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PRODUCTION OF SINGLE CYLINDER ENGINE COMPONENTS THROUGH HIGH PRESSURE DIE CASTING IN SEDI ENUGU.

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Abstract

This research work investigated the casting method employed in the production of aluminium based alloy components of a single cylinder engine in SEDI Enugu. A discussion of the casting processes, especially the die casting process used in the production of single cylinder engine components was carried out.

In addition, considerations that lead to the selection of die casting for the project, the main structure and working principles of die casting machine were explained. Besides, this paper treated mould design and mould materials requirement. In conclusion, the alloy analysis of aluminum alloys such as; aluminum-magnesium alloy, aluminum-silicon alloy, aluminum-zinc alloy was discussed. Although all the tests have not been carried out on the components to ascertain their strength and durability, but a functional test has been carried out by test running the component coupled to an engine.

Introduction

Today in Nigeria, there is hardly any street corner where one cannot find a vulcanizer who inflates tyres for cars, bicycles, tricycles motorcycle and balls for kids. And for this reason, the production of single cylinder engine and its components have become very important to the technological and economic development of Nigeria. Electricity generation for homes is also another area where the single cylinder engine has affected the lives of so many people in Nigeria positively. Since there is incessant power outages and economic difficulty in the country, so many Nigerians have switched to the use generators for their power generation(in most cases are alternators driven by single cylinder engines).

On the other hand, transportation is a key factor in any nation`s economic growth and development. In Nigeria, transportation by means of motorcycle and more recently tricycle is becoming more popular, especially in the face of bad roads every where. Due to the role this mode of transportation plays in reducing poverty and moving people from one destination to the other, there is an increased number of operators of the business in Nigeria. And as a result, other economic activities especially spare parts business and motorcycle/tricycle mechanics begin to thrive because these motorcycles/tricycles from time to time get damaged and spare parts are required to repair them.

Nigeria`s GDP would have been greatly enhanced if the volume of importations in this area from abroad is reduced drastically through local production of these spare parts, even the engines. In addition, employment opportunities would have been created, and vices would have be curbed in Nigeria.

Consequently, we then researched and developed these engine components especially the aluminium alloy components through high pressure die casting.

Casting

Casting is a manufacturing process by which a molten metal is usually poured into a mould, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mould to complete the process. Casting materials are usually metals and their alloys. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods.[1] The Mould casting is divided into two main groups Sand casting and Die casting. Other techniques such as lost foam or loss wax processes are also used but their economical importance is considerably lower than both listed techniques.

Sand Casting

In sand casting, re-usable, permanent patterns are used to make the sand moulds. The preparation and the bonding of this sand mould are the critical step and very often are the rate-controlling step of this process. Two main routes are used for bonding the sand moulds:

1 The green sand mould which consists of mixtures of sand, clay and moisture.

2 Dry sand consists of sand and synthetic binders cured thermally or chemically.

The sand cores used for forming the inside shape of hollow parts of the casting are made using dry sand components.

This versatile technique is generally used for high-volume production.

Die Casting

Die casting is the process of forcing molten metal under high pressure into mould cavities. Most die castings are made from non-ferrous metals, specifically zinc, copper, aluminium, magnesium, lead, and tin based alloys[1], although ferrous metal die castings are possible.[2] The die casting method is especially suited for applications where a large quantity of small to medium sized parts are needed with good detail, a fine surface quality and dimensional consistency.[2] This level of versatility has placed die castings among the highest volume products made in the metalworking industry.[1]

There are four major steps in the die casting process. First, the mould is sprayed with lubricant and closed. The lubricant both helps control the temperature of the die and it also assists in the removal of the casting. Molten metal is then shot into the die under high pressure; between 10—175 MPa (1,500—25,000 psi). Once the die is filled the pressure is maintained until the casting has solidified. The die is then opened and the shot is ejected by the ejector pins. Finally, the scrap, which includes the gate, runner, sprue and flash, must be separated from the casting. This is often done using a special trim die in a power press or hydraulic press. This scrap is recycled by remelting it.[3] Approximately 15% of the metal used is lost due to a variety of factors.

