Casting engine blocks automotive manufacturing processes engineering essay

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There are several different types of manufacturing processes to choose from out there and many different alloys that are at ones disposal to be used. Some processes include: sand casting, die casting, and lost-foam casting. In this report, sand and die casting will be discussed with the focus on sand casting. Also, choosing a suitable alloy will be discussed. Is the alloy going to be ferrous or non-ferrous and what qualities does the alloy chosen have, to make it a good choice to use with the manufacturing process is a question to ask oneself. In this case, sand casting has the capability of using any alloy whereas; die casting is generally limited to non-ferrous alloys. Aluminum is a very common alloy to use and it can be used for almost any process. Although, this alloy possesses some qualities that would be desired by most, gray cast iron was decided by us to possess even stronger qualities that led us to choose it for the material used in the design of a cast iron block. Sand casting is now and has been for some time one of the most commonly used manufacturing processes and the use of gray cast iron fits very well with this process. The reasons for choosing sand casting as the manufacturing process and gray cast iron as the alloy will be discussed further in the report.

Problem Statement:

To select a suitable casting process and material that will be as per the requirement of efficient, cost effective and environmentally friendly engine block production.

Objectives:

To discuss the various casting processes that can be used to manufacture an engine block.

To select a suitable alloy for the part.

To select a suitable casting process.

To justify the above selection.

To design the selected process to cast an engine block.

To discuss the defects in the casting and challenges to be faced while using the selected process and the methods to overcome these.

To discuss the cost consideration and environmental impact of using the selected process.

The Identification of Suitable Casting Processes

The manufacturing of cast engine blocks out of cast iron involves the consideration of what manufacturing process to use as well as a suitable alloy. The alloy chosen for our company is gray cast iron and the process of selecting this particular alloy will be discussed further in the next section. This section will discuss how our company came to choose sand casting as the manufacturing process by comparing this process with other processes.

There are several factors involved in choosing a suitable casting process for manufacturing cast engine blocks. Some of these factors include the type of material that can be used in the casting process, the type of part that can be cast, the finish of the product, the amount of time it takes for the process, and the cost involved. In this section, sand casting will be compared with die casting. Although both are good processes to use, the results vary depending on what process is chosen. There are some similarities between the processes, while there are mostly differences in most aspects of the processes.

Selecting a Suitable Alloy

An engine block is the main part of an engine which holds all most all the parts of the engine. It should house the internal moving parts, fluids and also withstand the forces and pressure developed during combustion.

It should have high strength, wear resistance, good machinability, good vibration absorption capacity, corrosion resistance, low thermal expansion, good thermal conductivity and manufacturability and should have less manufacturing cost.

In general, most of the industries use cast iron for manufacturing the engine blocks because of the following reasons:

It is cheaper,

excellent damping capacity,

good wear and high temperature resistant,

easily machinable,

inexpensive to produce, and

can tolerate high pressure and RPM.

Other materials which are considered for manufacturing engine blocks are aluminum alloys and magnesium alloys. But, after considering the above factors using cast iron is the feasible option.

For choosing the right alloy from cast iron variants, their material properties are compared.

Table 1. 1 compositions of the different cast irons

Name

Nominal composition [% by weight]

Form and condition

Hardness [Brinell scale]

Grey cast iron (ASTMA48)

C 3. 4, Si 1. 8, Mn 0. 5

Cast

260

White cast iron

C 3. 4, Si 0. 7, Mn 0. 6

Cast (as cast)

450

Malleable iron (ASTM A47)

C 2. 5, Si 1. 0, Mn 0. 55

Cast (annealed)

130

Ductile or nodular iron

C 3. 4, P 0. 1, Mn 0. 4, Ni 1. 0, Mg 0. 06

Cast

170

Ductile or nodular iron (ASTM A339)

–

cast (quench tempered)

310

Ni-hard type 2

C 2. 7, Si 0. 6, Mn 0. 5, Ni 4. 5, Cr 2. 0

Sand-cast

550

Ni-resist type 2

C 3. 0, Si 2. 0, Mn 1. 0, Ni 20. 0, Cr 2. 5

Cast

140

Table1. 2 comparision of the strengths of the cast irons alloys

Table 1. 3 castability of the different metals.

