User Centered Concept Development of a Hybrid Ski Binding

Authors: Anton Ohlslöf & Hampus Ågren
Department of Industrial and Material Science (IMS)
Chalmers University of Technology
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by ANTON OHLSLÖF & HAMPUS ÅGREN

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Department of Industrial and Material Science
Chalmers University of Technology
SE-412 96 Göteborg, Sweden
Telephone + 46 (0)31-772 1000

Cover: *A render of the proposed binding concept in a natural environment. It is further described in chapter 2.*

Department of Industrial and Material Science
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Abstract

The aim of this study was to understand the strength and weaknesses of current hybrid ski bindings, based on user centered research and benchmarking. Further on, to develop a high performance binding concept, based on the identified market gaps and user insights. After the conducted research a thorough market analysis and user segmentation could be presented. These results were further synthesized into a product statement explaining what the design concept set out to achieve:

The product should be a trustworthy and robust solution that provides the user with full alpine performance and touring possibilities. Through a transparent construction and self explanatory interactive features, the user should be able to seamlessly switch between ride modes and spend as much time as possible skiing.

The resulting concept is in essence an alpine binding toe piece with a modular pintech attachment positioned on top. It is a product with a separation of functions that embodies the need for robustness and ease of use found throughout the research. Positive aspects of the design are the low Stack height in Ski mode, multi-directional elasticity and easy changing of modes. While the negatives are the high stack height in touring mode along with the exposed pintech attachment in ski mode. The conclusion was therefore drawn that the proposed solution is a viable option to bring to market, but the stack height in touring mode needs to be further evaluated along with prolonged durability testing of a prototype strong enough for the slopes.

1 Introduction

This chapter sets the basis for the project and gives sufficient knowledge about what has been researched.

1.1 Background

Off-piste Skiing has over the last 30 years been divided into two segments, Ski Touring and lift-accessed Alpine Off-piste skiing. When performing the first, the skiers hike up the mountains on their own and ski down slopes in the backcountry. The second is performed in close proximity to a ski lift, often next to the pistes. Ski Touring Bindings benefit from being lightweight, but the strive for lightweight construction jeopardizes the durability and therefore safety. These features can be found in Alpine Ski Bindings while they on the other hand lack the walking functionality of a Touring Binding. This has created a spectrum of hybrid bindings, where features of traditional alpine and touring binding are combined, for good performance both uphill and downhill. Leading brands are producing hybrid bindings that let the user change between modes by transforming the binding. In touring mode the ski boot is attached to the toe only, where it rotates around metal pins while the boot heel is free. When set in Ski Mode, the boot is attached to both an Alpine Toe and Heel. This configuration can release the boot both laterally and vertically in a crash. The transitional state between the different modes demand the user to have high knowledge about their gear and how to interact with it. The bindings must therefore be self-explanatory and easy to use during harsh winter conditions, because a “faulty” user interaction might endanger the skier through binding malfunction.

Norse Skis is a young and competitive company that is located in the southern part of Gothenburg. They are focusing on providing a high quality off-piste skis with an emphasis on sustainability and durability. Norse Skis are currently not in the binding industry, but they see the potential for a simpler and more user-friendly hybrid binding to have success in the market. They therefore want to investigate the possibilities for entering the market, by taking on the performance paradox. Further on, Norse want to tackle usability issues regarding time consuming mounting procedures found in many products of today.

Lastly, the authors of this thesis have been skiing since they were young and have a well grounded basis in the products mentioned above. This has been beneficial since there was a very short learning curve for getting into the topic and understanding the problem. However, the authors also have their own views of skiing that might taint the project with these biases. This is something that needed to be considered throughout the process.

1.2 Aim

The aim of this study is to understand the strength and weaknesses with current hybrid ski bindings on the market based on user centered research and benchmarking. Further on, to develop a high performance binding concept, based on the identified market gaps and user insights. 1.3 Objective

The project is meant to result in a user-friendly ski binding toe piece concept in the form of a 3D-printed prototype as a basis for collaborative evaluation.

1.4 Issues Under Investigation

1. What key features make the current, project relevant, ski bindings successful on the market?
    - 1.1 How do they correspond to the usability and user experience of the product?
    - 1.2 What technical features are of importance?
    - 1.3 How do social norms affect customers' purchase decisions for hybrid bindings?

2. What things are currently malfunctioning on hybrid ski bindings and what are the reasons?

3. What boot systems should the binding accommodate?

4. How is a hybrid ski binding best designed in correlation with conducted research?
    - 4.1 How is the change of ride mode best designed to be easily understood?
    - 4.2 What indications should be in place to best communicate what mode is active?
    - 4.3 How is a hybrid binding designed to minimize the negative effect of the winter climate with the possibility of ice build up?
    - 4.4 How should a ski binding be designed to make the mounting to ski procedure fluent and efficient?
    - 4.5 What makes a mechanical ski binding satisfying to use?
    - 4.6 What makes the user trust a ski binding?

1.5 Demarcations

The study will not treat:

- Large scale manufacturability.
- Ski boot systems outside the Multi Norm Certification.
- Quantitative user data. The study will mainly be based around qualitative data from ski industry professionals and experienced skiers.
- In depth material analysis.
- Manufacturing costs and end pricing.
- Physical prototype of a heel attachment solution.

2 Final Concept Proposal

The Design Concept is in essence a toe piece from an alpine binding with a pintech toe attachment on top of it (see Figure 2.1). In its barebones construction it embodies a quote expressed by the first participant of the user studie “keep it stupid simple”.

Figure 2.1. *Final concept proposal.* (Authors’ image, 2022).

The binding has two modes of use, the first being the *touring mode* that takes the skier uphill. In this mode the pintech attachment is rotated 180 degrees and locked in place above the *alpine wings* (see Figure 2.1). The skier presses down with a ski pole on the lever to open the *pintech jaws* and steps down to lock the pins in the inserts of the boot (see Figure 2.2) and starts walking up with skins attached under the skis. Since the pintech attachment is located in front of the alpine wings the boot will not touch the heel piece.

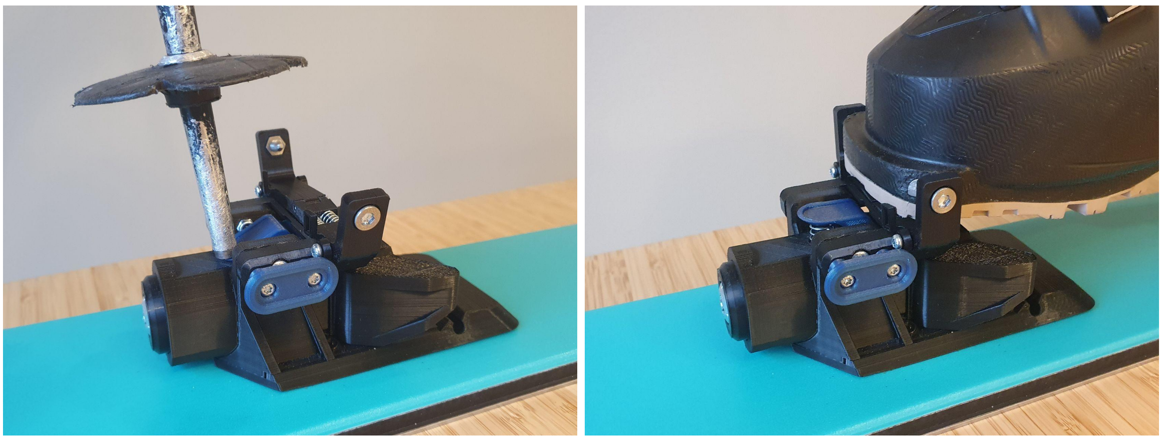

Figure 2.2. *Touring mode.* (Authors’ image, 2022).

When at the top the skier presses the same lever to release the boot from the ski and flip down the walking extension to enable *ski mode*. The pintech attachment is rotated forward and locked in place in its resting position on top of the spring housing, pointing down. In *ski mode* the skier uses the binding as a regular alpine binding with high elasticity and low stack height (see Figure 2.3).

Figure 2.3. *Alpine mode.* (Authors' image, 2022).

When conducting the evaluation of the product it was found that the simplicity of the user journey is the main strength of this concept, mainly because it performs a lot better in terms of learnability than competing hybrid bindings. While at the same time eliminating the need to remove parts of the binding to change modes, as seen needed in many hybrid bindings on the market today. Furthermore, milling parts out of aluminum to the highest extent possible was found to meet the user demand of a reliable binding that has a low likelihood of breaking (see Figure. 2.4).

Figure 2.4. *Render of Final design.* (Authors' image, 2022).

3 Theoretical background

This chapter provides an understanding for the theoretical point of departure in this development project.

3.1 Ski Industry Related Terminology

The following section discusses ski related terminology, equipment functionality and frameworks within the industry.

3.1.1 Skiing Equipment and Types of Use

Skiing is a sport reliant on a large amount of equipment. While off-piste and backcountry skiing are becoming more popular ways of skiing, companies are developing new ski equipment required for the more extreme areas of the mountains. The search for untouched snow and mountain adventure drive people to seek their way outside the ski lift operating systems on foot, using alpine touring equipment. For long alpine touring and system in-bound skiing has been quite separate activities which have required different types of gear, but now these ski activities are converging.

Alpine equipment

Traditional alpine skiing, in and off-piste, requires gear with good downhill performance. High durable materials and constructions are prefered to withstand aggressive downhill skiing. Off the piste, the use of wide skis makes the ski float better in deep snow, but adds more material and therefore weight. The boots and bindings should also be suitable for such skis for appropriate power transmission which often entails heavier system solutions.

Ski touring equipment

Ski touring equipment benefit from being lightweight since it is carried uphill by body power, but the strive for lightweight constructions jeopardizes safety mechanisms and downhill performance found in alpine bindings. The most common touring ski binding technology is the tech binding that allows two different riding modes. In touring mode the ski boot is attached to the tech toe only, where it rotates around metal pins for walking uphill. It requires removable skins at the underside of the skis to create friction between ski and snow while walking. At the top, the skins are removed and the boot heel is locked to the binding heel before skiing downhill.

Hybrid bindings

With more people performing backcountry skiing, a spectrum of hybrid bindings have emerged. Hybrid bindings are a combination of traditional alpine and touring binding constructions, for good performance both uphill and downhill. By merging touring and alpine binding properties, the area of use is expanded and therefore this new type of binding technology attracts many types of skiers. As a result, these bindings need to fulfill more diverse user requirements, which has become a balancing act between uphill and downhill performance for binding manufacturers. Hybrid bindings are generally designed to be compatible with a variety of ski boots since skiers with different skiing backgrounds might use different kinds of ski boots e.g. touring or alpine boots. However, there are still limitations on what bindings and boots that are compatible.

Figure 3.1. *Ski boot anatomy.* (Authors' image, 2022).

3.2.1 The Purpose of The Binding - The Great Paradox

The functional purpose of a ski binding can be considered quite paradoxical. The loads appearing when skiing, should be retained by the binding to avoid accidental release, but because high retained loads in any of the six degrees of freedom (see Figure 3.2) can lead to injury, it should still release at excessive loads (Senner et al., 2013). Rotation due to forces acting on the skier during falls can according to International Organization for Standardization (ISO) be categorized as:

> **6.1 forward fall**
> fall that results in the skier rotating about the y-axis in the positive direction
> **6.2 twisting fall**
> fall that results in the skier rotating about the z-axis in either direction
> **6.3 sideways fall**
> fall that results in the skier rotating about the x-axis in either direction
> **6.4 backwards fall**
> fall that results in the skier rotating about the y-axis in the negative direction
> **6.5 combined fall**
> fall that results in the skier rotating about an axis that has nonzero components in at least two directions (ISO, 1997)

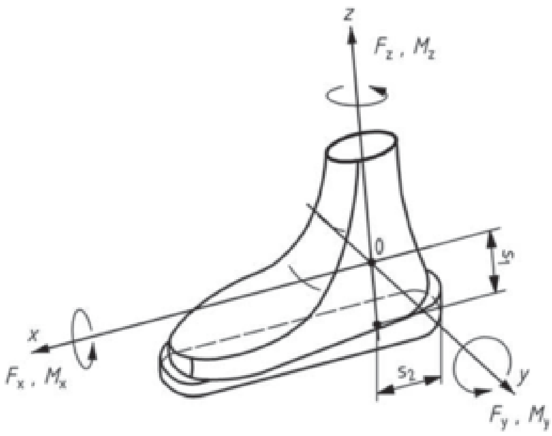

Figure 1 — Definition of the loads and torques

Figure 3.2 "*Figure 1 - Definition of the loads and torques"* by International Organization for Standardization, *(https://www.iso.org/obp/ui/#iso:std:iso:9462:ed-4:v1:en)*, 2014. Copyright 2014 by ISO.

The forces acting on the binding can from a mechanical perspective be a result of the skier's bodily movements or the skis' contact with the snow. Bindings that do not provide release in regards to the three forces and moments shown in Figure 3.2, will in combined falls jeopardize the bindings ability to release correctly (Senner et al., 2013). In contradiction, bindings providing release in all the six degrees of freedom will be more prone to release by accident, which can lead to severe injuries in exposed areas on the mountain. This is a paradox that challenges ski binding companies to find innovative ways of finding the right release thresholds and mechanism.

3.2.2 DIN and Release Value

To provide users with an indication of the forces needed for the binding to release, the Deutsches Institut für Normung (DIN) organization together with ISO has issued a norm (DIN ISO 1108) for such release values. The value indicates the forces that cause torsion (torque Mz) and forward bending (torque My) to the degree of binding release (ISO, 2018). The release value is calculated on a skier's height, weight, age, boot sole length, and skiing ability. The release value is usually visible on alpine ski bindings indicated by a scale of numbers and a moving marker along the scale which is adjustable by screw. When increasing a release value by screwing, it preloads a spring to demand a higher initial force to compress it. Many alpine binding manufacturers use this norm to ensure users that their bindings are following safety standards acknowledged by the ski industry. Since tech and hybrid bindings are constructed differently, these bindings are not always certified according to ISO1108.

3.2.3 Elasticity

Elasticity is an important mechanism found in alpine bindings for retain and release of the boot. The elasticity lets the boot travel sideways in lateral direction from the skis center axis, before it releases. This will as well allow the boot to get back in position if the distance the boot travels is still under the elastic limit. In that sense it works like a suspension which accommodates the forces during skiing. For retaining the boot to the ski a binding with low elastic travel will need a higher release value than a binding with high elastic travel (Olson, 2014). This will on the other hand entail a higher risk for torsion and bending injuries.

3.2.4 Types of Release Mechanisms: Alpine, Tech and Hybrid bindings

As mentioned in section 3.1.1 ski bindings provide different functionality for downhill and uphill performance. Due to the construction varieties in bindings (focused towards alpine skiing or touring) they also perform differently during release. Common injuries related to high forces before release are knee injuries and fractures due to torque in the lower leg (tibia torque) and knee sprains due to torque in the upper leg (valgus torque) (Davey et al., 2018). The lateral forces acting on a ski cause different torque values, depending on where the binding is constructed to release (Borro, 2020).

Most alpine bindings have a lateral release in the toe and allow for medial release in the heel. Although, some alpine bindings have an additional vertical release in the toe to lower the threshold for medial torque. Since the point of rotation is located in the lower leg towards the heel, a lateral release in the toe results in lower torque if a force is placed at the front of the ski than if it is located behind the heel (Borro, 2020). If a force hits the ski in the heel area, there is a “dead zone” where there is no lever to create tibia torque. However, there is a risk for knee sprain since the body inertia will create valgus torque in the knee area. In addition to lateral release, an alpine binding heel releases vertically to prevent fracture in the lower leg from frontal forces.

Generally, tech bindings as well allow for release due to twist or forward bending. The majority of tech bindings have a lateral release in the heel and a toe that opens along with the rotating heel, when a certain (spring) release value is reached. This gives the tech binding a dead zone at the toe instead (Senner & Hüper, 2020). Along with a very inconsistent release pattern where in some situations a lower force than the preset Release Value will result in release and in other situations a higher force than the preset value will keep the ski attached (Borro, 2020). Tech bindings also have a lower elasticity than alpine bindings which make them more likely to release accidentally (Senner & Hüper, 2020).

In conclusion, skiing comes with inherent risks of knee injuries, but the Alpine bindings provide a much safer alternative to tech bindings due to a more consistent release pattern and much more narrow dead zone.

Since hybrid bindings are such a new phenomenon and there is a strive for merging uphill with downhill performance, no solution is the other alike. However, the most common hybrid bindings on the market take advantage of the elasticity and power transmission in alpine bindings when in downhill mode. The binding will hence release similarly to an alpine binding when skiing. For uphill touring the binding provides a tech toe for walking only. The tech toe generally has two modes that either provide release values similar to when skiing or a locked state where the boot is locked to the binding when in a critical mountain zone.

3.2.5 Binding-Boot Compatibility

Throughout the history of alpine skiing, many variants of ski boots and bindings have been developed, driving each other's existence. Along with the progress new binding and boot standards and norms have been founded and abandoned. New norms has resulted in a quite confusing market due to many incompatible boot-binding configurations, which often requires the user to have in-depth gear knowledge when updating their ski equipment.

Due to the development of alpine, frame and tech bindings boot manufacturers have adapted their boot designs to be compatible with more than one alternative. At the same time new boot soles have been developed for comfort and safety reasons, which adds complexity to the boot-binding compatibility.

Regulating Organizations for Certifications and Norms

The ski industry norms and certifications are mainly issued by three organizations: DIN, ISO and TÜV (Technischer Überwachungsverein). DIN is a member of the ISO organization and has the norms for binding release value (in the industry known as DIN-scale) and also boot sole norms. The DIN norms that are internationally accepted therefore hold the indication DIN ISO. TÜV is an organization that in the ski industry develops test methods and performs tests to certify ski equipment.

Ski Boot Sole Norms

Although many ski boot designs vary in functionality, the boot sole is the most determinant part to affect binding-boot compatibility. Below are a list of the most common sole type norms:

DIN ISO 5355
This is a DIN certified sole and the most common sole type on alpine ski boots which dates back to 1982. This is a hard plastic sole with low friction and high power transmission (ISO, 1982).

DIN ISO 9523
This is a DIN certified alpine touring sole norm. The sole is made of rubber for better grip and facilitates walking through a rounded sole profile, in both toe and heel. This sole is mainly dedicated to tech bindings and can due to the rubber sole provide too much friction in other bindings. It also adds to the height of the boot which demands alpine toes with vertical adjustment (see MNC binding norm).

WTR (Walk To Ride)
WTR is a variant of the DIN ISO 9523 touring sole, created by Salomon, but is not certified by DIN, ISO nor TÜV. Like the alpine touring standard it has a rubber sole with similar height but with elements of plastic for better power transmission. It fits bindings with WTR compatibility (Corin, 2018)

GripWalk ISO 23223
The GripWalk norm comes from the companies Marker and Dalbello and is a sole comparable to Salomons WTR, in terms of a combined rubber and plastic sole. Though it is more similar in height to the DIN ISO 5355 and certified according to DIN ISO 9523. It has therefore replaced the WTR sole since the winter season of 2018/2019, and is now used in both alpine and alpine touring boots. In the fall of 2021 it was formally specified and named ISO 23223 (ISO, 2021)

TLT - non certified
This sole can be found in light weight boots dedicated for alpine touring and are not certified according to any standard.

Ski Binding Norms

In addition to the boot sole norms there are the following binding norms:

DIN ISO 9462
This is a DIN certified norm for alpine bindings which are compatible with DIN ISO 5355 alpine boots (Liljeroth, 2021).

DIN ISO 13992
Bindings with this norm is DIN certified and is an alpine touring standard. It includes tech-bindings, frame-bindings and some hybrid bindings.

WTR
As with the WTR boot norm, the WTR binding norm ceased to exist after the winter season of 2018/2019.

GripWalk
Bindings with this norm are compatible with GripWalk soles and DIN ISO 5355 alpine soles without any adjustments between the two.

MNC - Multi Norm Certified
MNC is a term created by Salomon and is certified for DIN ISO 5355, DIN ISO 9523 and WTR.

Sole.ID
Sole.ID is created by Marker and is similar to MNC. It is not certified as a standard but has parts that are DIN certified. Sole types that are compatible with this binding are GripWalk, DIN ISO 5355 alpine soles and DIN ISO 9523 touring soles.

3.2.6 Binding to Ski Mounting

When mounting bindings to a ski, holes are drilled into the ski, the holes are filled with glue and lastly screws are driven into these holes to fixate the binding. When forces are transferred from the skier to the ski they travel through the boot, into the binding, through the mounting screws and then into the ski. The spacing of the holes are dictated by the hole pattern designed into the mounting plates of the binding. This hole pattern affects the longevity and performance of the ski, since it dictates the concentration of stresses within the ski and power transfer to the ski when in use. When drilling the holes a Jig is used to produce the correct hole pattern.

3.2 Design terminology

The following section describes relevant design terminology used for the project.

3.2.1 User Experience Design

In this thesis, the authors used the definition stated by Karlsson (2021), ”User experience design (UX, UXD, UED or XD) is the process of enhancing user satisfaction with a product by improving the usability, accessibility and pleasure provided in the interaction with the product.”

