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Material Selection Report

Engineering Design and Materials ACHA4001

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1 Introduction

This report will outline the full process of what is involved in deciding a material and the manufacturing process to produce a Volkswagen Golf lower front suspension arm. Different material properties and costs are crucial to make sure the component is made most effectively. How easy the different materials are to work to produce the suspension arm is an important aspect of production, as some methods can be extremely costly. The main objective of in-depth product development is to ensure that the component is made as strong, durable, and cheap as possible.

2 Component Design Specification

2.1 Environment

With the Volkswagen Golf being produced, supplied, and driven in several different countries, it is important to make sure that the car and its components are built to be able to last and withstand a broad range of different climates, from Brazil in the height of summer reaching temperatures of 31 degrees to north China in the winter with temperatures of -40 degrees (Bryce, 2023). This is why materials that are chosen to produce car components are specially selected to make sure they are durable enough to withstand all the above different conditions the car might be driven in.

2.2 Cost

The cost of the material that the suspension arm is made from is arguably the most important part of the design and specification process. The manufacturer ideally wants the material to be as cheap as possible to reduce production costs, as well as the consumer wants the component to be cheap when replacement is necessary. But usually, cheap and longevity don't produce a reliable component. (Wayken, 2023)

2.3 Replacements

According to (paautoinspection, 2022), consumable car components should last at least 10 years, if not more. This will be reflective of the environment in which the car is driven in, and how well-maintained the car is. When it comes to the time to replace components on the car, the parts that wear the quickest, in an ideal world, would be cost-effective to replace, meaning that they need to be made of a relatively cheap and easy material to manufacture. The speed in which the part can be changed and the process in which it is changed, or having to remove other parts to be able to replace certain parts, has a big impact on the overall cost of the process of buying replacement parts and having them fitted.

2.4 Importance of Design

In Figure 1 below, you can see the standard Mk4 golf lower suspension arm. The ball joint at the end of the suspension arm that holds the bottom of the wheel hub in place is held onto this suspension arm via 3 bolts. This has an advantage over many other car manufacturers' lower arms, if the ball joint has worn out, you can change components of the lower arm without having to replace the whole suspension arm because of how well the golf suspension arm has been designed. This has a huge benefit on the car owner over other cars. Figure 2 shows this lower suspension arm from a Suzuki Swift in comparison.



Figure 1 standard mk4 golf lower arm



Picture is for illustration purposes only

Figure 2 lower arm from Suzuki Swift with fixed ball joint

2.5 Different Alternatives

The cost of the material and the manufacturing process have a huge impact on the choice of what the suspension arm is made from. With the Volkswagen Golf being used in different circumstances, some drivers would want more performance-enhancing suspension lower arms with more adjustability, lighter weight, or a stronger, more durable, longer-lasting lower arm. Below are some examples of different suspension lower arms that are available on the market today; all are a direct replacement for the standard Volkswagen component. (Partstech, 2023)



Figure 3 race spec fully adjustable lower arm



Figure 4 cast iron lower arm

3 Material Selection

3.1 Material Requirements

When it comes to material selection for the lower arm, there are endless possibilities of what it could be made out of material-wise. Most materials wouldn't be acceptable to produce a component like a lower arm because of the stress and strain that it is put under by the weight of the car and the forces exerted on it from driving with acceleration, braking, and cornering. For example, below in Figure 4 is an Ashby chart showing different materials compared with each other. On an Ashby chart, we want a material that has a density of around 3 Mg/m^3 or higher and a Young's modulus of 12 GPa or higher. Selecting a material above these values would then rule out other materials such as polymers, and natural materials like wood and ceramics, leaving metals, composites, and technical ceramics as the materials that would produce the best lower arm. (HR Shercliff, 2016)