As we need a material which is hard enough, having good strength and good castability, from Table 1. 1 we can find gray cast iron having enough and nominal hardness. There are materials which are harder than grey cast iron but as hardness increases material can wear the internal components and will be brittle in nature which is not a preferable property. From Table 1. 2 we can observe that elongation is less with good yield strength for gray cast iron which is one of the desirable properties. Both pearlitic and martensitic gray cast irons have less elongation with high yield strength but martensitic gray cast iron has more hardness which is against our requirements and Table 1. 3 tells that castability is excellent for gray cast irons compared to other metals and alloys.

For desired properties like

castability,

fluidity,

resistance to deformation,

relatively low melting point and cost

On the whole from the above mentioned tables 1. 1, 1. 2, 1. 3 and above desirable properties gray cast iron matches our requirement. So we finally decide to go for the pearlitic gray cast iron.

The Effect of Manufacturing Processes on the Product

Sand casting and die casting both consist of the pouring of molten metal into a mold, allowing the metal to cool until it solidifies. The type of mold used in these processes usually varies drastically from one another. Die casting uses the molten metal that gets forced into a mold and is subjected to high pressures so that it solidifies very nicely into the die cavity. Sand casting generally uses silica sand as its material for the mold. Sand is generally chosen as the mold material because of the characteristics that it possesses and the fact that it's relatively inexpensive. The strength of the mold is critical in the manufacturing process and using the right type of grains in the sand can improve the strength.

A specific type of sand is commonly used for sand casting, and that type is called green molding sand. Green molding sand uses a mixture sand, clay, and water. This mixture provides a moist sand to be present in the mold when the metal is poured into the mold. This moist sand then becomes easily reusable, which contributes to lowering the expenses in the process.

Sand casting is an efficient process to use because of the flexibility in what can be done as part of the process. There is no limitation to what material can be used, which means that gray cast iron is available to be used when sand casting engine blocks. There is also no limitation to the type of part that can be cast. The part can also be of any size or shape or weight. Another reason for using sand casting is the minimal costs when compared to other manufacturing process, the amount of time required for production of the parts, and the number of parts required in a production cycle. Sand casting allows for the production of one part at a time if necessary, with no limit to the number of parts to be produced. All costs, including mold material, tooling, and labor costs are relatively low compared to other processes.

Although, sand casting has many good qualities that persuade us to use this process, there are a few deficiencies in using the process too. These deficiencies include the finish of the material, porosity, and dimensional tolerance. The dimensional tolerance is much greater than that of other manufacturing processes which causes a greater rate of shrinkage. This shrinkage increases the porosity of the material, which results in a rough surface finish.

Die casting is an efficient process to use because more precise results. The die casting process allows for the production of solid, fine parts at a high rate. No additional machining should be necessary on these parts since the dimensional accuracy is so good to begin, with that these parts are ready for use after one cycle of the process. Although the types of materials that can be used are limited, which is mentioned in the next paragraph, experimental results show that gray cast iron is a very workable material for die casting. Even smaller sized parts like pins and fasteners can be casted using die casting, but the smooth surface finish and precision of the parts allow for them to be put to good use.

Similar to sand casting and any other casting process, die casting has its disadvantages too. Generally, only nonferrous materials can be casted using die casting. The materials work very well, but that still limits the resources out there for the process which could potentially cause some problems. Also, since the parts produced are small, this limits the potential uses of the part. Another problem that could arise is that even though the labor costs are very low since the process is mostly run on automated systems; these systems and all other equipment are relatively expensive. This is the one major difference between sand casting and die casting that cannot be ignored. Ways to lower the costs are still being worked on, but there is still some work left to do to bring these costs down a sufficient amount. It takes a long time to produce these parts, but being able to produce a large quantity at a time helps to make up for the long lead time. These deficiencies will be looked at in greater detail in a later section.

The Sand Casting Procedure

Sand casting

Sand casting is one of the oldest techniques of manufacturing. In this form, molten metal is poured into a mould made of sand. When the metal is hardened and cooled, the part is removed. In sand casting, the mold is made of packed sand.

Mold preparation

In the process, we chose green sand casting as our casting process. The sand mixture consists of sand, clay binder, water and additives. The sand also includes zircon($ZrSiO_4$), olivine(Mg_2SiO_4), iron silicate(Fe_2SiO_4), chromite($FeCr_2O_4$). Zircon, olivine and iron silicate have low thermal expansion, and chromite has high heat transfer.

