EPDM Material with Sustainable Content

Technical Readiness Level (TRL) and Potential Suppliers for Sealing and Tightness at Volvo Cars Corporation

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Abstract

On behalf of Volvo Cars Corporation, a study has been conducted of what types of EPDM materials with sustainable content exist on the market. This has been done as Volvo Cars aims to reduce its climate emissions by 40% per car by the year 2025, but also to become completely climate neutral by 2040. EPDM materials are made up of many different of components, the most of which are extracted from crude oil, which is environmentally harmful and bad for the human health. This is because oil is a precious and nonrenewable resource, polluting hydrocarbons are discharged into the atmosphere, and oil-based polymers degrade slowly, resulting in prolonged polymer pollution. A number of companies were found in this thesis, where some of them either had an EPDM material with sustainable content or were producers of a sustainable component that are included in the EPDM material. More investigation of the area is needed to be done for future work, however, the highlighted companies are good candidates for a future material change in the dynamic sealing system of Volvo Cars.

Keywords: EPDM, carbon black, recycled, sustainable content, sealings, tightness, vulcanization, devulcanization, biopolymers, Volvo.

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1. Introduction

1.1 Background

Volvo Cars Corporation uses the synthetic rubber material EPDM (Ethylene Propylene Diene Monomer) in their sealing system on the car's door moldings and tailgates. What is today considered as a problem in the EPDM material on Volvo Car's seals is that they want to replace the material with a more environmentally friendly one, as the company is constantly striving for more sustainable alternatives. Volvo Cars aim is to put 25% recycled polymers in their cars by 2025 and bio-based materials will also be included in the ambition of recycled plastics since it is a sustainable material. The problem does not lie in the properties of the material, but more in the fact that its content is not sustainable. The thesis will mostly be used by those responsible for the materials department for seals, which will lay the foundation for a further investigation into whether an EPDM material with sustainable content may replace the current choice of EPDM material for the seals. This means that Volvo Cars will know what environmentally friendly alternatives exist on the market today that reached a TRL(Technical Readiness Level) level that make them realistic alternatives in the short term in order to be able to test and investigate these in future work.

1.1.1 Plastics and Rubber

Ever since the first ever man-made plastic was founded in 1862, it has come to have a greater impact on of everyday life (Plastics Industry Association, 2021). In the early years of founding plastics, the consumption was low, and it was not until 1950 when the market for plastics grew by the introduction of plastics in consumers products, which lead the production of plastics that year to 2 million tons (Ritchie, Roser, 2018). This was the starting point for the plastic production to grow in an incredible speed as plastics was replacing traditional materials such as steel, resulting in a production of plastics in 2019 at 368 million tons (Plastics Europe, 2020). The reason for this is the versatility of plastics due to its properties, simplicity of processing and its cost effectiveness, which makes plastics a great material for many fields such as the automotive industry and construction (Plastics Industry Association, 2021).

The word plastic with specific properties originated from the Greek word *plastikos,* which has the meaning “to form or mold”, and the term plastic refers to the materials plasticity properties and its ability to deform without disintegrating. Plastic is an organic polymer that can either be synthetic or natural and has always carbon and hydrogen included (Helmenstine, 2020).

The word polymer originates from the Greek words *poly* which means many and *meros* meaning parts and are made of chain-shaped molecules, which in turn are made up of smaller molecules, monomers. The process of making polymers is called polymerization (Nationalencyklopedin [NE], *gummi*, 2021).

In order to make a plastic it is required to have additives mixed in with the polymers, which includes fillers, colorants, plasticizers, stabilizers and reinforcements. The plastic’s chemical

composition, chemical and mechanical properties along with the costs, are all affected by these additives (Helmenstine, 2020).

Rubber is a commonly used term for a group of polymeric and organic materials with elastic properties, which are also referred to as elastomers. It is divided in to two types, natural rubber and synthetic rubbers. Natural rubber is extracted from rubber trees by making incisions in the bark from which the milky liquids can seep out of. However, synthetic rubbers are derived from petroleum, natural gas and polymers. Up until the end of the 19th century the production of rubber was low and only based on natural rubber. It was not until after the second world war that a large-scale production of synthetic rubber was initiated (Stenberg, Gunnarsson, Langstedt & Erlandsson, (2021). As the years have gone by the world production has steadily increased each year, and 2019 the production of rubber was at a total of 28,8 million tons, with synthetic rubber accounting for 15,1 million tons were synthetic rubber (Malaysian Rubber Board. 2019).

1.1.2 Rubber in car sealing system

The first car, which was steam-powered, was manufactured between 1769-1770 by the Frenchman Joseph Cugnot. It took about 15 years before the first car with the internal combustion engine (petrol) was introduced to the market by the German Karl Benz which was attached to a tricycle that was used as a carriage (Tekniska museet, 2020). Today, 136 years later, the passenger car is the most common means of transport and according to the European Automobile Manufacturers Association (ACEA), there were 342 million passenger cars in Europe in 2019 that were in use.

Since rubber had an early breakthrough and became popular due to, among other things, its elastic property in combination with high durability, it could be applied in many places. One of many fields of application is in the sealing system of cars where the synthetic rubber material EPDM, is used. This is water-resistant material that withstands high and low temperatures and does not age as much as other rubbers. This makes it work perfectly for the conditions required in a car sealing system. The main function of a sealing strip in car doors and tailgates is to separate two spaces and protect one space from liquid/air/sound/pollution (Volvo sealing education, 2009). When producing a sealing strip, you need to go through three general steps:

1. Material mixing - The mixing plant has an important function, and it is to produce a rubber compound that is specific to a particular application.

2. Extrusion - a technique for making seals with a profile that has a continuous cross section. To achieve this, EPDM material is pressed or drawn through a mold.

3. Casting - the component takes shape and then let the component vulcanize clearly in an oven.

These steps can be done in different ways depending on what characteristics you want to fulfill.

