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Introduction

This report will discuss the importance of choosing a good material and a specific manufacturing process to make a specific component from that material of choice. The component of choice will have its environment of use, material requirements and impact of the manufacturing process discussed to come to a proper conclusion of the most effective method and material to make. There will also be value ranges displayed in charts to show the estimated cost of production. The material of choice will be broken down into its properties to further clarify why this material has been chosen such as the areas this material will benefit the environment the component will be used in.

Component Design Specification

Exhaust system from M1 Yamaha MotoGP

The main role of the exhaust is to route the exhaust gasses produced from combustion of the engine away and out of the vehicle. This means that there needs to be an efficient pathway from the engine's cylinders to the tip of the exhaust at the back of the car. A secondary function of an exhaust is to effectively reduce the amount of noise produced from the gasses as they exit the vehicle. Exhaust gas scavenging is important in a high-performance race bike as the exhaust system is designed to optimize this affect by using the exiting exhaust gasses to draw fresh air and fuel into the mixture of the combustion chamber therefore increasing engine performance and efficiency. (1)

The size of the exhaust system can vary depending on what needs to be improved. Shorter exhausts tend to be much louder than longer exhausts as there is less noise reduction. Longer exhausts tend to extract a higher performance than shorter exhausts as it creates a better vacuum for the exhaust gasses out and the Fresh air and fuel ratio into the combustion chamber. (1)

The operating conditions of this exhaust will be high stress situations where the temperature gets very high for a duration of time, so these conditions need to be taken into consideration when choosing the material of choice to produce this exhaust. (1)

Material Selection

Common materials used in production of these exhaust systems are Titanium as it has a very good strength to weight ratio and is very heat resistant which is very useful when considering the operating conditions of the exhaust which are going to be very intense and high stress on the system.

Another common material used in production of these systems is Inconel which is a nickel-based superalloy, which has a very high temperature and corrosion resistance, its most common use is the headers of the exhaust as this is where the exhaust experiences the most stress and high temperatures.

Carbon fibre is also used as it has very similar properties, but it does not have the same heat resistance making it not as good as titanium.

Titanium Properties

High Strength to weight ratio, Excellent Corrosion resistance, high temperature resistance, low thermal expansion, easily fabricated. (2)

Inconel Properties

High Temperature Strength, Corrosion resistance, Fatigue resistance, resistant to thermal expansion. (3)

Carbon Fiber Properties

High Strength to weight ratio, low density, Fatigue resistant, tailorable properties by adjusting factors like the weave pattern, resin type, or Fiber orientation. (4)

The material is very important when producing an exhaust for a race bike as it needs to be able to withstand extreme conditions and not break or change shape under the extreme heat this suggests that carbon fibre would not be a good material to produce a full system as it has a low temperature strength. Inconel and titanium are both very strong materials that can withstand the extreme conditions and perform all the same function of an exhaust to a similar ability but with a race exhaust performance is the focus and Inconel is almost double in weight as titanium weight roughly 4.6g/cm whereas Inconel weighs 8.3g/cm. (4)

Manufacturing Process Selection

Casting

Casting is the process in which turning the metal into its liquid state and pouring it into the desired final shape, this allows the maker to be precise in design for maximum accuracy. The process of casting can produce dendrite grains which are root like structures, this makes the metal weaker limiting its usage for various applications. This process is extensively difficult as titanium has a high reactivity. (5)

Forging

This process is the application of thermal and mechanical energy onto titanium which can cause the material to change shape whilst staying in a solid state, due to these intense conditions it coats the metal with a glazing which stops it reacting with the atmosphere but also allows it to deform into the desired shape the machine used for this process is a forging press in which the metal is exposed to high pressures to reshape it into its desired form, this process may require multiple repeats of steps to ensure that the metal maintains desired properties to accurately transform into its required shape for applicable usages. Once this step is completed the formed titanium piece must be cooled slowly to room temperature to relieve the metal of all stresses and improve its mechanical properties. The forged titanium will then undergo surface treatments such as grinding or machining to achieve the correct dimensional accuracies. (5) (6)

Forging will be a much better production method for a MotoGP exhaust as the metal will undergo various heat cycles and treatments to make sure it is perfect, and it is much easier to replicate this process rather than casting, MotoGP exhausts need to be moulded into the correct shape further ensuring that this would be the much more effective method of production for this desired component.

Insight to Production

A MotoGP exhaust has a very intense production method as it must be perfect as in racing every slight performance increase is required. First the exhaust must be designed and engineered to fit around the chassis of the motorcycle. Then the correct material must be selected to ensure that all qualities of a good exhaust are met. The Selected material will the be forged into sheet metal and built into the correct tubes, these tubes will then be bent and formed into the full system. These separate tubes will then need to be welded together to ensure there are no gas leaks throughout the entire system. This full exhaust system will then undergo heat treatment to enhance the mechanical properties to ensure durability to withstand the extreme conditions of application. It will be completed by some surface finishing and then tested in a controlled environment.

Conclusion

In conclusion a MotoGP exhaust system is a very complicated component as it is a high-performance system that must be inch perfect. This is why there is thorough design and engineering gone into this part. Furthermore, the correct material must be selected as it is very important to maximise all areas possible in this case titanium does that job perfectly as it has a high strength to weight ratio, it can withstand extreme conditions which it will be put through as it is on a high performance race bike and it will not deform easily so it can withstand crashes and stay in the correct shape much better than other materials.

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