Usability

According to Nielsen (2012) the usability of a product is the result of to what extent the idea of the product as being easy to use has been taken into account during the design process. He then moves on to define usability through five quality components:

- **Learnability:** How easy is it for users to accomplish basic tasks the first time they encounter the design?
- **Efficiency:** Once users have learned the design, how quickly can they perform tasks?
- **Memorability:** When users return to the design after a period of not using it, how easily can they reestablish proficiency?
- **Errors:** How many errors do users make, how severe are these errors, and how easily can they recover from the errors?
- **Satisfaction:** How pleasant is it to use the design? (Nielsen, 2012)

Accessibility - Design for All

A way of working with Accessibility in a product would be to use the Design for All approach that is defined by the Design for All Foundation (2022) as: “Design for All is the intervention into environments, products and services which aims to ensure that anyone, including future generations, regardless of age, gender, capacities or cultural background, can participate in social, economic, cultural and leisure activities with equal opportunities.”

Pleasure - The Four Product Pleasures

According to Jordan (2002) there are four ways a product can be pleasurable for a user. They are:

- **Physiological:** The physical stimuli a product possesses, these mainly within two divisions tactile feedback such as satisfying buttons and robust weight along with olfactory stimuli which is a nice smell.

- **Sociological:** Tightly linked to the social relationships the product results in, it could be that it is a conversation starter, a way of belonging to a group or reason to get together.
- **Psychological:** “Pertains to people’s cognitive and emotional reactions” (Jordan, 2002). If the user feels like a product is giving them a higher likelihood of success than failure both in using the product or at a certain task when using the product. It is likely to result in a positive emotional experience.
- **Ideological:** Stems from a person's view of themselves, when comparing to socio-pleasure that is in need of a social interaction or another person viewing the user a certain way. The product that aspires to fulfill Ideo-pleasure intends to resonate with peoples tastes, moral values and personal aspirations. Examples of products in this category are books, music and art.

Signifiers

The Affordances of a product are the different actions that a person is able to perform with it. It stems from both the physical properties of a product that enables manipulation and the past experiences of the person that gives them the ideas and knowledge in how this manipulation might be performed. To encourage the user to perform a certain manipulation a designer can use a Signifier. This is an attribute given to the product that is meant to guide the user in seeking the wanted Affordance. To exemplify, a door that is meant to be pushed is easily understood if it only has a flush flat plate on it, clearly stating the intended manipulation (Norman, 2013).

Product Expression

According to Österlin (2016), everything that exists has an expression. In his view the communication of expression is one directional and the people are passive observers. He continues to state the three different types of expression:

- **Character:** The form is central here and it stems from the observers' references and expectations. A product can for instance be meant to express things like luxury, durability, simplicity etc. He also mentions the importance of form language and styling when referring to the product Character.
- **Identity:** When talking about product Identity the main focus is stated to be the product heritage and belonging. This is done by giving the product the same look and features as other products from the same company and/or products in a specific range within the company. The other way of doing it is to enable the user to give their product a specific identity by changing it in different ways.
- **Function:** The expression and form can also be emphasized towards explaining the functions and ways of using the product. The ideal here is if the product is self-explanatory, logical and simple. This is also dependent on the previous knowledge of the user and cultural background (Österlin, 2016).

Diffusion of Innovation

When a new product and revolutionary product is launched there will always be a time delay until it is the new norm and the predecessor is considered old and outdated. In Figure 3.3 a curve showing the Diffusion of Innovation can be seen. It splits the different percentages buying the new product into groups called Innovators (2.5%), Early adopters (13.5%), Early

Majority (34%), Late Majority (34%) and Laggards (16%), it also shows how they relate to one and other in terms of time. This results in a peak showing the time the product is most likely to bring in the most revenue (Jobber & Ellis-Chadwick, 2016).

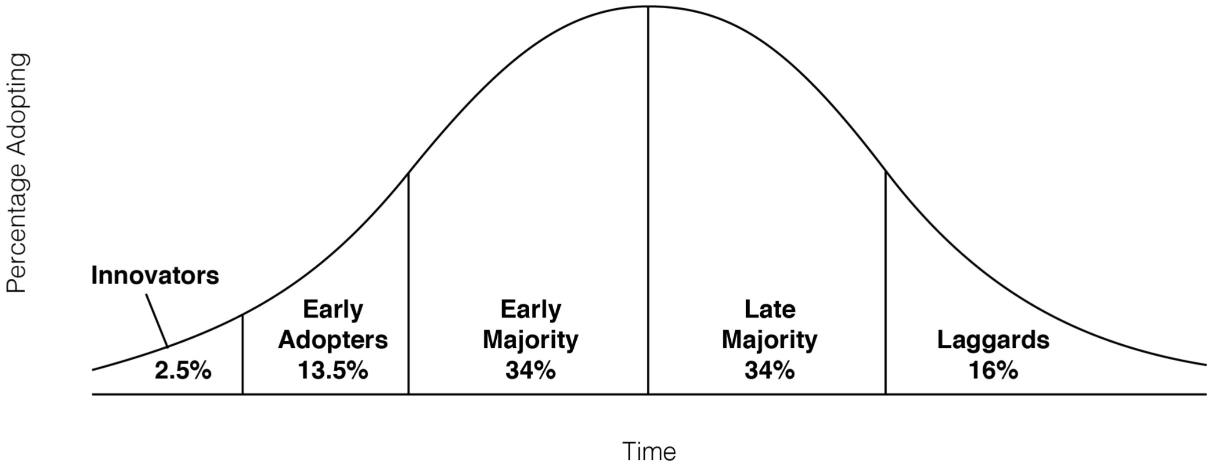

Figure 3.3, Placeholder, The diffusion of innovation curve, author’s image.

Market Analysis and Reverse Engineering

Jobber & Ellis-Chadwick (2016) state that in order to reach success it is important to conduct proper research into what the competition is doing along with clearly framing who the intended customer is. This can be done through interviews with both customers and/or sales people in close proximity to the customer, along with clearly investigating the competing products. When investigating competing products similarities can be drawn with Reverse Engineering, this is done by deconstructing a competing product and making a very similar product but with modifications and updates to improve the final product. When working with Reverse Engineering it is important to not make any direct copies or patent violations (Johannesson, Persson, Pettesson, 2013) .

4 Methods and Procedures

Chapter four is dedicated to presenting the course of action and methodology used for research, evaluation and ideational work.

4.1 Project Design Process

The Double Diamond method is a framework for solving complex problems in multiple forms. It consists of four phases called Discover, Define, Develop and Deliver. The Discover and Develop phases are divergent since the idea is to think broadly and take in all types of information relevant to the subject along with creating as many solutions as possible. While the Define and Deliver phases are convergent since they are about pinpointing the problem from the information gathered in the Discover Phase along with evaluating the ideas generated in the Develop phase (Design Council, 2022).

The essence of the Double Diamond method was used in this project and not followed in detail. Some phases were therefore renamed and contained methods and frameworks that were deemed relevant for the project. The Discover phase was renamed Explore, the Develop phase was renamed Ideation and the Delivery phase was renamed Evaluate. The reason for this was that a great portion of the time was going to be spent on finalizing the prototype to make it as high fidelity as possible. To better show the process an ending Finalization phase was therefore included to showcase the linearity of the second half of the project. The project was performed in a total of 14 weeks where the first eight were dedicated to the Double Diamond method and the remaining six weeks were spent on the Finalization Phase.

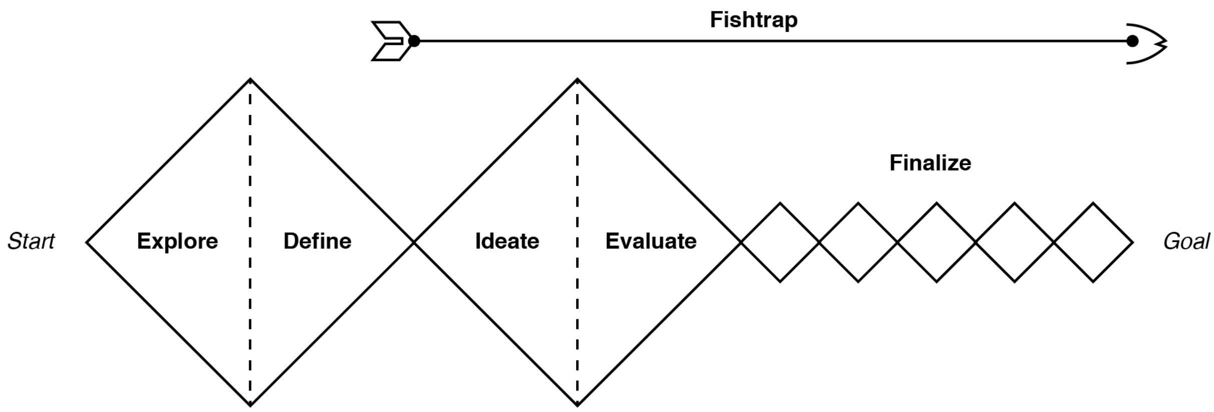

Figure 4.1 *The Design process of the project.* (Authors' image, 2022.)

4.2 Exploration Phase

This phase was performed with an emphasis on defeating previous biases, getting an objective perspective of the current state of the binding market and understanding the user needs.

4.2.1 Competitor Products Analysis

Jobber & Ellis-Chadwick (2016) writes about the market and the importance of knowing both the potential customer in the market along with the other products competing for attention on said market. A rigorous compilation of a large variety of ski bindings was therefore conducted. The compilation was divided into categories of Alpine, Tech and Hybrid bindings. When compiling the data an emphasis was put on documenting technical specifications along with estimations on market presence and traits that differentiated the bindings from one and other. The compilation grew over time and served as a database that could be easily accessed and updated in accordance with what functionality or product trait that was under investigation at the time.

4.2.2 Reverse Engineering and Mapping of Parts

Reverse engineering is performed by disassembling a product to see what parts it is composed of to accomplish its functionality. This can also be taken a step further by performing measurements that can be used when setting requirements in product development processes (Johannesson, Persson, Pettesson, 2013). This method was used to properly understand the different mechanisms of competing bindings. Simplified illustrations of the most common spring placements and power transferring sliding parts were created to map out what parts were the most crucial in terms of functionality. Weight measurements were also performed to gain insights into what parts of the different bindings contributed to the biggest portions of the total weight along with material choices to give strength. Lever ratios between release springs and contact points with the ski boot were also investigated to identify critical measurements that would be relevant in the development process. When choosing bindings to investigate the most important factor was getting a diverse selection to gain holistic knowledge. The selection was mainly provided by Norse skis, along with private donations from both the authors and a kind provider from the internet forum Freeride.se. The resulting selection included:

Hybrid:
- Atomic Shift 13
- Marker Duke PT 12 & 16

Alpine:
- Marker Jester 16
- Tyrolia Attack 11,14 & 16
- Look SPX 12
- Salomon Guardian 13 & 16

Pin-tech:
- Marker Kingpin 13
- Dynafit FT 12
- ATK Raider 12

To further increase the mapping study product visualizations of the following binding were used.
- Dynafit ST Rotation
- Frichi Techton
- Salomon Strive

4.2.3 Patent Exploration

Johannesson, Persson and Pettersson (2013) states that patents were first created to promote technological progress by giving the inventor a possibility to regain investments and economic reward, along with spreading the information and promoting further development when the initial patent has expired. However, they also state that infringement can be an issue when designing products that have similar functionality to already existing products and they therefore stress the importance of searching for patents. Patent exploration was therefore used both to reduce the risk of creating a binding that would not be possible to bring to market, along with gaining better knowledge and spurring ideas for further development. The reviews were performed by searching the Espacenet and Google Patents data bases. Along with contacting the support at Patent- och Registreringsverket.

4.2.4 Think-Aloud Mounting Workshop

The Think-aloud method proposed by Hanington & Martin (2012) is performed by letting a user complete a series of tasks in order to reach a goal while at the same time vocally expressing their reasoning. The observer is only there to listen, take notes and record video to later be able to synthesize the data. However, during the test the observer is allowed to remind the user to keep talking if they become quiet (Hanington & Martin, 2012). This method was applied when a certified binding technician both mounted a Tyrolia Attack 11 and a Atomic Shift 10 binding to two different pairs of skis, along with simulating a mounting procedure of a Salomon Warden 13 binding. These bindings were specifically chosen since they all have different placements of the mounting screws and preload adjustments. Through the entirety of the test the technician vocally expressed his reasoning with experienced issues and this data was later included in the later KJ analysis. To wrap up the workshop and to better sympathize with the technician each author got to mount one pair of Atomic Shift 10 bindings. To gain further knowledge of the mounting process of the Cast Freetour system, a review of mounting manuals was conducted.

4.2.5 Online Review Study

To gain nuanced perspectives on the public opinion an online review study was conducted. It was completed by first looking at product reviews and articles conducted by online magazines such as Freeride.se, Skimo.co, Blisterreview.com and Switchbacktravel.com. This information was later leveraged against posts from the forum sections of Freeride.se, Skitalk.com and Tetongravity.com. The acquired information was later synthesized in the KJ analysis.

4.2.6 Interviews

Rexfelt (2019) mentions two ways of conducting interviews; structured and unstructured. The structured interview is supposed to follow a strict set of questions much like a quiz survey focusing on quantitative information while the unstructured interview is more focused on following a tail of thought and gaining deeper qualitative knowledge from each participant (Rexfelt, 2019). These two formats were combined into a semi-structured format, where a set of questions was created to suit the anticipated knowledge areas of each participant but with an emphasis on promoting the participant to describe their thoughts and opinions through letting them focus more on the subject they had most knowledge of. The preset questions functioned as a way of knowing that everything that each point of preconceived interest was covered. The study had a total of 10 participants that could be divided into groups of ski shop personnel, mountain guides and well experienced skiers. All participants had a lot of experience of using and working with different skiing equipment and were therefore seen as expert users.

4.2.7 User Journey Mapping

The definition of a Journey map states “A journey map is a visualization of the process that a person goes through in order to accomplish a goal.” (Gibbons, 2018). This was used to gain knowledge of how many steps a user would need to go through when ski touring with the most relevant competing hybrid bindings. Maps were compiled through interaction with the Salomon/Atomic Shift, Marker Duke PT, Marker M-Werks, Cast Freetour and Fritchi Techton bindings. The first two were performed on physical bindings wearing skiing gloves to simulate a real use case, while the latter three were compiled through observations of videos showing the different bindings in use. In the physical mapping a mountain guide was present to give further insights to what steps he had observed guests have had problems completing.

4.3 Definition Phase

The Define phase main function was to synthesize all acquired information from the Explore phase to lay the ground for the later development phases.

4.3.1 KJ-Analysis

The KJ-analysis was invented by Jiro Kawakita to make structuring large quantities of data into relevant categories and sub-categories. This is done by writing or printing out quotes from users and short information quotes on individual slips of paper. These are then put up on a wall with the only intention of placing slips where similarities can be found next to each other. The groups are not named until all information has been assigned a group. This method is used to work from a bottom up perspective helping the researchers work past their prejudices and gain an objective perspective on the information that has been gathered (Rexfelt, 2019). This method was used in a digital format to maintain accessibility from multiple places. A board was therefore created in the software called Figma and quotes from the Interviews, Mounting Workshop and Online Review Study were written on different colored digital post-its that were then placed in groups and later categorized. After the categorization short summaries of each group was written to further develop meaning and deeper insight into the essence of each category.

4.3.2 Personas

Creating personas are meant to aid designers when creating a product for a specific user. They are created through creating a fictive person through a specific set of traits and ways of behaving (Haningtin & Martin, 2012). Four personas were created to represent different users that would be of interest for the project based upon the information gathered in the Explore phase. When moving into the development phase a combination of three personas was selected as the main focus in order to represent the users.

4.3.3 UX: Four Pleasures

To paint a more detailed picture of each persona, the Physio-, Socio-, Psycho- and Ideological pleasures of each character were stated for each persona. This was used primarily to connect the persona to their motivations, purchasing behavior and manifestation of self image through the products they own.

4.3.4 Perceptual Mapping

To create an overview of the market through visualizing how different relevant products perform in relation to one another, a Perceptual Map is a common tool. It is performed through choosing a relevant set of competing products, defining important attributes, scoring the products in how well they perform within each attribute and lastly plotting them on a two axis map. When reviewing the map one can easily identify market gaps with unfulfilled attributes (Jobber & Ellis-Chadwick, 2016). Eight perceptual maps were created, seven of which weighed different Hybrid binding against one another while one consisted of Pin-tech bindings. The attributes that were looked at were Weight, DIN release value, Transitioning steps from walk-to-ski and vice versa and Pricing.

4.3.5 S.W.O.T Analysis

Strategic positioning of businesses and products could be done through identifying internal Strengths and Weaknesses and waying those against the external Opportunities and Threats. These aspects are then summarized into a SWOT-analysis to give an overview of what strategies should be done to best utilize the strengths and minimize the threats imposed by other businesses or products (Jobber & Ellis-Chadwick, 2016). This method was used on a product level to summarize all information gathered and the results on how they related to one and other. The products included Salomon Shift, Marker Duke PT, Cast Freetour, Fritchi Techton and Marker M-werks.

4.3.6 Requirements List

To better frame the problem and create a document saying what should be done to solve a specific problem, a Requirements list is a commonly used tool. It is done by first specifying what functions the product should have and if needed further noting down what measurable performance values the product should have. For example strength, weight and torque output. The trick is to only specify *what* the product should do, not *how* it is going to do it (Österlin 2016). The Requirements list was divided into three sub headings containing Functional Requirements, Technical Requirements and Semantic Requirements. Within these subheadings all previous acquired and synthesized knowledge was structured into short and easily understood phrases. These were later categorized into hard Requirements that the product had to fulfill and Wishes that would be good to reach but were not crucial in order to still maintain proper functionality.

4.3.7 Inspiration Board

Different Image boards can be created to communicate what visual look a product that is under development should have. These images can contain colors, shapes or other products that have relevant visual traits (Österlin 2016). This method was used to form a coherent expression that was agreed upon by both the company and the authors from the basis of the user study. The board was later used as inspiration and a conversation tool when working with sketching.

4.4 Fishtrap Model

The fishtrap model is a tool created to be used for form development and is structured through three stages. Starting out by creating *topological variants* with rough basic blocks representing the different functions of the product resulting in *structural concepts* focusing on the general structure of the product. In the second stage the most interesting *structural concepts* are further developed into several *typological variants* by working with transitioning surfaces and shapes, these variants are then synthesized to create *formal concepts* where the first representations of a functioning product is taking shape with ideas of dimensions and material choices. In the last stage the most interesting *formal concept* is diverged into multiple *morphological variants* focusing on specific dimensions, detailed material choices and surface finishes, the strongest *morphological variant* is represented in a *material concept* that is meant to be a representation of how the finished product is intended to be. Each stage therefore has a divergent part by creating a lot of variants as well as a convergent part where these variants are synthesized into concepts (Muller, 2001). The essence of this method was used throughout the later stages of the development process with other methods for evaluation in between.

4.5 Ideation Phase

This was a highly divergent phase generating many solutions to the problems defined in the previous phase.

4.5.1 Stop and Go Brainwriting

This is performed by setting a timer and sketching ideas in silence. When the alarm calls the participants let go of the pen and take a step back and reflect for a while, when the alarm calls a second time ideation continues. This sequence is repeated for how many times as the participants deem it being productive. Working like this is meant to prevent idea fatigue (Österlin 2016) and was used early on in this phase.

4.5.2 6-3-5 Brainwriting

This is performed in a group of about six people, each working on three ideas for five minutes. After the five minutes have passed the papers containing the three ideas change hands and the participants continue working on the previous peers' ideas. This method is ment to create group cohesion and promote inspiration through other people's ideas (Österlin, 2016). This was instead performed with two persons with the intention of mixing creative insights.

4.5.3 Structural Concept Stage

The topological variants were created in a planned manner by taking the components that were deemed essential to enable functionality and placing them in a variety of different ways. To enable the widest solution space possible no judgment in regards to feasibility was made in this step. The Topological variants were sketched out in a 2D-format and used as headings for creation of the structural concepts. When making the structural concepts the Stop and Go Brainwriting method was used as described above. While the essence of the 6-3-5 method was used when reviewing and further developing the concepts. This was done by using each other's sketches as references and inspiration when changing and combining ideas.

4.5.4 Rapid Prototyping with 3D-printing

The Research and Development field is a fast paced environment where quickly creating a physical prototype to answer questions is essential. Rapid prototyping through additive manufacturing such as 3D-printing is a well used method. It works by instead of removing material from a solid block, material is instead added layer by layer to build up the form with only the required amount of material. The technology used in this project is called Fused Deposition Molding and builds a part through melting a spool of plastic through a heated nozzle and deposits it layer by layer fusing them together (Johannesson, Persson, Pettesson, 2013). FDM 3D-printing was used to a great extent throughout the last half of the project to be able to spatially evaluate concepts and mechanical solutions.

4.5.5 Formal Concept Stage

When creating typological variants from the Structural Concepts, sketching and 3D-modeling in a software called Blender was used in parallel. This helped with getting a better sense of size and feasibility through the use of a digital model of a GripWalk ISO 23223 ski boot. Multiple iterations were made and a quite large variety of Formal Concepts were created where some of the most promising ones were 3D-printed to get a better sense of real life size, functionality and expression.

4.6 Evaluation Phase

A convergent phase used to hone in on what solution was going to be materialized as a high fidelity prototype.

