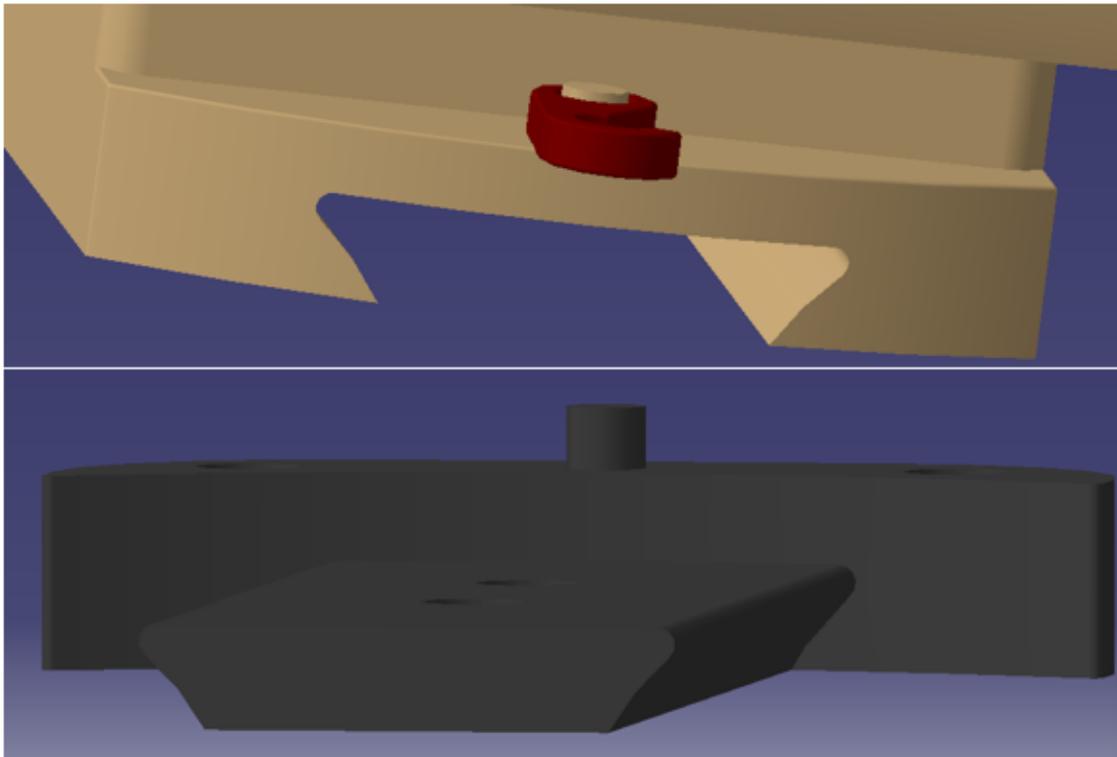


Figure 7.26: Final concept - Attachment profile of the alpine toe

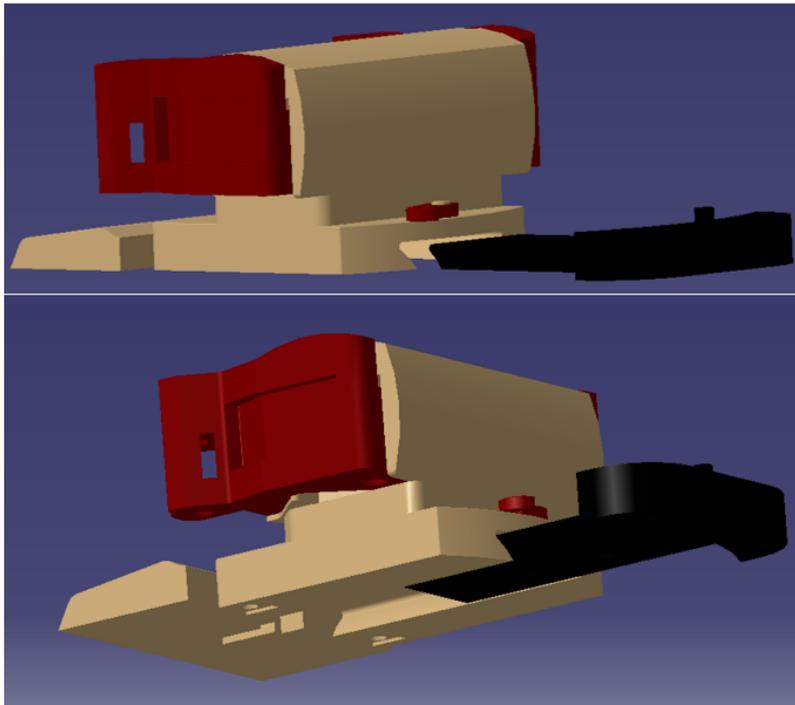


Figure 7.27: Final concept - Alignment of modular alpine toe on guided slots

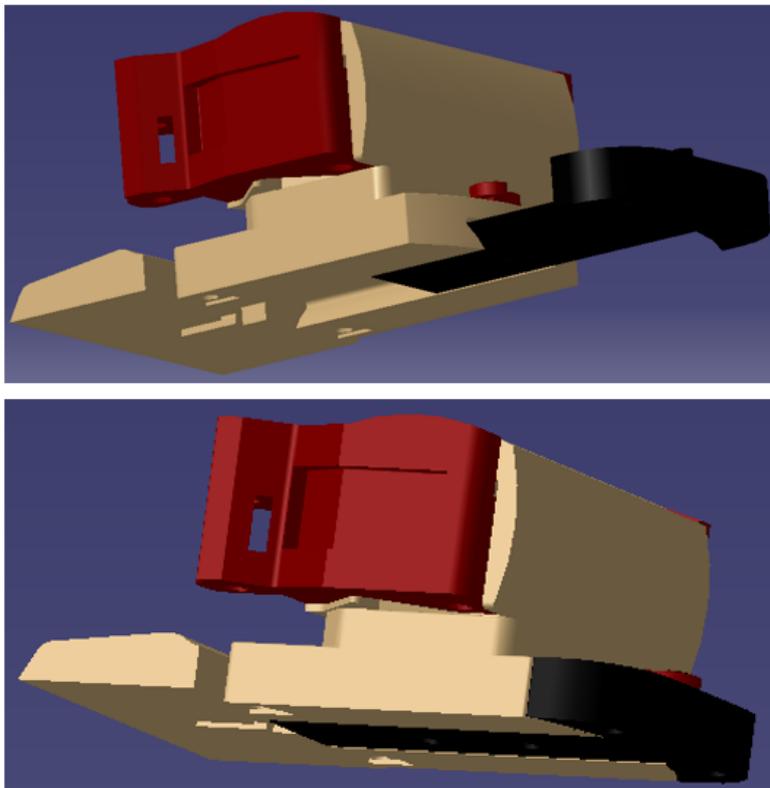


Figure 7.28: Final concept - Attachment of modular alpine toe

Once the modular attachment is positioned correctly, the user locks the binding from sliding back in the opposite direction by closing the lever in front of the "toe housing". The lever closes around a pin and prevents the modular part from moving. To detach the binding, the user rotates the lever back to the opened position and slides the modular part backward along the slots, illustrated in 7.29. For the lever concept to work, an elastic material should be utilized in the lever as there must be some flexibility in the material to bend and snap around the pin of the base plate. The lever should also be constructed with an additional integrated profile that enables the user to push the lever and thus rotate it by using their thumb.

Due to the narrow time of the project, the housing of the alpine toe was not fully developed. The toe housing should be designed to include mechanical systems. It should have an integrated DIN spring that the user can adjust according to their preferences using a screw. The spring should be connected to a mechanical system connected to the toe wings, to enable elastic travel, ensuring the retaining and release of the alpine toe-piece. Additionally, an indicator inside a window at the top of the toe housing should be integrated into the design. Through the window, users should be able to see a scale that indicates the correct settings for their preferences.

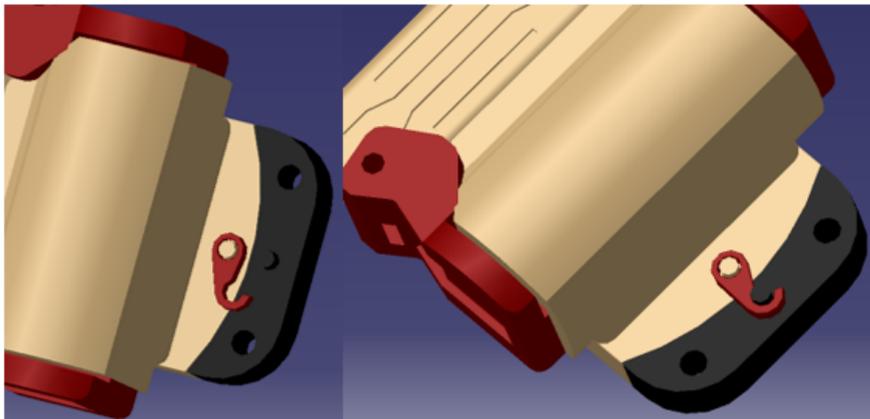


Figure 7.29: Final concept - Locking mechanism of modular toe piece

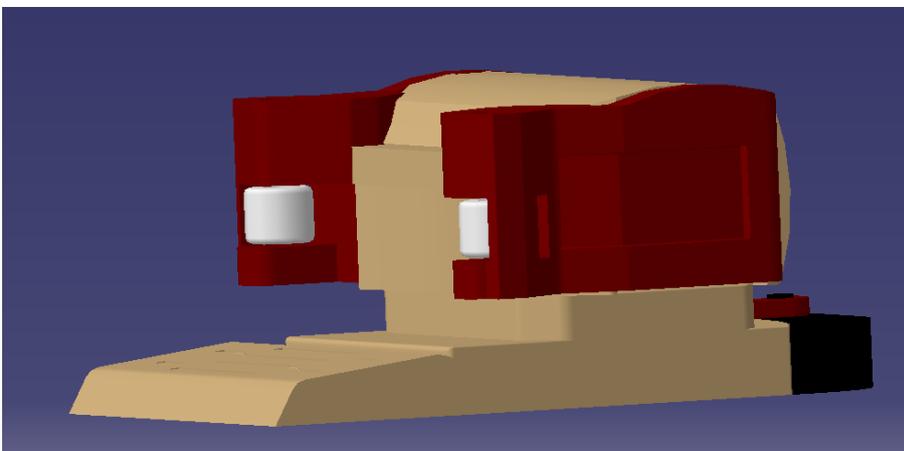


Figure 7.30: Final concept - Fully assembled alpine toe piece

The final concept is illustrated in 7.30. During the development process of this concept, no reverse engineering of an existing product could be carried out, therefore measurements have been made by hand using a folder rule. There are no technical drawings of alpine bindings available, and the only reference measurements available for the construction of this product have been the boot measurements given in ISO23223, which have been used as reference. There is a knowledge gap regarding the mechanical systems in the housing of the alpine toe and not enough time for testing and troubleshooting, hence the concept was constructed as a whole, but with important parts of the construction in mind. The stack height of the binding system has been considered in the development, and the toe piece is designed to represent as realistic a size as possible. From the interviews, clean and simple design was an important aspect, and to maintain the design language used in the heel piece of the binding system, straight lines with slight curvature have been implemented to be able to present a cohesive whole. The concept is designed with safety aspects and elastic travel in mind. Thus, it is constructed in different parts to enhance the realism and increase the understanding of the parts to be integrated with the mechanical system, to demonstrate what a final product should fulfill. The final assembly of the modular heel-piece and the toe-piece is illustrated in, Figure 8.1.