Seals have become a significant role in the car's development through the ages as it has succeeded in drastically reducing leakage, air intake and sound attenuation. *Figure 1* below illustrates how the sealing system on one of Volvo Cars' vehicles is used. The green-marked

strips are the ones with EPDM-material, while the purple/pink-marked strips are made of a material called TPE. In this thesis the focus will be on part where the EPDM-material is applied (Volvo sealing education, 2009).

Figure 1. A schematic image of the sealing system in one of Volvo Cars vehicles.

1.1.3 Sustainability

The most common definition of what sustainability means is generally quoted as: "Sustainable development is a development that satisfies the needs of today without jeopardizing the ability of future generations to meet their needs." (Globala Målen, 2020). There is a massive increase in population in the world that puts pressure on the planet's natural resources such as - water, forests, land, raw materials and the earth's atmosphere. These factors contribute to climate change where the planet gets increased temperatures and melting ice, which in turn make it very challenging for environmental sustainability (United Nations Population Fund [UNPF], 2013). This has contributed to the **circular economy** becoming a necessary factor in order to be able to achieve the global environmental goals that have been set by the UN. Circular economy is partly about striving to reduce new production, reuse more and recycle more materials in order to reduce carbon dioxide emissions and reduce the use of resources (Naturskyddsföreningen, 2020). This is something that is important for car manufactures to consider as they can reduce much of their carbon dioxide emissions only by choosing right materials that are recycled or biobased.

Volvo Cars is a company that constantly strives to environmentally compensate their products and solutions on all possible fronts, everything from design to recycling. Their environmental goals focus on reducing their climate emissions by as much as 40% per car by 2025 and also to become a climate-neutral company by 2040, which is their long-term goal. This will be done, among other things, by mainly electrifying their cars but also by replacing the materials with recycled or bio-based ones, and also to focus on circular economy. It is important to try to compensate the small parts of the production and manufacture of cars for the environment, as the small parts also affect emissions. (Volvo Cars)

1.2 Aim

The aim of this thesis is to map companies that produces EPDM material with sustainable content. Volvo Cars has not yet done a detailed examination of what the industry has to offer and what constraints their application, in terms of more environmentally compensated EPDM material sealing system alternatives. This thesis will give an understanding of what is available on the market for potential EPDM material options for door and tailgate seals on Volvo cars.

1.3 Delimitations

This thesis is completely devoted to determining what types of EPDM materials with sustainable content are currently available on the market and then presenting them, which makes it a theoretical study. However, all the components in the EPDM material will not be investigated due to the limited time. The main factors to present in this study will be density, hardness, and sustainable material. The works focus is in the material properties, not if the alternative materials require additional change of design, production and supporting processes. Tests of EPDM materials will be conducted depending on the time and availability of materials. The thesis is limited to about 10 weeks and due to the current Covid-19 pandemic, the thesis will be carried out from home.

1.4 Research questions

The following questions will be answered:

- What is EPDM and what are its uses? Why is it non-environmentally friendly?
- What changes can be made to the EPDM material in order to make it more environmentally friendly relative main engineering properties?
- What is available on the market regarding EPDM material with sustainable content?

2. Theoretical background

In the following chapter, EPDM is described. It is important to separate the EPDM component consisting of only ethylene propylene and diene, from the EPDM material partly containing of the EPDM component along with other ingredients. To avoid confusion the thesis will separate these two by naming them; EPDM = EPDM component, EPDM material = EPDM material.

2.1 EPDM – Ethylene Propylene Diene Monomer

EPDM is a synthetic rubber, elastomer and copolymer (formed by three monomers) consisting of ethylene, propylene and diene (Chauhan, 2019). Since the diene molecule consists of a double bond, the EPDM molecule changes to an unsaturated molecule, which enables sulfur vulcanization and contributes to crosslinking. This gives the material a

resilience, flexibility and durability. The reason why the EPDM material is one of the most popular synthetic rubbers used today is due to its outstanding heat, weather and ozone resistance. Due to its insulating properties, there is resistant to chemicals, vapors, acids etc. (GGF, 2019).

When producing an EPDM material different types of components are required, and the amount of each of these are dependent on the wanted properties. The components are (NE, *gummi*, 2021; Standard Cooper, 2019):

- EPDM – this is necessary for elasticity.
- Carbon black – carbon black is needed for reinforcement of the material.
- White filler – chalk is the most used white filler, and it is a way of lowering the cost of the material.
- Oil – this is used as a plasticizer that adjust the hardness of the material.
- Vulcanization agent – sulfur or peroxide are the most commonly used vulcanizers, enabling the material to become elastic.
- Other – examples of these are antioxidants that prevents aging, processing aids that helps the extrusion.

Figure 2 illustrates the composition of the sealing material (dynamic) used in automobiles. This mixture produces the properties necessary for a seal. (Standard Cooper, 2019)

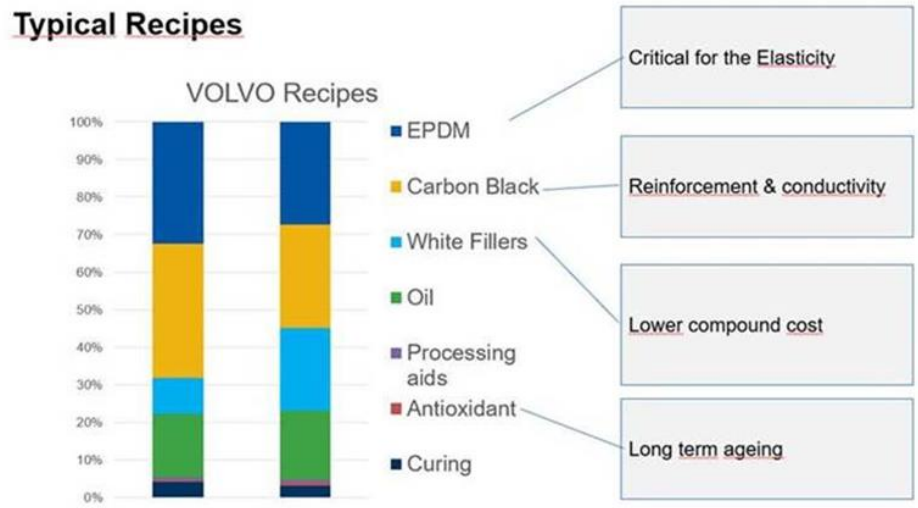

Figure 2. Compounds of EPDM for seals.