During the process, all the ingredients are mixed together and the sand should be moist and not dry.

Figure 1. Green Sand Casting Mold

Sand casting procedure

During the process, patterns and cores are made; sand is thoroughly mixed and then formed about the patterns as per our need. The patterns are removed and the two halves of the molds are put together and are thus ready for pouring the molten metal. The preheated metal is then poured slowly into the mold until the mold is full. The part is then cooled and after the part solidifies thoroughly, the sand mold is removed by striking the part. Lastly, we machine the casting to give it its final shape.

Defects

Sand castings have many defects such as inclusion, shrinkage, air holes, sand holes, cold shut and cracks. In this procedure, the granule shape, granule size and collapsibility of sand mold effect sand mold casting.

Quality inspection

Quality inspection of sand casting can be done by sharp impact test, x-ray inspection, pressure test, magnaflux inspection and ultrasonic test. Whereas, to inspect the casting in the foundry itself; visual inspection, dimensional inspection, chemical component inspection and testing to figure out the physical properties by doing the hardness or tensile strength test are commonly used.

Casting products and mass production

The sand used in making the mold can be used again and again(reclaimed), thus the green sand casting process is cheap and widely used compared to other casting process. Due to this mass production of this process in a cost effective manner is possible.

CASTING DEFECTS

Some of the possible defect that may arise during the sand casting process

Shrinkage defects: These defects mainly occur when feed metal is not available to compensate the shrinkage as the metal solidifies. These defects can be avoided by providing proper gates, vents and risers in the mold.

Gas porosity: They are formed as bubbles on the casting after it is cooled. This is due to the presence of large amounts of dissolved gas in the molten metal. To prevent this, the metal is melted in vacuum or in the presence of specific low solubility gases such as argon or carbon dioxide. To minimize gas solubility, the super heat temperature can be kept low.

Misruns and cold shuts: They are the empty cavities in solidified metal, due to the lack of fluidity, narrow cross sections, back pressure and turbulence. These are rectified by reducing the pouring temperature, adding sprue and proper gates.

Metal penetration: This is the presence of rough surface finish because of the liquid metal penetrating the sand mould. This penetration is due to high pouring temperatures. Lowering the pouring temperature will avoid this phenomenon.

Hot Spots: They are formed on the surface that is very hard because of the quick cooling compared to the surroundings. Changing chemical composition and providing proper cooling methods like using chills, these can be avoided.

Inclusions: These are metal impurities generally oxides, sulfides, nitrides and carbides formed from the material that is eroded from furnace or impurities present in the mold. These inclusions can be reduced by using ceramic filters or melting the metal in vacuum

Hot tears: Also called as hot cracking, these are the failures in the casting that are formed while cast metal starts cooling because of the weak strength of the metal when it is hot and the internal stresses. These can be prevented by proper mold design.

Mold erosion: Erosion of the mold sand occurs while filling molten metal into the mold, caused due to sand having less binding strength or high pouring velocity of metal. This can be avoided by redesigning the gating system or by using large runners.

Identifying challenges in the process and how they are being addressed

An engine block has a very complex geometry. The engine block has internal recesses for the coolant, i. e., water to circulate and the cylinders for the piston to reciprocate. So casting such an intricate shape is always challenging.

First, the pattern for making the mold must be very carefully designed because the quality of our casting is as good as the quality of our pattern.

For such a complex machined part, we must carefully monitor the cooling of the casting; as such a complex part is bound to cool in an uneven manner.

We all know that the major problem concerned with sand casting is the poor surface finish, but in an engine block the only important surface is the cylinder where the piston will reciprocate and it is not important for the cooling water to flow through highly machined surfaces. In sand casting, the surface finish can be substantially improved by using finer sands and we are adding zircon to the sand which will result in a better surface finish.

Another challenge in sand casting an engine block is the pouring of the molten metal. Since an engine block is huge and has a complicated geometry, the pouring rate of the metal should be carefully monitored. We should not pour it at such a slow rate that the metal solidifies in the pouring vessel itself and it should not be so fast that molten metal could not reach some regions resulting in voids. In fact, the metal should not be poured. It should be pumped against the gravity so as to avoid gas entrapment.