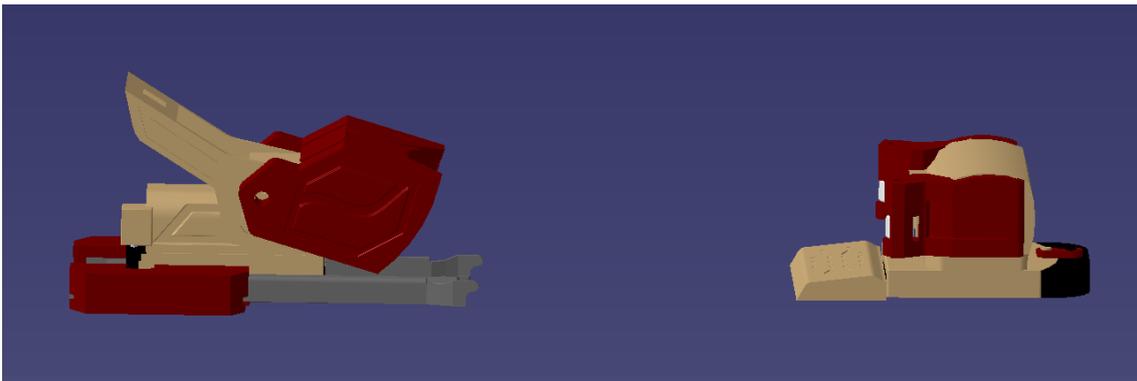


Figure 7.31: Final concept - Assembly of modular heel-piece and toe-piece

7.6 Conceptualization of tech-toe

An attempt to conceptualize tech parts was made early on in the project, though put to a halt, as the alpine parts and especially the alpine heel were of higher priority. The concept is based on guided slots and consists of a base plate, a modular attachment, two wings, and a lever.

The idea of this concept is that the wings should be mounted on the modular attachment on axles, in one mounting point on either side. The wings should allow for rotational movement, inward and outward. The two wings are connected in a mechanical system, with one spring on each pin, thus four springs, and connected by an additional component positioned in the middle of the two wings. A lever is attached to the modular attachment and positioned in a way that provides a "grip" around the component in the middle which connects the two wings. The lever enables the binding to be locked or open. If the lever is pushed down, it will apply pressure on the wings from underneath, which will open the wings. The user can insert their ski boot into the tech inserts. By pushing the lever upward the pins will be forced to snap into the tech inserts of the ski boot and lock its position, thus retaining the ski boot. The development is currently only an idea to a concept, the conceptualization was never finished and the solution has great potential for development in the future.

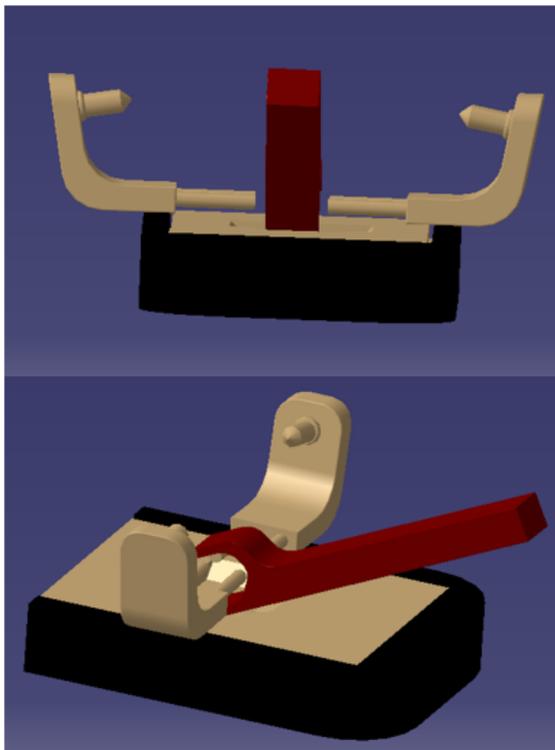


Figure 7.32: Conceptualization - tech toe

7.7 3D printing of final concept

Throughout the conceptualization process, the models generated in CAD have been iteratively evaluated through 3D printing. Design refinements related to measurements and tolerances have been made, to ensure an assembled prototype that enables attachment and detachment of modular parts. 3D printing is an iterative process, as a model may function correctly in CATIA but presents issues once 3D printed. This is primarily due to tight tolerances, as the 3D printer has limitations in the inherent accuracy of the printing. The 3D-printed components aid the development of the final concepts by visualizing incorrect measurements, as it is a physical model, instant feedback is obtained regarding any inaccuracies in dimensions. By using 3D printing as an approach for evaluation and validation, the refinement process can be accelerated whilst ensuring a final concept that meets the design and functionality requirements.

A GripWalk ski boot sole, according to the drawings of ISO23223, was created in CAD. The sole was 3D printed and successfully tested for its compatibility by physically testing the ski boot sole in different alpine and tech- bindings on the market. The ski boot sole was created to ensure that the prototype of the binding system is compatible with GripWalk ski boots, and thereby compatible with both alpine skiing and touring. In figure 7.33, the final heel concept is visualized with the GripWalk ski boot sole.



Figure 7.33: 3D-printed ski boot sole and alpine heel concept

The 3D printed alpine heel concept is presented in 7.33 and 7.34, and is the physical representation of the full assembly of the conceptual model in CATIA. The final heel concepts show the feasibility of many aspects regarding the functionality of the prototype, as stated in the requirement specification. This, even though it's a proof of concept rather than an actual prototype since components such as springs are missing. The proof of concept meets the requirements established in the requirement specification regarding: a few conversion steps attaching and detaching the modular parts, allowing for the removal of the whole heel piece, designed to enable adjustment to accommodate different lengths of ski boots, compatible with ISO23223, lies within the dimension of the heel-piece, allowing quick attachment and detachment of modular parts, and provides a low stack height. Regarding the safety and performance of the binding, the heel piece has been designed to mitigate the risk of exposed parts, enclose mechanical systems, and allow for adjustment of

DIN-setting and thereby the ability to retain and release the ski boot. The housing of the locking mechanism, the spring pin, is not fully developed. The housing is, however, designed with consideration to enclosing the mechanical components and to be able to access parts for maintenance or replacement in case of breakage.



Figure 7.34: 3D-printed heel concept

The 3D printed toe-piece followed the same process as the heel-piece, but due to a narrow time frame, the resources for design refinement were limited. The proof of concept consists of guided slots, the modular toe piece, a lever, an AFD plate, toe wings that allow for elastic travel, and mounting points for the AFD plate. The components are presented in the figures, 7.35 and 7.36. The modular toe piece provides attachment and detachment of the modular toe-piece, and the guided slots ensure alignment and precision. The guided slots were refined and in comparison with the heel-piece rectangular corners, the guided slot of the toe-piece has a rounded shape to reduce the risk of breakage caused by stress. The concept has not been refined to integrate the DIN spring connected to the toe wings that allow for elastic travel, but the different components have been printed to visualize that the external design and overall functionality have been considered. The refinement of the DIN housing and internal mechanics was not prioritized due to the complexity of integrating the spring-loaded mechanism and connecting components. Instead, the focus was located on visualizing the form and assembly of the modular toe-piece to ensure feasibility and alignment.

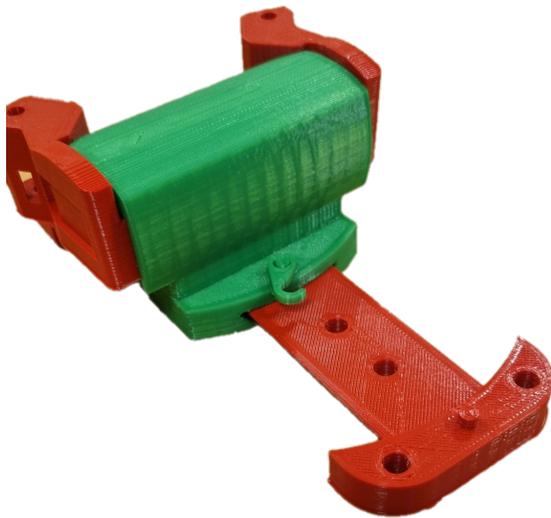


Figure 7.35: 3D printed base plate and modular toe attachment

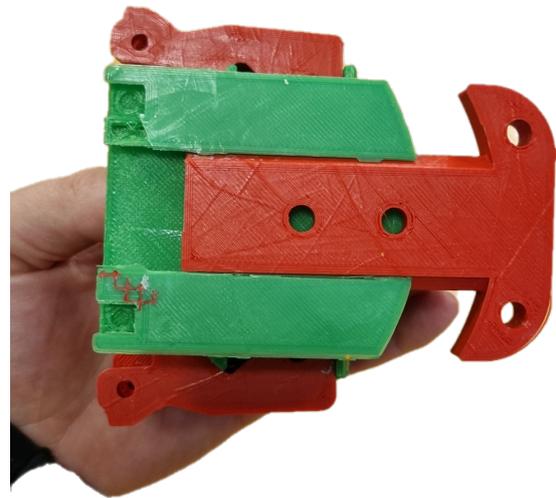


Figure 7.36: Attachment feature from underneath

The final proof of concept is presented in figure 7.37, 7.38, and 7.39. The proof of concept of the toe-piece meets the requirements and needs of the requirement specification regarding: a few conversion steps attaching and detaching the modular parts, allowing for easy attachment and detachment of modular parts, compatible with ISO23223 (with minor refinements required), lies within the dimension of the size of the toe-piece, and provides a low stack height. Future design refinements include optimizing different components. The housing of the DIN-spring requires additional development to integrate important components for retaining and releasing the ski boot, the width of the housing should be adjusted to allow the optimal fit of the Gripwalk ski boot. The current design relies on approximate measures, therefore minor adjustments of dimensions will enhance precision and compatibility. Additionally, the locking mechanism of the lever needs further design refinements, such as an extended surface which allows the user to unhook the lever using their thumb to attach and detach it from the base plate more efficiently.



Figure 7.37: Assembled toe with AFD plate



Figure 7.38: Locking mechanism



Figure 7.39: View of alpine toe piece from the side

8

Further recommendations

The development of the modular alpine binding system and the proof of concepts had its limitations, while also providing valuable insights regarding: the functionality, design, and feasibility of the modular binding system. Since the system developed is only a proof of concept several areas could be explored and improved to refine and enhance its potential for real-world application and testing. The following recommendations outline the key areas for future development:

8.1 Emphasis on Reverse Engineering

It is recommended to emphasize reverse engineering to gain further knowledge regarding the existing mechanical systems within the different binding parts. By analyzing and deconstructing existing products, detailed technical drawings can be produced as they are company secrets and not accessible. Technical drawings aid in greater accuracy of dimensions, measurements, design parameters, and improvement of the overall concept. Acquiring this knowledge provides a stronger foundation for design refinements, testing, and validating the modular binding system.

8.2 Refinement of the Design

To present a modular binding system with full functionality, design refinements of the proof of concept are necessary. Since critical components, such as springs, are missing, these should be integrated to improve performance and reliability and enable tests of the functionality of the prototype as well as real-world testing. The design can also be optimized for assembly to ensure the system is easy to manufacture, assemble, and maintain in case of breakage. To validate these improvements, design refinements and iterative testing are recommended.

8.3 Material research

To enhance the performance of the binding system material research is recommended. By conducting material research lightweight, durable, and sustainable materials can be explored. The focus of the material research should be to investigate materials that provide a balance between strength, weight reduction, durability, and sustainability to best accommodate different users' preferences while also aligning with global sustainability trends.