The whole manufacturing process begins by producing the monomers required to make the synthetic rubber. In order for these monomers to combine and form polymers, a process called polymerization, which is a chemical reaction, is required (Hanhi, K., Poikelispää, M., & Tirilä, H.-M. 2007).

In order for a polymerization process to be able to create polymers, it is required that the monomers have the ability to bond with the other components. This can sometimes be facilitated by applying different temperatures and pressures to supply the energy that the

monomers require to react and bond to each other. Sometimes catalysts can also be used to accelerate the chemical reaction (Shrivastava, A. 2018).

For the EPDM material to have the properties. which it is known for, different types of additives are required in the mixture. These additives are used to improve the properties of the material but can also be additives required for the vulcanization. After adding the additives, the rubber must be vulcanized, which means to form crosslinks and it is here that elasticity and stability are achieved. In the final process, the rubber must be formed into that required product and the process is then complete (Hanhi, K., Poikelispää, M., & Tirilä, H.-M. 2007).

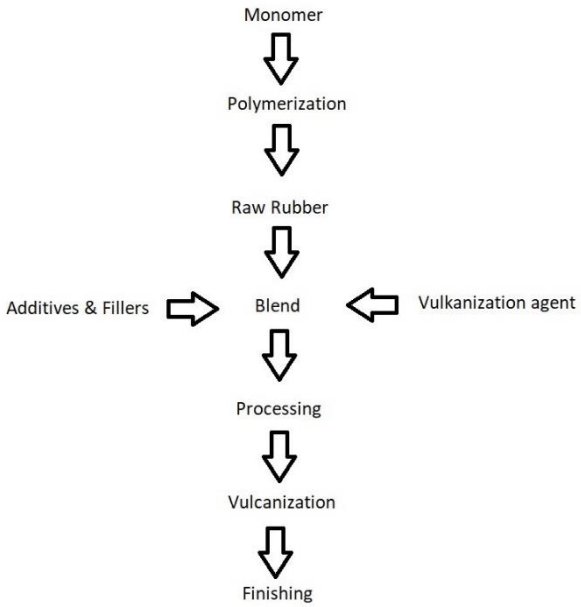

Figure 3. Manufacturing of synthetic rubbers

2.2 Synthetic rubbers from a sustainable aspect

In the following section, a description of why the compounds of the EPDM material are not environmentally friendly.

2.2.1 Polymers and crude oil

Since most of the plastics and polymers today are made from fossil oils that causes environmental issues because: first and foremost, oil is a nonrenewable and precious recourse, secondly, all the polluting hydrocarbons are released into the atmosphere and thirdly, the oil-based polymers degrade slowly which causes long-term polymer pollution (Ashby, 2015).

To produce synthetic rubber, there are a range of components required. Petroleum, also known as crude oil, is the raw material that is mainly used in the process of polymerizing monomers to polymers. Petroleum has many areas of application, in addition to synthetic rubber such as fuel to airplanes and cars, to heat homes, and to make medicines to name a

few. It is safe to say that petroleum makes everyday life easier, but this comes at a price, the whole process of finding, producing and transporting crude oil have negative effects on the environment (U.S. Energy Information Administration, 2020). The combustion of crude oil is one of the main causes to carbon dioxide emissions, which is known for being a dangerous greenhouse gas, that leads to climate changes, extreme weather by trapping heat. It also has a negative health effect, caused by air pollution (Nunez, C. 2019; World Wide Fund For Nature, 2020). Carbon dioxide also has a negative effect on the oceans, by an acidification making a shift in the pH-levels which puts the marine life at a risk (Borunda, (2019).

2.2.2 Vulcanization

Vulcanization is an absolutely necessary process for rubber to achieve its elastic properties and for it to have the required consistency. Unvulcanized rubber in general is not strong enough to make any products at all, which make the vulcanization important. At the same time as vulcanization increases the elasticity, the plasticity is reduced which is required in lot of industries. What happens when the rubber gets its elastic properties is that crosslinks are created between the molecules. In order for these chemical crosslinks to be created, different chemical vulcanizing agents are required, which enable the molecules to react with each other and thus create crosslinks. The EPDM material is mainly vulcanized by two methods and depending on the structure and quality that is wanted on crosslinks, there exists two curing systems (Mark, Erman, & Roland, 2013, chapter 7):

i. with sulfur, creating sulfuric cross-links (C–S and S–S covalent bonds).
ii. with peroxides, cross-linking polymer chains through C–C covalent bonds.

Sulfur is one of the oldest vulcanizing agents used in the rubber industry for unsaturated elastomers. The reason why it continues to be used even today is for its fast and effective action in reaction with the rubber molecules that easily create sulfur crosslinks. When sulfur-vulcanization first was introduced, it was a very slow process that could cause poor properties, until it was found that by adding chemical substances that can expedite the curing time and improve the properties. These substances are called activators and accelerators, where the activators help the accelerators to become more effective during the vulcanization (Matador Rubber s.r.o., 2007). In order for the sulfur to react chemically with the chain molecules in the rubber, a high temperature of up to approximately 140 ° C is required. The vulcanization normally takes place at 140-200 ° C and the process is controlled by three factors: time, temperature and pressure. Simply explained, you heat the rubber mixture together with finely divided sulfur together with a set pressure at a determined time and then crosslinks are created between the polymers (NE, *vulkning*, 2021).