4.6.1 PNI

PNI is an acronym for Positive, Negative, Interesting. It is an evaluative method that puts an emphasis on the discussion that is taking place when filling out points within these three categories. It helps the researcher cover many aspects of the product that is under review (Österlin, 2016). This method was used to a great extent, mainly because the problem is niche and through the evaluation it was important to attack the problem from multiple angles. PNI was therefore a helpful method both when evaluating within the development team but also with the company and the users. When evaluating with users, the PNI forms were created beforehand in order to have a document to follow to ensure that all concepts were discussed and that the users had to come up with both positive and negative things. This made them think not just in harsh evaluative ways, but also in thought provoking and inspiring ways.

4.6.2 Evaluation Interviews

The evaluation interview was conducted with one mountain guide, one ski equipment sales person, two users and a Norse Skis representative. The interviews had a qualitative focus and followed the PNI document. The subjects under review were the *formal concepts* represented mainly by the digital 3D-models. However in the last interview with the ski equipment sales person the two most liked concepts from the previous interview were materialized in low fidelity mock-ups made through a combination of 3D-printing and polymer clay. These mock-ups were presented along with the digital 3D-models to ensure proper coverage. Lastly, all information gathered in the evaluation interviews was compiled into a data sheet categorized by who said what about each concept.

4.6.3 Concept decision

When deciding what concept was going to be focused on when working with the morphological variants and the material concept, a discussion session was held with the representative from Norse Skis. By reviewing the Evaluation data sheet and comparing it to the requirements list a decision was reached and planning for the last phase of the development process was made.

4.7 Finalization Phase

When finalizing the concept that was going to be presented an emphasis was put on working with solid modeling in a software called Fusion 360. The *formal concept* from Blender was imported as a reference that was used as a starting point for honing in on the final dimensions and precisely designing a functioning prototype. Multiple iterations with 3D-printing were made in this phase to work up to a prototype that met the specified criteria and was easy to use even when wearing thick skiing gloves. Reverse engineering and patent reviews were also used in this phase to ensure a prototype that would feel and function closely to a production grade product. Testing with a GripWalk ski boot was also a big part of this phase along with trying out different ways of fixing the boot in tour mode. This phase therefore still had some of the essence of the methodology *formal concept* stage in it, but with a lot higher fidelity resulting in the final *material concept*.

4.8 Final Concept Evaluation

When the *material concept* was completed final concept evaluations were conducted through telephone interviews and physical workshops. The mountain guide and ski equipment sales person that had been participating throughout the process participated in one telephone interview each. It was deemed a fitting method since they already were well informed about the different concepts and could give relevant feedback on the *material concept* without seeing it. However, in order to get relevant feedback from other users an evaluation workshop was held during a get together at the Norse headquarters. A total of 11 users were presented with the *material concept* and gave their feedback and thoughts. Some of them were presented with the task of explaining the functions of the product back to the authors, without knowing the intended steps of use. This was done to test the signifiers and learnability of the product.

5. Results

In this chapter the results from research, analysis and generative work described in the previous chapter are presented.

5.1 Market Analysis

The market analysis includes results from the comparison of bindings (see section 4.2) that were made to overview the competition and potential market gaps.

5.1.1 Market Overview

Since the hybrid ski binding market is new in the history of modern skiing, the existing solutions on the market differ remarkably between brands and even within company product portfolios. The authors chose to divide the concept of hybrid bindings found into two categories; *alpine hybrid* and *pin tech hybrid*. Alpine hybrid bindings were defined by allowing a full alpine binding retention/release with high elastic travel while skiing. This is where established binding producers Salomon and Marker have high market shares with their bindings Salomon Shift MNC 11/13 and Marker Duke PT 12/16. CAST freetour 15/18 is another binding placed in this category which consists of a classic alpine binding from LOOK with an additional upgrade kit from the company CAST touring. Bindings that utilize elastic pin technology for skiing down hill, in combination with an alpine heel, were categorized as pin tech hybrids. This type of hybrid bindings are produced by companies such as Marker (e.g. Marker M-werks 12) and Fritschi (e.g. Fritschi Tecton 12). The bindings mentioned above share similar functionality but the designs are very distinguishing from each other. Throughout the years companies such as BAM Pindung, SkiTrab and Dynafit have made attempts to enter the hybrid binding market as well, but with little success. Although failing attempts were analyzed and learnt from, the comparison in the following section will treat the five best selling hybrid bindings on the market today.

5.1.2 S.W.O.T Analysis

Based on the market analysis, interviews and perceptual mapping a S.W.O.T analysis was carried out on a product level and contained the models: Salomon Shift 13, Market duke PT 16, CAST Freetour 18, Marker M-werks 12 and Fritschi Tecton 12. Comparative parameters were technical specifications such as weight, release value, elasticity, stack height, price and boot compatibility together with the number of interactive user steps needed to transform the binding between ride modes. Full list of strengths, weaknesses, opportunities and threats are found in Figure 5.1 below.

S.W.O.T ANALYSIS ON PRODUCT LEVEL

Alpine hybrids

Salomon Shift 13 MNC

Strengths
+ Low price for low weight
+ High lateral elasticity
+ Average at everything
+ Two in one toe
+ Preload adjustment on screw
+ MNC
+ Recognition - looks like an alpine binding

Weaknesses
Use of plastic
- Toe riser plate mechanism is weak
- Ski stopper lock does not provide a good grip
- Changing modes are done in reversed order
- Difficult to remember to lock toe lever in ski mode
- Plastic on the heel lever breaks when pressing with the ski for release
- Change of toe riser demand losing screws from the ski base
- No boot alignment for tech toe
- Walk-to-ski requires release of boot
- High stack height

Opportunities
First two in one solution with alpine toe sets the standard - can be seen as a "classic"

Threaths
Point of departure for competition.

Marker Duke PT 16

Strengths
+ Relatively high DIN
+ High elastic travel in heel
+ Durable - metal details
+ Stable AFD on slope

Weaknesses
- Quite expensive for weight and DIN
- Heavy
- Possible to lose alpine toe part
- Ski stopper lock does not provide a good grip
- Many interaction steps to switch ride modes
- Can not ski with tech toe
- Bad heel release feedback (when stepping in

Opportunities
Enough charge image to be a competitor to CAST

Threaths
Not a two in one solution might hinder "the average skier" to choose duke before shift

CAST Freetour Pivot 18

Strengths
+ High DIN for money
+ Durable built
+ Have a "charge" image bc of pros
+ Vertical and lateral toe elasticity
+ Rotating heel increase elasticity
+ Relatively few parts
+ Low stand height
+ Fewer steps in walk-to-ski transmission than shift
+ Can choose to ride with one toe only
+ Ok DIN/weight ratio

Weaknesses
- Risk of loosing parts
- Heavy
- Ice and snow build up
- No boot alignment for tech toe
- Requires perfect mounting

Opportunities
Already seen as a "classic" binding with charge image

Threaths
A very nische collaboration that might be difficult to keep alive

Pin tech hybrids

Fritschi Tecton 12

Strengths
+ Light weight
+ Good weight-DIN trade off
+ Can keep ski on during transition
+ Few steps in switching ride modes
+ Good toe elasticity for tech
+ Boot alignment for tech toe

Weaknesses
- Only skiable with tech inserts
- Elasticity not comparable with alp. toe
- Not fully DIN-certificated
- DIN 12 not enough for many skiers

Opportunities
Good alternative for those who spend much time in the backcountry

Threats:
No similar solution might scare skiers with alpine background from buying it

Marker Kingpin M-werks 12

Strengths
+ Few steps in switching ride modes
+ Can keep ski on during transition
+ Low price for low weight
+ Easy to understand
+ Boot alignment for tech toe

Weaknesses
- Only skiable with tech inserts
- Elasticity not comparable with alp. toe
- Low DIN for high price
- Lot of plastic (though carbon reinforced)
- Heel prone to break

Opportunities
Can become a good alternative for "the average skier" with new found touring interest

Threats:
Have inherited the dirty history of the Kingpin

Figure 5.1 *S.W.O.T analysis.* The product images are artistic alterations. (Authors' image, 2022.)

5.1.3 Reversed Engineering for Mapping of Crucial Parts and Mechanisms

By disassembling bindings from leading brands on the market a variation of construction solutions were found. Since alpine and tech bindings are indirect competing products they were among bindings of interest as well as hybrid bindings. This section contains analysis of toe parts only. Illustrations of heel constructions can be found in Appendix A.

Example of alpine toe mechanisms

All the explored alpine bindings relied on compression springs. The foundational difference among alpine solutions was direction of the spring, wing movement in relation to the spring, length of the wings, number of parts and type of assembly. The weight was highly dependent on spring size and fixating elements.

Figure 5.2 shows two bindings with horizontal springs. This type of solution allows for a compact design but requires a spring centered between the wings which are more or less constrained by the boots toe lug width. Some models like the Tyrolia attack therefore use two overlapping springs to gain a high amount of retention in a relatively small space. One difference between the two illustrated bindings in Figure 5.2 is how the spring is compressed. When binding H1 releases the boot, the wings are pivoting around a point in the front of the wings and apply a dragging force from the opposite direction, which compresses the spring. Binding H2 to the right instead compresses the spring in the same direction as the wing rotation. The difference in release characteristics were not tested properly but were considered very similar by interviewees with many years in the business.

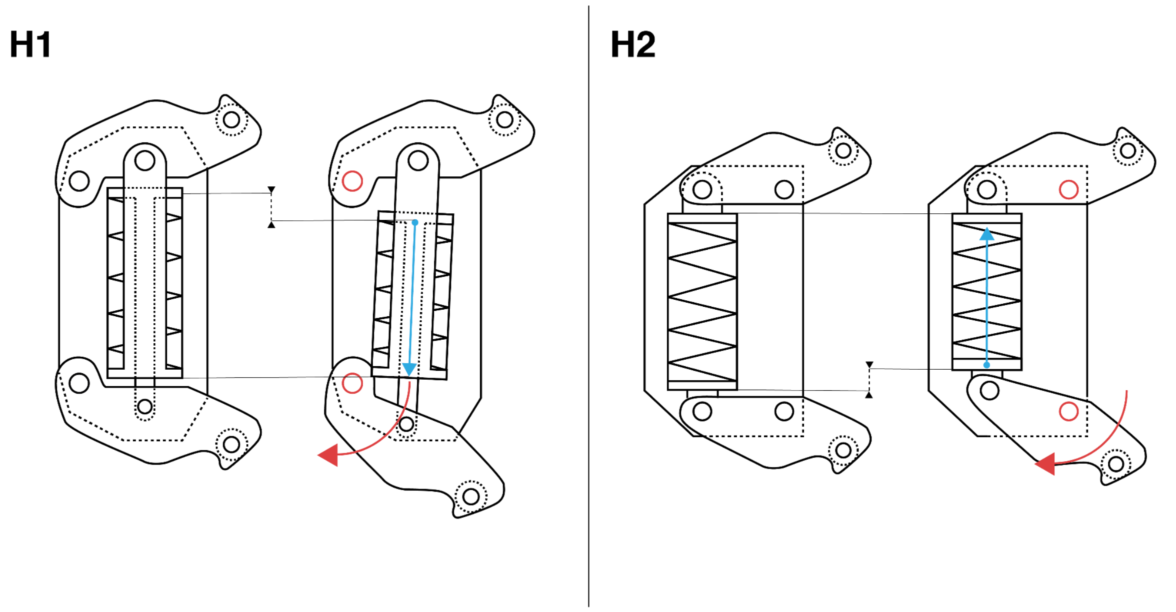

Figure 5.2 *Horizontal springs.* Illustrations of two binding mechanisms where a horizontal spring is used. (Authors' image, 2022.)

The two bindings in Figure 5.3 below have springs which leap vertically (in ski direction) instead of horizontally. These mechanisms occupy more space towards the front of the ski, but leave room for larger wings. The tall design of these bindings can however, according to an interviewed binding technician, make them more sensible to the flexing of the ski. V1 to the left is a mechanism similar to the one found in e.g. the Salomon Shift where the rotating wings, fixated in the spring house, pull an anchor which in turn compresses the spring. The wings used in Binding V2, illustrated in the same figure, are instead attached to a single rotational axis. When the wings rotate their individual rotation points occur at the contact points between the wings and the springhouse. The wings are not attached to the spring house which means that this type of design allows for more rotational freedom in every direction and therefore can inherit both lateral and vertical elasticity. When high frontal forces are transferred from the boot to this type of binding, the more narrow wheel placement on the wings forces the binding to flex which adds an extra degree of elasticity.

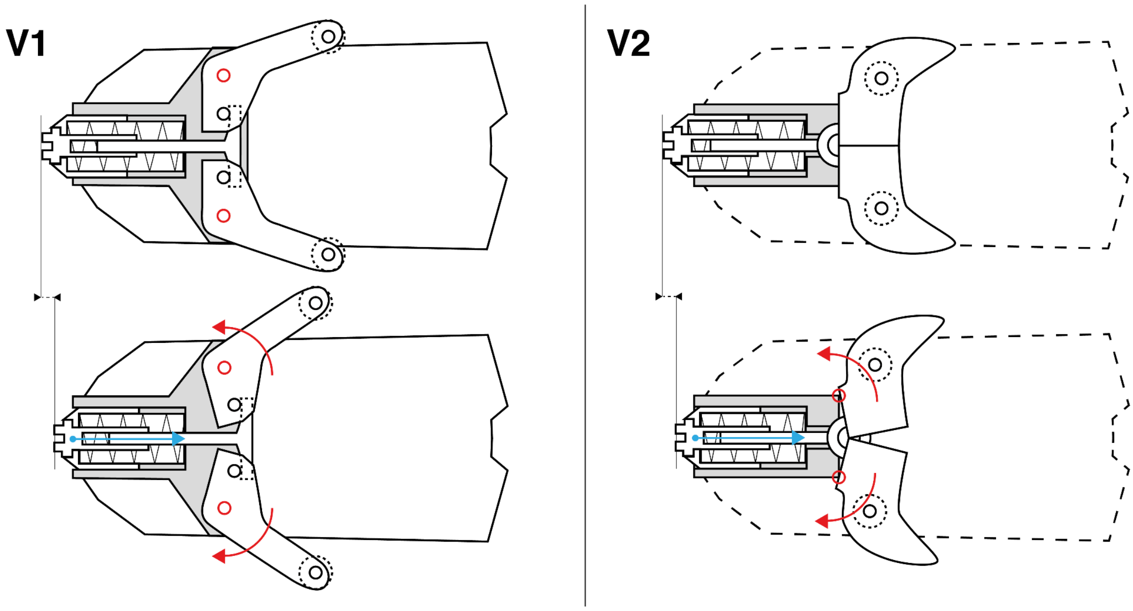

Figure 5.3 *Vertical springs.* Illustrations of two binding mechanisms where a vertical spring is used. (Authors' image, 2022.)

For inspecting pin tech bindings, a similar procedure was carried out. In Figure 5.4 below a simplified illustration of a "general" tech toe mechanism is shown. Even though some models were designed to provide higher elasticity than conventional tech toes (see Appendix B) they did not differ as much in construction as alpine toes. The largest differences were the clamping power, lever lengths and stack height.

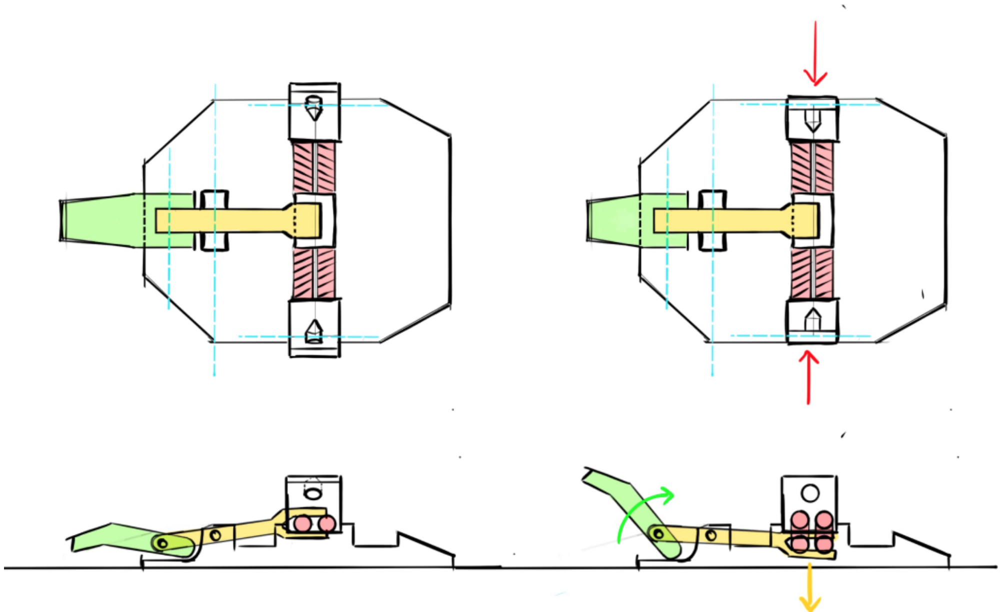

Figure 5.4 *Pin tech toe.* A simplified illustration of the closing of a pin tech toe. (Authors' image, 2022.)

5.2 KJ-Analysis

The following section contains analysis of statements made during interviews with ski shop personnel, mountain guides and great skiers. The section is divided into five subtopics that emerged during the KJ-analysis.

5.2.1 Norms Are Shifting The Market

The ski shop personnel, mountain guides and skiers interviewed were all in agreement that hybrid bindings are becoming a more frequent alternative among skiers and are here to stay. The developing hybrid binding market along with the new Gripwalk boot standard (see 3.2.5) were seen as a new understandable system, in the for long confusing binding-boot system djungle. The interviewed ski shop personnel, who meet customers with a varying skiing background everyday, expressed that this new system is inviting skiers with no experience of touring to consider the activity. Further on, hybrid bindings are also becoming a more interesting alternative for skiers with touring experience who want a more versatile setup for both touring and powerful inbound skiing. Although safety norms and certifications in the industry were considered to be a good thing and a convincing selling point, it was intended to come with more obligations as a seller to inform customers about what combinations of equipment that are recommended and possible. The release value certificate issued by DIN (see 3.2.2) was mentioned to be of higher importance for less experienced skiers while e.g. mountain guides trusted their own gear intuition and skiing ability rather than tests. Some interviewees with many years in the industry were critical to the release value certifications because of the sterile environments these tests were allegedly performed in. It was therefore concluded that accomplishing certification might not be of most importance.

5.2.2 Types of Use

Hybrid bindings need to fulfill both alpine and touring requirements which might be prioritized in different ways depending on the type of skiing the user prefers to do. The interviewed ski shop personnel's general view was that people who tend to buy hybrid bindings are in many cases users who spend most of their time on lift-bound skiing. They want to have the opportunity to do ski touring even if it happens once a year. The age span for those who inquire for touring possibilities has increased as well in both directions according to the interviewees, who might not be interested in the same technical specifications. As many hybrid bindings allow for both Gripwalk and Alpine ski boot soles, some users buy skis with hybrid bindings without owning ski boots with tech inserts. Instead they ski with alpine boots with the intention to complete their ski touring equipment in the future. Others own the right boots but do not buy a pair of skins, necessary for touring uphill. This implies that a large amount of hybrid bindings sold in Gothenburg are used as alpine bindings during the majority of the time, but allows the user to own a single ski-boot-binding system for all types of use.

5.2.3 Knowledge and Experience

The level of experience, gear knowledge and skill self-perception influence the purchase decision and result of product use. According to interviewed ski shop personnel and several mountain guides, many skiers buy advanced equipment that they do not necessarily need or are able to utilize the full potential of, for several reasons. The first implied reason was that users often consider a high retention to be suitable in every occasion, with less reflection of the release characteristics. Many of their customers have never heard of elasticity and simply think of the binding as a fixating tool only. The second reason might be a product of the first; professional skiers who ski fast and aggressively through dangerous terrain are the one's promoting the products, which are often designed in terms of their preferences. It affects the purchase behavior for those who have low skill self-perception to go for the most extreme binding alternatives. This might become a safety issue in terms of twisting injuries and fractures to the lower leg because of incorrect release. One mountain guide feared high retention, as a lack of knowledge, to be a faulty trigger for people to ski more aggressively in hazard environments, where an accident could lead to severe injuries.

On the other hand, users who have low gear knowledge were said to be less focused on technical specifications and put more trust in the salesman, but might not be eager to learn their equipment. Among the interviewed mountain guides many pointed out an issue with users spending too little time getting to know their hybrid bindings and touring equipment in general. When using the touring mode seldomly, users might forget how to use the binding. While touring in large groups it could lead to malfunctioning bindings, loss of a ski or varying walking pace. In the worst case it can become a safety issue for the whole group. There was also a concern for users buying too heavy equipment and not having enough experience to realize they are not fit enough to carry it through the whole day. There were split opinions regarding weight of the equipment. As mountain guides argued for users buying too heavy equipment, ski shop personnel argued that the weight is not a large concern for users who spend most of their time skiing inbounds. One interviewee with many years of experience in the industry predicted the hybrid bindings on the market today to be very close to a functional minimum weight, before they start to break due to solidity issues.

Among the interviewees there was a shared understanding of the importance of nurturing the ski equipment. Many interviewees with long experience of backcountry skiing emphasized that they were cleaning their bindings and boots from snow thoroughly before entering the binding, whether it was a pin tech binding or alpine binding. The mountain guides made endless examples of users that had experienced false releases due to snow and ice build up in the interface between ski boot and binding. Further on, the binding was expressed in need to endure rough handling when being tossed in and out of roof boxes and kicked on to get rid of snow.