8.4 Production scalability

For the modular binding system to be able to transition from a prototype to an actual market offering, the scalability needs to be explored. By conducting a cost analysis, insight regarding manufacturability and production expenses can be obtained, thus the pricing of the actual modular binding system can be assessed. The supply chain options can also be explored to determine the feasibility of large-scale manufacturing and distribution. By implementing these analyses key cost factors affecting the price can be identified and considered to present a commercial product that targets the selected segment of customers.

8.5 Summary of recommendations

By conducting more research focusing on reverse engineering, design refinements, material selection, and exploring the scalability of the modular alpine binding system the proof of concept could in the future, potentially be commercialized. The recommendations enhance the technical feasibility of the product while also increasing its potential to successfully enter the specialized market of different alpine binding systems. In the figure, 8.1 the full assembly of the 3D printed proof of concept is illustrated.

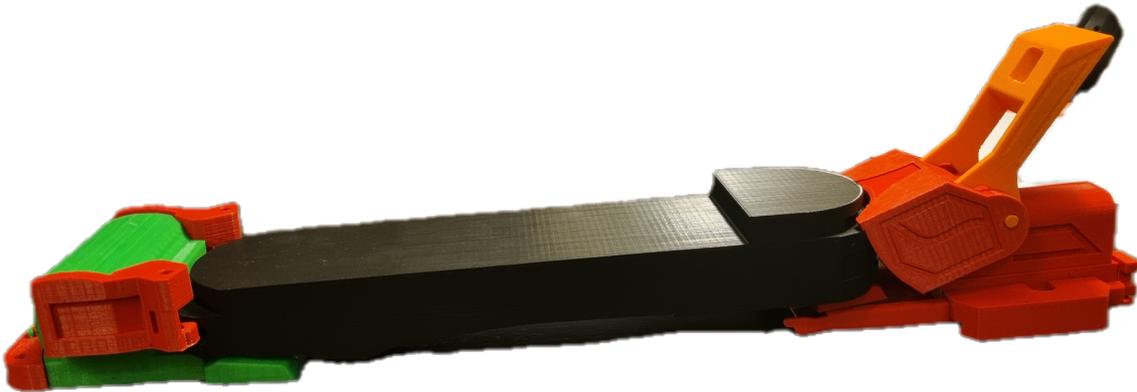


Figure 8.1: Final proof of concept, 3D printed

9

Discussion

This chapter discusses the findings of the study and analyzes how the results align with the research objectives. It also presents the strengths of the developed proof of concept, as well as addresses the key limitations of the project.

9.1 Evaluation of the modular binding system

The research successfully addressed the study's primary objective, the development of a modular alpine binding system for alpine skiing. Multiple options for attaching and detaching the modular pieces to the base plate of the binding have been investigated. There were four promising concepts for the attachment and detachment of the binding parts: Cylinder solution, Push button, Pin solution, and Door concept. All were further developed as digital models in CAD to investigate the feasibility of the concept's various constructions, those that were not deemed feasible were discarded. The Cylinder solution was discarded due to the complexity of the construction. The push button was further investigated and conceptualized, but later discarded as the means of detaching the modular part from the base plate was too complex and difficult to construct, additionally, the solution did not align with the customer's need as it contained protruding parts. The Door concept was a promising solution, and the function of using a ski pole to unlock and detach the binding strongly aligns with the customer's needs, to mitigate the number of conversion steps and facilitate quick transitions. It was discarded due to knowledge gaps, but it would be interesting to investigate it further as the solution itself seems very promising if it can be realized on a satisfactory level. The remaining concept which was further developed was the Pin solution in various constellations, push button, snap ramp, and spring pins. The main features of this concept are the guided slots and a pin or lever with a loaded spring. The final developed concept is an evolution of the previous concepts investigated since product development is an iterative process.

The development of a modular alpine binding system resulted in a CAD model and a functional prototype accommodating different user preferences and customer needs. From the market and competitor analysis, the current market offerings of hybrid binding systems compromise regarding performance, weight, robustness of construction, and cost. These aspects have a significant effect on the perceived attractiveness of the product for versatile skiers. The concept developed of a modular alpine binding system in this study addresses these limitations, enabling users to switch binding systems from alpine- to tech binding parts. Although the tech parts

of the system are not yet developed and only attempted, the developed proof of concept of the modular attachment and detachment features shows that the development of these parts is possible. Hence, the optimization of the overall performance of the binding system for different styles of skiing without compromising on safety and performance is feasible.

The final concept of the heel utilizes guided slots and an enclosed mechanical system of a loaded spring pin solution whilst the attachment of the toe-piece locks the binding into position with a lever. The attachment and detachment require minimal conversion steps, one for the attachment of the heel versus two for the toe. Both the heel and the toe require two steps for detaching the modular parts, unhook the pin versus unhook the lever followed by sliding the modular piece of the base plate. The attachment and detachment features make it possible for the user to switch between binding systems or skis and enable the user to remove the modular parts entirely. The final concept is designed and constructed to keep a low stack height, be compatible with ISO23223, and accommodate different boot sole lengths. This aligns with the information gathered from the interviews and observations during the study, as the customer requires a binding system that accommodates different styles of skiing, is easy to use with few conversion steps, ensures safety, is lightweight, and mitigates the risk of snow and ice build-up. Furthermore, the final proof of concept offers improved functionality over existing market offerings and strengthens the competitive advantage, as there are no solutions for the modularity of the heel-piece currently on the market.

Objective 1 - Conduct research related to modular binding systems by obtaining information about current offerings on the market and competitors

From the market analysis conducted in the study, gaps in the market were identified, especially the lack of hybrid bindings capable of meeting the demands of versatile skiers without compromising on performance, safety, durability, weight, and cost. The current offerings on the market highlight the challenges of creating a single binding system that can meet the same needs and requirements expected of a binding system specialized for different types of skiing. The findings of this study confirm this and emphasize the need and potential for a modular alpine binding system that can bridge this gap and solve the trade-off issues.

Objective 2 - Identify the customers and users

The second objective of this study was to identify customers and users, this was obtained by conducting in-depth interviews and user observations. The lead users are defined as advanced skiers dedicated to backcountry skiing and ski-touring they have a high level of skiing technique. The typical users are intermediate to advanced skiers dedicated to resort skiing and moderate ski-touring. Through the in-depth interviews, key user groups were identified and customer personas could be created based on the data provided from the interviews to enhance the different user needs and requirements to further aid and guide the design and construction process.

Objective 3 - Obtain information and understand the needs and requirements of the customers

In order to realize a solution that meets the customer's needs and requirements, these need to be identified. The utilization of the KJ analysis ensured that the different needs of the customers were systematically translated into design requirements. The insights generated were implemented in the design process of the modular system. The aspects that were taken into account during the design process were easy attachment and detachment of modular parts, adaptability for different boot sole lengths, compatibility with GripWalk boots (ISO23223), low stack height, and safety according to existing standards.

Objective 4 - Develop a CAD model and a functional prototype of a modular alpine binding system with exchangeable parts

By developing a CAD model and a functional prototype a concept can be physically evaluated regarding its functionality and feasibility. The model successfully presents a modular system with exchangeable parts, even though it's not fully developed and designed for optimization. The prototype is a conceptual prototype at this stage and represents a significant step toward realizing a modular alpine binding system, and the prototype confirms visually and conceptually that there is potential for the feasibility of the modular design. The prototype is not fully functional because detailed technical drawings are company secrets and the prototype relies on approximate dimensions and measurements gathered using a folding rule. Additionally, critical components such as springs are missing, therefore, the functionality of the prototype cannot be tested. Despite the limitations of the project, a conceptual prototype has been established and a solid foundation for further development as areas of refinement have been identified.

9.2 Strengths of the proof of concept

The modular alpine binding system enhances competitive advantage in the market offering a unique solution, allowing users to switch binding systems depending on preference. The most prominent design innovation is the modularity of the heel as no competitor on the market provides modularity of the heel piece. The modularity addresses key limitations in current hybrid bindings as it bridges the gap in the market providing a solution that accommodates different needs without compromising on performance. The modularity of the system and its exchangeable parts can contribute to a longer product life cycle and reduce waste, as the housing of the locking mechanisms is designed with accessibility in mind, to be able to open and exchange components. The modularity also reduces the need to replace an entire binding in case of breakage. Additionally, the modular design can aid in reducing the environmental footprint of skiing equipment as users don't need multiple setups. This in turn leads to reduced demand for raw materials, and thus also reduces waste during production. The modular system targets a wider segment of customers from aspirant skiers to advanced skiers. This as the threshold for upgrading equipment decreases when users don not have to buy an entire new set of skis or new bindings, but also as the versatile skiers are provided a binding system that targets specific

areas of skiing depending on preference.

9.3 Limitations

The limitations of this study regard the testing environment, the conceptualization of the prototype, material constraints, time constraints, and the scalability of production. Since the prototype is not fully functional, missing critical components, and constructed in 3D-printed PLA plastic it cannot be fully tested considering its functionality against the performance objectives. The 3D-printed prototype does not reflect the durability and performance expected of a final production model, as common materials used for construction identified in the analysis of current offerings are 7075 ALU, POM/Acetal (polymers), and stainless steel. Consequently, a limitation is that the prototype cannot be tested and evaluated in real-world scenarios and real-world skiing conditions. The study did not allocate resources to investigate the scalability of production as it was not within the project's scope. Further recommendations include investigating and conducting research regarding the supply chain, design for assembly, material selection, manufacturing processes, or costs associated with large-scale production. Since there is a knowledge gap regarding the assembly, manufacturing processes, material selection, and suppliers, it's not possible to calculate the production costs and the price per/unit for the modular system. The limited time frame of the study and the complexity of the product had a significant impact on the results. Product development is an iterative process, and resources must be allocated to design refinement, testing, and validating as these are critical aspects of a product's functionality to introduce a successful product in the market. Companies such as Rossignol, Salomon, and Cast had years to improve test, and validate their designs and before Salomon released the SSLab Shift binding, they were working on the project for two years. For future studies to be successful the limitations addressed need to be considered to validate and refine the function and design of the system.

9.4 Summary of the discussion

To summarize the findings, the discussion presents this study's significant contributions to the alpine skiing industry. The modular binding system provides a versatile and sustainable solution to the existing challenges of alpine, hybrid and tech bindings and bridges the gap in the market. Despite the research limitations, the findings provide a solid framework and foundation for future development, with valuable insight for the industry. Provided further refinement of design, testing, and validation, the modular alpine binding system has the potential to drive innovation and set a new standard in the field of skiing equipment and alpine binding systems.

10

Conclusion

In order to fulfill the goals of the thesis, the following questions are investigated through the study:

- **Which properties are of higher value for the customer regarding this kind of product?**

Through the in-depth interviews and the systematic analysis of the KJ method a customer needs list was created. The relative importance of the needs in the customer needs list created the foundation of the requirement specification where needs were translated into actionable data used in the conceptualization process of the final proof of concept. From the customer needs list it was evident that the customers expect the binding to work as other specialized products on the market regarding the release mechanisms and safety of the binding system. Other important aspects of higher value were performance, lightweight compared to other hybrid offerings, ease of use with few conversion steps, and compatibility with GripWalk ski boots. The specific needs included removing the whole heel piece for ski-touring, time-efficient transition between modes, and maintaining the performance of the binding for downhill skiing. By identifying the properties of higher value for the customer, key insights fundamental to the design process were gained.