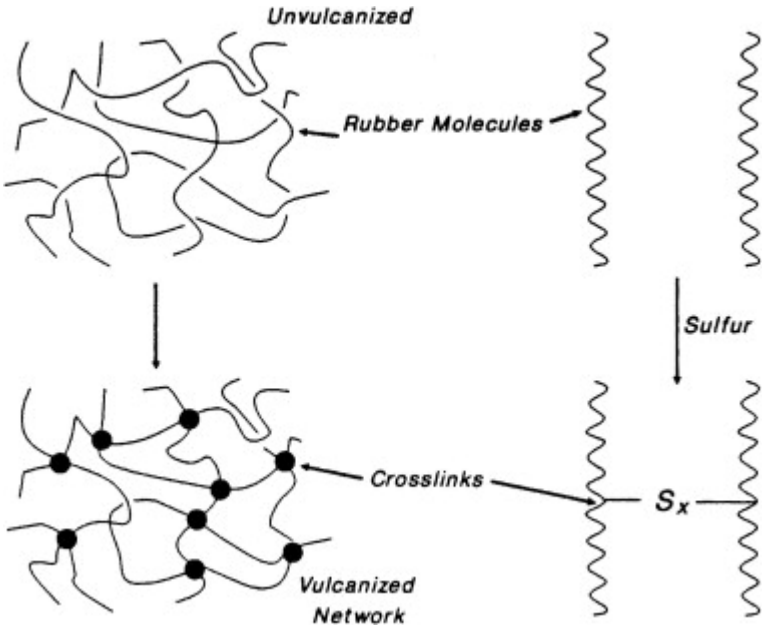

Figure 3: Sulfur Vulcanization.

Peroxide vulcanization, on the other hand, can vulcanize both saturated and unsaturated elastomers. In sulfur vulcanization, as previously mentioned, sulfur crosslinks are created, while in peroxide vulcanization covalent crosslinks are created instead. The biggest difference between sulfur curing and peroxide curing is what the material gets for properties after the process itself. Peroxide-cured rubber compounds have better chemical and thermal resistance. The covalent C-C bonds formed in peroxide vulcanization usually have a higher limit of decomposition compared to the sulfur crosslinks, which means that C-C bonds show higher thermal stability and strong resistance to aging (Hudec, Kruželák & Kvasničáková, 2019).

Figure 4. Sulfur and Peroxide systems.

The vulcanization process is an irreversible reaction that takes place between elastomers, sulfur/peroxides (usually) but also other chemicals that lead to a three-dimensional chemical network between the bindings. These strong chemical bindings give the material curable properties, that are very difficult to break, which creates major challenges from an environmental perspective where there is an effort to recycle as much of the rubber material

as possible. This becomes problematic as a lot of rubber that is produced and which in the end will no longer fulfills its function, cannot be reused in any way (Isayev, 2014, chapter 16).

2.2.3 Carbon black

Carbon black is a fine carbon powder that is extracted from oil and is used in a variety of applications to improve different properties. Due to its unique properties, it strengthens the rubber material, provides better friction and wear properties and ultraviolet stabilization. This makes the carbon black filling important for the rubber to achieve the required properties (Volvo Sealing Education, 2009). One of the largest areas of use for carbon black is in the tire industry but also in general in the automotive industry where it is used in many rubber materials due to its good properties it contributes. Except for the tires, a car has many different rubber components, including seals, suspensions, plugs, wiper blades and hoses (International Carbon Black Association [ICBA], 2016).

Every year, 1 billion tires reach their best pre-date and are at the end of their lifespan. This consists of millions of tons of rubber being incinerated, landfilled or dumped in many places in the world where they create major environmental problems. Approximately 38 billion liters of oil were used in 2017 to produce carbon black, which corresponds to approximately 35 million tonnes of carbon dioxide. Not only environmental problems, but also places where malaria-bearing mosquitoes can expand as water accumulates in the tires and forms the perfect condition for them to nest (Verheul, 2017).

2.3 Alternative solutions to produce a more sustainable EPDM material

This section describes how EPDM compounds can be replaced with more sustainable alternatives.

2.3.1 Biopolymers

As previously mentioned, it is necessary to replace the oil-based polymers used today with more environmentally friendly polymers, such as bio-based ones. Biopolymers are polymers derived from biomass where hydrocarbons are derived from example corn, cellulose and polysaccharides from, for example, sugar cane, sugar beet etc. (Ashby, 2015)

Because biopolymers are derived from plants, this means that they are always renewable and means that they can usually be grown indefinitely. These two factors make biopolymers sustainable alternatives to oil-based polymers, where oil is actually a natural resource. The use of biopolymers also reduces carbon dioxide emissions into the atmosphere as their carbon dioxide emitted during decomposition can be reabsorbed by trees and plants, making them carbon neutral.

Another important aspect to discuss is that many bio polymers that are built on renewable raw materials are often also biodegradable. As mentioned earlier, these polymers are most often synthesized from sugar, starch or other organic components. When these bio polymers encounter bacteria found in, for example, compost, iodine or sea sediment, they are naturally

broken down by the bacteria. This in turn leads to reduced CO2 emissions compared to oil-based polymers that are difficult to degrade by nature. Biodegradable polymers thus contribute to a reduction in global warming (Niaounakis, 2013).

2.3.2 Devulcanization

The rubber industry till this day creates large amounts of waste, making it a material science problem that enables the establishment of a circular economy of rubber. This is because EPDM materials and all the other rubber products cannot be broken down nor melted due to its covalent cross-links that make up its structure, making the standard methods that are used today when reprocessing ineffective for rubber recycling. There has been a suggested potential solution for this issue, which is the process of devulcanization that would turn vulcanized rubber waste back into its initial, uncured form. This method works by selectively breaking cross-links, meanwhile the polymer chains preserve their initial length, making it possible to revulcanize or incorporate it into virgin rubber, and thus reducing waste and increasing the use of primary resources. Due to unfavorable chain deterioration and oxidation, true devulcanization is yet to be achieved. In the end, the side reactions change the mechanical properties of the recycled rubber (Pirityi & Pölöskei, 2021).