5.2.4 Trust

Since bindings play a crucial role in terms of safety the user wants to feel high trust in the product. It was expressed that many skiers do not know how their binding works, but they still put all their trust in the product. One interviewee stated accordingly: *"A binding is just supposed to work, because in the end people just want to ski".* Ski shop personnel described less experienced customers to feel trust in hybrid bindings that had similar expressions to alpine bindings, such as the Salomon shift binding, because of the familiar look. Among more experienced skiers a transparent construction was more important to build trust. Such a user wants to understand the structure of the binding, to be able to evaluate possible disadvantages in functionality and material used. A mountain guide stated that simple constructions are easier to repair and that it was an important consideration, especially if parts are malfunctioning in the critical parts of the mountains.

Materials also turned out to play a convincing role in how prone users are to feel safe with the product. The use of plastic in crucial parts was highly criticized. A mountain guide stated: *"There is too much plastic in [Fritschi] Tecton, a lightweight binding with a lot of plastic is scary. I don't want to ski on that."* The majority of the interviewees had similar opinions and preferred the use of metal to the greatest extent possible.

The binding market has developed fast in recent years and with companies competing to be first in launching new product concepts, plenty of bindings have been launched with major issues. This is not unique for this particular market, but a binding is a safety product which was expressed as one of the reasons why it causes users to condemn a model and even the brand for a long period of time due to experienced concerns.

5.2.5 Usability from a Skier Perspective

Hybrid bindings on the market today need to be configured to switch between ride modes, which adds complexity in the user interaction. The interaction can be more or less complex depending on the binding model. Complex transitions between modes were expressed as one of the major issues with hybrid bindings today, because users cannot figure out how they are supposed to be used. This in turn requires a long learning curve before having a pleasant experience with the products. As an example, there have been plenty of Salomon shift models returned in ski shops due to customers pulling the wrong lever, leading to breakage and binding malfunctioning. A ski shop owner made the following statement: *"It is super important that a binding is easy to use. You can build an exceptionally powerful binding but if people cannot understand it, you will not get it sold."* Another ski shop employee commented similarly on the Salomon shift: *"Customers come to the store and try to figure out how it works and meanwhile scratching their heads"*. The advice was to minimize the possibility of doing wrong, or as a mountain guide put it: *"Keep it stupid simple".*

In general interviewees were highly skeptical towards demounting parts from the binding to access the touring mode, as with the Marker Duke PT and CAST touring system. One concern was that demounted parts could get lost in critical situations, which can have serious consequences such as hindering the user's possibility to ski down the mountain. Loose parts also take up extra space in the backpack and add additional interactive steps when mounting and demounting the parts. Snow and ice build up also becomes a problem in the interface between loose parts that need to be mounted back on the binding with small tolerances.

As few parts as possible were prefered, as a high number of moving parts increases the risk for malfunction due to ice build up, human error or durability issues. As mentioned in the last section transparent constructions build trust, but it also adds to the understanding of how the binding is supposed to be used. Even though features provide good learnability it is not always enough. If levers and other interactive elements are too small, the users have to perform the transition without gloves on. It increases the risk of freezing and getting clamped between moving parts.

Another commented usability issue found in e.g. Salomon Shift among others, was the lack of feedback in moving parts. Distinct default modes were appreciated by interviewees, as a confirmation of correct use. As an example, the touring mode benefits from having a snapping sound that, according to interviewees, makes the pin technology feel powerful and boot feel secured to the binding. Skiers with no or little experience of touring might find it difficult to enter the pins in touring mode, which was expressed by ski shop personnel and is something that the authors can verify with their own observations. When entering the binding the boot sometimes gets misplaced and therefore benefits from some type of boot guidance.

When locked in touring mode, there are also usability issues to consider. Mountain guides with long experience of touring highlighted the importance of a long stride. In touring mode the boot should have as much rotational freedom as possible. This is especially important when performing kickturns and touring steep terrain. Further on, a low stack height was considered positive in both touring and alpine mode. The opinions were stronger about having a low stand height in alpine mode for closer contact to the snow which could emphasize the surfing experience in soft snow. This is something many hybrid binding producers have failed to accomplish. As many hybrid bindings enable stack height adjustment from the bottom, skiers with lower ski boot soles are the ones who will stand heighest. The balance of the ski created by the boots attachment point to the tech pins was also considered important when walking. If the ski tip or tail is heavily gravitating due to lack of balanced equipment, there may be maneuvering issues when changing walking direction.

5.2.6 The Binding Technician’s Perspective on Usability

Although the skier is the main user of a single pair of bindings, workshop personnel encounter high quantities of the same models everyday. As ski shops and workshop personnel mount a large amount of bindings, mounting efficiency was considered very important for revenues and customer service. If they encounter poor usability, it will result in fewer mounted bindings per day and likely lower their willingness to order a high frequency of that specific binding. Problems that add a small amount of time to each mounting sequence, can become frustrating and expensive in the long run.

An interviewed binding technician implied that when a binding is delivered from the manufacturer the technicians do not want to perform any unnecessary assembly. If possible, the binding should come in two pieces, consisting of a toe and a heel. Entailed issues with loose parts were that they add workload and easily get lost, which can result in time consuming extra work or need for ordering spare parts. On the other hand, the change of parts such as e.g. skistoppers should not require screw detachment from the ski base. These suggestions do not have to be contradictory but are something many brands are failing with. Sliding features should also be minimized as they require extra steps in the mounting process. Distinct default modes were expressed as important when fitting such parts together, since they are often combined with threaded fastening procedures that need small tolerances.

The binding mounting pattern affects the performance as well as the mounting efficiency. A wide mounting pattern increases the power transmission from skier to ski and is also faster to mount because it does not require diagonally attachment of screws. The interviewed binding technician also expressed his frustration over having to use various screwdrivers for mounting a single binding model. Preferably the mounting should require one tool only. Since hole patterns vary between brands and models, the binding technicians need a large setup of mounting jigs which is both an extra cost and requires storage space. A suggestion was therefore to use an existing hole pattern for this project.

When the binding is mounted it requires personalized configurations with regard to ski boot length, boot sole height and release value adjustments. Since the skier relies on the binding technician's adjustments, it is important that it is performed correctly for the skier's safety. To do so the interviewee needed the binding to provide clear feedback of the set state.

Figure 5.5 *Mounting a binding.* (Authors' image 2022)

5.3 Segmentation

Through the findings during interviews and market analysis four convincing segments emerged: the Convenient skier, the Passionate skier, the Skibum and The Performance seeker. The Passionate skier was concluded as a good segment because of the quantity of users, purchasing power and desire for quality. The performance seeker is also an important segment since they put high demands on their equipment and have large influence on both the Passionate skier and Skibum segments. Following are descriptions of the four segments including Jordans parameters for pleasure (see tables 5.1-5.4):

The Convenient skier:

- Skis ~8 days a year, tours max 0.5 day a year.
- Want's one "All Mountain-ski" that works everywhere, skis mostly on-piste.
- Average skier that likes to go fast but keeps their skiing on the ground (DIN 7-10)
- Often travels with family but would prefer to go with friends
- Might forget how the binding works in between uses.
- Has money and "treats themselves" to new equipment by a 5 year period at the time
- Early to late majority

Physiological

- Have never reflected on the bindings role in their experienced pleasure while skiing
- Appreciate low weight while carrying their equipment

Sociological

- Read magazines before a purchase to see what bindings other people use.
- Rather buys advanced equipment than basic to get confirmation by others
- A beer in the sun is as important as the skiing activity

Psychological

- Trusts the salesman
- Just want the binding to work
- Need a simple interface with good learnability

Ideological

- Might have low awareness of their skiing limitations
- Might not identify themselves as a skier
- Prefer a product expression with sporty character

Table 5.1 *The convenient skier.*

The Passionate skier:

- Skis ~14 days, 11 inbound, 3 touring
- Seeks one “off piste-ski” that works everywhere, but often owns more than one pair of skis.
- Is or has been an advanced skier with good technique (DIN 9-11)
- Are interested in technology and gear
- Has an annually booked ski trip with friends.
- Has money and “treats themselves” to new equipment
- Tries to stay up to date on new equipment on the market
- Early adopters

Physiological

- High physiological pleasure from technically well built solutions
- Binding semantics are important

Sociological

- Likes to talk about skiing and seek for people with similar interests
- Like to tease friends with new purchased equipment

Psychological

- Do not take many risks
- Eager to learn new things (early adopters)
- Needs a solution with high memorability

Ideological

- See themselves as skiers
- Middle to high self-awareness and know their skiing capabilities
- Prefer a product expression that is closely related to function

Table 5.2 *The passionate skier.*

The Skibum:

- Skis ~100 days, 70 inbound, 30 touring
- Excellent skier that needs robust and reliable equipment.
- Skis aggressive and want a binding that does not break (DIN 13=thin, DIN 14=enough, DIN 15=good.)
- Tours a lot but puts a higher emphasis on descent than ascent
- Works in a bar during the season or has saved up money to afford only skiing
- Buys equipment before the season and needs reliability, are very influenced by the PROs and what is currently trending
- Innovators to early adopters

Physiological

- Want maximum power transfer and surf feel
- Gets suspicious if the equipment is too light

Sociological

- Are very aware of groups within the ski society
- Highly influenced by pro riders choice of equipment

● Want their equipment to express their skiing abilities **Psychological** ● Take risks ● Rather skis with high release value than to lose a ski due to false release ● Prefer a product with high efficiency for maximizing skiing time **Ideological** ● Live and breathe skiing (if only for a particular time in life) ● Skiing plays a large role in good self-esteem and confidence and they therefore put high emphasis in product brand and heritage

Table 5.3 *The Skibum.*

The Performance seeker:
● Skis ~100 days, 50 inbound, 50 touring ● Excellent skier that needs robust and reliable equipment. ● Skis hard and want a safer alternative than "locking the tech toe" (DIN 13=thin, DIN 14=enough, DIN 15=good.) ● Tours a lot and therefore think weight is important ● Often works within the skiing industry ● Get free equipment or purchase prices ● Can be affected by contracts and sponsorship responsibilities ● Innovators - late majority
Physiological ● Want maximum power transfer and surf feel ● Prefer light weight equipment ● Able to experience physiological pleasure from small adjustments **Sociological** ● Have high influence on other skiers ● Trust their own experience rather than others **Psychological** ● Take risks but with high awareness of consequences ● Trust their skiing abilities ● Prefer a product with high efficiency for maximize skiing time ● High emphasis in trust - can be skeptical to new equipment ● Values customization **Ideological** ● Live and breathe skiing ● Are focused on performing and derive pleasure from equipment that encourage them to perform frictionless ● Prefer a functional product expression

Table 5.4 *The Performance seeker.*

Despite skiing experience, good usability is important for all of the four mentioned segments, since bindings can be seen as a safety product. With an increasing interest in ski touring and hybrid bindings that attract users with less experience, the need for user friendly products becomes even more important and a strong business advantage. If this trend continues, the *Convenient skier* and *Passionate skier* segments have a possibility to grow fast. With an eagerness to buy new gear and a genuine interest in skiing they will probably develop their skiing abilities and expand the *Passionate skier* segment over time.

Even if very few *Passionate skiers* will become as skilled as the *Skibum* or *Performance seeker*, they are interested in developing their skiing abilities. Even though they want to have the "right gear" and easily get affected by others, they are not blind to quality and put trust in durably built products. As a result they may look for equipment that is rather suited to the *Performance seeker*. The *Passionate skier* needs simple solutions that provide high learnability and memorability, due to quite a few ski days a year. Even if the *Passionate skier* may own more than one ski setup, their skiing is associated with travel where a versatile setup is preferred. The weight of a hybrid binding is seen as an important parameter for the *Passionate skier*, but is not compared to the weight of tech bindings.

Although this segment was considered interesting from a market point of view, the *Skibum* and *Performance seeker*'s needs were valued at least as important for product development. They have a high influence on the *Passionate skier* and their needs drive products of high quality, but constitute less purchase power due to sponsorship and other purchase patterns.

5.4 Product Specification

This section includes a summary of the product's functional and semantic user requirements used as a basis for ideation.

5.4.1 Requirements and Product Statement

The following product statement is a condensed expression of the product requirements and ground for its existence:

> *The product should be a trustworthy and robust solution that provides the user with full potential alpine performance and touring possibilities. Through a transparent construction and self explanatory interactive features, the user should be able to seamlessly switch between ride modes and spend as much time as possible skiing.*

The solution should more specifically:

Minimize the number of interactive steps for shifting between alpine and tour mode.
Provide large interactive elements with good indication of state.
Consist of as few parts as possible.
Weigh less than the salomon shift to be an interesting alternative for more touring focused skiers.
Provide a maximum release value of DIN 15.
Have a robust construction where crucial parts should be built in metal.
Prohibit snow and ice build up.
Boot guidance in tour mode.
Low stack height.
Provide time efficient mounting.

Table 5.5 Extract from the requirement list.

An extended list of requirements can be found in Appendix C.

5.4.2 Inspiration Board

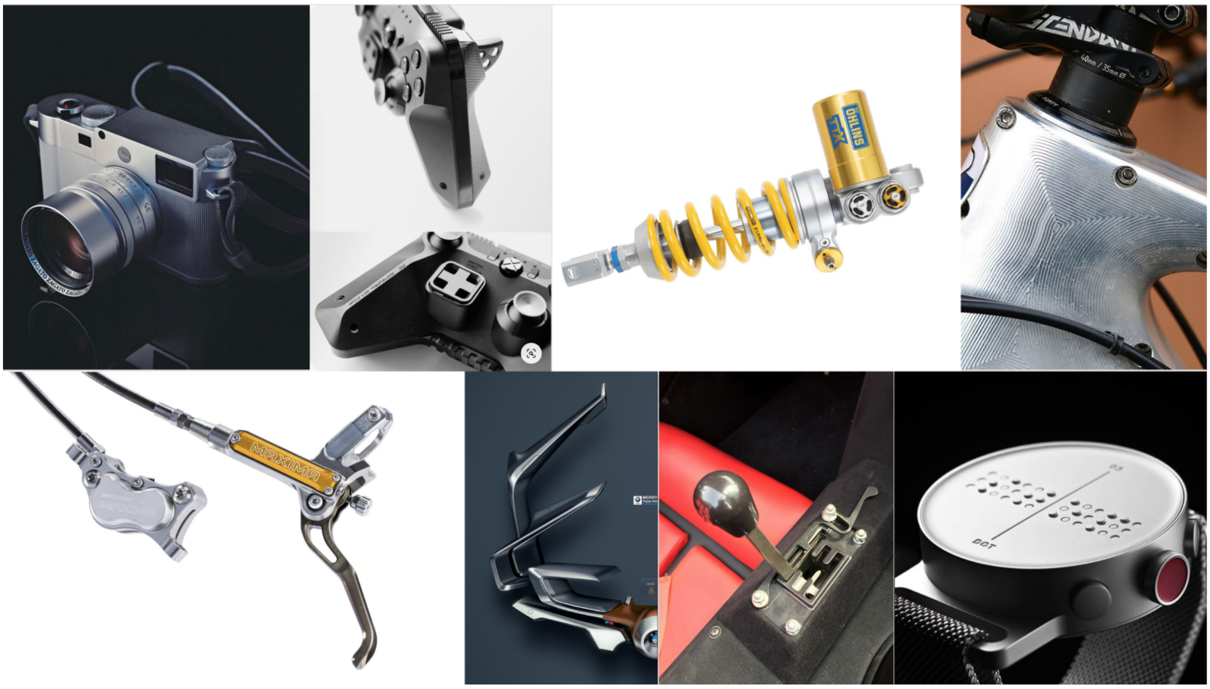

Figure 5.6 *Inspiration board.*

The most important features visible in the inspiration board are minimalistic yet functional expressions in combination with geometric shapes and surface finishes coming from milling as a manufacturing method. This board was used as an inspiration for finding semantic values that would represent the sought trust, robustness and mechanical feel the product should provide.

5.5 Ideation (2D & 3D) and User Input

This section describes the following ideational work in regards to the product specification.

5.5.1 From Napkin Sketches to Formal Concepts

What was initially explored was how the structural elements could be arranged to switch between ride modes. The topological sketching resulted in 23 topological variants sketched from an orthographic side view. Each variant consisted of three basic shapes that represented the alpine toe, tech toe and spring arranged in different combinations. From these variants, 60+ structural concept sketches were created including ideas on how the three components would move relative to each other. By an evaluation of the structural concepts, five categories of concepts were considered interesting for further exploration based on credibility and user insights.

These concept categories were called *horizontal rotation*, *vertical rotation*, *slide, layers* and *static*. To get a better understanding of the concept's possibilities and spatiality, simple sketch models were made together with low fidelity 3D CAD models. Here the use of ski boots became an important tool for measuring distances and the mode's accessibility. On this concept level, focus was on minimizing the mental and physical effort for shifting between ride modes. Along with more three dimensional work, the concepts developed into more formal states where e.g. durability concerns, ice and snow resistance and stack height were considered.

The *horizontal rotation* category contained solutions that accessed the two different ride modes by rotating the toe 180 degrees around the z-axis (transverse plane)(see Figure 5.7). The alpine toe and tech pins were resting on the opposite side of the rotation point while not being used. This concept was supposed to require minimal modification of the binding and provide a transparent solution that was easy to understand.

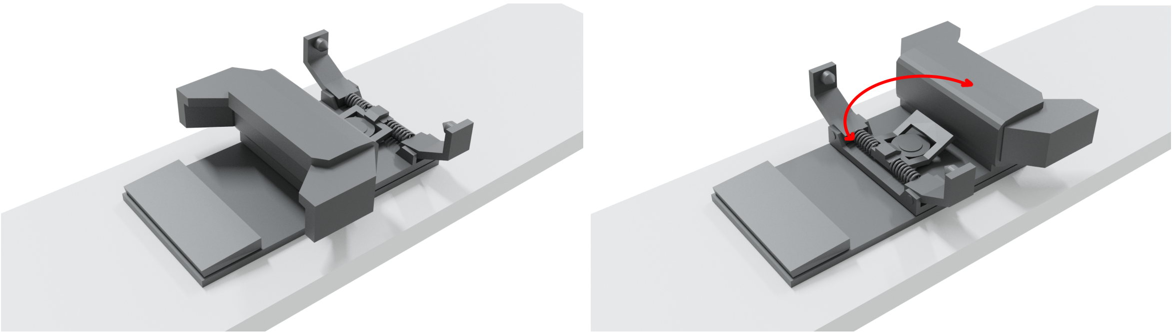

Figure 5.7 *Example concept from the Horizontal rotation category.* (Authors' image, 2022)

The *vertical rotation* category accessed the two different modes through rotation around the y-axis (sagittal plane)(see Figure 5.8). Either the alpine toe alone was rotating, or both alpine toe and tech toe were rotating at the same time. Here the binding's main body would be fixed for more solidity while change of mode was done through one rotating interaction.

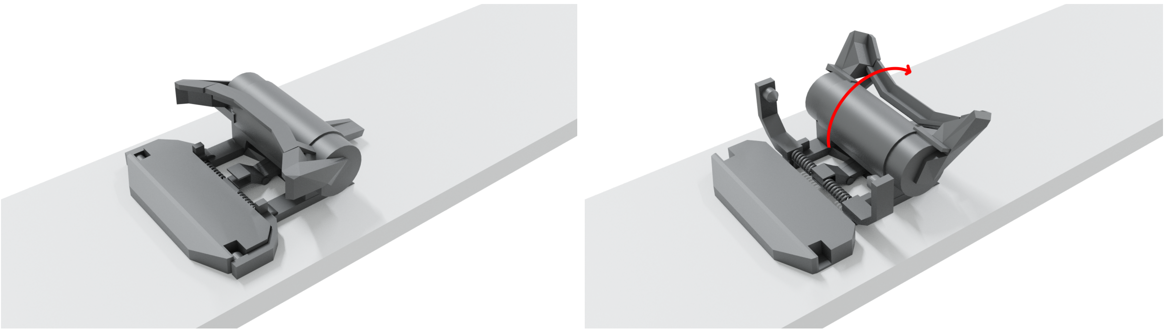

Figure 5.8 *Example concept from the Vertical rotation category.* (Authors' image, 2022)

In the *slide* category the solutions were based on an alpine toe that was supposed to be slid forwards to access the tech pins (see Figure 5.9). The alpine toe would have room to hold the tech toe when being inactive and binding used in alpine mode. Another alternative was to have the tech toe resting flat to the ski around the AFD when being inactive, to then be rotated 90 degrees when used in touring mode.