- **Are there similar solutions on the market? In which way do they solve modularity?**

The market analysis conducted revealed that existing specialized offerings of alpine-, tech- and hybrid binding systems are a compromise for versatile skiers. Either multiple setups for different areas of applications are needed or a hybrid version that can accommodate various styles of skiing which does not meet all the expectations of the performance of such a binding. Hybrid bindings often compromise on performance, weight, or cost, and though one competitor offers full modularity of the toe-piece, no system currently offers modularity of the heel-piece. This highlights a significant gap in the market that the modular system in this study seeks to fill and a modular binding system can therefore bridge this gap.

- **In which environment do the users use the product? In what way are they using it?**

From the market analysis and in-depth interviews, user preferences and areas of applications were identified. Skiers use bindings in a variety of environments from carving turns in the resort to steep lines in the backcountry. Versatile skiers often have multiple setups of skis and binding systems to meet these needs. The modu-

lar system addresses these challenges by enabling users to exchange binding parts, switching between alpine and touring configurations on a single binding platform, thereby reducing the need for multiple setups.

- **How can the product be designed to be modular and allow for the assembly of exchangeable parts**

To design a modular binding system that allows for exchangeable parts the study developed a design incorporating guided slots, spring-loaded pins, and lever mechanisms to enable precise, secure, and easy attachment and detachment of modular parts. Additionally, the housing of the mechanical system of the spring-loaded pin is designed with accessibility in mind to enable maintenance in case of breakage. The prototype developed is a proof of concept, but it demonstrates the feasibility of modularity in binding systems and provides a solid foundation for further refinements and development.

One of the thesis goals was to address the critical gap within the alpine skiing industry: the absence of a binding system that does not compromise key abilities, such as performance and safety. A versatile system that meets the user's different needs depending on the skiing style and offers more sustainability than competitors' systems. The research and development process in this study successfully developed a conceptual prototype for a modular alpine binding system that meets the needs of a broad segment of customers and versatile skiers, while identifying and addressing the limitations of existing hybrid binding systems. Through the market analysis, significant compromises in the current capabilities of the binding systems were identified. By identifying the customer needs and translating them into requirements, the knowledge needed to guide the design process for the system was obtained. Although not fully functional or design-optimized, the final CAD model and conceptual prototype demonstrate the potential feasibility of modularity and the opportunity for technical innovation in the field. Which in turn can revolutionize the skiing experience.

The most prominent contribution of this study regards the innovation of the modular alpine heel, which is unique in the market, and the emphasis on sustainability provided by exchangeable components. This is by allowing the replacement of specific parts, rather than an entire binding system. The environmental impact is predicted to be smaller as the product's life cycle is extended and waste is reduced through its modularity. This aligns with the globally growing demand for sustainability in various industries.

The development of the final concept faced several limitations that affected the study and its results. Lack of knowledge related to technical drawings, reliance on approximate measurements, and time constraints that prevented design refinement, testing, and validation of the concept all had an impact on the final result. The absence of critical components, such as spring, prevents some prototype functions from being tested. The conceptual prototype does however lay a solid foundation for further refinement and development.

To conclude, the modular alpine binding system developed in this study provides a conceptual prototype that has the potential to innovate the technology of binding systems currently on the market without compromising on performance and safety. Further design refinement and validation of the concept could ensure that it meets the needs and demands of versatile skiers and promotes sustainability within the industry. It demonstrates that it is possible to bridge the gap in the hybrid binding market and is a significant step in enhancing the skiing experience.

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A

Appendices

A.1 Customer needs list

No	The binding system	Need	Imp.
1	The binding system	should withstand continuous usage (several times per day/week)	4
2	The binding system	should enable alpine skiing and ski touring	5
3	The binding system	should accommodate to different boot sole lengths	4
4	The binding system	should not be too expensive compared to similar options on the market	3
5	The binding system	should be functional in temperatures between -40 to 20 degrees	4
6	The binding system	should automatically release the skier's boot above a certain threshold value	5
7	The binding system	should fixate the skier's boot in various conditions and allow applied forces within a certain threshold	5
8	The binding system	should allow the user to manually release the skiboot from the binding	5
9	The binding system	should mitigate the risk of snow/ice build up on exposed and sensitive parts	3
10	The binding system	should be easy to use with few conversion steps	4
11	The binding system	should prevent injuries when managing the different conversion modes	4
12	The binding system	should allow for energy efficient conversion of modes	3
13	The binding system	should be esthetically appealing (compact/clean design)	2
14	The binding system	should allow for energy efficient walking options (heel raisors)	3
15	The binding system	should provide functioning locking mechanism for ski brakes and heel raises in walking mode	4
16	The binding system	should provide functioning locking mechanisms of ski brakes and heel raises in alpine mode	4
17	The binding system	should enable user to easily switch between heel raisor options	3
18	The binding system	should enable user to use tech inserts for ski touring and downhill skiing	5
19	The binding system	should enable alpine toeiece to allow for elasticity	5
20	The binding system	should enable alpine heelpiece to allow for elasticity	5
21	The binding system	should enable tech heelpiece to allow for elasticity	4
22	The binding system	should provide indicators of proper DIN-settings	5
23	The binding system	should provide indicators of proper mounting of modular parts	5
24	The binding system	should be light weight compared to similar options on the market	5
25	The binding system	should contain durable and reliable materials	5
26	The binding system	should withstand corrosion	5
27	The binding system	should not be affected functionally by exposure of UV-light	4
28	The binding system	should be designed and constructed to mitigate exposed parts (brakeage)	4
29	The binding system	should enable easy alignment and attachment of skiboot	5
30	The binding system	should enable easy attachment and detachment of modular binding parts	5
31	The binding system	should enable easy conversion of modes in cold temperatures	3
32	The binding system	is not bulky and heavy to store when not in use	2
33	The binding system	should mitigate the risk of injuries (steep angle)	3
34	The binding system	should allow for a low-weight binding system in walking mode (detach as many heel parts as possible)	5
35	The binding system	should be time efficient (5 min)	5
36	The binding system	should be designed to reduce the risk of forgetting parts in dangerous environments	3
37	The binding system	should be easy to use and understand	4
38	The binding system	should provide alpine performance downhill	5
39	The binding system	should allow for a smooth/follow through release mechanism	2
40	The binding system	should have a low stack height	3

Figure A.1: Customer needs list

A.2 Gantt Chart

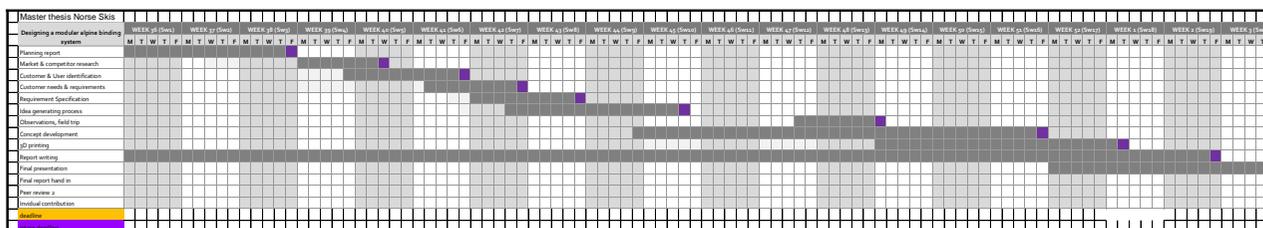


Figure A.2: The Gantt chart of the thesis

A.3 List of patents

A.3.1 Atk heel-piece

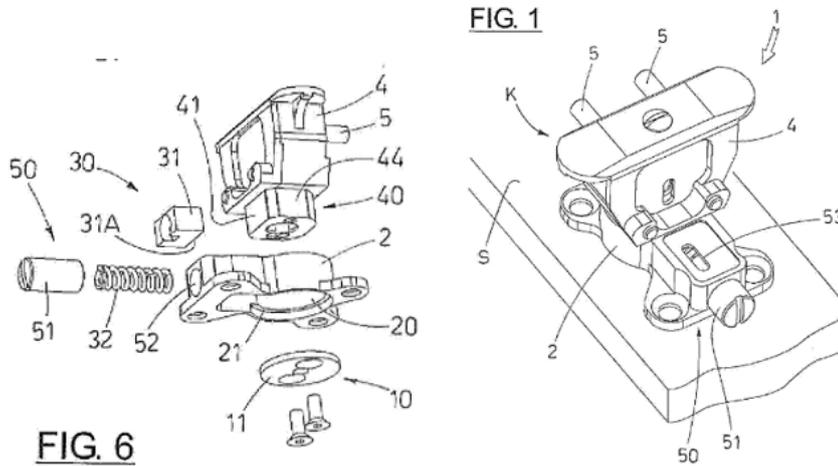


Figure A.3: Atk heel piece - Tech binding

Title: A jointed heel piece for an alpine ski binding

Applicants: ATK RACE SRL [IT]

Inventors: INDULTI GIOVANNI [IT]

Indulti Giovanni developed a patent for a jointed heel piece for an alpine ski binding, to keep the ski boot fixed in the binding while skiing and to allow the skier to ski-tour up the mountain allowing the ski boot to move in the z-axis (vertical) while walking. The heel piece consists of a base that is fixated to the ski and an upper block with attachment pins allowing the ski boot to be fixated while skiing. The block with the attachment pins can rotate around the vertical-axis joint with respect to the base plate. This rotation allows the heel piece to function in two ways, to hook and non-hook the skier's boot with the attachment pins. The rotating movement allows the heel piece to have multiple uses, for skiing downhill and ski-touring up the mountain. In front of the heel piece, there is a block with a window that allows the user to set the resistance of the rotating movement of the heel piece according to the weight of the skier, this is done by tightening a screw. The heel piece will keep the ski boot hooked as long as the stresses are within a predetermined value, once this value is exceeded the ski boot will unhook from the heel piece.

The patent provides a lightweight heel piece, which is a strength when touring mountains. The binding unhooks the skier when a predetermined range of stress is exceeded. A weakness of this patent could be that the pins might not unhook the skier properly when exposed to stress, or the pins might be fragile and break due to them being exposed when not in use, for instance, while traveling etc. (It might not be an issue, but could be)

A.3.2 Atk toe-piece

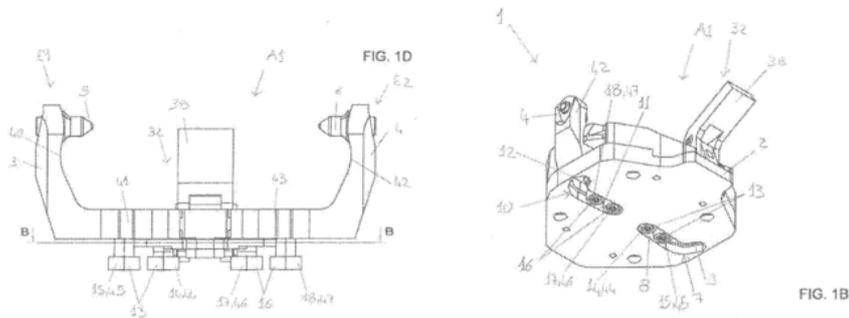


Figure A.4: Atk toe piece - Tech binding

Title: TOE-PIECE OF A SKI BINDING

Applicants: ATK RACE SRL [IT]

Inventors: INDULTI DAVIDE [IT]

This patent is a solution of a toe-piece to a ski binding. The binding consists of a base that can be mounted to the skis, and two jaws with a pin attached to it for inserting the ski boot. The binding also has a contact element to be able to unhook the ski boot from the binding. The toe-piece is designed with guides, for sliding operations along the direction of the ski and away from the longitudinal axis. When force is applied downward on the toe-piece, the jaws, and pins, which are at a predetermined distance from each other, will slide inwards (away from the longitudinal axis) and fixate the ski boot to the binding.