As mentioned before, the EPDM material is primarily vulcanized in two ways, either with sulfur or with peroxide. When discussing devulcanization, there are two key factors that are mentioned, first factor is that the sulfuric cross-links, C-S and S-S covalent bonds, have lower bond energy than the C-C covalent bonds that make up the polymer backbone. This results in a breakage that is likely to occur in the sulfuric cross-links than the covalent bonds in the polymer backbone, when heating a vulcanized EPDM material. The second factor is that the covalent C-C bonds have an elastic constant that is approximately 30 times greater than the S-S bonds, resulting in strong shearing forces that will allow stretching of the sulfuric cross-links to the extent of which they are more prone to cleavage, compared to other bonds. These factors indicate that devulcanization of EPDM materials that have been vulcanized with peroxide cannot be fully devulcanized, since the cross-links consists of C-C covalent bonds, which are the same bonds that make up the polymer backbone. Thermomechanical stimuli may cause a random breakdown of peroxide vulcanized EPDM materials, but maybe efficient in the selective degradation pf sulfuric cross-links (Pirityi & Pölöskei, 2021).

There have been numerous strategies for devulcanization of rubbers and EPDM materials investigated. One method is done microbiologically, which is done by microorganisms that get energy by consuming the sulfuric elements in organic material, such as rubber. Another devulcanization method is by using microwaves which works by the microwaves creating an even heat in the material, without having much effect on the surface. Then there is the method of thermomechanical devulcanization, that includes the technologies of extruders and high shear mixers, as well as traditional rubber processing technologies such as mills and internal mixers. Using ultrasonic waves to devulcanize rubber is another technique, which destroys the networks in rubbers. This technique is commonly used along with an extruder to merge the effects of thermomechanical and ultrasonic treatments. Today, only the thermomechanical and microwave techniques, have shown to be efficient enough for industrial use. However, the combination of the ultrasonic and the thermomechanical

methods of devulcanization are preferred, because of their greater scalability and higher specificity for a cross-link cleavage (Pirityi & Pölöskei, 2021).

Studies have shown that when devulcanizing EPDM material in an internal mixer, resulting in a rubber batch where a great amount was successfully devulcanized, up to 75%. Temperature, shearing speed, fill amount and process time were the key factors influencing the devulcanization. It has been shown that it is essential to have a high temperature in along with a high shearing rate, in order to have an extreme chain deterioration, as devulcanization is does not occur when having the shearing rate not high enough (Pirityi & Pölöskei, 2021).

2.3.3 Recycled carbon black

The recycled carbon black is extracted by old tires undergoing a process called pyrolysis (Verheul, 2017). The process is started by heating shredded rubber in a reactor that has an oxygen-free environment. This is to be able to break down its constituents such as carbon and pyrolysis oil and the carbon in this case, is where the carbon black is extracted from. It is very important to control the heating rate in the reactor as it is the one that affects the reaction time, product quality and energy demand in the pyrolysis. You get different shapes in different temperatures. If the reactor stays at 450°C, a liquid product is obtained which consists mostly of carbon and at 700°C synthetic gas is obtained. This synthetic gas can also be placed in a condenser that converts the gas into oil, pyrolysis oil in this case which can also be called bio-oil. This oil can then be used as a biofuel or as a crude oil (Zafar, 2020).

A tire contains about 30 percent carbon black, which makes them a good candidate for extracting carbon black. By recycling carbon black and oil from old tires and other rubber products that contain carbon black, it is possible to create a cycle of circular economy. This contributes to significantly less emissions into the environment but also a sustainable society where the need for resources will decrease (Scandinavian Enviro Systems, 2021).

3. Method

In the following section, the used methodology for this thesis will be described.

3.1 Theoretical research

The analysis methods used specifies the approaches taken during the study's execution. The researcher's approach establishes the parameters for the collection of data, which can include qualitative or quantitative methodologies. It is important for the thesis that the purpose of the study is recognized. In order to address the research questions, it is crucial to gather the required information to successfully manage the data that has been collected.

Qualitative and quantitative data are two distinct categories of information. The qualitative approach gathers information using words, while the quantitative approach gathers data through the use of quantifiable values (Jacobsen, 2002). Qualitative analysis, according to Repstad (2007), focuses on researching events in order to acquire a detailed knowledge of the event. Jacobsen (2002) suggests that there would be no superior solution in this case, only that these are merely two distinct data collection methods.

For most of the study, a qualitative data collection approach has been chosen since the purpose of the thesis is to gather information on what EPDM materials with sustainable content exist on the market, but also to investigate whether there are companies that are in the process of creating such a material. The aim has been to collect necessary data to enable analysis and comprehension. However, a small part of the of the study has also used a quantitative data collection approach, for a statistical compilation of the gathered data of EPDM materials with sustainable content. The quantitative data that was collected was the found materials *hardness*, *density* and the *sustainable content* in per cent.

Jacobsen (2002) defines the theoretical collection, also known as secondary data, as the used data which has been obtained and presented by others, i.e., a secondary source that one refers to. Typically, the material obtained comes from other studies with different agendas, but in which other researchers discover something that is to be informed about.

The theoretical compilation is primarily comprised of literature and online platforms from which material has been collected that is considered necessary and pertinent for the study. Prior to conducting interviews, the theory included background information on the topic of the research. Following the interviews, it was apparent that additional information was needed, as we identified lack of knowledge about some topics in the respondents' responses, such as carbon black and its role in the EPDM material. For that reason, further information research was done in order to get a better picture. To obtain a deeper understanding of the EPDM material and the different processes that can be altered to create a sustainable content, literature searches were conducted through the internet. The used databases were Chalmers Library, Science Direct, Material ConneXion® Skövde and the search engine Google Search, with search words such as *"EPDM rubber"," Polymeres, "Biopolymer", "Vulcanization", "EPDM devulcanization" and "Recycled Carbon Black"*.

The aim in the interviews was to engage in an open dialogue with the interviewees, in order to obtain as much information as possible regarding the thesis. Preparatory information was hence gathered in order to provide a groundwork for the interviews with the respondents. This knowledge was gathered from research. During the interviews, some respondents discussed points that had not previously been identified. As a result, further research was conducted on these points, which was later incorporated into the theory section.

3.1.1 Choice of company

In order to get an overview of what companies that are working in the area, in other words with EPDM materials and rubbers, a study of the market was required. When examining, which relevant companies exist on the market, a selection was made of the relevant companies who were contacted for further interview.