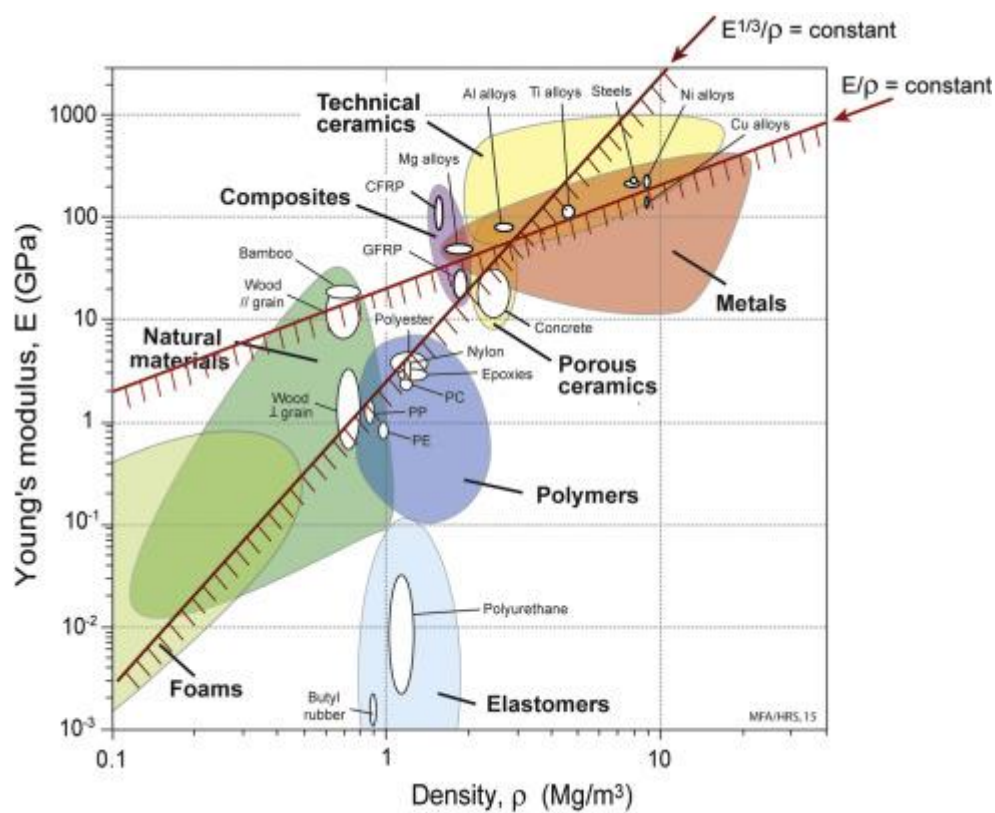


Figure 5 Ashby Chart (HR Shercliff, 2016)

3.2 Material Choices

According to the Ashby chart, the most obvious metals to choose for suspension arms to be made from are cast aluminum, stamped steel, cast iron, and carbon fiber. All of these material choices have their own individual perks. For example, cast aluminum is cheap to produce and lightweight, but it's not particularly strong. Stamped steel is cheap to produce, and relatively strong, but doesn't have very good longevity. Cast iron is strong but heavy and also cheap to produce. Carbon fiber, on the other hand, is extremely strong, and very lightweight, but very expensive to produce components from its raw state. Below in Figure 6 shows the different characteristics of the different materials stated above.

Property	Cast Aluminum	Cast Iron	Stamped Steel	Carbon Fiber
Density (g/cm ³)	2.7	6.9	7.7	1.5-1.6
Strength	Moderate	High	Moderate to High	Very High
Corrosion Resistance	Good	Poor to Moderate	Poor to Moderate	Excellent
Weight	Lightweight	Heavy	Moderate	Very Lightweight
Thermal Conductivity	High	Moderate to High	Moderate	Low
Manufacturing Process	Casting	Casting	Stamping	Layering/Weaving
Cost	Moderate	Moderate to High	Low to Moderate	High
Flexibility	Low	Low	Moderate	High
Fatigue Resistance	Moderate	Low to Moderate	Moderate	Very High

Figure 6 Material Characteristics chart

Where a balance of strength, durability, and weight is crucial, cast aluminum would likely be the best-suited material for the lower arm. It offers a good compromise between strength and weight, while also providing adequate corrosion resistance and manufacturing feasibility.

3.3 Material Cost Considerations

The cost of the different material choices is difficult to put an exact figure on, as prices are constantly fluctuating, and prices can vary on things like the quantity of raw materials bought in one go and the sheer amount readily available at a particular time. The general comparisons for the materials stated above are:

Cast aluminum is more affordable compared to carbon fiber but can be more expensive than stamped steel and cast iron. It is currently commonly used in automotive applications due to its lightweight properties and relatively lower cost compared to carbon fiber.

Stamped steel tends to be one of the most cost-effective options among these materials. Its affordability makes it a popular choice for various automotive components, including suspension parts.

Carbon fiber is typically the most expensive option per kilogram due to its advanced manufacturing processes and high-performance properties. While it offers exceptional strength-to-weight ratio and durability, its cost can be prohibitive for certain applications.