To unhook the binding, forces downwards in the z-axis (vertical) are applied to the contact element which is connected to the sliding elements and the jaws. When force is applied to the contact element it will in turn force the sliding operations of the jaws so that they open and return to their predetermined distance from each other allowing the ski boot to unhook from the bindings. When too much force is applied to the ski boot in a hooked position while skiing, like a twisting movement of the ski boot or when the ski boot transmits to the toe-piece a transversal force directed towards the outside, a force greater than the threshold value, the binding will unhook the ski boot.

The strength of this solution is that it is lightweight, and specially designed for ski-touring. It's easy to attach the boot to the pins and due to the pins, the movement of walking is enabled. It's a strength that the jaws can unhook independently as they are not directly connected to each other but independently connected to the system. This is also a risk as the ski boot might get unhooked from one pin but not the other which might cause injuries as the ski boot might not release properly. Since there are not volumes of materials used in this toe-piece to make it lightweight an issue could be that it's more exposed to ice and snow and also the guides might get worn out during use.

A.3.3 Salomon toe-piece

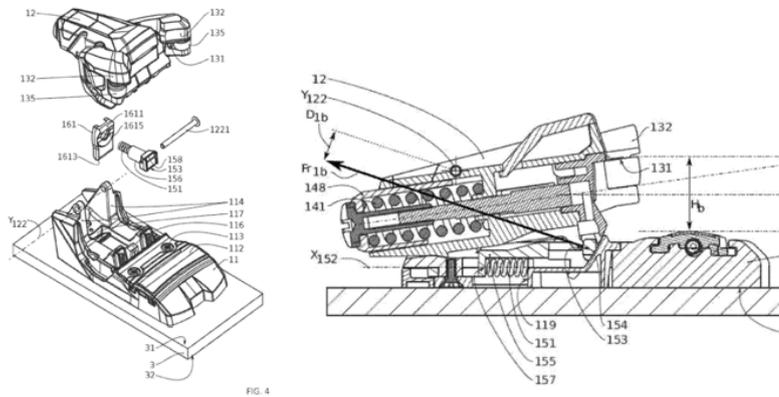


Figure A.5: Salomon toe piece - Alpine binding

Title: Binding toe-piece for gliding board

Applicants: SALOMON SAS [FR]

Inventors: SOLDAN DANIEL [FR]

The patented solution from Salomon SAS is related to ski boot bindings on a gliding board (SKI) and it's stated that the invention has an advantageous application in the skiing field. The ski boot is inserted into the toe-piece and a heel-piece which are equipped with stopping means that block displacement of the boot in longitudinal, vertical, and transversal directions in relation to the gliding board (SKI). The combined actions of the stopping means will fixate the boot to the ski binding when engaged in the binding. The toe-piece is equipped with "wings" that independently rotate vertically to fit ski boots with different dimensions and tolerances when manufactured. The wings can also move/rotate vertically when a force larger than the threshold is applied to the ski boot which will release the ski boot from the binding. A movable surface (number 112) enables the ski boot to move vertically and reduces the friction otherwise obtained when the ski boot is in contact with the surface of the ski binding. By reducing the friction the risk of injuries when the boot is released from the binding is lower as the ski boot will release properly without getting stuck on the surface of the binding. The movable body can also be adapted to a heel-piece of a binding. The heel-piece fixates and releases the ski boot in the z-axis, if the predetermined value of the threshold is passed, the binding will release the ski boot. The heel piece of the binding is also equipped with a moveable body in the longitudinal direction. The function is the same as in the toe-piece, to reduce the potential friction of the boot against the surface of the binding.

The strengths of this patent are the movable bodies as they reduce the friction when the binding releases which decreases the possibility of injuries correlated to the lower legs of the skier. Simultaneously the movable body also enables small displacements

of the ski boot which could also protect the skier from unnecessary release of the ski boot which can cause injuries.

A.3.4 Salomon braking device

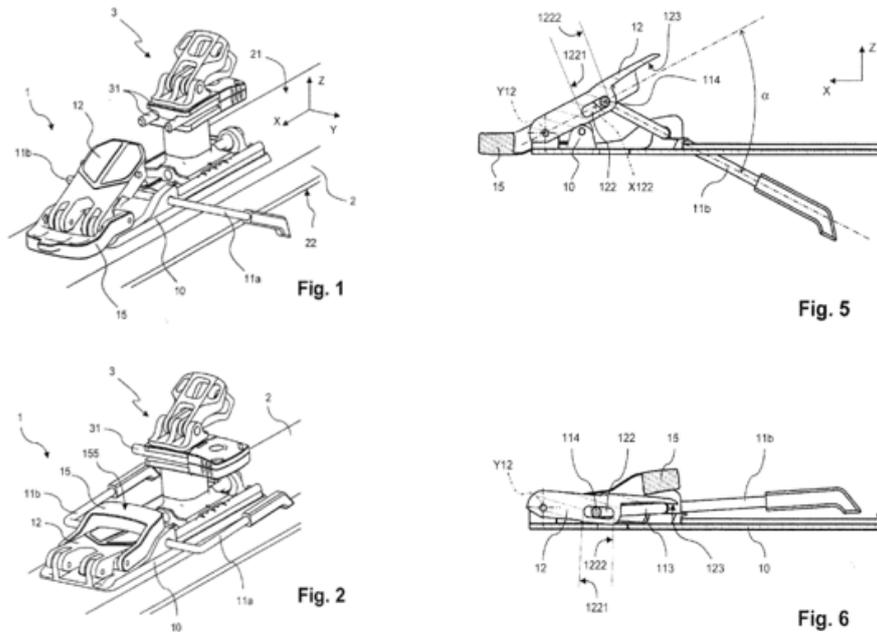


Figure A.6: Salomon braking device - Ski stopper

Title: BRAKING DEVICE FOR A BINDING FOR A GLIDING BOARD

Applicants: SALOMON SAS [FR]

Inventors: LAPIERRE STÉPHANE [FR]; DAMIANI LAURENT [FR]; CONVERT FRANÇOIS [FR]

The patented solution is a braking device for a ski binding, it is suitable for alpine skiing and ski-touring. The breaks are activated when the skier boots are released from the binding, and locked in a position that will not disturb the skier whilst skiing, thus when the ski boot is engaged in the ski binding the brakes will be in a position when they do not interfere with the gliding movement of the skis. The breaks consist of lateral breaking arms pivoting about an axis transverse to the ski. Elastic mechanisms are activating or deactivate the braking operation of the arms. While ski-touring a device is provided to keep the breaks in a locked position so as not to interfere with the skier while walking. When a force is applied to the body that holds the breaking arms they will be locked in position, when this force is removed the breaks will be activated. Therefore, this solution uses a device that locks around the vertical axle of the arms and applies a force on the body that locks the arms into position so the skier can walk without the brake activated.

The advantage of this solution is that the breaks can be activated and deactivated depending on use and are easy to operate for the user. So, while skiing the load from

the ski boot is applied to the body that holds the brake arms, since this distance is predetermined the brakes will be constantly aligned with the ski. When in walking mode the user pushes down a lever so that the arms are locked in a position where they can't move. When releasing the lever, the brake arms can automatically pivot back into the brake position. Potential disadvantages can be that the mechanics of the solution malfunction causing the lever to be fixated in a locked position, which in turn will make the brakes useless as they will not work properly.

A.3.5 Rossignol heel piece

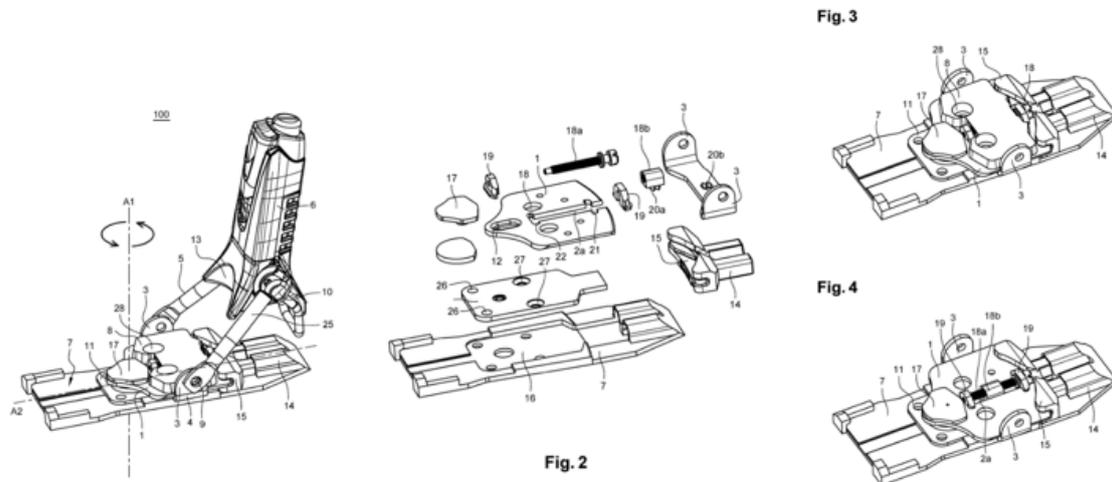


Figure A.7: Rossignol rear element of safety ski binding
- Heel piece

Title: REAR ELEMENT OF A SAFETY SKI BINDING AND SKI PROVIDED WITH SUCH A BINDING

Applicants: ROSSIGNOL SA [FR]

Inventors: GABOYER CÉDRIC [FR]; GIROT PIERRE [FR]

The solution provides a mounting element for a heel piece of a ski binding, allowing the heel piece to rotate around the z-axis. The element consists of several plates, that are assembled, and then mounted to the heel piece, which is then mounted directly to the ski. The body allows the pivoting movement of the heel piece by rotating around a small axle and in guided slots. The pivoting heel works similarly to other bindings and will release the skier's boot when the predetermined force applied causes too much stress and passes the threshold value. The clamp, which is a holding mechanism, fixates the back of the ski boot to the binding. The screw in the bottom of the body or base plate allows the user to set a distance and resistance which affects how easily the binding will release the ski boot and which size it will accommodate. The screw is also a structural element which aids in holding the construction together. In the clamp there is also a screw that has similar functionality, setting the tension of the clamp and how much stress it will take to release the ski

boot from the binding. The arms (nr 25) are connected to the heel piece and can rotate around a central point (pivot) when the skier twists their foot or falls. But the arms are also under tension from a spring mechanism. The arms are kept in place when skiing regularly but can also pivot when a certain level of force is applied, the spring ensures that the arms return to the original position once the force is removed.

The advantage of this solution is that unnecessary releases of the ski boot can be avoided as the pivoting movement allows certain displacement of the ski boot but also brings it back into position unless the threshold value is passed. The solution might better withstand unexpected forces impacting the ski boot from the sides.