The high-pressure injection leads to a quick fill of the die, which is required so the entire cavity fills before any part of the casting solidifies. In this way, discontinuities are avoided even if the shape requires difficult-to-fill thin sections. This creates the problem of air entrapment, because when the mould is filled quickly there is little time for the air to escape. This problem is minimized by including vents along the parting lines, however, even in a highly refined process there will still be some porosity in the centre of the casting.[4]

After die casting, other secondary operations to produce features not readily castable, such as tapping a hole, polishing, plating, buffing, or painting are carried out.

When no porosity is required for a casting then the **pore-free casting process** is used. It is identical to the standard process except oxygen is injected into the die before each shot. This causes small dispersed oxides to form when the molten metal fills the dies, which virtually eliminates gas porosity. An added advantage to this is greater strength. These castings can still be heat treated and welded. This process can be performed on aluminium, zinc, and lead alloys.[5]

Advantages

- Excellent dimensional accuracy.
- Smooth cast surfaces.
- Thinner walls can be cast as compared to sand and permanent mould casting.
- Reduces secondary machining operations.
- Rapid production rates.
- Casting tensile strength as high as 415 MPa[6]

Die casting materials

The main die casting alloys are: zinc, aluminium, magnesium, copper, lead, and tin. Specific dies casting alloys include: ZAMAK, zinc aluminium, AA 380, AA 384, AA 386, AA 390, and AZ91D magnesium.[7] The following is a summary of the advantages of each alloy:[1]

- Zinc: the easiest alloy to cast; high ductility; high impact strength; easily plated; economical for small parts; promotes long die life.
- Aluminium: lightweight; high dimensional stability for complex shapes and thin walls; good corrosion resistance; good mechanical properties; high thermal and electrical conductivity; retains strength at high temperatures.
- Magnesium: the easiest alloy to machine; excellent strength-to-weight ratio; lightest alloy commonly die cast.
- Copper: high hardness; high corrosion resistance; highest mechanical properties of alloys die cast; excellent wear resistance; excellent dimensional stability; strength approaching that of steel parts.
- Lead and Tin: high density; extremely close dimensional accuracy; used for special forms of corrosion resistance. Maximum weight limits for aluminium, brass, magnesium, and zinc castings are approximately (32 kg), (5 kg), (20 kg), and (34 kg), respectively.[8]

The material used defines the minimum section thickness and minimum draft required for a casting as outlined in the table below.[7]

Metal	Minimum section
Aluminium alloys	0.89 mm
Brass and bronze	1.27 mm
Magnesium alloys	1.27 mm
Zinc alloys	0.63 mm

Equipment and Materials

There are two basic types of die casting machines: **hot-chamber machines** and **cold-chamber HPDC machines**.[3] These are rated by how much clamping force they can apply. Typical ratings are between 20 tons and 800 tons [1]

The dies used in die casting are usually made out of hardened tool steels because cast iron cannot withstand the high pressures involved. Dies may contain only one mould cavity or multiple cavities of the same or different parts. There must be at least two dies to allow for separation and ejection of the finished products. Dies also often contain water-cooling passages, retractable cores, ejector pins, and vents along the parting lines. These vents are usually wide and thin approximately 0.13 mm so that when the molten metal starts filling them the metal quickly solidifies and minimizes scrap. No risers are used because the high pressure ensures a continuous feed of metal from the gate.[9]

In addition to the dies, there may be cores involved to cast features such as undercuts. Sand cores cannot be used because they disintegrate from the high pressures involved with die casting, therefore metal cores are used..[6]

A die's life is most prominently limited by wear or erosion, which is strongly dependent on the temperature of the molten metal.[7] Aluminium alloy die usually have a life of 100,000 cycles, if the die is properly maintained.[10]

Alloy Development and Charge Calculations

Aluminium alloys are characterized by high susceptibility towards oxidation and gas absorption in liquid state. Hydrogen, which dissolves most in the alloys, as well as the inclusions from Al_2O_3, sharply lowers the quality of the castings. Therefore, it is necessary to take measures to protect the alloys from gas absorption and oxidation. These measures involve correct choice of the melting unit, use to remove gases already dissolved in the melt.