To be considered relevant for the study, the companies were required to work with an EPDM material. This could mean that they: were the supplier of a material, were a manufacturer of a material, use a more environmentally friendly process during production of substances that the EPDM material consists of, are working with sealing systems in cars or were a materials laboratory. The majority of the companies were discovered via an internet research, but also

through recommendations from respondents and Volvo Cars. The used search engine was Google Search with words in both Swedish and English such as: *"Bio-EPDM", "Green-EPDM", "Environmentally friendly EPDM", "Material lab EPDM", "Recycled EPDM", "Recycled Carbon Black".*

3.2 Interviews

By conducting interviews, data is collected which then is to be interpreted by the researcher. This data is referred to as primary data. Primary data is the data that answers questions and can be collected using various methods such as interviews, surveys, observations, etc. In other words, a data that is gathered directly from the source, avoiding any existing sources. Typically, this data is highly specific to a particular purpose or issue (Jacobson, 2002).

In this thesis, interviews were conducted with the companies that were reviewed and considered relevant for the purpose. Prior to the interviews, it has also been important to contact a material manager at the company who possesses the right knowledge to get the right information for the thesis. Some interviews that were conducted had very specific questions while others had similar ones. Companies were contacted via email, and digital interviews were then held. The general questions that were asked to all the companies was:

- Would you like to introduce yourself and your company?
- Do you have any EPDM material that consist of sustainable substances? If so, is it possible for the material to be applied in a sealing system of a car?
- Is it possible for you to share a datasheet of the existing data for the material in question?
- Do you use any particular process to ensure that the material is sustainable and has a low environmental impact? If so, which type?
- What does your future look like in terms of environmentally compensating your materials?

As explained earlier, the companies were also asked additional specific and more clearly aimed questions. However, not all responses to these questions will be included in the results section, as not all answers from respondents were highly relevant.

3.2.1 Interview method

Conducting an interview evokes a response in the form of motives and emotions, which are difficult to discern through the use of a survey alone. This is a significant advantage of using interviewing as a method. The conversation between interviewer and respondent also becomes more open, which can result in more detailed and accurate responses, as it is typically focused on a single theme. Certainly, this is dependent on the intention of the motive (Bell, 2005).

There are two types of interviews: formal and informal, in which the respondent acts as an objective registrar in the formal type. Here, specific information is gathered and only on the basis of the request. Informal interviews are frequently driven by a specific theme instead of by questions. As an interviewer, it is necessary to keep in mind that the appropriate type of

information must be produced; otherwise, the interview may result in the requested information being excluded (Bell, 2005).

The focus of this thesis has partly been on the formal type, but primarily on the informal type, as this was considered to be the most appropriate for the thesis. Although questions for the respondents have been prepared and sent to them in advance of the interview, the interview has been left open for additional discussion on the subject. This is because knowledge about the company and its materials could not be determined solely through internet research, resulting in certain question being far too specific. As a result, the method of informal interview was chosen.

3.3 Validity of the research

The methods used in the thesis are considered reliable. The majority of the used literature and articles are all published within the last five years, making the found information up to date. To verify that the correct information was used, it was cross-checked against many sources. This ensures that no inaccuracies are included in the thesis.

The choice of methods used in the thesis are based on literature that may be viewed as old and thus irrelevant. However, it can be argued that the subject itself is still relevant since methodology is not something that is in constant change.

Prior to conducting the interviews, it was determined that the appropriate person would participate. Interviews with a material manager at the organization was conducted to ensure that the report contains accurate information. This validates that the data collection is secure, as the respondent is accountable for the materials department and is capable of appropriately answering the questions. As previously mentioned, the interviews are referred to as primary data and does not jeopardize other sources.

4. Result

The detailed table of results is shown in appendix 1. The companies' material is shown together with its density, hardness, sustainable content in percent and functionality as a spongy or dense part.

These companies that were find relevant for the thesis:

- AnVa Polytech AB
- Trelleborg
- Arlanxeo
- National Sweden AB
- Hutchinson
- Cooper Standards
- Volvo Cars Lab
- Standard Profil
- Black Bear Carbon
- Scandinavian Enviro Systems
- M.D.S Meyer GmbH
- VIP Rubber and Plastic

- ECORub
- Gislaved Gummi (Hexpol company)

The companies that did not answered any mails or had anything to come up with were: Hutchinson, Cooper Standards, Volvo Cars Lab, M.D.S Meyer GmbH, VIP Rubber and Plastic and Gislaved Gummi.

The interviewed companies were: AnVa Polytech, Trelleborg, National Sweden and Ecorub. The rest of the company's information were collected from their website and were considered as adequate.

According to GRANTA EduPack (2020), the general carbon footprint for virgin EPDM is estimated to 3.25-3.59 kg CO2/kg EPDM.

AnVa Polytech AB

AnVa Polytech is a part of AnVa Industries AB, and is a company that develops and manufactures EPDM, TPE and silicone. In the material laboratory, custom made materials can be developed based on the costumers' criteria and construct the materials to fit the products environment. AnVa Polytech has three EPDM materials, of which two are commercially available and one that is in the stage of development and is therefore not yet available. The materials are:

- **ClimaRub 0.7** - this EPDM material is like the virgin EPDM material, except its fillers are recycled. This makes the CO_2-emissions decrease by 0,7 kg/produced kg of rubber.

- **ClimaRub 1.3** - this EPDM material is a further development of the ClimaRub 0.7 and apart from the recycled fillers, the Ethylene part is now also biobased. The polymers in the ClimaRub 1.3 are approximately 50 % biobased. This makes the CO_2-emissions decrease by 1,3 kg/produced kg of rubber.

- **ClimaRub ?** - this is the EPDM material that is under development. This material is too a further development of the ClimaRub 1.3 and consists of biobased oil.

These materials are not suitable for extrusion process at the moment due to the need of a particular form of polymer. However, AnVa is positive for the development of a functional material for their customers.