A.3.6 Marker toe piece

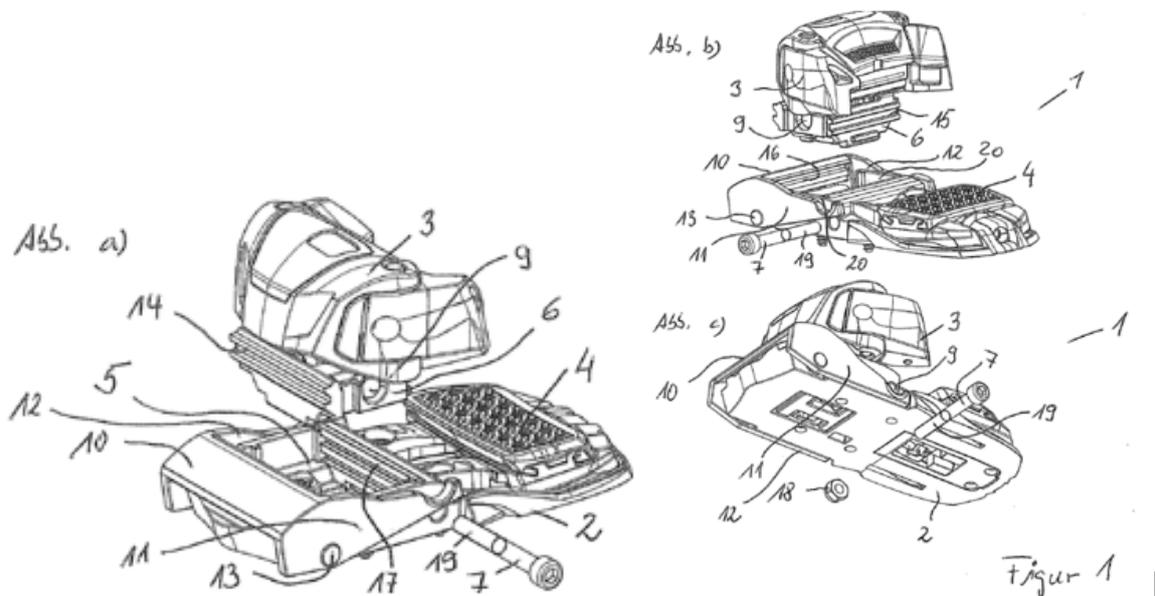


Figure A.8: Marker height-adjustable ski boot holder -
Toe piece

Title: Höhenverstellbarer Skischuhhalter

Applicants: MARKER Deutschland GmbH

Inventors: Bader Manfred; Hanz Holzinger, Michael Mangold

The patent is a solution for a toe piece of an alpine binding. It consists of a housing, the main structure to hold the ski boot at the front. The housing includes various mechanisms to fixate the boot while skiing and allow release during a fall. The housing also consists of two jaws on either side, responsible for gripping the sides of the ski boot toe. They apply pressure on the boot to keep it locked in the binding, they are spring-loaded to provide locking and releasing functionalities if the predefined forces on the jaws are exceeded. The housing is mounted on a base

plate attached to the ski. The baseplate provides a mounting point for the entire toepiece to ensure alignment of the binding with the ski. The solution contains elastic components (such as springs) that are integrated in the binding to allow for slight movements of the ski boot within the binding while skiing, the functionality of those is to absorb shocks and ensure that the ski boot stays locked in the binding despite minor impacts. The spring also regulates the tension of the toe jaws and influences when the binding releases the boot.

The jaws are held in place by a spring-load mechanism, which exerts a constant force on the ski boot. When the skiing forces exceed the preset value, the springs compress or stretch, which allows the jaws to open and release the boot.

The toe piece has a height adjustment feature to accommodate to different sole types, the height adjustments are achieved by moving the toepiece vertically, ensuring a secure binding for different sole types. A sliding mechanism guided along slanted tracks adjusts the height using a set screw.

The spring-loaded jaws of this concept are an advantage as they provide the system with elasticity, which absorbs shocks and allows for slight movement of the boot. The more complex the system the more additional parts are needed, and therefore can add weight to the binding. The binding is supposed to accommodate both alpine and touring soles as the user can set different height settings, this is possible as the toe piece is designed to pivot in walking mode, allowing the skier to lift the heel for walking motion, by front and rear holding elements, which engage differently depending on if the skier is in alpine or touring mode. Disadvantages of this patent could be that the height adjustment and pivoting mechanism could lead to less rigid construction when in alpine mode as it might allow for gaps and looseness of the toe-piece.

A.3.7 Other relevant patents

This section presents other patented solutions that can be relevant for the development of a modular alpine binding system.

A.3.7.1 Tarkett floor

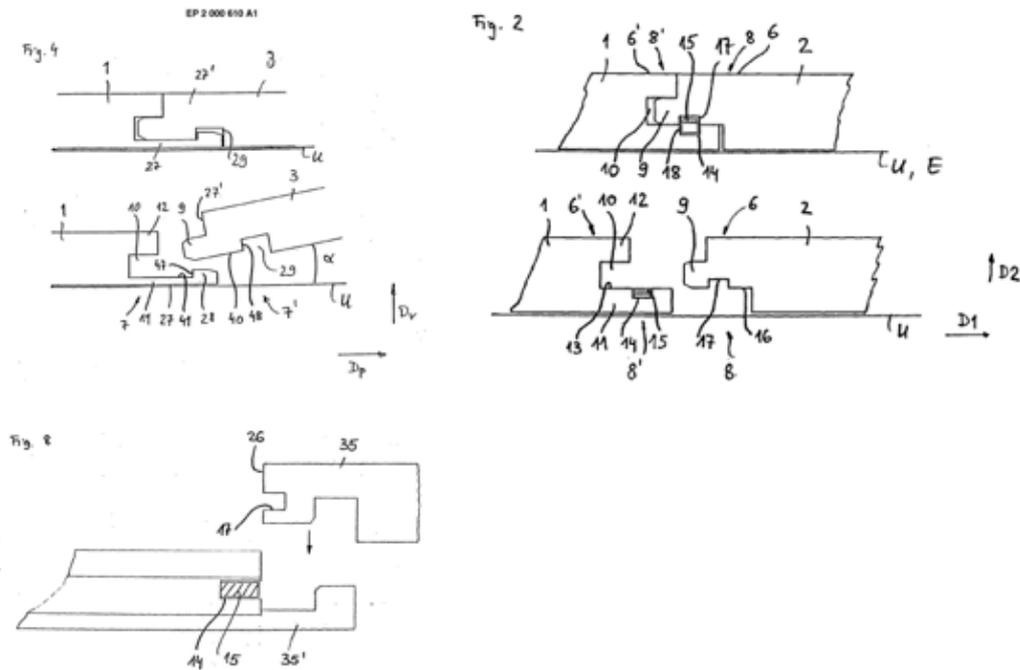


Figure A.9: Tarkett floor - Multiple locking mechanism

Title: Set of tabular panels with moveable locking element

Applicants: AGEPAN TARKETT LAMINATE PARK G [DE]

Inventors: EISERMANN RALF [DE]; LEWARK MATTHIAS [DE]

The patent regards the assembly of floor planks without using adhesives and glue to fixate planks to the floor. The technique allows less experienced people to lay their floor without hiring floor layers as it is easy to use. The solution consists of floor panels with different side profiles. The floor panels have two different profiles on the respective long side, and two different profiles on the respective short side of the panel. One of the sides is shaped like a hook, which matches the profile of the other side of the floor panel which is constructed to fit the hook profile. The different profiles are mounted together provided a specific angle when mounting, the angle when inserted into the profile causes a bending force in the panel that will enable the profile to snap together in a locking groove. The solution is interesting as it's a means of locking the floor panels in position from different directions, which could be implemented in the project for developing ski bindings.

A.3.7.2 Burton split board

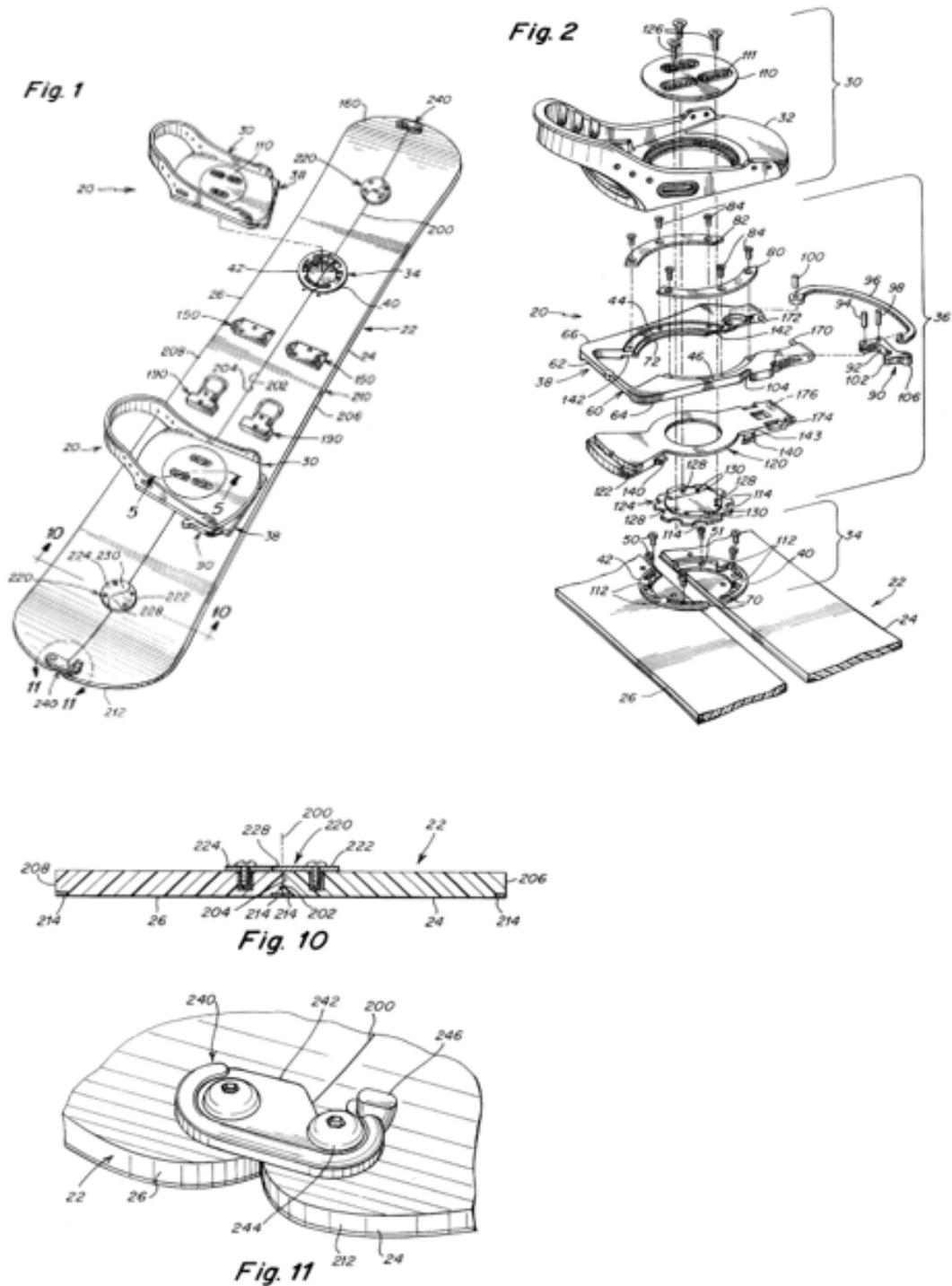


Figure A.10: Burton - split board binding

Title: Binding mechanism for a touring snowboard

Applicants: BURTON CORP [US]

Inventors: MARAVETZ PAUL T [US]

The patented solution is a binding mechanism to securely couple board sections of a touring snowboard. It consists of a first interface on the first and second board section and a second interface mounted to the base. For coupling the board together, a clamp is mounted on the first or second interface and can be moved between a closed configuration and an open configuration, which determines if the interfaces engage with each other or release each other. The concept consists of a baseplate, which hold the entire binding together and connects the snowboard using discs, which also allows the user to adjust the stance. The heel cup and heel back provide support for the snowboarder and lock the heel in place. The baseplate offers pivoting movement of the heel back to allow different riding positions but also to support proper boot alignment. The baseplate is mounted on the snowboard whilst the other plates are integrated with the clamp and can be removed from the baseplate, when the clamp is closed, the binding is fixed in the baseplate to allow snowboarding and when the user wants to configure to walking mode, they release the clamp and attach the binding with the clamp to the ascension mode interface (nr 150). When closing the clamp, the binding will be fixed on the ascension mode interface allowing the snowboarder to tour up the mountain. In snowboard mode the clamps aid in closing the gap of the half circles of the baseplates so that the binding is fixed to the board, but also so that the interfaces of the sides of the snowboard are aligned. The snowboard is also equipped with a two-plate section (fig 11) that is mounted on each section of the board. The first plate has a section that overlies the other section of the board, and the second plate has a section that overlies the opposite section of the board. A latch is provided on each plate which will aid the snowboarder to position the board adjacent to each other before tightening the clamp of the binding. The latch also aids in limiting the vertical movement of the board sections.

