

Automotive engineering

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Material Selection Report & GD&T Drawings

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Introduction

In this report I will be covering certain aspects which go into the design of manufacturing of a piston. When designing any given component aspects such as the materials being used, and its properties should be considered and taken to account as it is very important that a suitable material is chosen with properties that help to ensure the component functions properly and effectively. In this report I will be talking about material selection, their properties and which material would be best suited for a piston to ensure it functions effectively. Values will also be placed where needed to ensure a clear understanding of the properties a material must have to withstand certain forces and environments. I will also be discussing the manufacturing process of the piston and how once a suitable material has been chosen for the piston the best way for the piston to be manufactured.



Figure 1, piston, ms-motorservice

Material Properties

For any given piston to function properly and effectively its given material properties should be taken into account, for example when creating and designing a new piston the required properties of a piston should be carefully looked at as it will ensure a suitable material is used to manufacture the piston to ensure it functions effectively and how it was designed to. The required material properties of a piston include its ductility, strength, temperature resistance, thermal conductivity, seizure resistance, low friction, and wear resistance according to MAHLE International GmbH, 2016, p59. Pistons themselves are usually made to last 150,000 plus miles that is why it's essential a good all-around material is selected for the manufacture of a key component of an engine.

Due to the piston having a mechanical movement associated with surfaces rubbing against each other it is essential that the piston is able to withstand friction forces which could cause it to wear and cause it to perform ineffectively. The piston's material needs to be a material that is wear resistance to ensure it performs its operation effectively meaning when it's carrying out its mechanical process it is not wearing away from its operation, so it doesn't fail.

Also due to the friction forces acting upon the piston the piston needs to be able to withstand great amounts of heat which is created by the surfaces making contact with each other because if the piston heats up too much it can cause the piston to expand which is bad as it can cause mechanical issues within the engine when its running. The piston needs to have seizure resistance as it is essential the piston is able to keep running when the engine is on, If the piston was to seize up the engine would fail. The piston itself needs to be quite strong and have a lot of strength due to the forces acting upon it when the engine is in operation. The piston needs to be able to withstand the compression forces acting upon it to perform effectively and have a successful operation of the engine. If the piston does not have a material with a high strength property you can expect failure within the operation of the engine. Due to the piston being compromised by a lot of heat the piston's material needs to have a thermal conductivity so that the piston performs correctly and effectively when ignition occurs in the engine.

During power stroke the piston is exposed to a lot of pressure resulted by the combustion of gases acting upon it. The amount of force the combustion of gases creates upon the piston can be around 1000 psi in a standard engine however in a high-performance engine that figure can be increased to around 1500 psi, that is why it's essential the material of the piston has a high strength property to withstand these high forces. Due to engines typically running at a value of 195 to 220 degrees Fahrenheit according to Van Chevrolet, 2017, a guide to your car's temperature gauge: what's normal and what's not, the piston's material needs to have good heat resistance to be able to withstand this heat and perform its operation effectively and properly.

Material Selection

When selecting a material for any given component it is crucial that the properties of the material that is going to be used ensure the component functions effectively and the best it possibly can when the component is carrying out its operation. For a component such as a piston the material that is going to be used needs to have the required properties to ensure its smooth operation and run time. As stated in the required properties a piston's material must have high strength, temperature resistance, thermal conductivity, seizure resistance, low friction, and wear resistance in order to function properly. When choosing a material for a major component such as a piston there are certain things which need to be taking into account for example stated by van den Bergh, 2021 "whether I want high ductility at the cost of a higher thermal conductivity, or something harder, with better wear properties and lower thermal expansion". Once we have fully chosen our desired properties which allows for the best performance of the piston it is time to choose a material which will be used to manufacture it. Most pistons these days are made out of aluminium alloys although other materials can be used such as grey cast iron.