Cast iron can vary in cost depending on the specific type and quality. Generally, it tends to be less expensive than aluminum and carbon fiber but heavier. Its strength and durability make it suitable for certain automotive components, though it may not be as common for suspension parts due to its weight.

(Letters, 2016)

4 Manufacturing Process Selection

4.1 Aluminum Casting Process

Aluminum casting can be done in two main ways: hot and cold die casting. The process that is involved with aluminum casting is listed below in Figure 7.

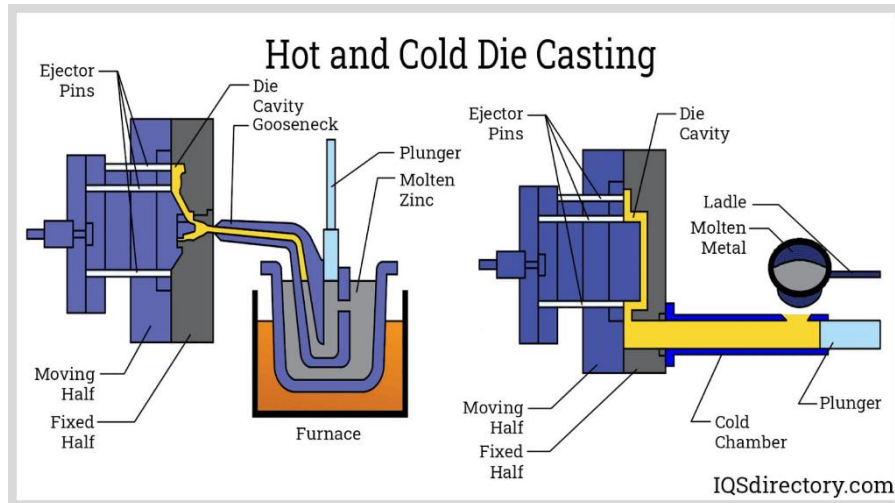


Figure 7 Cast Aluminum Casting process diagram (Directory, 2022)

1. **Pattern Creation:** First, a pattern of the desired part is created. This pattern can be made from wood, plastic, or metal and represents the shape and dimensions of the final product.
2. **Mold Making:** A mold is created around the pattern. This mold is typically made from a material like sand, plaster, or ceramic. It's made in two halves so that it can be opened to remove the pattern and then closed for casting.
3. **Pattern Removal:** The pattern is removed from the mold, leaving behind a cavity that matches the shape of the desired part.
4. **Melting Aluminum:** Aluminum is melted in a furnace at temperatures ranging from 650°C to 900°C (1200°F to 1650°F), depending on the specific alloy being used.
5. **Pouring:** Once the aluminum is molten and at the correct temperature, it is poured into the mold cavity. The mold is filled to ensure that the entire part is formed.
6. **Cooling:** After pouring, the aluminum is allowed to cool and solidify inside the mold. Cooling times can vary depending on the size and complexity of the part, as well as the type of alloy being used.
7. **Removal and Finishing:** Once the aluminum has cooled and solidified, the mold is opened, and the casting is removed. Any excess material is trimmed off, and the casting may undergo additional finishing processes such as machining, grinding, or sandblasting to achieve the desired surface finish and dimensional accuracy.

(Directory, 2022)

4.2 Component Hardware

Hardware is an important part of manufacturing components to consider when choosing which material they will be made out of, as cast components may require less hardware than a component that is metal stamped. When a component is cast, it allows for bushes to be pressed straight into it and threads to be able to be tapped into premade holes. This poses a cheaper alternative to metal stamped components, where countersunk nuts and sleeves would have to be inserted and welded into the raw component to be able to make it functional as a lower arm.

4.3 Finishing Process

The most common and durable finishing process for all of the metal material choices is powder coating. Powder coating provides an extremely durable and rust-resistant coating, which can be applied easily over the component and ensures a nice finish. Carbon fiber, on the other hand, requires a form of lacquer applied by liquid, sometimes with a UV-resistant quality, to protect from the sun and provide a hard-wearing aesthetic finish.

5 Conclusion

In conclusion, the design requirements and specifications for the suspension lower arm were carefully considered, with cost-effectiveness and material suitability for the car's environment being the main factors. After research cast aluminum is the best fit material choice. Its balance of affordability, lightweight properties, and corrosion resistance match great with the design specifications. By choosing cast aluminum to make the lower arm, we ensure both performance and durability, meeting the demands of the vehicle's possible usage conditions while remaining mindful of costs. This decision shows the importance of thoughtful material selection in achieving an optimal balance between functionality, cost-effectiveness, and environmental suitability in automotive design.

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