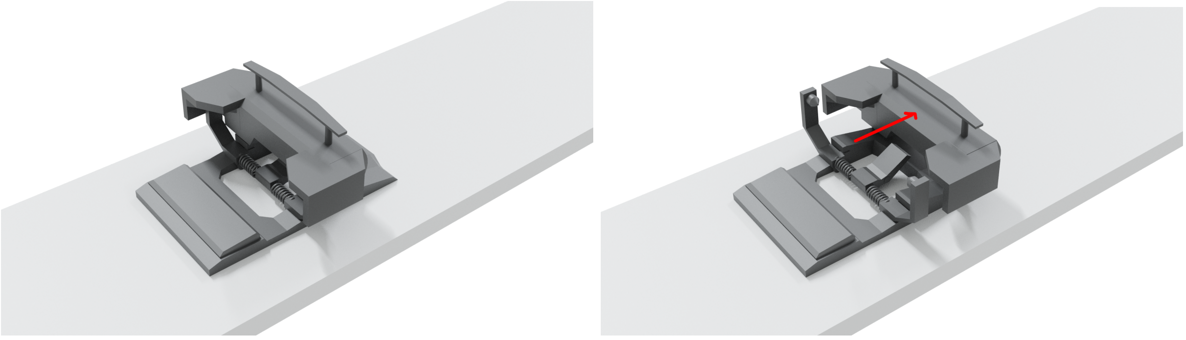

Figure 5.9 *Example concept from the Slide category.* (Authors' image, 2022)

The *layers* category included concepts that had the tech toe placed inside the alpine toe as the common denominator. In some of them, the tech toe would be accessible through moving a "layer" of the alpine toe, in others the tech toe was the moving part. One with time distinguishing solution from this category was the "stomp concept", where the bindings transitional stage was meant to be naturally embedded in stepping into the tech toe and meanwhile lowering the touring stack height (see Figure 5.10).

Figure 5.10 *The "Stomp" concept from the Layers category.* (Authors' image, 2022)

The purpose with the fifth concept category, *static*, was a binding with no modification between ride modes for minimizing user errors and the number of moving parts. Instead the user was supposed to change the boot position between the alpine toe and a tech toe which was statically mounted on top of the alpine binding (see Figure 5.11). The tech toe was supposed to be a minimalistic tech toe that only used material flex to hold the boot in place while touring, to keep the number of moving parts and weight down.

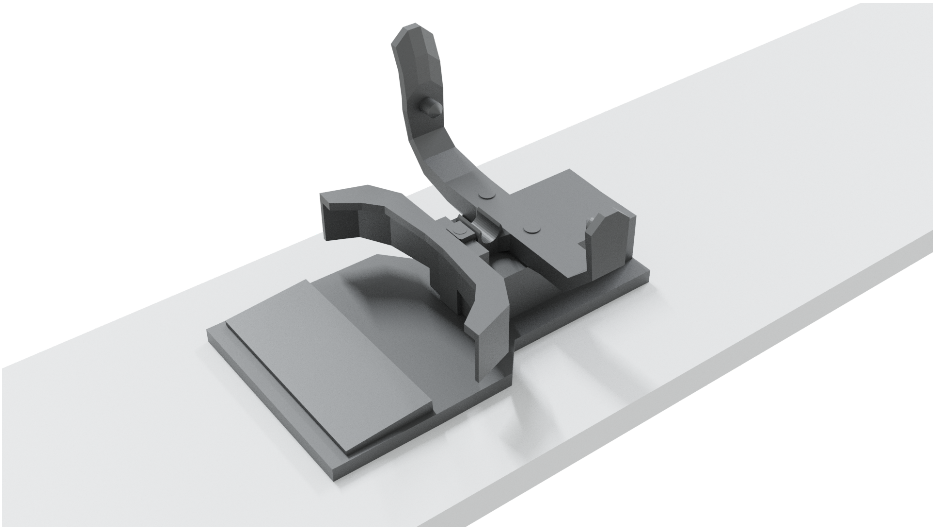

Figure 5.11 *Example concept from the Static category.* (Authors' image, 2022)

5.5.2 Concept Evaluation

During the PNI evaluation with interviewees several concerns were highlighted, as well as possibilities. The most frequent expressed concerns were construction issues, usability concerns and ice and snow build up. Following are the individual concept categories commented by interviewees followed by issues discovered by the authors.

Horizontal Rotation

It was considered positive to use already proven technology that people recognize and trust. One concern was how to lock the rotation in a convenient way without any mechanical play. The placement of the tech toe would also make it exposed when skiing, because of being upright and pointing forward. Some also thought that the rotation of the whole binding would demand large contact surfaces which could be sensitive to freezing.

Additional comments from the authors: For the boot to have enough rotational freedom this solution requires much space between the spring and tech toe and the rotating tower to be low enough. This makes it difficult to include a trustworthy lever mechanism for opening of the tech toe, since the rotational pivot point needs to sit closer to the tech toe than the alpine toe to free the boot heel.

Vertical Rotation

This category was dismissed adding too many interactions for executing the transformation. The weight shift when rotating the alpine toe into a forward position was feared to create a disbalance while touring. It was also said to remind of the Marker Duke PT and therefore shared common critique.

Additional comments from the authors: The alpine toe rotates in the same direction as the power transfer from the boot which might be a durability issue and also increases the risk for play. Additionally, no convincing solution was found for the tech toe's implementation.

Slide

One user thought it seemed like a genuine and durable solution due to inheriting a traditional look, but others were skeptical of the sliding mechanism. Rotating mechanisms were preferred before sliding mechanisms because the latter could result in unwanted movement between parts after a period of time used. The frontal position of the alpine toe was also expressed to affect the balance when touring.

Additional comments from the authors: By simulating the boot movement in Blender, it was shown that the alpine toe needed to slide a long distance to allow enough boot rotation while touring. Further on, the tech toe lever had a hidden position since it was placed under the alpine toe.

Layers

The stomp solution was praised as a smart and smooth solution because the change of state is done through a natural stomp movement, which is the same as to how a tech binding is commonly used. It was also considered positive that the tech toe was less exposed than in other solutions, which also could benefit the associations to an alpine binding. The negative input was how to make the required movement of the alpine toe durable enough. Concerns were also made about the open design that could be sensitive to snow.

Additional comments from the authors: This solution would further require a locking of the alpine spring, to prohibit the alpine toe from flexing due to forces created by the skier's weight while touring. This would add another interactive step for the user and could be dangerous if the user forgets to unlock the spring before skiing.

Static

The implied strengths with the static concept was the solidity in using few moving parts. The interviewees considered the risk for freezing to be eliminated with this approach. It was also said to be simple from a usability perspective since it did not require any transformation. The critique was aimed at the exposed tech toe due to semantics, risk for impact and skepsis towards a tech toe with only the material flexing. There were also opinions about the touring stack height and risk for tearing down the alpine toe while walking.

Additional comments from the authors: Besides the user input which the authors agreed on, this solution would require a large boot transfer distance between the two ride modes.

5.5.3 Concept Decision

The Horizontal rotation and Slide concept did not pass the screening because of risk for mechanical play and large shift in balance while touring. Although the Horizontal rotation concept implied a simple mechanism for change of state, the toe was feared to become too large and therefore heavy with the needed distances between the tech and alpine parts. Even if they became screened out, the importance of recognizable elements and use of proven technology was once again seen as important and learnt from these two concepts. The Vertical rotation concept had both usability and durability flaws mentioned in the last section and therefore got dismissed.

The two most convincing concepts were the Stomp and Static concepts for dissimilar reasons. The Stomp concept allowed for good usability where the transitional interaction fit the users mental model while the Static concept was satisfying due to few parts and solid construction, which also had been expressed as highly important attributes. In contrast to the other concepts, the static concept did not require modification of the alpine toe for shifting modes. This was seen as a strong safety argument because hybrid binding malfunction had been seen in connection to the transitional stage. This increases the possibility of being able to ski down if something breaks.

With these arguments the mission for further developing work became to investigate how the possibilities with the Static and Stomp concepts could be combined to overcome the discovered individual issues and become a user friendly and durable unit.

5.5.4 Reaching a Final Concept

This section focuses on the most practical part of the process where ideas were materialized and iterated to physical form.

First 3D Printed Prototypes

This phase of the project started off with printing low fidelity volumes to explore different stack heights and pin placements. This was done in order to get a spatial understanding for the issues expressed during the evaluation. The resulting insights was used to create two models with as low stack height as possible.

The first prototype had horizontal spring and alpine wings with similar function as the illustrated binding “H2” shown in Figure 5.2. (see section 5.1.3) The intention was to use a conventional tech toe solution that was fixed in a low position in the alpine toe spring house and separated from the wings. To reach a low stack height the wings therefore had to rotate outside the tech toe while flexing. Because of the low positioning of the tech toe and sloped boot sole, the boot interfered with the wings. To solve the problem the wings were shortened to a point where the boot was no longer in contact, but resulted in minimal surface contact between alpine wings and boot in skiing mode (see Figure 5.12). The surface contact was seen as critical and therefore other options were further discovered.

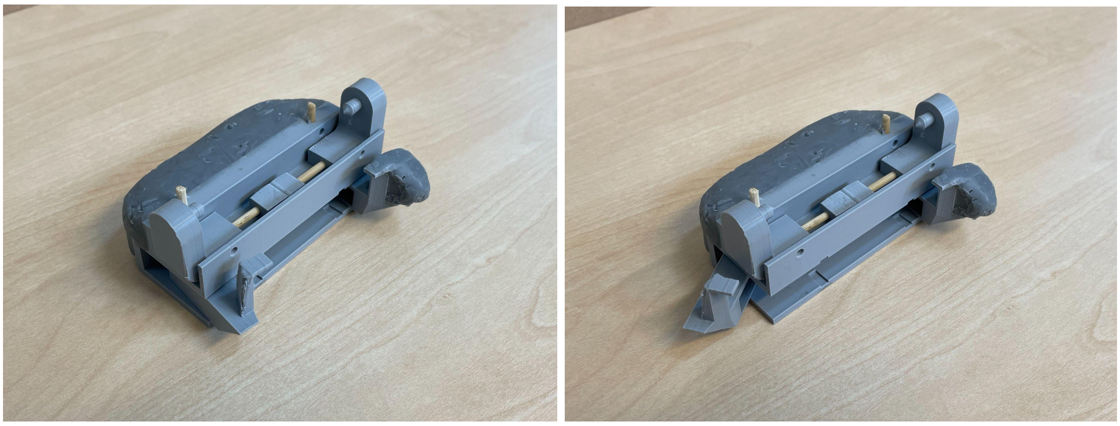

Figure 5.12 *Static prototype.* The picture shows the wings’ rotation around the submerged tech mechanism. (Authors’ image, 2022)

Instead the tech toe was moved from the spring house to an alpine toe consisting of one solid part. The initial idea was to create an alpine toe that could be movable in height between the two modes. The higher default position would be used while skiing and the lower mode for touring. The lowering of the alpine toe would allow a taller distance between the pins and alpine toe to avoid boot interference, without increasing the stack height compared to the first prototype. Even if the idea seemed great from a user perspective, it was difficult to see how the alpine toe would move frictionlessly to the spring house when using a hard spring. Since the stack height was still not considerably high when in its tallest position, the idea was still considerable. Since the evaluation had shown dislikes about an exposed tech toe, the concept still had issues. To solve those issues, another prototype was 3D printed where the tech toe was foldable into the alpine toe, when not used (see Figure 5.13). This way it became more aesthetically in line with a conventional binding and less exposed. One crucial problem discovered through this prototype was that the alpine toe was in need of fixation before touring, to avoid unwanted flexing due to spring compression. This would add an interactive user step, where the reason might not seem obvious to the user and could be dangerous if kept locked while skiing. This risk was considered severe and therefore all attempts to lock the alpine toe were abandoned.

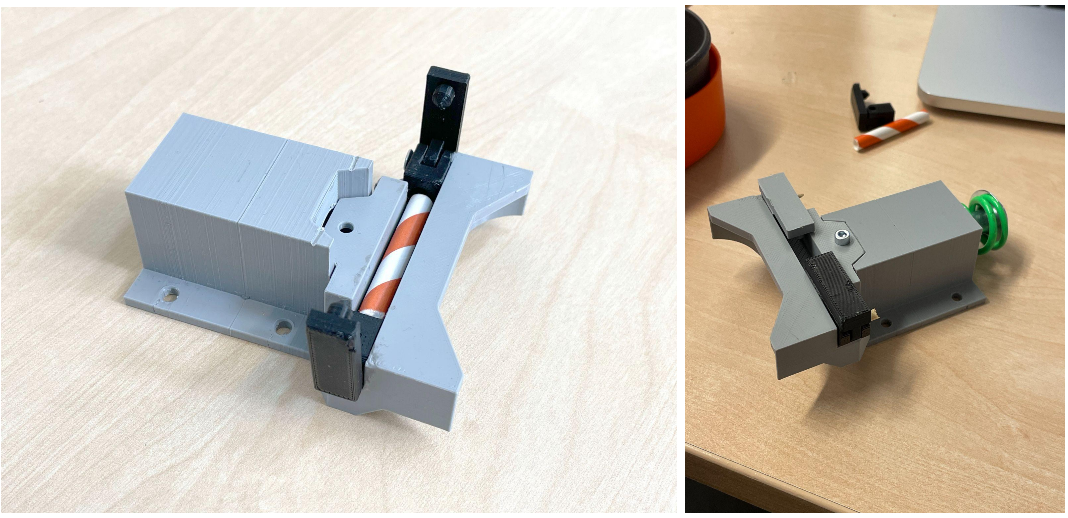

Figure 5.13 *Foldable jaws.* Prototype with foldable pin tech jaws and alpine toe with adjustable height. (Authors' image, 2022)

U-Shaped Metal Bracket

With these new insights, the idea of a flexing u-shaped bracket was rediscovered. The reason was that such a solution would decrease the number of moving parts, weight and stack height compared to a conventional tech toe which requires vertical space for the variational spring positioning. The decision was based on assumptions made on a similar product on the market which was a carbon fiber bracket made for ski mountaineering racing. A discussion was held with a material expert about finding a metal material with the right amount of tensile strength and elasticity to allow for the correct functionality. The conclusion from the discussion was that the idea had credibility and the challenge instead became to create a bracket with the right amount of flex to allow entering the binding with the help of a ski pole, but at the same time hold the boot in place steady enough while touring.

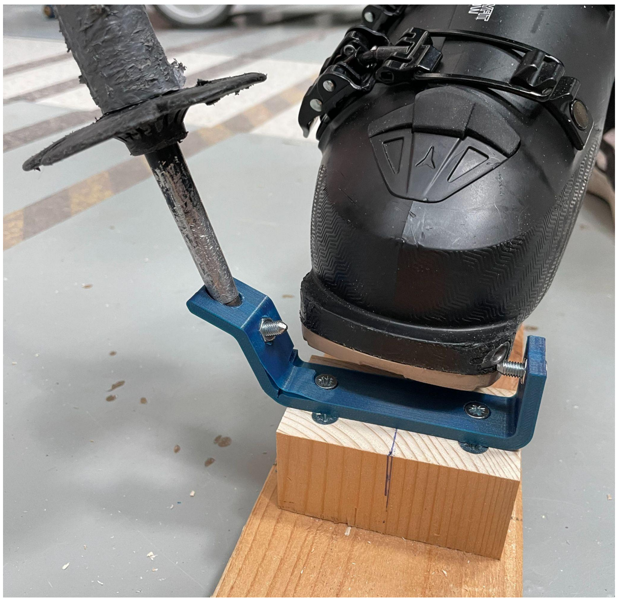

Figure 5.14 *U-bracket.* Testing of a flexible bracket prototype. (Authors' image, 2022)

Meanwhile exploring the brackets dimension and functionality, its position on the binding was investigated. The most convincing way to store the bracket was by rotating it 180 degrees between the two modes. When touring, the bracket was supposed to rest on the spring house close to the alpine toe but when skiing be rotated so that the bracket pointed towards the ski . By making a modular 3D printed prototype it was possible to explore different lengths on the rotational lever holding the bracket, to compare the resting position in the two different ride modes (see Figure 5.15). The aim was to find a rotational sweet spot for having enough spring house support in touring mode and at the same time find an aesthetically pleasing and not too exposed position when being inactive.

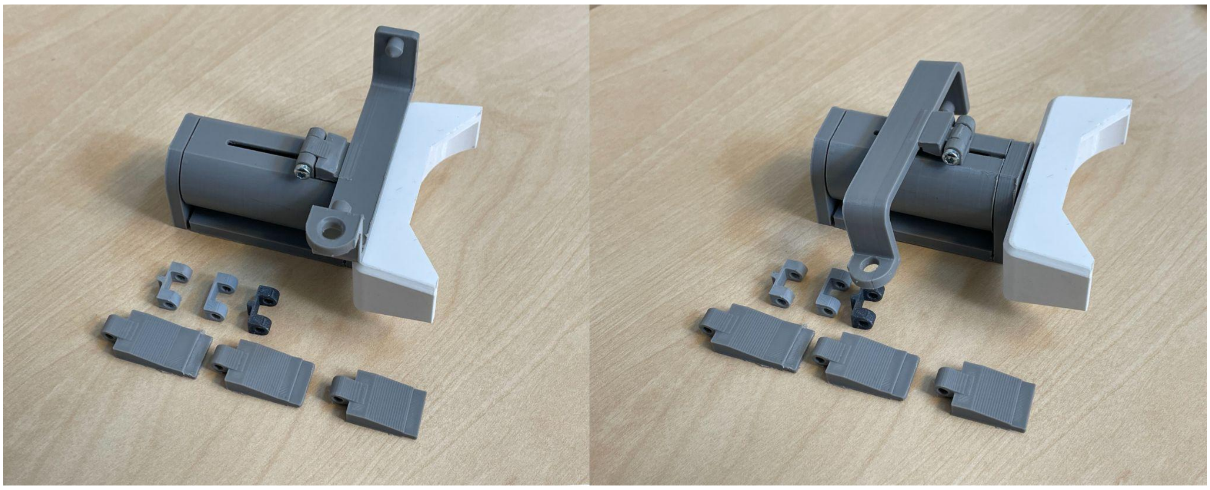

Figure 5.15 *Modular prototype.* Modular prototype with levers of various lengths.(Authors' image, 2022)

The width of the bracket's mounting points to the alpine toe was also considered by this time. A wider mounting between the two was found to give a more stable tech toe and a more favorable material flex in the bracket. The mounting points were explored through additional prototypes shown in Figure 5.16. The prototypes also served a purpose of exploring expression through varying the proportions of the alpine toe in comparison to the tech toe, with the mission to further integrate the two components into one product.

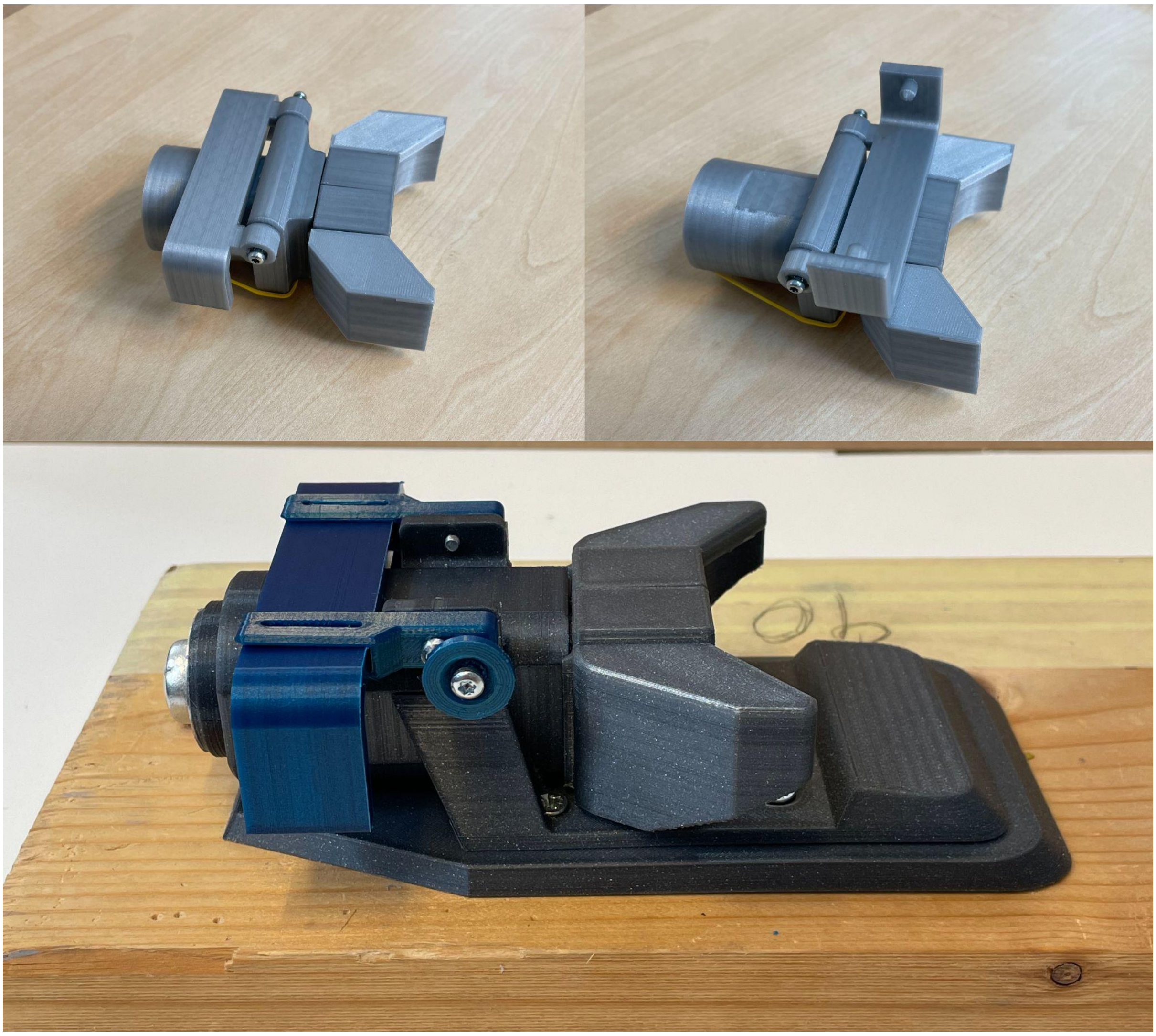

Figure 5.16 *Prototypes in different fidelity.* These prototypes served the purpose of mechanical and semantic evaluation. (Authors' image, 2022)

At this stage, brackets with different geometry and mounting points had been tested in 3D printed plastic. Although it was possible to get an understanding of the brackets' elastic behavior and stress with plastic material, a bracket in spring steel would be necessary for further evaluation. Attempts were made to order such a prototype but with no success due to production time. Therefore attempts were carried out to print brackets with higher infill to try mimicking spring steel. These prototypes had holes for accommodating the ski pole as leverage for opening the binding. This was considered a reasonable way to open the binding since it is recognized from other binding models on the market and an effective way of transferring power. During the testing of these stiffer prototypes it was found that the binding suffered a higher risk for rolling over in the entering moment, especially when mimicking snow as a softer underlay. The reason was that the force had to be applied far from the bindings center of mass. Even if the procedure was still possible to carry through, it was considered too troublesome in a real environment. This approach also lacked convincing feedback to confirm that the boot was locked in place, which is something that had been criticized in other products. As a combination of the test results and the fact that they were carried out with the wrong material, a decision was made to find an alternative solution to the envisioned steel bracket.