The benefits to using iron includes its wear resistance, castability, machinability and resistance to deformation. However, the advantages that aluminium provide out way the use of using cast iron, examples of how aluminium is more beneficial to use include that it is a better conductor of heat, has a higher strength, is lighter, is easier to manufacture and has a high resistance to corrosion, a lot of these factors are very important when trying to get the best performance out of an engine. As most pistons these days are made from aluminium alloy due to the beneficial factors over other materials it would be better to choose an aluminium alloy due to their reliability and high-performance rates. Aluminium pistons are made from alloy containing silicon, as stated by Greg Acosta, 2021 "It is a key element used by piston manufacturers to enhance the features that aluminium alone wouldn't have." Now that we have our raw material selected which is aluminium an alloy containing silicon needs to be chosen. Different amounts of silicon within the alloy have different effects on the material. For example, a lower amount of silicon within the alloy causes high ductility, high thermal conductivity, high expansion, has lower wear resistance, is not good at high temperatures and can make the piston run louder. An alloy with a low amount of silicon is known as Hypoeutectic.

An alloy with a high amount of silicon causes low ductility, low expansion, low thermal conductivity, higher wear resistance, quieter when in operation and is better at handling high temperatures. An alloy with a high amount of silicon is known as Hypereutectic, this means that the alloy contains a high percentage of silicon up to 20 %. The middle of both of these terms is known as eutectic meaning the alloy contains around 12% of silicon. A material which contains around 12% silicon is 4032 aluminium alloy. This is the material that I think will have the best performance outcome of the piston when in operation. I think this due to its benefits which it will provide also being able to suit the required properties of the pistons material to make the component function as best it possibly can. The benefits of using the eutectic alloy include that it has a high ductility which is good as it will be able to withstand the forces acting upon it, is a relative thermal conductor meaning there will be mild thermal expansion, has a high heat resistance which is crucial to the successful operation of the piston, has high wear resistance and when in operation the piston will run relatively quietly.

Manufacturing Processes

Once a suitable material has been selected to be used for the piston having the required properties It is then moved on to the manufacturing stage. Before the material goes into manufacture tests such as FEA will be carried out on the design of the piston to see whether the material will be able to effectively perform the best it can. Once the material has been fully tested and passes all tests, it then goes onto manufacture. There are two main ways in which a piston is manufactured which include casting and forging. These two main ways of manufacturing the piston can cause variables of the piston to change for example a cast piston will have higher silicon content alloys whereas forging pistons are generally stronger.

Cast and forged pistons are very different as stated by Matt Griswold, 2012 “cast pistons are generally more affordable, light weight and often plenty ample for street applications”, whereas as stated by Matt Griswold, 2012 “a forged piston is typically much stronger than a cast piston”, this means that forged pistons are generally used for high performance engines where there is high horsepower as these pistons are a lot stronger. Cast pistons are generally used for normal street engines where not a lot of horsepower is required. Although forged pistons are a lot more stronger and more durable when exposed to extreme temperatures, I feel that cast pistons are a better option due to their overall benefits and being cheap to manufacture. However, if the piston being manufactured was to be used in a high performance engine I would choose a forged piston as they would be more capable of handling the increased forces as well as high temperatures acting upon it.

Conclusion

To conclude this report, I was able to fully list a range of properties which a piston's material would be required to have to make sure the piston was to be able to complete its function the best it can. These properties were each defined with some of the properties having values on the type of environments and forces that would be acting upon the piston's material when the piston is in operation and the engine is running. Some of these values are crucial to the making of a piston as it can help choose the right material to be used to make the piston, this is important as it will have an effect on how well the piston performs. After listing the properties required to make the piston it was then time to decide what material would have been best suited to fit the piston's function while also meeting the desired properties of that component.

Different materials were looked at however one material which was best suited for the pistons function was chosen this material was 4032 aluminium alloy, this material was chosen due to it being better suited to the required material properties of the piston which would allow for a better performance of the piston when in operation. Once a material had been selected, I then moved onto the manufacturing process of a piston where I stated different types of ways a piston can be manufactured outlining benefits to each way of manufacturing the component. Then by comparing the different types a given way of manufacturing the component was chosen which was casting due to its overall benefits it provides.

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