Trelleborg AB

Trelleborg Seals & Profiles are a part of the group Trelleborg AB. This is a company that is a global supplier within polymer-based sealing solutions, but also other industrial and automotive components. They have not yet made an EPDM material with a sustainable content suitable for the sealing system for cars. However, they have developed a mixture consisting of recycled carbon black, which results in a decrease in the CO2-emission, but it used for other purposes. Their material laboratory has previously made an attempt to

devulcanize EPDM material, but the revulcanized material did not meet the scent standards and was therefore not further developed and the project was ended. Trelleborg Seals & Profiles are now in the process of making an EPDM rubber with sustainable content suitable for the sealing system for cars.

Arlanxeo

ARLANXEO is a synthetic rubber manufacturer and one of the largest in the industrial sector. Their products are used in a range of different industries, including those related to automotive, electrical, and construction. Today, they manufacture a variety of EPDM with sustainable content that can also be used in a material mixture for automotive sealing systems. Their EPDM, which contains sustainable content, is called Keltan ECO and is available in a variety of setups depending on the desired result. Two of these examples are provided below:

- **Keltan ECO 6950** - This product is entirely composed of ethylene derived from sugar cane. Due to the extremely low ethylene content, this material exhibits excellent low temperature properties. This grade is ideal for sponge applications in automobiles, dense profiles, and wiper blades.

- **Keltan ECO 8550** - This product is entirely composed of ethylene derived from sugar cane. Dense profiles, coolant hoses, and potable water seals are examples of applications.

National Sweden AB

National Sweden is a well-known material subcontractor in a wide range of industries across several countries. They bring extensive expertise in polymers and rubber to the table and manufacture their materials accordingly. Today, they manufacture EPDM materials with a sustainable content, focusing on non-naphtha-based ingredients. Furthermore, they have chosen not to use recycled materials in their ECO EPDM material due to the possibility that these materials may contain unwanted or defective ingredients. According to an IVL Swedish Environmental Institute analysis, the materials have a 35% lower climate impact than virgin EPDM material. The three EPDM materials listed below are examples of what is available today, but National Sweden promotes that the material can be modified to meet the customer's requirements.

- **TDS EPDM 811165** - This EPDM material is based on biopolymer.

- **TDS EPDM 811166** - This EPDM material is based on biopolymer.

- **TDS EPDM 811167** - Based on Biopolymer with high proportion of fossil free ingredients.

Ecorub AB

Ecorub is a cleantech company that have a big focus on circular economy. They are producers of EPDM pellets that are based on recycled plastics and rubbers. The company have developed a new material called TPRR that consists of more than 90 % recycled material, making the end EPDM material 100 % recyclable. The TPRR material mixture is available for different types of processes in order to get the costumers desired product, and by breaking down the TPRR material to pellets, an advanced extruding process is made possible. 1 kg of EcoRub's raw material for extruding, the TPRR pellets, saves 2,5 liters of crude oil which equals to a saving of 2,7 kg of CO_2-emission. It is important to mention that Ecorub does not have a material that is suitable for EPDM seals for Volvo Cars at the moment, because the company makes custom-made EPDM raw materials and are therefore in need of the Volvo Cars specifications for the sealings.

Black Bear Carbon

Black Bear Carbon is a company that produces recycled carbon black from waste tires through an innovative process. This increases the possibility of achieving a complete circular economy and reduced cost of waste, but above all a drastically reduced negative environmental impact. Their recycled carbon black is called BBC TR30 and is equivalent to the virgin carbon black, which makes it possible to replace the carbon black with BBC TR30 in many applications where extrusion is required.

- TR30 – Recycled carbon black
- TR30S – An upgrade of TR30 which improves tear strength and reduces electrical conductivity.

Scandinavian Enviro Systems AB

Enviro is a company that recycles tires and processed materials effectively, mainly for the rubber industry. With their patented CFC-pyrolysis technology, high quality carbon black from old tires can be recovered in Enviro's own facilities. All the components that make up tires, carbon black, oil, steel and gas are recovered, making Enviro a company that works entirely with circular materials. The generated gas is used as energy for the pyrolysis process, and the three remaining components: carbon black, steel and oil are then sold externally. Each kilo of reclaimed carbon black instead of virgin carbon black results in a savings of 1,5-2 kg of crude oil.

- EnviroCB – Recycled carbon black

5. Discussion

The purpose of the thesis was to identify which companies that produce EPDM material with sustainable content or only certain components of it. The achieved results will enable Volvo Cars to conduct future studies on these companies, which have the potential to contribute

significantly to the development of a more sustainable material for their sealing system. However, after completing this thesis, the student's knowledge increases the knowledge at Volvo Cars engineers in this area significantly. This thesis is the first information available in the field and is thus only the beginning of the study of producing a material that can replace today's choice of material.

Numerous difficulties have arisen during the progress of the project. Multiple companies have stated that they are only at the early stages of their process, as the rubber industry faces numerous obstacles as a consequence of the rubber's chemical structure. As a result, it has been challenging to find additional companies that suit the thesis's requirements.

Due to the thesis aim to map the market of what companies that exist related to the EPDM material, whether it was the production of the EPDM component, carbon black or a finished EPDM material, the method of conducting this is not the conventional way of starting from the top going “downstream”. It was necessary to start by finding the results, which in this case are the companies and from thereon working “upstream”, meaning that after collecting the results the research questions were adjusted.

It is important to mention that all possible components that are required in a production of the EPDM material, has not been researched on. The main focus of this thesis has been to find companies that either produce their own finished EPDM material, companies that only produce the EPDM component or companies that produce components that are required to a finished EPDM material such as carbon black. However, as a next step for the future of finding an EPDM material with sustainable content, it is important to look into the fillers that are required in a finished EPDM material. There is an existing market for the white filler and the different ways of procurement, that can be produced in a sustainable way, and by doing this, there is a possibility of finding a material that have a high percentage of sustainable content.

Given that certain companies already are in the making of recycled carbon black that can be substituted for virgin carbon black in the recipe for EPDM-materials, this is something that is ready to be implemented. This only requires that Volvo's EPDM material suppliers have access to recycled black. However, biopolymers are more complex and untested in sealing systems, necessitating the involvement of additional actors and expertise who can determine if processes of EPDM-material with biopolymers should be adjusted.