In the preparation of large quantity of Aluminium alloy, flame reverberatory and induction tunnel furnace are used, while for small quantity of aluminium alloy, crucible (fuel or electric) furnaces are used. In operation with flame reverberatory and other furnaces, fluxes are used, which consist of mixture of NaCl, KCl, NaF_4, CaF_2 and others. These fluxes react with the **charmotte** lining of the furnaces. Therefore, it is recommended that these furnaces be lined with **magnesite** bricks instead of charmotte. In this way, the life of the furnaces is increased and scrap due to formation of foreign inclusion in the castings is reduced as well.

The electric furnaces employed in foundry shops can hold 0.5 to 1 ton, the melting loss being equal to **1%.** The electric furnaces of above capacity consume 550 to 600 KWh/ton. The charge for aluminium alloys usually consists of 30-70% scrap (remelted waste, rejected castings, flow offs, gates, risers and so on), and 70-30% primary materials such as aluminium blocks (pigs), aluminium-silicon pigs, blocks of Mg, Zn, and ligands.

The charge is calculated with due regard for melting loss of elements constituting the alloy. The melting loss depends on the degree of oxidation of scraps, kind of pig aluminium, performance of the melting unit, method of refining, time of melting cycle, and other factors. The melting loss in electric and crucible furnaces comes to **0.5 – 1%.** In reverberatory combustion furnaces, the loss is higher, **1 to 2%** and even reaches **2.5%** if the charge has oxidized heavily.

The melting loss of silicon averages **0.5 – 1%** and depends little on the condition of the charge and the type of melting unit. Magnesium burns out **2 to 3% and even to 5%** on melting a heavily oxidized charge. The copper loss ranges from **0.5 to 1.5%.** The high melting point alloying elements are added in form of ligands. The ligands are double alloys of high melting point component (Cu, Si, Ni, Mn and others) with the base metal (Al and others). They are used to introduce the high melting point component of the alloy into the alloy, without being burned out. For aluminium alloys the following ligands are used; Al-Si (25% Si); Al-Cu (50% Cu);

Al-Mn(10% Mn); Al-Ni(10% Ni). Obviously the charge should be made up of such materials and so proportioned as to bring the quantity of oxides to a minimum. [11]

Charge Calculation

Calculation of the charge for melting of Aluminium alloy of composition 4.5%Si, 1%Cu, 0.5%Mg and the rest Aluminium. Assuming the melting loss of Si, Cu, and Mg is 1%, 1%, and 2% respectively. The charge comprises the following materials: Al-Si with 12%Si, A binary Al-Cu alloy ligan(50%Cu), A binary Al-Mg ligan(10%Mg) and a 100kg of alloy is targeted.

Solution:

Calculation of the respective losses as well as the total percentages of elements in the charge;

Si loss is 1% of 4.5%:

$$\text{Si loss} = \frac{1\%}{100} x\, 4.5\% = 0.045\%$$

$$\text{Total } \%\text{Si} = 0.045\% + 4.5\% = 4.545\%$$

Cu: 1% of 1%:

$$\text{Cu loss} - \frac{1\%}{100} x\, 1\% - 0.01\%$$

$$\text{Total } \%\text{Cu} = 0.01\% + 1\% = 1.01\%$$

Mg: 2% of 0.5%:

$$\text{Mg loss} = \frac{2\%}{100} x\, 0.5\% = 0.01\%$$

$$\text{Total } \%\text{Mg} = 0.01\% + 0.5\% = 0.51\%$$

Calculation of alloys and ligands in kg:

Al-Si(12%Si):

$$(\text{Al} - \text{Si})\text{kg} = \frac{4.545\%}{12\%} x\, 100\text{kg} = 37.8\text{kg}$$

Cu-Al(50%Cu):

$$(\text{Cu} - \text{Al})\text{kg} = \frac{1.01\%}{50\%} x\, 100\text{kg} = 2.02\text{kg}$$

Mg-Al(10%Mg):

$$(\text{Mg} - \text{Al})\text{kg} = \frac{0.51\%}{10\%} x\, 100\text{kg} = 5.1\text{kg}$$

Total mass obtained = 37.8 + 2.02 + 5.1 = 44.92kg

Consequently, pig iron of quantity 100 – 44.92 = 55.08kg will be required to make up the charge requirement. This calculation is done for all the other alloys to be developed. [12]

Mould Design and Mould Material

The quality of the casting to great extent depends on the quality of the mould. Foundry mould serve to give definite configuration and size to the casting together with this however, by determining the nature of interaction between the mould and the metal, the former also strongly affects the mechanical properties of the casting. The mould determines the following: rate of cooling, resistance during contraction of the metal, path for removal of the gases formed during casting. In addition, mould should withstand injection pressure of the liquid metal as well as withstand high temperature and conduct heat away.

Application of CAD/CAM Technology in Die casting

1 Scanning of product

2 CAD/CAM(computer aided design and manufacturing)

3. CAPP (computer aided process planning)

4. CAI (computer aided inspection)

5. 2D drawing To 3D modelling

6. 3D model to 2D drawing

7. Conceptual base designing

(a) Make rapid prototype sample

(b) CNC machining of wooden /acrylic prototype

8 Analysis & Simulation-stress, Strain, thermal analysis through finite element analysis

9 Analysis of Gate, runner, ejector pins and cooling line

9b. Die casting part with gate and runner

10 NC Data Generation

11 Rapid Prototyping

12 Concurrent Engineering-CAD/CAM/CAE/CAI/CAPP and many other activities can go simultaneously after preparation of 3D model. This saves

lot of time in various activities. [13]

Melting and Casting Using Pressure Die Casting Machine

The aluminium alloy ingots of desired specification are charged into the furnace to about 2/3 full and the furnace is put on and set a temperature of 750°C. As the ingot was being heated, the mould for the desired product is mounted on the die casting machine, the water lines for cooling are connected and the graphite oil is smeared on the die cavities to prevent sticking of the cast on the cavity. When fully molten, the temperature is reduced to 690°C, the dies are closed and the die casting machine set to automatic mode. In addition the first speed button is switched on. The furnace is opened and the metal slag is scooped off before the molten metal is poured into the channel using the ladle, followed by pressing the shot button for the plunger to drive the molten metal into the mould. After about 5-10 seconds the die opens automatically and the ejector pins ejects the casting. Coolant is applied on the surface the die before the same operation as described above is repeated for about ten times before the second speed button is turned on and the speed dial is set to the appropriate value for production of the desired components.

When the components are cast, they are placed in jigs and mounted on the press to remove the gating system. These casts are then taking to the sand blasting machine for colour enhancing. After this, the casts are mounted on milling, lathe or drilling machines for the final machining operations

Conclusion

We have been able to demonstrate the possibility of producing the components of a single cylinder Engine in Nigeria, but not without major challenges which include: insufficient power, lack of some basic test equipment, poor funding to mention but a few. Although all the tests have not been carried out on the components to ascertain their strength and durability but a functional test has been carried out by coupling and running the components in an engine. The underlisted are the components developed: (a) Top Cylinder (b) Connecting Rod (c) Conrod cap (d) Carburetor System (e) Air inlet Manifold (f) Carburetor Head (g) Float Well (h) Oil Sump (i) Covers (j) Piston

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