Finding an Alternate Touring Mechanism

Back at the drawing board with further insights, alternate ways of locking the tech toe were explored. The sought solution needed to work with lower applied handling forces than the bracket but still provide minimal height build, low weight, trustworthy feedback, durable construction and be able to rotate 180 degrees. This phase resulted in five alternate solutions presented below.

The first idea was a two-in-one bracket that consisted of bodies with varying material flex (see Figure 5.17). The inner bracket was thought to be non flexible to prohibit lateral ski boot movement while touring. The inner bracket, which holds the pins, would be flexible enough to provide a boot entry that did not require any high applied forces from the ski pole. This idea showed tendencies to chafe the plastic ski boot while walking and therefore got dismissed.

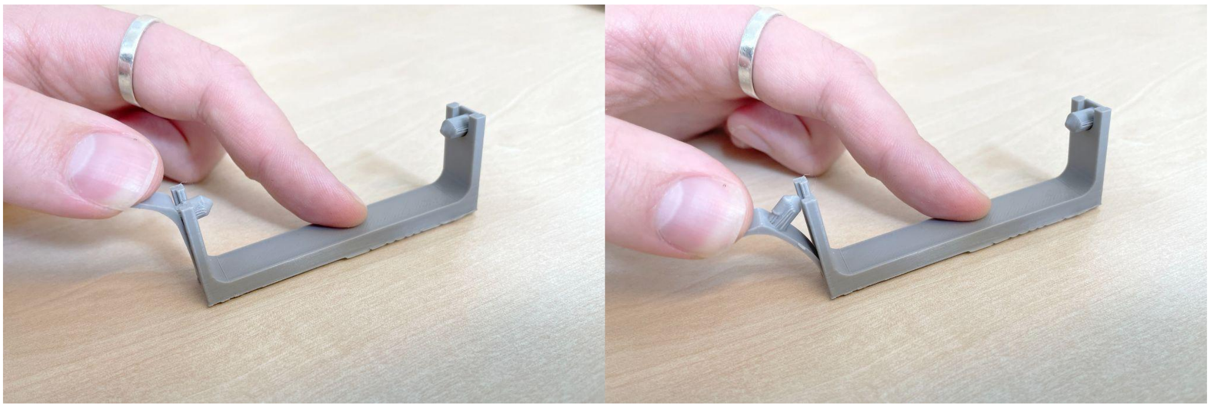

Figure 5.17 *Two-in-one bracket.* The prototype was an attempt to facilitate boot entry while keeping retention, through using two similar geometries with different material flex. (Authors' image, 2022)

The second idea was that one side of the bracket would be spring loaded to give a distinct clicking feedback when closed (see Figure 5.18), which seemed as a hopeful solution. But when tested it had usability flaws since the user still had to aim the boot correctly for the pin to enter the boot insert correctly, while closing the jaw with the hand instead of a pole.

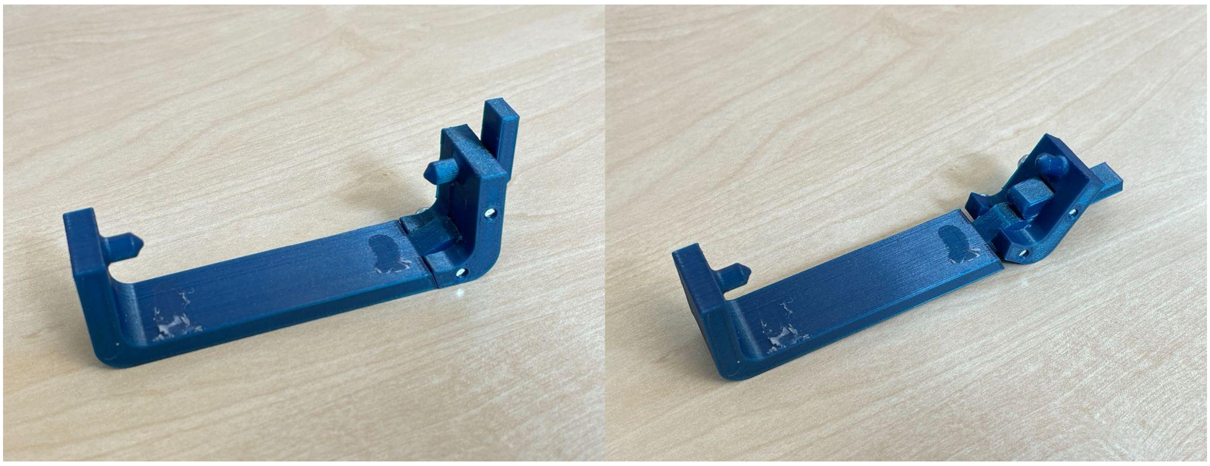

Figure 5.18 *Snap solution.* Investigating how to implement good feedback with two distinct resting modes. (Authors' image, 2022)

The third solution utilized material flexing similar to a torsion spring. The "spring" also worked as a lever that could be pushed with the pole to initiate the opening of the tech pins (see Figure 5.19). This idea was lightweight, centered above the binding, low profile but provided a short lever that was difficult to reach with the ski pole. The lever length had to be limited due to the wanted tech toe rotation when shifting mode. Another weakness was the lack of snappy feedback while entering, since the spring was closed in its natural position.

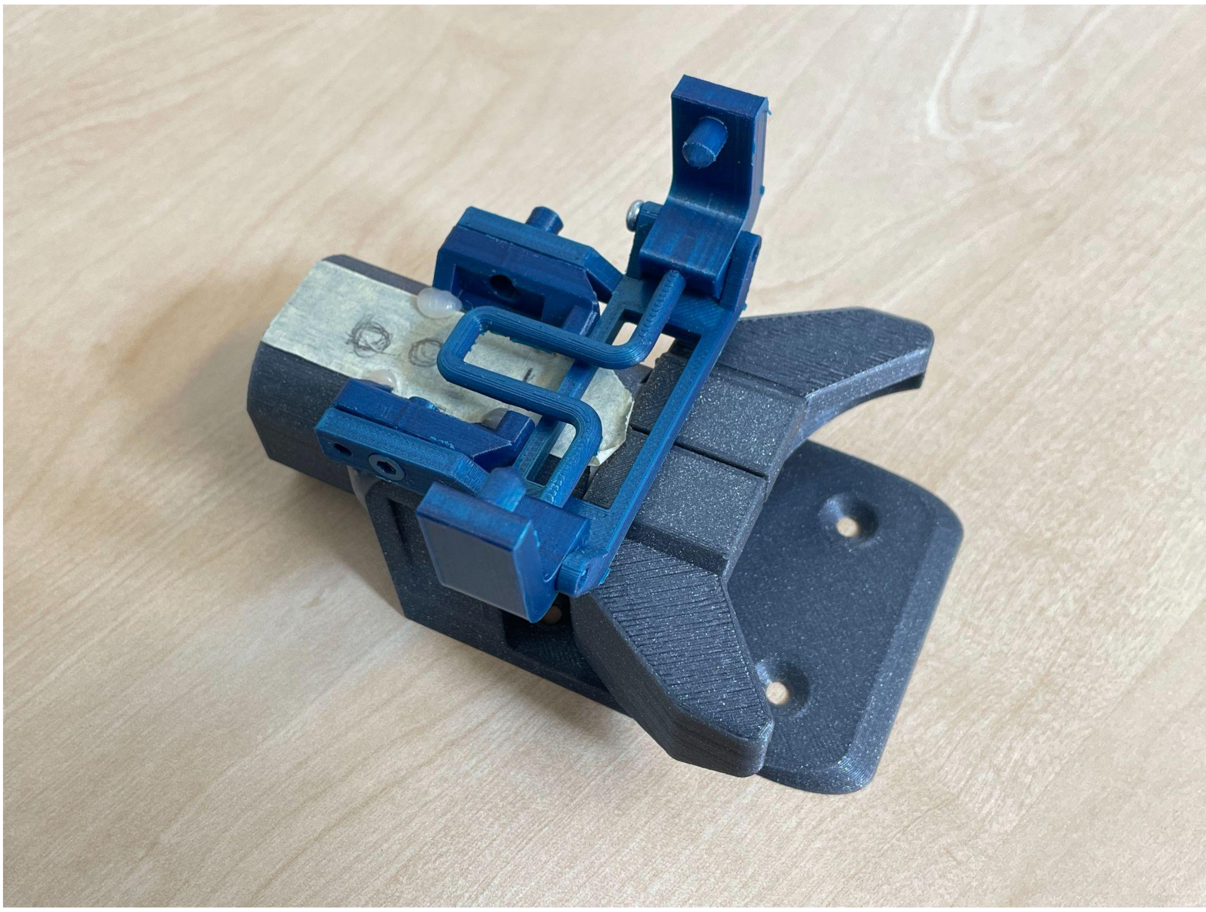

Figure 5.19 *Torsion spring.* An attempt to keep the touring attachment low in weight and height by the use of material torsion. (Authors' image, 2022)

With the fourth alternative the leverage and snappy feedback was investigated by moving the lever to the side of the spring house where it could rotate freely when shifting mode (see Figure 5.20). With the forces applied closer to the body the expectations were to lower the risk for a potential roll over compared to the bracket solution. Although keeping the lever on the outside allowed space for a longer lever, the location was more exposed. It could potentially increase the risk of accidental release while walking if e.g. the skis would cross.

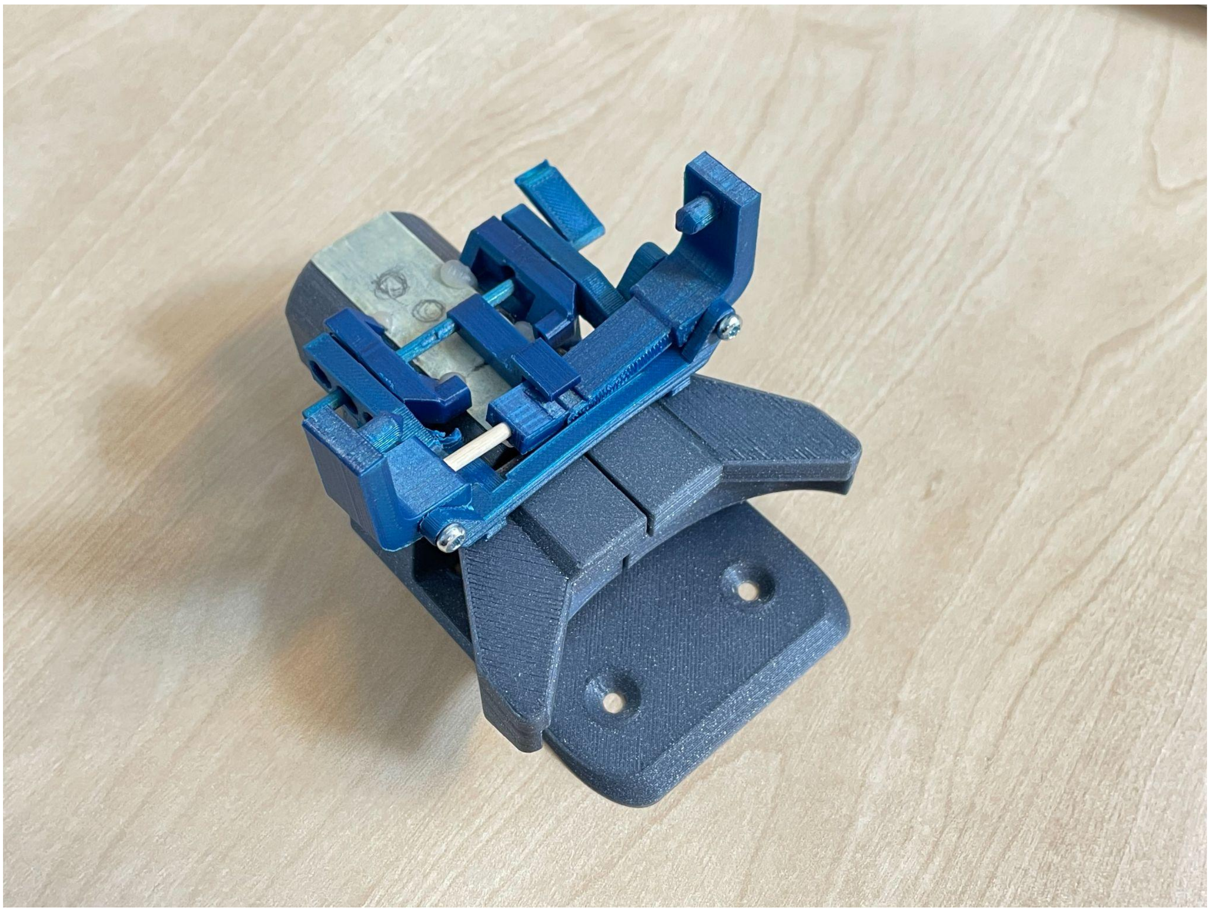

Figure 5.20 *Outside lever.* A lever on the outside was more exposed but could potentially be longer. (Authors' image, 2022)

The fifth and last prototyped solution was a low profile tech toe mechanism, similar to a conventional tech toe, but with two asymmetric springs (see Figure 5.21). Because of the wanted leverage, the lever was only attached to a rotational axis in the spring house and not to the tech toe jaws. This solution made it possible to create a longer lever because it was not in need of rotating with the tech toe component when changing ride mode. It also made it possible to lower the pin stack height and the resting position in alpine mode. The lever was centered above the binding to allow for high applied forces from the ski pole, without the binding rolling over. As stated during interviews a spring loaded toe provides trustworthy feedback as it closes on the boot. The recognition in this type of solution was also a beneficial argument for why this final alternative was chosen.

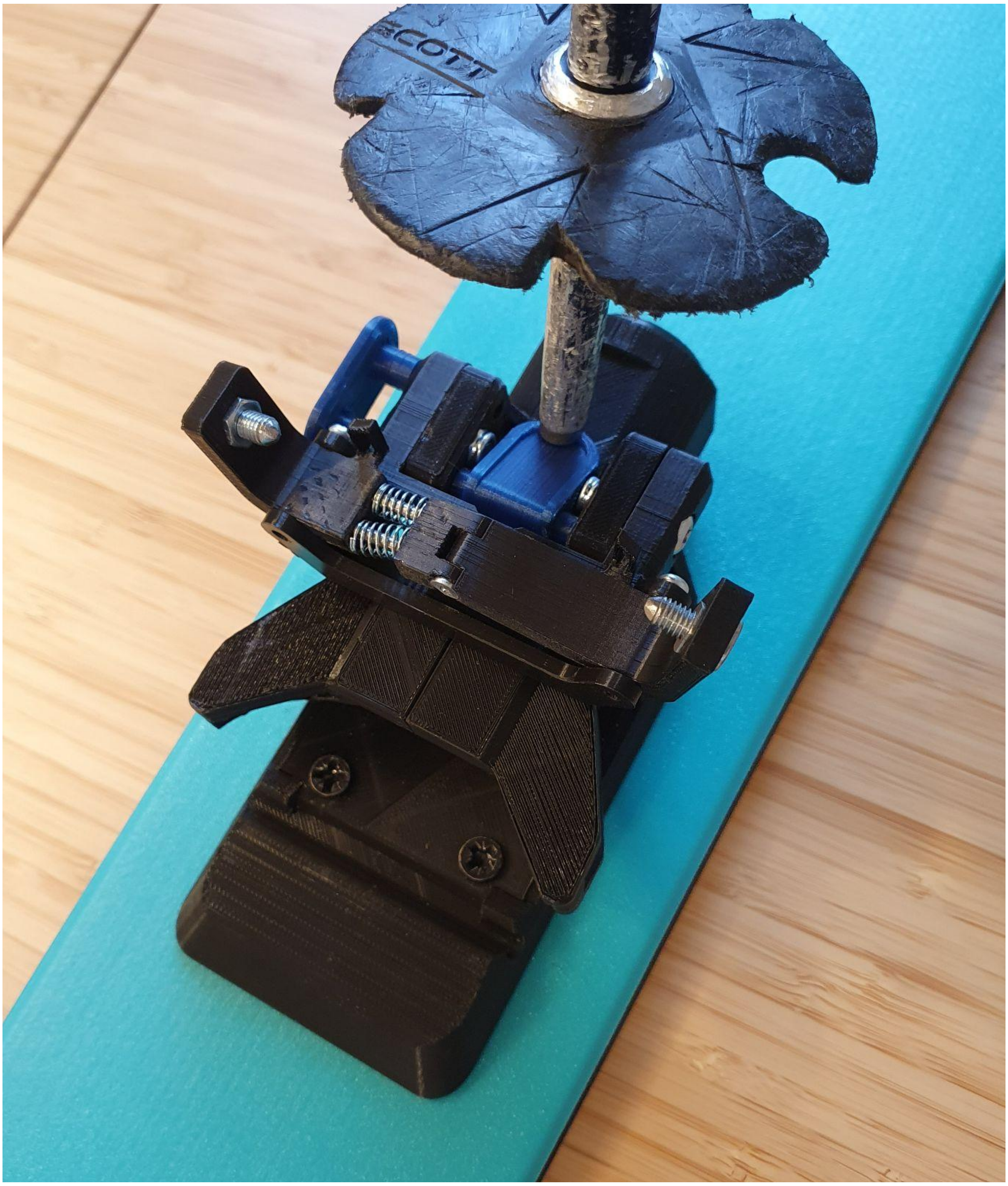

Figure 5.21 *Centered lever with a fixed position.* A lever that was not attached to the jaws could provide leverage beyond the rotation point used for rotating the whole tech toe. (Authors' image, 2022)

Locking Mechanism

The rotating tech toe was in need of having a fixed position in both ride modes. It was important that this interactive locking mechanism would be possible to handle with ski gloves. It required a large sized interactive element providing good haptic and visible feedback to ensure the user of the component being locked in place. It was found that the locking feature benefited from being positioned on the moving tech toe, since the same interactive element could be used to perform the rotational change of ride mode. By making and evaluating several physical prototypes it was found that a spring plunge solution was a reasonable and recognizable way of locking the rotation. After testing different shapes, pins, and sizes with ski gloves on, a spring plunge with two locking pins bridged by a stadium shaped top, provided good balance and feedback (see Figure 5.22).