One of the strengths of this thesis is the development of examples and materials that may be used to replace the EPDM content, which was the intent of this work. However, the outcome will have an effect on not only the department responsible for sealing and tightening, but also on other departments that utilize EPDM material. This could result in a major change for Volvo Cars and other companies in the same industry, as many are focusing on sustainable product development. Furthermore, it will benefit the companies that are included in the results section and have contributed to this research to appear as a company that is committed to environmentally compensating its products/materials.

Research questions:

- What is EPDM material and what are its uses? Why is it non-environmentally friendly?

EPDM is a synthetic rubber that is made up of ethylene propylene diene monomers, that have been polymerized into a polymer chain that require the presence of petroleum. When the EPDM is mixed with other components such as carbon black, white filler, oil, vulcanization agents, an elastic material is formed, that is flexible and durable, making it a great material for the automotive industry. However, the procurement process for the majority of the components in the EPDM material require crude oil, which is a limited resource that emits carbon dioxide gases when combusting, and hence making the EPDM material it non-environmentally friendly.

- What changes can be made to the EPDM material in order to make it more environmentally friendly/make it sustainable?

There are a few changes that can be made to the EPDM material, to make it more sustainable. Instead of using crude oil for the polymerization process, biopolymers derived from biomass obtained from sugar canes, sugar beets etc. This leads to a decrease in the CO_2 emissions, and often makes the material biodegradable. Another change is the process of devulcanization, meaning that the covalent cross-links between the polymers are broken turning the material into its initial uncured form. This would lead to a usage of the large amount of rubber waste that is being created. Recycling used tires to procure carbon black is also another way of making the EPDM material sustainable. To utilize old tires and obtain carbon black that otherwise would require combustion of crude oil, leads to less use of resources and hence decreasing the carbon dioxide emissions.

- What is available on the market regarding EPDM with sustainable content?

There are many companies that work with the EPDM material, unfortunately not everyone has chosen to take a step to develop and produce a more sustainable material. Nevertheless, the companies that were found in the thesis fulfilling the requirement of having either a sustainable EPDM material or EPDM component or recycling carbon black, were:

- **AnVa Polytech AB – ClimaRub**
- **Arlanxeo - Keltan ECO**
- **National Sweden AB - TDS EPDM**
- **Ecorub AB - TPRR**
- **Black Bear Carbon - TR30**
- **Scandinavian Enviro System – EnviroCB**

6. Conclusion and recommendation

Since the world is going towards using more sustainable alternatives in many industries, the rubber industry is no exception. However, in this thesis it has become clear that the rubber industry is only in the beginning of the sustainable journey. That is why further investigation is needed to find an EPDM material that suits Volvo Cars dynamic sealing system and sustainability goals. Nonetheless, the companies highlighted in this research are great candidates toward attaining these goals, but because this thesis is only a kick-start, and thus more study regarding the companies' materials are necessary. The thesis aim is therefore considered achieved.

Lastly, there are several recommendations that should be considered in future work:

- Reconnect with the companies that were found in the thesis with relevant solutions, to gain more information and to get some test material if possible. This is necessary in order to be able to eliminate companies' products at an early stage that do not meet Volvo Car's requirements specifications.
- Reconnect with the companies that did not respond, since it is not possible to exclude that they do not offer any relevant solutions.
- Investigation of the white filler components, both its environmental impacts and if it can be replaced with other sustainable alternatives.
- The different processes of the manufacturing of EPDM have not been properly investigated and needs thus a thorough examination of the environmental impact.
- How does Volvo Car Corporation define eco-friendly and how is it measured? How to compare final materials and manufacturing processes regarding eco-friendliness?
- Theoretically it is possible to replace the content in EPDM-material, but is it possible in practice?

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Appendix

Appendix 1:

Company	Product Name	Density (g /cm³)	Hardness (ShA)	Sus.Content	Functionality	Solution	Status	Comments
ARLANXEO	Keltan ECO 6950	0,86		15-20%	Sponge		A	The ethylene used in this process is derived from ethanol produced from sugarcane.
	Keltan ECO 8550	0,86		15-20%	Dense		A	
AnVa	Climarub 0.7			36% recycled CB	Dense	Recycled CB	A	
	Climarub 1.3	1,14	62	36% recycled CB 15% Biological raw material	Dense	Bio Polymerer(Eten) & Recycled CB	A	AnVa does not produce sealings for car doors at the moment, but they are open for future collab. Can customize.
National Sweden					Dense/Sponge	Bio Polymerer, sugarcane		A partly bio-based EPDM but also a change in the recipe that reduces climate impact, 35% less impact. They have different types, can be customized. Carbon footprint ≈ 1.4 kg CO2ekv. /kg EPDM
	TDS EPDM 811165	≈ 1,23	60 ± 5	Based on biopolymer		Bio polymer	A	
	TDS EPDM 811166	≈ 1,23	60 ± 5	Based on biopolymer		Bio polymer	A	
	TDS EPDM 811167	≈ 1,23	65 ± 5	Based on biopolymer		Bio polymer	A	
Enviro Systems	Recycled carbon black					Recycled CB	A	- Each kilo recycled carbon black used as replacement for virgin means savings of up to 1,5 - 2 kg crude oil. - Circular economy
Black Bear Carbon	Recycled carbon black			-"Net Negative" production: take more CO_2 out of the atmosphere than the operations cause.		Recycled CB	A	- Factories generate more energy than they consume. (green energy) - Circular economy: Tires-> Waste tires->Carbon black
Trelleborg							E	In the beggining to start a project to develop a EPDM with sustainable content.
ECORub				Recycled plastics and rubbers.			A	Can customize its material according to customer specifications.
Sabic - Saudi basic industries corporation							D	Working with EPDM, we contacted them but no answer. Think they might be interesting

A - Material is existing

B- Material in testing

C - Material in Development

D - Need to Investigate

E- No solution


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