The solution is interesting since it uses a clamp to fixate the binding to the snowboard, and allows for touring and snowboarding. The clamp system might apply to an alpine binding system, and the latch/lever to secure the board from vertical movement can be implemented as a solution for fixation in an alpine binding, therefore this patent is relevant to the study.

A.3.7.3 Bike pedal - locking mechanism

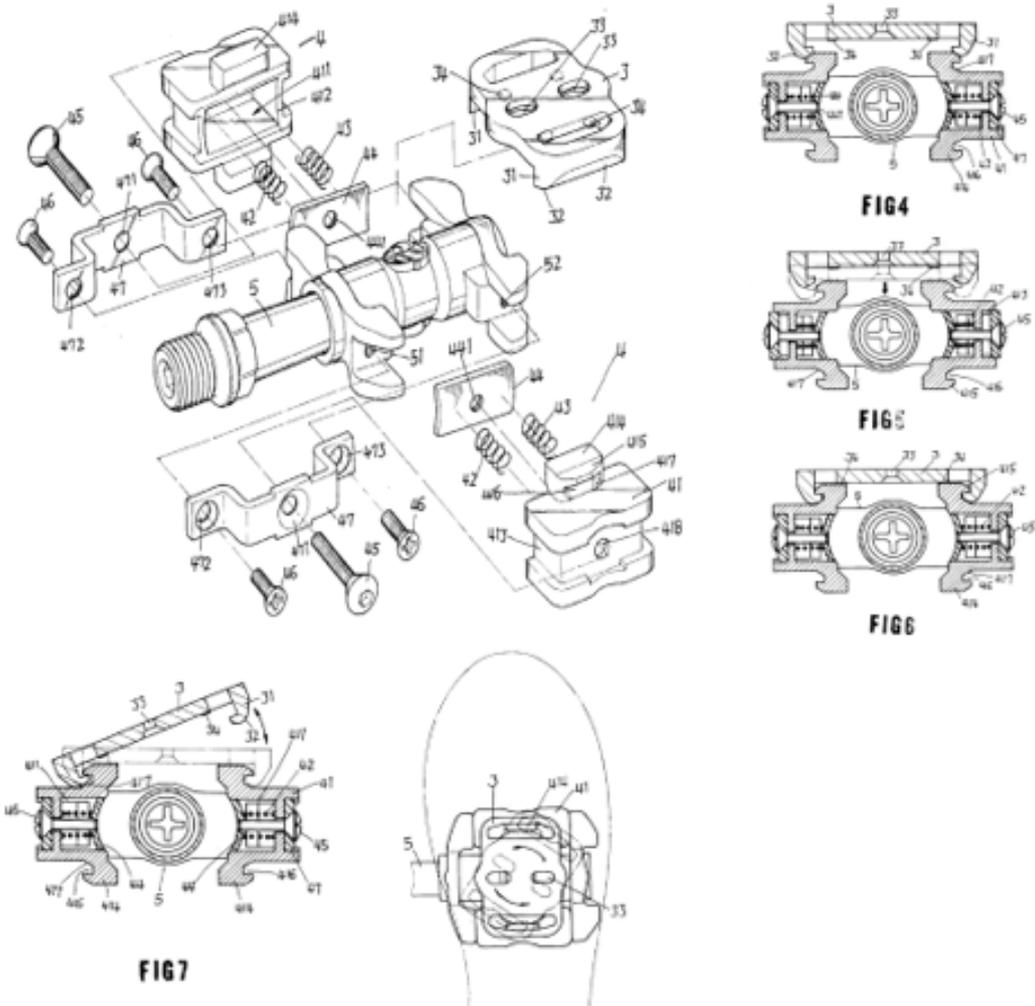


Figure A.11: Bike pedal - locking mechanism

Title: Snap-in bicycle pedal

Applicants: OURWAY ENGINEERING Co Ltd

Inventors: Hsiu-Wei Ho

The solution is a concept for snap-fitting a shoe used in biking to a bike pedal. The patent is an invention of an easy snap-in mechanism that strives to minimize the complexity and parts of such a solution.

Figure 1, is an example of the present solution, with springs, screws, and interfaces and profiles. The solution illustrated in figure 4-7 is designed so that the user pushes down the interface attached to the shoe vertically on the interface of the pedal, the inclined profile of the interface of the shoe matches the inclined profile of the interface of the pedal. This will make the surfaces glide on one another and snap together, allowing the shoe and the foot of the biker to be fixed to the pedal. An

alternative way of snapping the shoe to the pedal is illustrated in figure 7, showing a tilted interface of the shoe which is inserted into the slot of the pedal interface and then tilted into the vertical position, the different interfaces then glide on each other as described before and then snaps together. This is possible since the interfaces of the pedals are connected to bodies with springs that will be forced to move inwards in the direction of the center of the pedal and thereafter snap into position when the force of the movement inwards decreases.

The shoe is fixed to the pedal since the springs are loaded during fixation and relaxed when detached. To detach from the pedal, the user twists their foot as illustrated in the last picture.

The advantage of this solution is that the springs are not exposed to the outer environment like dust, sand, etc. Another advantage is that the user can attach their shoe to the pedal in more ways than one, making it easier to understand and use.

If implemented in an alpine binding system a solution must be developed to lock the twisting movement as this will release the binding and be a direct issue to the safety of the skier.

A.3.7.4 Coupling - locking mechanism

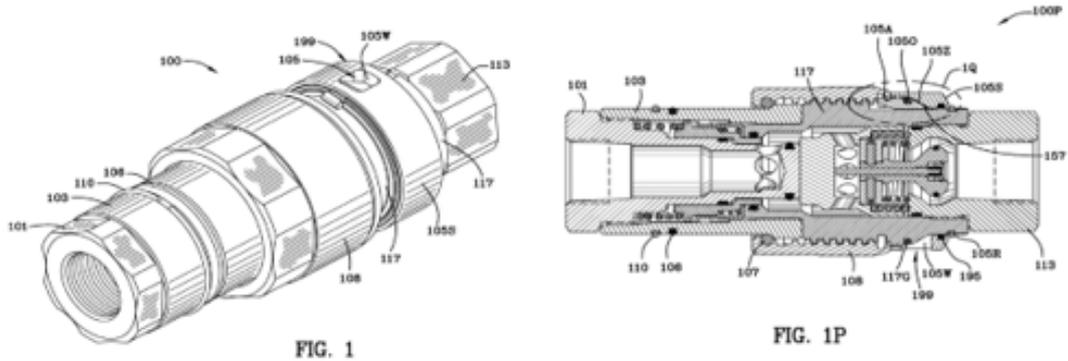


Figure A.12: Coupling - locking mechanism

Title: Coupling lock-mechanism

Applicants: NICK LEONARD J [US]; ZEIBER DENNIS [US]; SNAP TITE TECH INC [US]

Inventors: NICK LEONARD J [US]; ZEIBER DENNIS [US]

This patent describes a coupling lock mechanism that uses threaded couplings to prevent them from disconnecting due to vibrations or unwanted loosening. It consists of male and female coupling halves; the male part has external threads, and the female has internal threads. The parts are screwed together to secure the connection. The patent also describes a locking-sleeve that covers the exterior of the male, and female parts to prevent them from unscrewing. The male body and the locking lever include O-rings, to ensure that the lever stays securely in place and to create resistance to rotation of the male body. The locking lever engages with the locking sleeve, pivots, and latches into place to lock the sleeve, preventing the coupling from being unscrewed. To reach the lever there is a window in the locking sleeve, this window allows the user to rotate the lever to lock or unlock the coupling. The advantage of this solution is that it can handle vibration and is easy for the user to navigate and use.

A.4 Requirement specification

Chalmers		Document Type	Requirement Specification	Legend: D=Demand, W=Wish		
Project		Modular alpine binding system				
		Created: 2024-10-17				
		Modified:				
Criteria	Target Value	D/W	Rank	Verification method	Reference	
1. Functions						
Protect mechanical systems	< 1 mm gap	D		Test of prototype	Customer	
Keep mechanical systems in place	< 0.5 cm	D		Test of prototype	Customer	
Attach alpine/tech parts to base plate	< 5 min	D		User test	Customer	
Detach alpine/tech parts from base plate	< 5 min	D		User test	Customer	
Robust attachment of binding parts	2 mm	D		Test gap distance	Customer	
Fixate ski boot		D		Prototype and User test	Customer	
Attach ski crampons	< 2 min	D		User test	Customer	
Detach ski crampons	< 1 min	D		User test	Customer	
Enable activation/deactivation of ski brakes	< 30 seconds	D		User test	Customer	
Allow different heights of ski raisers	< 30 second	D		User test	Customer	
Enable automatic release of ski boot heel (alpine/touring)	DIN	D		Simulation	Developer	
Enable manual release of ski boot (alpine/touring)	DIN	D		Simulation	Developer	
Enable adjustment of length of ski boot	3 cm	D		Test prototype	Developer	
Allow for the removal of the whole heelpiece	< 5 min	D		Test of prototype	Developer	
Compatible with GripWalk skiboos	ISO 23223	D		Test of prototype	Developer	
2. Performance						
Work for continuous use	< 3 years	D		Simulation	Norse	
Work for continuous use	< 5-10 years	W	3	Simulation	Developer	
Withstand vertical forces	DIN, elastic travel	D		Simulation	Developer	
Withstand lateral forces	DIN	D		Simulation	Developer	
Withstand rotational forces	DIN	D		Simulation	Developer	
3. Environment						
Temperature	<-30°C	D		Material selection	Developer	
Temperature	20°C	D		Material selection	Developer	
Water resistance	IP4	D		Material selection	Developer	
Water resistance	IP45	W	5	Material selection	Developer	
4. Life-span						
Life-span	5 years	W	3	Simulation and Test	Customer	
	10 years	W	3	Simulation and Test	Customer	
6. Size						
Size heel-piece						
Height of housing	< 5 cm	D		Measure test	Developer	
Width with baseplate	< 10 cm	D		Measure test	Developer	
Length	< 18 cm	D		Measure test	Developer	
Size toe-piece						
Height of housing	< 5 cm	D		Measure test	Developer	
Width with baseplate	< 10 cm	D		Measure test	Developer	
Length	< 10 cm	D		Measure test	Developer	
8. Misc						
Weight	1730 g/pair	D		Weight test	Customer	
Weight	< 1730 g/pair	W	4		Customer	
7. Ergonomics						
Provides indicators of proper DIN settings	Visual	D		User test	Customer	
Provide indicators of proper attachment/detachment	Sound/Visuals	D		User test	Customer	
Allow easy alignment of ski boot with tech inserts	Optimise contact surfaces	D		User test	Customer	
Quick attachment/detachment of modular parts	< 5 min	D		User test	Customer	
Allow for few conversion steps of modular parts	< 3 conversion steps	W	4	User test	Customer	
Provide low stack height	< 2 cm	W	3	User test	Customer	
Designed to mitigate exposed parts	Reduce snow/ice build up	W	3	User test	Customer	
8. Safety						
Safe usage converting between different modes		D		User test/Simulation	Customer	
Automatic release of ski boot	DIN	D		Simulation	Developer	
9. Aesthetics and surface finish						
Smooth edges	min 0.3 radii	W	3	User test	Customer	
Create appeal	Perceived as appealing	W	3	User test	Customer	
10. Material						
UV-resistant	Material selection	D				
Durable material	Resistant to wear and tear	D		Walter test	Norse	
Sustainable Materials	50% Recyclable	W	3	Data analysis	Norse	
11. Cost						
Price	Maximum price 9000 (SEK)	D		Calculation verification	Product developer	
Price	Maximum price 7500 (SEK)	W	4	Calculation verification	Product developer	
12. Reuse and recycle						
Standardized parts	springs, screws	D		Disassemble test	User	
Design for modularity	ski brakes, heel raisers	W	4	Disassemble test	User	
13. Maintenance						
Provide spare parts		W	2	Changing test	Norse	