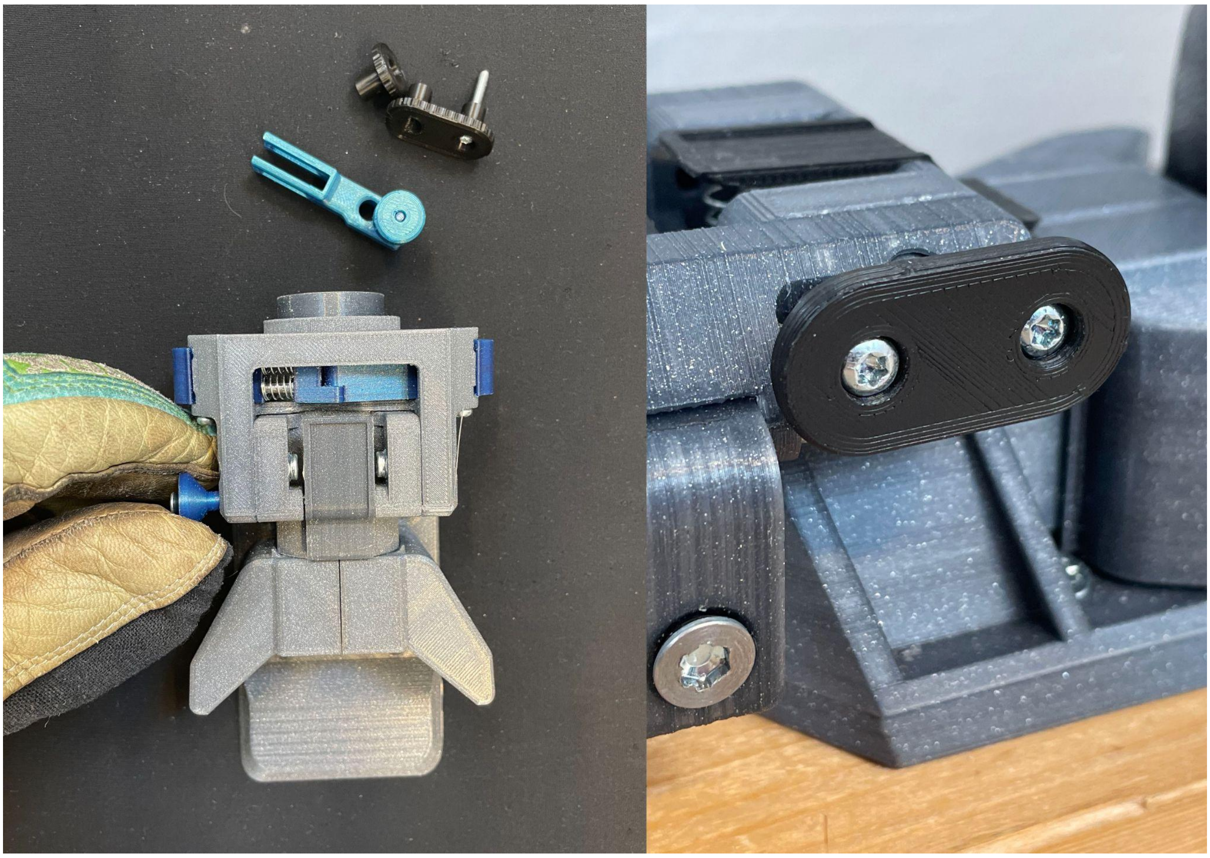

Figure 5.22 *Locking mechanism.* Through testing the interaction with ski gloves, a spring plunge mechanism with double pins and stadium shape provided the best interaction. (Authors' image, 2022)

Alpine Release Mechanism: Lateral, Vertical and Frontal

When working with how the binding would function in Alpine mode, inspiration was taken from the Look Pivot 14 toe. The patent expired in 2018 and is therefore not subject to possible infringement (Quillard & Chevalier, 2000). The functionality of this binding is illustrated as Binding V1 in section 5.1.3. Positive aspects of this mechanism is the combination of simple construction and high degree of flexibility. The layout is a reiteration of the solid toe piece design from *First 3D printed prototypes* and was chosen in favor of the horizontal layout also seen in the same section. This decision was made because of semantic reasons expressed by the users along with the previous prototype not allowing elastic travel in the same amount of directions. Moving on, to enable a lower and more streamlined appearance, updates to the Look Pivot 14 design were made through reducing the angles between the spring and the wings along with making the interface lower (see Figure 5.23).

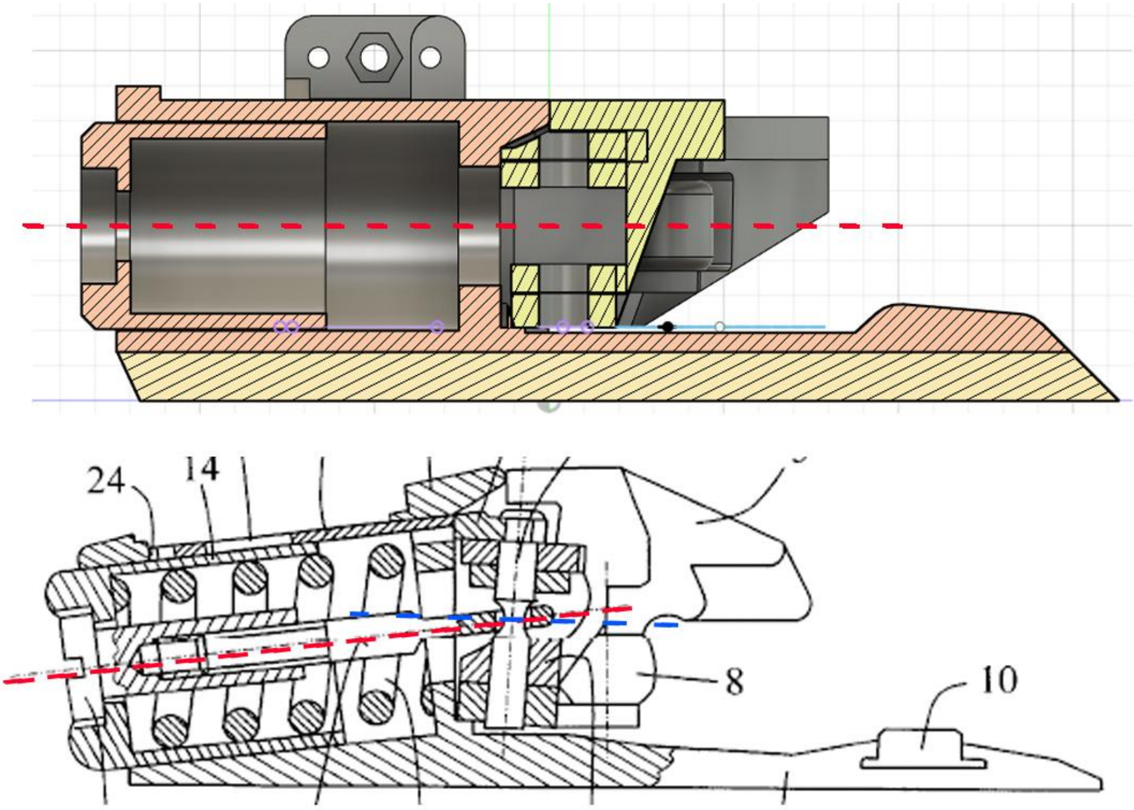

Figure 5.23 *Section comparison between the concept and LOOK Pivot 14.* Artistic alteration of patent no US6053523 https://patentscope.wipo.int/search/en/detail.jsf?docId=US39257850&_cid=P22-L38HL0-39411-1. (Authors' image, 2022)

The Release Mechanism works through two spring loaded Wings that are connected with a pin. The pin is connected to the spring through a screw assembly keeping the wings in tension against the Spring Housing (see Figure 5.24).

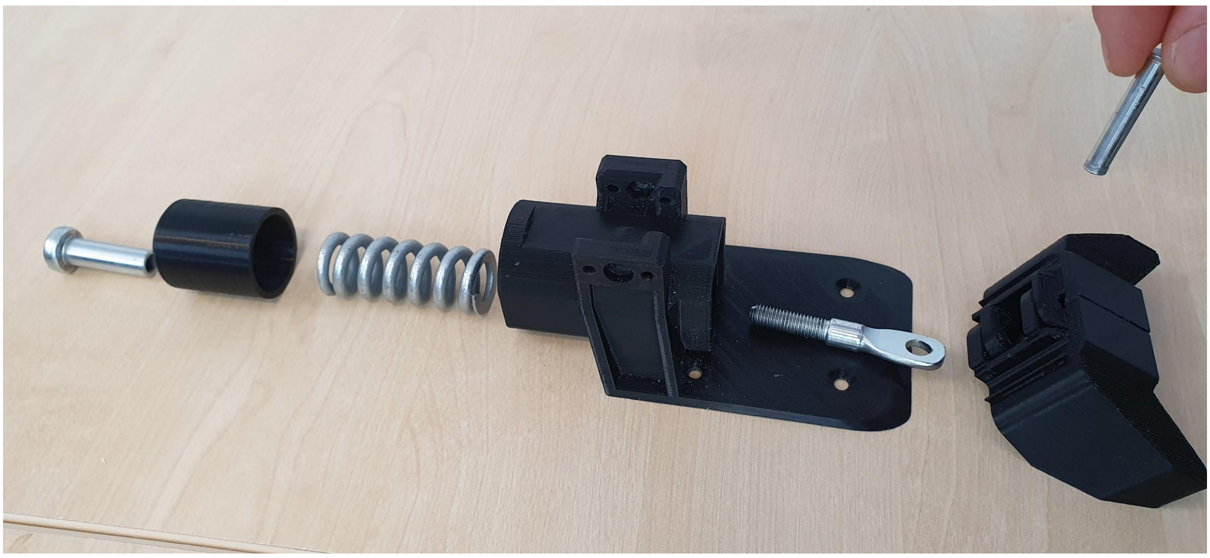

Figure 5.24 *Exploded view of the alpine assembly.* (Authors' image, 2022)

This design enables movement laterally, vertically and frontally. When the mechanism reacts to lateral and vertical forces the wings hinge against the spring housing along one edge at the time (see Figure 5.25).

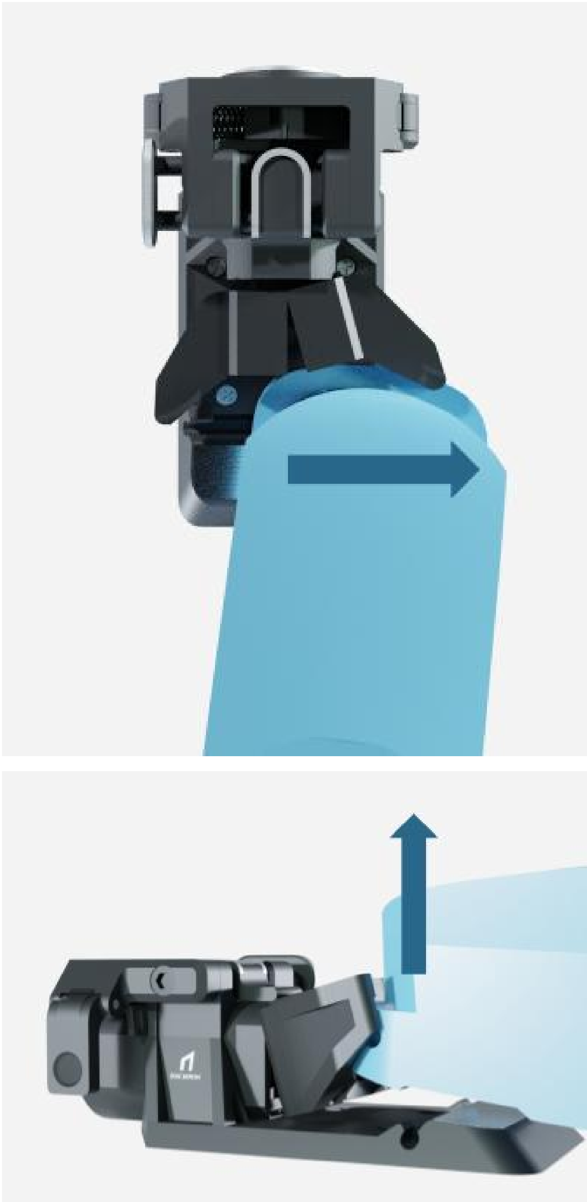

Figure 5.25 *Lateral and vertical release.* (Authors' image, 2022)

However, when it reacts to frontal forces, the lug of the boot puts pressure on the rollers of the wings, in this scenario each wing hinges against a separate side of the spring housing. This results in a spring loaded opening of the wings, reducing the stress on the mounting points of the ski and most likely reduces the risk of knee injury (see Figure 5.26).

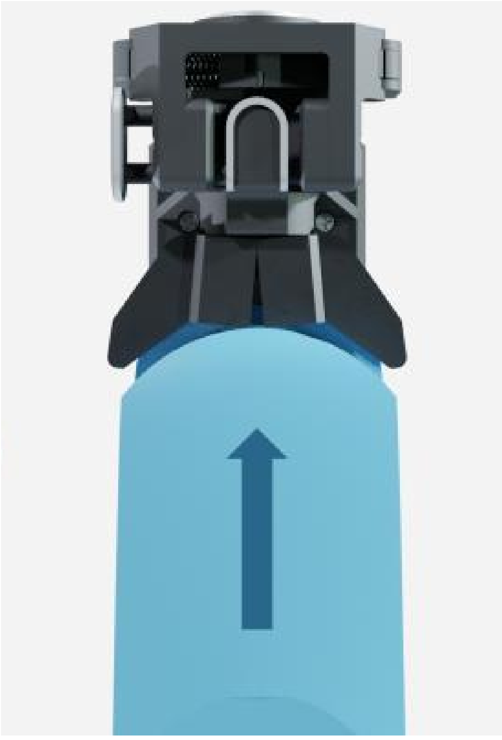

Figure 5.26 *Frontal elasticity.* (Authors' image, 2022)

Furthermore, to reduce the overall height, the wings have been lowered through moving the lateral contact points with the boot from the toe box to the toe lug (see Figure 5.27).

Figure 5.27 *Boot contact points*. LOOK Pivot 14 to the left. Concept to the right. (Authors' image, 2022)

The stackheigh of the toe piece is 10mm , this is achieved through not including a height adjustment since the binding is meant to be used with GripWalk boots only. The slight height difference seen within this segment of boots will be accommodated by the vertical flexibility of the wings. To increase the release value by preloading the spring, the screw that holds the assembly together is turned until the correct value is the last to be seen in the front of the housing (see Figure 5.28).

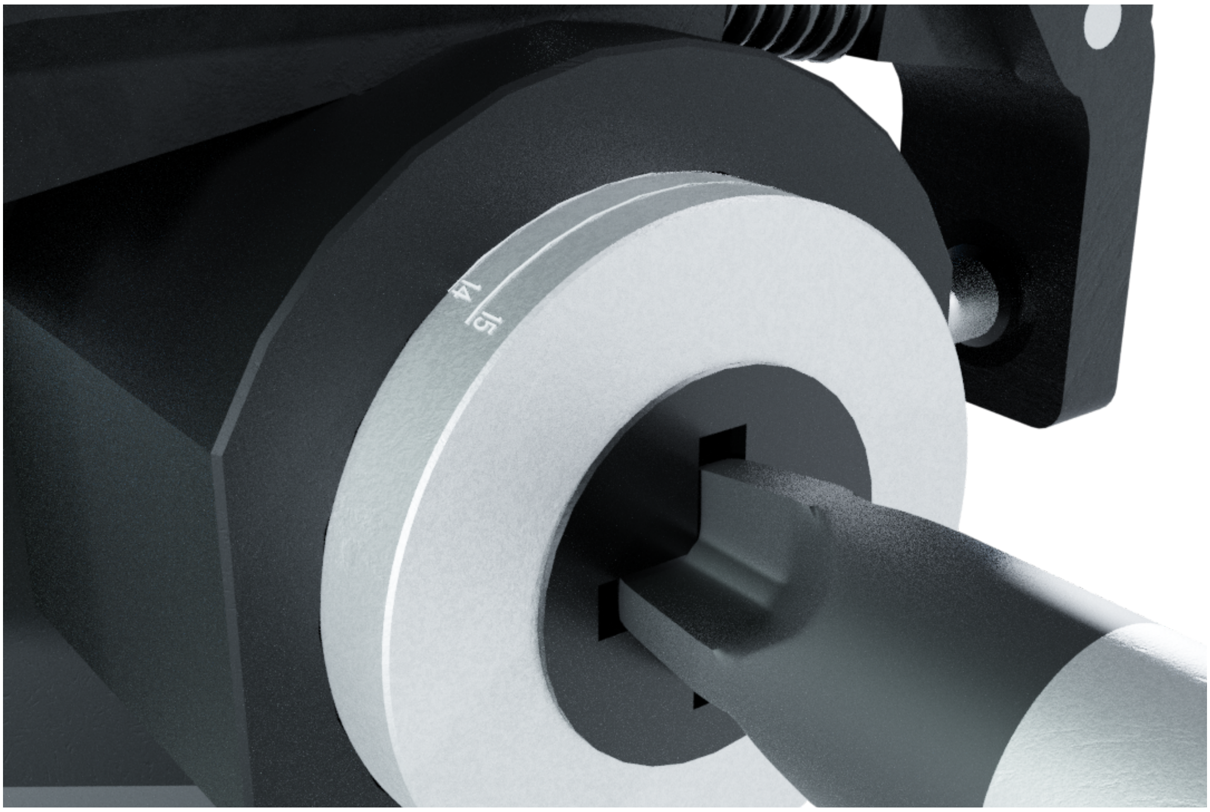

Figure 5.28 *Release value indication.* The alignment of the graphics on the spring socket to the spring house communicates the set release value. (Authors' image, 2022)

To further reduce friction, polymeric parts will be added to all contact points between boot and binding. This simple design is meant to convey strength and appeal to the reliability needs of many users, while still being easy to repair since it can be disassembled by unthreading one single screw.

Lastly, to enable a spread out purchase, the idea is to provide the *pintech attachment* as an *upgrade kit.* This meets the need for a modular product without compromising the alpine functionality. When the *pintech attachment* is removed it will be replaced by a small metal part that will be mounted between the attachment points on top of the spring housing. This increases the durability of the attachment points and enables the skier to remove snow and ice from under their boot by performing a scraping action (see figure 5.29).

Figure 5.29 *Modularity.* The *pintech attachment* is replaced by a colorful part with a printed logo on top .
(Authors' image, 2022)

5.5.5 Final Concept Evaluation

The opinions were mixed about the final concept (see Chapter 2) when shown at a Norse event at the very end of the project. Everyone that interacted with the prototype understood how it was supposed to be used, without receiving any instructions on how to use it. One female participant expressed that with this solution her male friends would have no reason to "mansplain" how it is supposed to be used, which she had experienced as tiresome with other types of ski equipment. The modularity was appreciated from a user perspective and many could see it come in handy as a travel setup, since they could use it as an alpine binding with the possibility of touring. Some expressed that they really could see the business potential in the modular interface, expressed as an "outside the box" concept compared to other hybrid bindings on the market. The elasticity and low stack height in alpine mode was considered a large benefit in terms of trust from those who had experience from such alpine binding solutions although some questioned the novelty of the concept.

The stack height in touring mode was a feature that many participants were skeptical about. Some argued that it felt unnatural to stand above the alpine binding but had never walked on such heights before. The ones who had experienced such walking heights said that it could be a problem when hiking in steep terrain because of the changed force pattern. These suspicions were based on products used earlier in their skiing career that were not pin tech solutions. The touring stack height also raised questions about crampon compatibility. They could not see how a crampon could be used with this type of concept. The same participants therefore came to the conclusion that they would not use this binding when touring in steep exposed terrain, because of the stack height and suspicions towards crampon compatibility. They could on the other hand see potential in the concept as a whole for hikes in less extreme conditions.

The binding aesthetics was a topic of debate although it was in unity considered robust. One participant used words such as “Frankenstein” and “ugly” to describe his impression of the binding. Some seemed to partly agree but rather described it as “different” or “a bit weird”. In contradiction, the concept was also said to look “functional” and “newsworthy” and drew parallels to other hybrid bindings which they thought had a more complex expression in an overwhelming way.

The conclusions drawn from the evaluation are that there were mixed feelings about the visual expression and skeptical views of the stack height in touring mode, along with positive remarks of the simple use sequence and modularity of the concept.

6. Discussion

This chapter reflects on positives and negatives of the process and the resulting consequences the proposal might have.

6.1 Process and Results

This section reflects on the success of the project regarding the work performed.

6.1.1 Result in Regards to Issues Under Investigation

To prove that all initial questions when initiating the research project were covered, short answers to each Issue under investigation from section 1.4 is provided below. The answers are on a low level of detail and are meant to explain the general insights established through the conducted research.

1. What key features make the current, project relevant, ski bindings successful on the market?
Mainly that they fulfill the dual functionality sought after by the customer along with either fulfilling the need for a lighter weight or a stronger construction, never both. The choice between these two features are the main dividing factor when skiers are making their purchasing decision.

> **1.1 How do they correspond to the usability and user experience of the product?**
> In these areas they underperform by having complex user interaction sequences and/or forcing the skier to remove or replace parts of the product during use.
>
> **1.2 What technical features are of importance for the user?**
> Purchase decisions today are mainly based on weight, retention and price but the study shows that understandable interactive elements which provide mode changing functionality and adjustability are of equal importance, as well as elasticity and stack height.
>
> **1.3 How do social norms affect customers' purchase decisions for hybrid bindings?**
> The most influential factor when it comes to social norms affecting purchase decisions is what products are praised by athletes and people with great social respect within the skiing industry. This is shown in magazine and youtube reviews in combination with sponsorships, resulting in great sales impact. The buyer wants to compensate for their inexperience by listening to role models and purchasing the same products as they use.

2. What things are currently malfunctioning on hybrid ski bindings and what are the reasons?
The parts that are used to change binding mode and provide adjustability were found to be prone to breaking i.e. parts that are difficult to repair and necessary for the bindings functionality.

3. What boot systems should the binding accommodate?
Since it was found that the GripWalk system is close to becoming the norm for the target group, the Multi Norm Certification was therefore deemed redundant.

4. How is a hybrid ski binding best designed in correlation with conducted research?

4.1 How is the change of ride mode best designed to be easily understood?
With a low amount of interactive parts that are easy to spot and grab while wearing gloves.

4.2 What indications should be in place to best communicate what mode is active?
Clarity was deemed key, the skier should be able to see it at a glance though severe form differences.

4.3 How is a hybrid binding designed to minimize the negative effect of the winter climate with the possibility of ice build up?
By excluding pockets where snow can get in and not come out, along with enabling easy removal in critical areas.

4.4 How should a ski binding be designed to make the mounting to ski procedure fluent and efficient?
By using a standard mounting pattern, few required assembly moments, minimizing the required variation of tools and having the mounting screws easily accessible.

4.5 What makes a mechanical ski binding satisfying to use?
With responsive audible sounds and sufficient haptic feedback. Often using strong springs and magnets to reduce the chance of an interactive element getting stuck between stages.