As said earlier, an engine block, due to its geometric complexity will tend to cool irregularly. So the risers should be properly placed to take into account this irregular cooling.

Addressing the cost consideration

The cost associated with sand casting can be divided into three broad categories: Material cost, Production cost and Tooling cost.

Material cost

As the name suggests, material cost includes the cost of all the materials used in the sand casting process. These materials include the metal, the mold sand and the core sand. The cost of the metal will depend on a number of factors such as cost of the alloy, purity of the alloy and the castability of the alloy. For more pure alloys, the cost will be higher. For alloys with lower castability, additional metal will be required in order to fill the flow channels and the feed heads to assure a good casting, so in such cases, the cost will be higher. The cost of the mold sand and the core sand will depend on the shape and size of the mold and the core respectively. In this case, since our part is an engine block, due to its size and geometric complexity, the cost is bound to be high.

Production Cost

Again as the name suggests, production cost will include the cost of all the operations that will take place during the process of sand casting. These will include core making, mold making, pouring, and cleaning. The addition of cores to the casting will increase its cost because it will slow the process down. An engine block, a very complicated part, will definitely have cores which will increase the overall production cost by slowing down the production. Pouring and cleaning costs are determined by the size and weight of the casting. So these will be high for an engine block as it is a big and heavy component, and the mold will take longer to fill and the cast block will take longer to be cleaned.

Tooling Cost

Tooling cost is the cost associated with the tools used during the sand casting process. These include the patterns used to make the molds and the core-boxes to make the cores. Since an engine block is huge and geometrically complicated, tooling cost will be high. Also, since we are designing for mass production, the patterns as well as the core-boxes will have to be used more frequently. The constant use of the tool will result in the wearing down of the tool at a high rate, which in turn will increase the overall cost as the tool will have to be replaced. A solution to this problem will be to use patterns and core-boxes of a better quality material, but again the cost will be high.

Environmental Impact of using Sand Casting:

Foundries are generally regarded as being dirty and unfavorable to the environment. The primary issues being faced by the casting industry are the excessive volumes of by-products that are to be sent to landfills, and the Hazardous Air Pollutants (HAPs) which are released during the process.

Of all the by-products generated by volume, sand is the largest. Even in processes which involve a high level of sand recovery, some amount of new sand is always required to maintain the optimum quality of sand in the system. This in turn will result in loss of sand from the system. After its use, the sand is either sent to a landfill for disposal, resulting in soil pollution, or it is reclaimed off-site.

Not all foundry sands are considered hazardous, especially the ones from ferrous foundries, which pass the TCLP (Toxic Characteristic Leaching

Procedure), which, after use can be sent to unlined landfills for disposal. Some non-ferrous sands on the other hand contain high levels of metal because they have to be sent to secured landfills and not the unlined ones. Chemical binders’ inwaste sand can become a crucial issue if resin-coated sands are wasted in large volumes before the pouring stage as most of the binder in the mold is burnt off during the pouring stage. Hence, the binder level should be carefully monitored so as to prevent it from reaching unacceptable levels over a period of many reclamation cycles.

The second largest by-product by volume in the sand casting process is the baghouse dust. It is typically formed when the sand is reclaimed multiple times, which results in the sand grains breaking down to dust particles. Not only will it affect the quality of the casting, but it will also result in health issues such as silicosis.

Slag is yet another by-product which is formed during the sand casting process. When flux is added to the molten metal to remove impurities, it reacts with the impurities to form slag which floats to the surface and is to be removed before pouring the metal. The slag so formed has a glass like appearance and is not really hazardous as it can be easily disposed of in unlined landfills.

Apart from these solid wastes, there is also a substantial amount of gaseous waste (emissions) produced during the sand casting process. These include benzene, carbon monoxide, hydrogen sulphide, sulphur dioxide, phenols, nitrous oxide and other HAPs. Of all the pollutants, benzene is the most emitted.

Conclusion

In many ways the job of an engineer is not simple, because to choose between one material or one process over another is never easy. There is no process or material which can be considered as perfect. Each process has its advantages and disadvantages. An engineer's job is to find an optimum solution so that the huge amount of investment in this industry is justified. In this project we, as engineers have done a similar job. We have selected sand casting for manufacturing the engine blocks and have justified our decision by discussing various aspects, both good as well as bad, of the selected process.