Figure A.13: The Requirement Specification

A.5 Function tree - Bullet points of sub-functions

1. Enable alpine skiing

- Secure boot (toe and heel)
- Release mechanism for safety
- Fixate and release the ski boot
- Compatible with GripWalk ski boots
- Engage ski brakes in case of release
 - Lock brakes when the ski boot is engaged
 - Activate ski brakes when the boot is released
 - Ensure sufficient breaking force/friction to stop the ski

2. Enable touring and tech mode

- Secure boot with tech inserts (toe)
- Secure boot with pins (heel)
- Enable rotation of heel for touring mode
- Locking mechanism for heel (descending)
- Provide heel raisers (touring angles)
- Enable attachment of ski crampons
- Compatible with GripWalk ski boots
- Fixate ski brake for touring
 - Mechanism to hold the brakes in a fixed position for touring
 - Easy to rearrange mechanism to activate the brakes during descent

3. Enable modularity for different parts

- Modular toe
 - Switch between alpine toe and tech toe
 - Provide quick attachment and detachment of different parts
 - Reliable and stable attachment to the ski
- Modular heel
 - Switch between alpine heel and tech heel
 - Provide quick attachment and detachment of different parts
 - Reliable and stable attachment to the ski
- Modular heel raisers
 - Enable attachment and detachment of heel raisers depending on different ski modes
 - Allow for switching between different raiser heights
 - Lock raisers in place during use
- Modular ski crampons
 - Enable easy attachment and detachment of crampons for touring mode
 - Ensure the stability of ski crampons during use
- Modular ski brake
 - Provide ski brakes with different widths for various sizes of skis
 - Ensure reliable locking and deactivating of ski brakes for touring

4. Provide adaptability

- Adjust boot sole length
 - Adjust the heel piece position to accommodate different boot lengths
 - Visual feedback for correct adjustment of sole length
- DIN-adjustment
 - Adjust the release force of alpine parts (toe and heel)
 - Indication of DIN setting
- Touring lock mechanisms
 - Lock tech toe for tour mode
 - Prevent unwanted release of ski boots during tour mode
 - Lock ski brakes during tour mode

5. Ensure safety

- Lightweight and durable materials
- Weather-resistant coatings, materials (snow, ice, extreme temperature)
- Enable release of ski boot during skiing mode
 - Test load limits of the binding system to prevent breakage
 - Automatic activation of ski brake when the ski boot is released

6. Enable user preferences

- Quick attachment and detachment of alpine and tech parts
 - Easy-to-use mechanism for switching between ski modes
 - Tool-less attachment and detachment of toe and heel pieces
 - Enable heel raiser adjustments during touring
 - Quick attachment and detachment of ski crampons

7. Comfort and usability

- Ergonomic design of mode-adjusting features
 - Easy to use without tools (hands)
 - Designed considering operating with gloves in cold conditions
- Minimize weight
 - Optimize components for lightweight without compromising strength, durability, and performance
- Intuitive use
 - Visual feedback when switching between modes
 - Feedback of correct attachment of ski boot enabled by sound

A.6 Customer personas

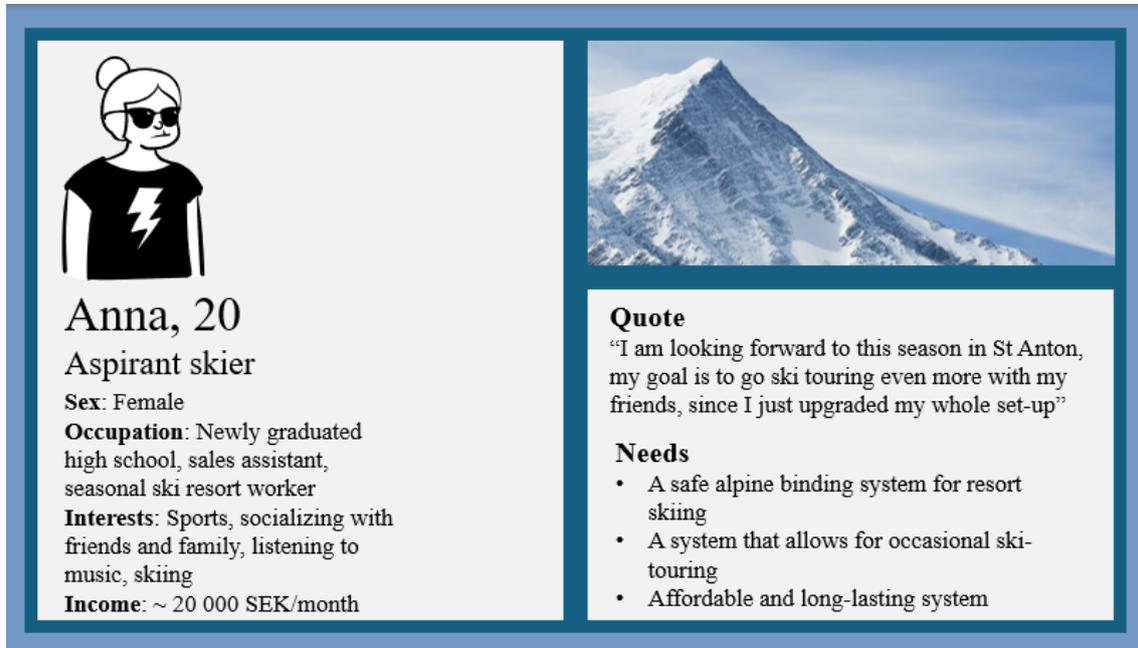


Figure A.14: Customer persona 1 - Anna

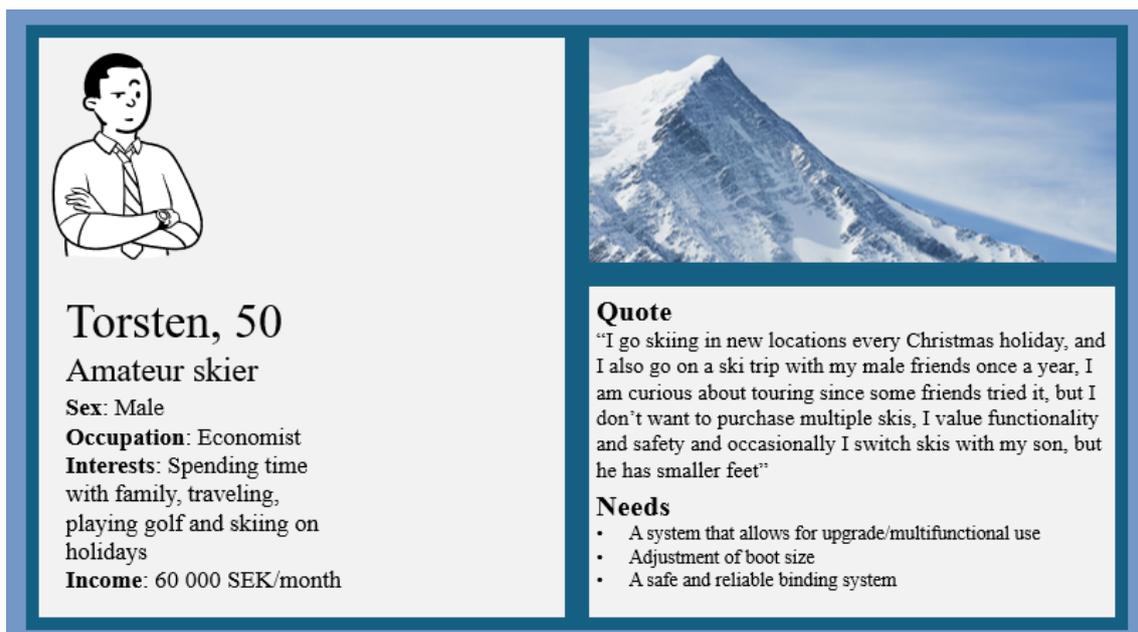


Figure A.15: Customer persona 2 - Torsten

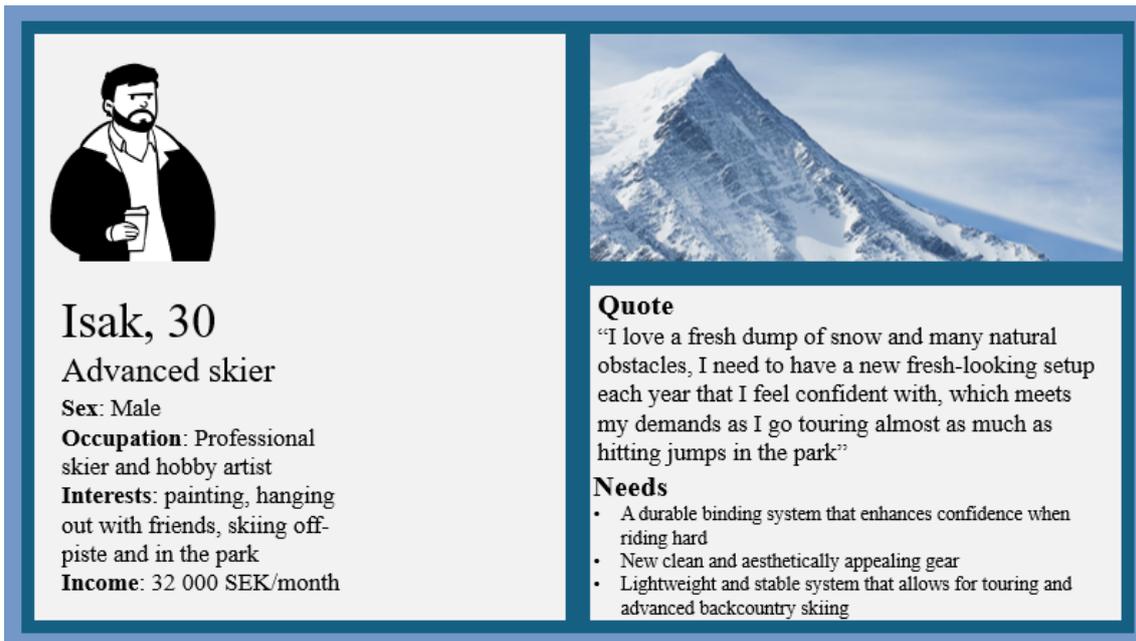


Figure A.16: Customer persona 3 - Isak