4.6 What makes the user trust a ski binding?
Through the use of an honest construction that is transparent in how it is made enabling an easily understood use sequence, along with having few moving parts. In essence, if the binding feels robust and not prone to breaking.

6.1.2 Positioning the Result According to Aim

The aim of this study was: *to understand the strength and weaknesses with current hybrid ski bindings on the market based on user centered research and benchmarking. Further on, to develop a high performance binding concept, based on the identified market gaps and user insights.*

This study has resulted in a broad market analysis and in depth discussions with ski industry professionals in an attempt to find a solid point of departure for developing a performance hybrid binding. By combining a reverse engineering methodology together with global user insights the market analysis has been successful in bringing a holistic perspective of the binding market during the last decades until today, as well as future product releases. This approach has brought a nuanced picture of what is sought in hybrid bindings in terms of both interaction and mechanical design.

The result highlights the importance of an understandable product due to the high risk the sport implies. The user has enough difficulties with making risk assessments while skiing and the gear therefore needs to work frictionlessly in the background to provide as low mental effort as possible. This sense of trust is not only anchored in understanding the features, it is highly affected by the expressed rigidity of the construction and materials. This is something hybrid bindings manufacturers today have a difficulty succeeding with and leaves a potential gap in the market. The market is still young which might be why no competitor has yet achieved to fulfill these important aspects. The evaluation of the final prototype shows that the design suggestion in this study provides good learnability and expresses a trustworthy construction due to its simple functionality.

But there were also concerns regarding the concept that may be of great importance for the assessment of the result. The touring stack height was the most prominent one, which was something the authors had predicted. Tendencies to such dislikes had been discovered quite early on in the development process but continued with optimistic intentions to lower the stack height. As the prototyping continued, these requirements successively received lower priority with the strive for a durable built prototype which added dimensional height. As the height also resulted in concerns about crampon compatibility, the seriousness of these requirements should have been managed earlier in the development process at a lower fidelity concept level. A ranking of the requirements through e.g. a Kesselring matrix would have brought up the discussion before the ideational work. On the other hand, it was still important to develop a functional prototype with trustworthy dimensions for users to be able to tangibly evaluate the concept and the perceived trust. When the stack height became a realization, the authors made a decision to continue with the concept based on these aspects and the project time left. The prototype instead became a means of communication for expressing the interactive functions and modular attributes.

It was difficult to disregard the fact that the toe piece only constituted a half binding during the evaluation of the concept. Initially, the development of a heel solution was considered since the functionality between toe and heel piece is closely related. However, a high resolution prototyped toe was considered more valuable for the company than developing a complete binding on a less tangible level. Another reason was that an alpine heel with raisers is a more straightforward task since the market alternatives were considered less complex from a user perspective.

No proper method was used for semantic evaluation and it is therefore difficult to tell if the aesthetics was conformed to the semantic specification, or if the Inspiration board was created on misinterpreted statements. Although some thought it was not aesthetically appealing, the results from the study also showed that users can be skeptical of new technological expressions. Some might argue that the general opinion changes over time when new equipment proves to work, while others stay firm in their disliking. This is a potential risk with the proposed concept.

6.1.3 Target Group and User Involvement

Through a close collaboration with *Norse*, the selection of interviewees has been both efficient and effective. The point of departure for this project, as seen as a time for learning and testing design skills, has been to work tangible with prototyping. It has therefore been helpful to involve people with great experience within the industry, who meet users and various ski equipment everyday. Ski shop personnel have brought insights about customers' common concerns, questions and purchase decisions. Besides, many more or less described their personal preferences as well. Mountain guides have provided insights about safety aspects, touring technique and observed their customers use hybrid bindings on the mountain in more or less critical conditions. By interviewing these users, one can argue that both qualitative and, to some extent, quantitative data has been provided. To be critical to this approach, many statements are indirect comments on how the interviewees perceive and interpret their customers. It might add an extra portion of communicative noise that would at least have been reduced if spoken to the described customers directly. That approach would not have been as time efficient enough though.

The approach for defining a target group was highly affected by the found market gap: the lack of a simple, relatively lightweight and alpine performance oriented hybrid binding. For long, the project continued without a distinct definition of who this type of product was for. This partly led to inconvenient requirement priorities and might be one of the reasons why e.g. the resulting stack height became higher than desired. One possible argument to why this happened could be that the authors had difficulties in separating the interviewees' pronounced desires and their customers' interpreted sayings and behavior, together with the authors own biases due to spending much time with different types of skiers.

The first female participant came in by chance in the last stage of the development process. The feedback that was given by that individual gave new and important perspectives on the product. This resulted in relevant reflections regarding the process due to the lacking diversity among the interviewed users. It was not a conscious decision to exclude women in the study, but on the other hand, efforts to actively find women that could contribute to the research was not made either. Besides from an unresponded email sent to one professional female skier in the beginning of the project. The lacking diversity is seen as a failure and could potentially be explained by the masculin bias that can be seen in the skiing industry at large. It is regarded as an unfortunate mistake and an eye opening remark that will serve as an important learning experience for the authors.

6.2 Ethics

This section reflects on the possible ethical paradoxes and questions raised through process and result.

6.2.1 Robust Binding Enables Aggressive Skiing in Exposed Areas

A possible hazard with designing a product that enables a higher degree of risk taking when skiing far away from rescue personnel was expressed by one of the *mountain guides* during the initial interviews. Since the previously used *pintech* bindings does not promote the skier to jump from big cliffs because of the lower sense of trust and safety. These are features that the proposed design provides. However, this was not deemed a point relevant enough to stop the development process since there are still a large variety of bindings that already promote a more advanced way of skiing far away from safety personnel. The decision was therefore made that it is relevant to put an emphasis on education and risk assessment regarding these issues, so that the skiers are able to make safe decisions when being in the backcountry.

6.2.2 Reverse Engineering and Patent Exploration

The possible ethical issue when working with *reverse engineering* is that the product can be seen as a copy of the original. Since the final concept uses a similar technology to the *Look Pivot 14* binding in terms of alpine mode functionality it bears a greater risk of getting that reputation with the greater audience. However, *Look bindings* are in general well spoken about in the skiing community and it might also result in it being praised for that specific resemblance. Another thing to consider is the fact that the *pintech* binding was invented by *Dynafit* and when that patent expired multiple brands started using the same technology and are not considered copies by the skiing community. Since the patent has expired and one of the initial reasons for the creation of patents was spreading innovation over the world to enable further development. It is considered relevant to use a similar layout due to the benefit it brings in terms of multiple release patterns and shock absorption.

6.2.3 Skiing Accessibility

The authors have privately noticed a steady price increase of skiing equipment correlating to increasing technological complexity. However, when holistically compared to the sport of cycling the conclusion is drawn that prices are on average higher in that industry, assuming also because of even higher technological complexity. Since mountain bike components have served as inspiration during the process (see section 5.4.2) it raises two questions:

- Is it possible to potentially make this product a very exclusive one?
- If you are able to focus on customers with a large purchasing power, should you?

It is assumed that if you are working as a force for higher technical complexity and a larger price point it might cause prices to go up on lower rated entry point products, resulting in the risk of excluding users from picking up the sport. However, it is also considered that for a smaller company to compete with large organizations with streamlined manufacturing processes, starting out with an exclusive product is a more viable option because of the lower quantities required. It was therefore decided that trying to influence the industry by providing a product with higher repairability and modularity is a more efficient method of provoking change.

6.3 Sustainability

This is the most important subject of our time and a relevant subject to reflect upon regarding the project.

6.3.1 Lift vs. touring

Alpine skiing can be viewed as a quite counterproductive activity from a sustainable point of view. It is reliable in low temperatures, good snow conditions and stable glaciers. At the same time, skiers travel far to go skiing, buy multiple skiing setups and pay a fortune to access lift systems with semi-artificial terrain. The extraordinary conditions needed for performing the activity are slowly being ruined by the material prerequisites for accessing it.

Hybrid bindings and touring bindings however allow for accessing nature without the help of a ski-lift and are therefore not bound to geographical areas exploited by ski lift-operators and tourism. Instead, such equipment entails that nature closer to home can be explored in a more natural way. This is a comfortable thought, but is sadly not the truth for everyone. Ski touring still requires traveling for many people living in cities far from hilly terrain. Besides traveling, one can argue that nature is best untouched and that it would therefore be better to gather as many skiers as possible in already built lift-systems where they share the same geographical area, services and physical artifacts. But being able to perform ski touring in the wild as an activity, can in the long run affect a person's relation to nature in a positive direction and the will to nurture it. It does not necessarily have to correlate with decisions made while skiing, but can also affect decisions made everyday. It also promotes a healthy lifestyle since it requires the user to stay fit. Therefore the authors believe that accessing nature by ski touring is a relatively sustainable way of skiing compared to lift-bourne alpine skiing, and something that this type of binding solution contributes to.

6.3.2 Modularity

The developed hybrid binding concept in this study contributes to the possibility of having one versatile ski setup. This solution could be a potential alternative for skiers who want full downhill performance and touring possibilities that today would use one touring setup and one alpine setup.

Compared to other hybrid bindings, it is unique because it can be sold as an alpine toe only with the tech toe as an additional feature. It therefore becomes an alternative for people who just want an alpine binding without the extra parts that a tech toe requires. At the same time it prolongs the expiry date and need for changing equipment along with developing interest for ski touring. In a sense it becomes less governed by the type of ski choice and can wander from ski to ski.

The simple construction and use of few parts is beneficial from a refurbishing perspective. The solution is considerably less confined than bindings disassembled during this study. The material accessibility and disassembly possibilities can encourage users to repair the product with common tools or recycle them in an easy way if needed.

Choosing *GripWalk* as the boot compatibility norm for this concept, can from a sustainable perspective be seen as a healthy choice. With less deviations in “what ski boot is compatible with which binding” the users have a higher possibility of keeping their existing gear if in need of updating another.

6.3.3 Material

At this concept level where no in depth material specification has been made, it is difficult to evaluate the physical materials impact on the environment without performing a *life cycle analysis*. The authors would love to use recyclable metal and plastics since it is energy efficient and has lower CO_2 emission compared to raw materials. Whether this is possible from a manufacturing and durability perspective is not further investigated. The authors have noticed that PFAS-materials is becoming phased out in outdoor products and sports equipment and is something to be aware of when considering material choice for surfaces with low friction in this product.

6.4 The Suggested Concept's Positives and Negatives

Stated below are a summary of both the users and the authors positive and negative aspects of the *final concept proposal.*

Positives:

- Low stack height in Skiing mode
- Skiing performance through multi-directional elasticity
- Easy to change ride mode
- Separation of functions
- High reparability
- Few parts to manufacture and assembly
- Good haptic and audible feedback

Negatives:

- Touring stack height
- Exposed Pintech position while skiing
- Might require high crampons
- Limited by narrow ski widths
- Mixed feelings about the visual expression

7. Conclusion

This project has brought up issues with hybrid bindings from both a user centered design and mechanical design perspective. The two views have shown to be of equal importance for the user experience in this product category, where binding producers of today have been discovered to prioritize the latter. Even if the suggested solution had its criticism towards touring stack height, the study has provided insights in how a hybrid binding can be designed in an understandable way, through a thorough market analysis and user study. The final concept is further one among many discovered novel alternatives for fulfilling such needs, which legitimize the identified market gap and leave hope for future development. The study has further shed light on the chaotic norm djungle within the industry. It resulted in an active positioning by allowing *GripWalk* compatibility in the suggested solution, with the divine potential of hybrid bindings and *GripWalk* boot soles becoming a convincing combination that is here to stay. To be modest, it will still be a balancing act to develop products in between two recognized genres of use where compromises have to be made.

Further suggestions will be:

- Stack height evaluation with real testing on snow in a variety of terrains.
- Investigate the potential of a lower spring house, although the boot sets the final limit.
- Perform user testing and calculations on a U-bracket in spring steel to investigate if it is a possible solution.
- Further testing and calculation on the alpine toe leverage to provide the right amount of retention and release together with suitable spring characteristics.
- Investigate the tech toe’s level of exposure in resting position when skiing in various terrains.
- Evaluate manufacturability with regards to an in depth material selection.
- Develop a heel prototype to evaluate the overall form and functionality of the concept.
- Provide a thought through concept of a crampon suitable for the stack height.
- Geometrical weight optimization

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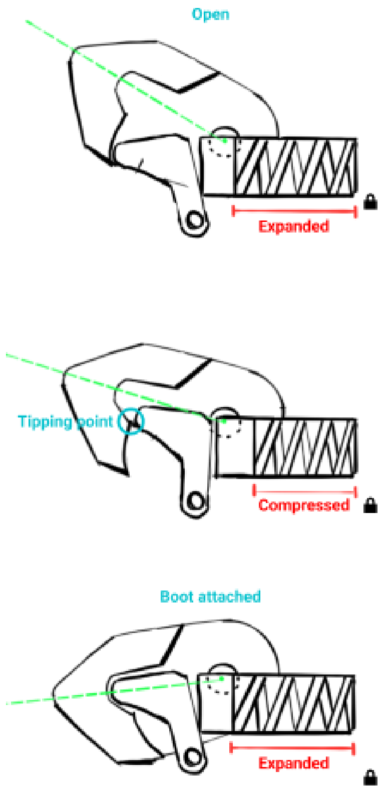
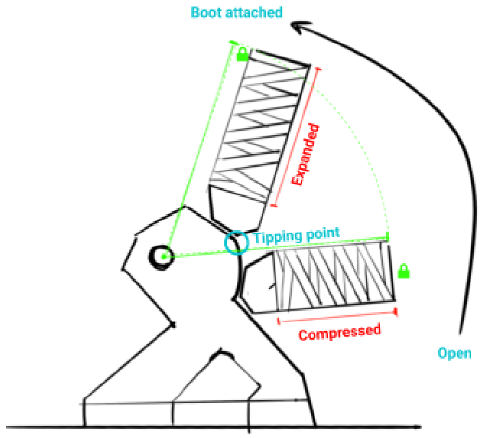
Appendix A

Horizontal spring

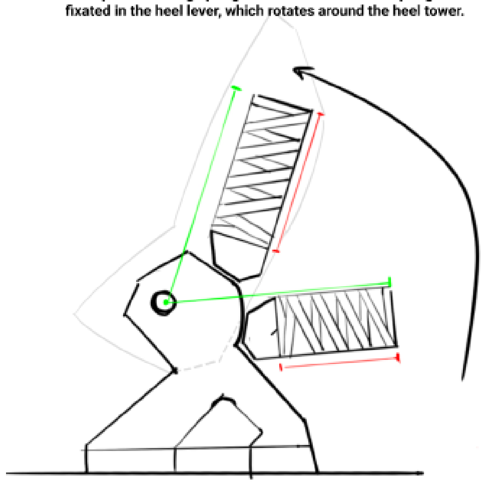


Example of horizontally locked spring found in Tyrolia attack 14. The spring is fixated in a lying heel tower.

Rotating spring

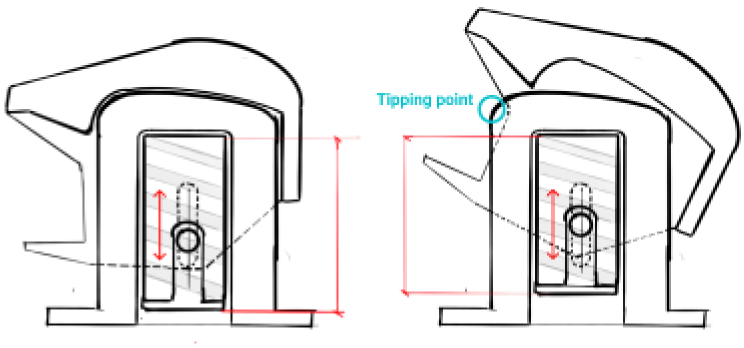


Example of rotating spring found in Duke PT. The spring is fixated in the heel lever, which rotates around the heel tower.



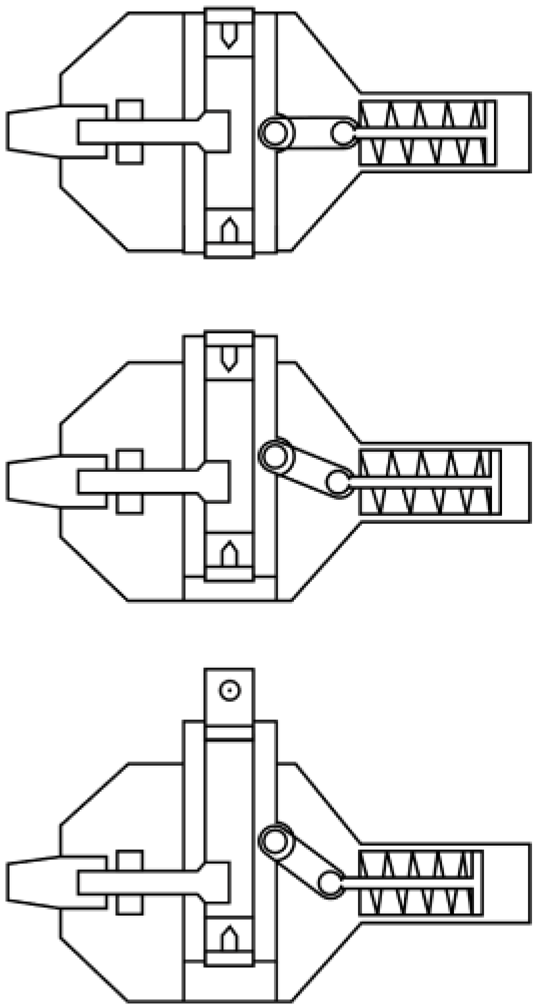
Does the spring need to rest (expand) when the binding is open?

Vertical spring

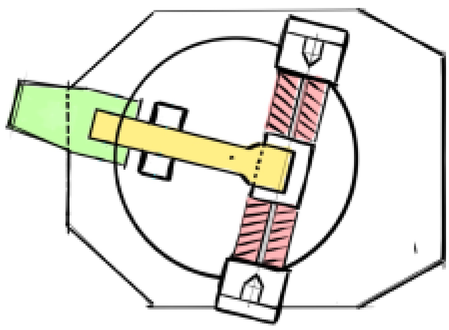


Appendix B

Lateral sliding tech toe



Rotating Tech toe



Appendix C

Main Aim					
Weight	<885g /binding				
DIN	4-11/8-15				
Elasticity	Equal to Marker Duke PT 16				
Usabillity	No doubt about configuration				
Krav	**Gränser**	**(K/Ö)**	**Viktning (1-5)**	**Ursprung (vem)**	**Kommentarer (ytterligare beskrivning)**
1. Functional criterias					
1.1 Skiing					
Retain boot toe when skiing				Brief	
Retain boot heel when skiing				Brief	
Provide Elasticity in toe-piece				Brief	
Provide Elasticity in heel-piece				Brief	
Allow lateral release				Brief	
Allow vertical release				Brief	
High power transmission				Norse	Increses sensitivity (Find the right ballpark)
Reduce friction between boot and binding				Brief	
1.2 Touring					
Retain boot toe when touring				Brief	
Lock toe-piece when touring				Brief	
Release in toe-piece when touring				Brief	Duke, Shift and ATK Raider release in walk mode
Alpine toe should not inhibit tech stride.	rotational degrees			Interview	
Crampon compatibillity				Benchmark	
Clear feedback when engaging tech pins		Ö?			
1.3 DH Touring		Ö			
Retain heel in with toe-piece in touring mode		Ö		interview	
1.4 Transition					
Easy pin entrance	boot alignment			Benchmark	
Lock skistopper				Brief	
Release skistopper				Brief	
Provide climbing aid	degrees			Brief	
As few interactive steps as possible				Interviews	
Understand transition mechanism without explanation					
Step in and out without using hands				Johnn	
Order of interaction when changing ride modes	Reversed order between ski/touring mode				
2. Technical requirements					
2.1 General					
Boot compability	Grip Walk	***K***			
Elastic travel before release	mm	K			
Release value	15	***K***			
Prohibit snow and ice build up		***K***		Interviews	
Weight balance between toe and heel while walking		***ö***		Krister	
Should not prohibit/endanger flexing of alpine toe		***K***		one piece crab	
Prohibit tech-toe from impact when skiing		***Ö***		Interviews	
Use as few parts as possible		Ö		Interviews	
Maximum boot travel distance between ride modes	As low as possible	Ö		Interviews	
Stand height Alpine	≥ 20mm	K		Robert	
Stand height Pins	≥ 45-60mm ? (55ist?)	K		Robert/Patrik/Krister	
Crampon compability	Dynafit crampons	Ö		Johnn	
Toe riser should not have pre-assigned steps		Ö		Benchmark	

2.4 Material					
General: use metal avoid plastic					
2.5 Mounting					
Holepattern for common Jig		Ö		Norse	Define common Jig
Low force to flip heel lever				Norse	Marker deisgn harder than Tyrolia
Remount toe with heel still attached to the ski		Ö		Norse	Impossible? Jig in the way, new jig is solution?
Change Skistopper without removing ski mounted part				Norse	
Preload adjuster with fine and precise increments				Norse	Screw?
Time efficient mounting					
Same bit pattern to all screws (one tool only)					
As few loose parts as possible when delivered					
Height self adjustment					
Distinct feedback to know that the binding is adjusted correctly.					
Wide mounting hole pattern					
3. Semantic requirements					
Pins should be fused into the overall shape					
Communicate relation between parts					
Product should have alpine binding recognition					