Casting and Performance Evaluation of Pump Impeller and Housing using Local Raw Materials

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Abstract- Casting of pump impeller and its housing was carried out using locally available materials. Performance evaluation was conducted to show if the locally produced pump impeller and its housing could be compared favourably in terms of performances with the imported ones. The sand used for the moulding of the pump housing and impeller was blended in the sand mixer with bentonite, wood dust, water and others as desired in their correct proportions (Bentonite-3.5%, Water 3.5%; Wood dust 4.2%). Pouring of the molten metal unto the assembled mould was done at a temperature of about 1380^{o}C. Portable optical pyrometer was used to measure the temperatures. The charge make ups was 135kg of cast iron scraps, 0.58% FeSi, 0.035% FeMn and 0.0045% Inoculants. Replica of the two components were carefully produced in wooden patterns to make the sand mould easy, while the casting was made using grey cast iron because of the need to machine it to its final dimensions with ease. The results obtained from the various test carried out shows no significant difference from the standard result of the imported ones.

Keywords: Casting, Pump housing, Impeller, Raw Materials.

1. Introduction

Casting process is one of the earliest metal shaping techniques known to human being. It means pouring molten metal into a refractory mold cavity and allows it to solidify. The solidified object is taken out from the mold either by breaking or taking the mold apart. The solidified object is called casting and the technique followed in method is known as casting process. The casting process was discovered probably around 3500BC in Mesopotamia. In many parts of world during that period, copper axes (wood cutting tools) and other flat objects were made in open molds using baked clay. These molds were essentially made in single piece. The Bronze Age 2000BC brought forward more refinement into casting process. For the first time, the core for making hollow sockets in the cast objects was invented. The core was made of baked sand. Also the lost wax process was extensively used for making ornaments using the casting process. Casting technology was greatly improved by Chinese from around1500 BC (Singh, 2006).

The Egyptian Ctesibius, a contemporary of the brilliant Greek Archimedes were the first people to systematically investigate the possibility of water pressure. Ctesibius discovered that liquid always seeks an outlet to an area in which low pressure prevails. So he used water pressure to blow air into pipes and with the invention of pump (Lahanas, 2017). These days, it is all about re-design and modifying the details such as housing and impeller (Zinger, 1970). Looking critically at the components of these pumps, it was discovered that between 75-80% of them are foundry products. The following questions then arise:

- Why are we still importing pumps into developing Countries like Nigeria and Ghana?
- Why can't we cast and machine most parts locally to compliment the remaining parts that are imported?
- Can't we cast the whole part locally?

In answering these questions we decided to embark on producing a locally made pump housing and impeller using a casting method. Therefore the objectives of this research was to develop the pattern for the pump housing and impeller, cast the pump housing and impeller using local raw material, and to evaluate the performance and compare it with the imported ones.

A lot of researchers have worked on pump; its design and production by sand casting. Some of them included Ryder, (1983), Nevelson, (1964), Ross (1975); Dietert, (1972), Hoeard, et al (1966); Rollason, (1985), Cherkassky, (1985); Norton, (1949); Adejuyigbe, (2002 and 2005).

Some of their work includes:

- Working in the area of overall different pressure required to have a liquid flow through a particular pipe which include the velocity of flow, the length of piping, the number of bend, the differences in height and the composition of the liquid;
- Working in the area of different parts of impellers and pump housing;
- Discussion on type of Mechanical seal to use and
- General foundry processes including sand casting process.

The component parts of pumps include: impellers, pump housing (casing) and mechanical seal. There are different types of impellers but the one we are considering in this paper is the closed type of impeller as shown in Fig. 1 below.

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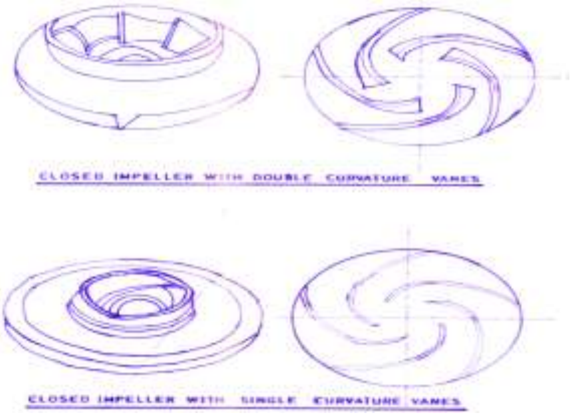

Fig. 1: Closed impellers with single and double curvature vanes

The pump casing has two openings for both suction and delivery. The suction pipe is at the same level as in flow opening of the impeller. The delivery pipe opening is at the circumstance, tangential to the pump housing. Both pump and suction line must be filled completely with the liquid to be pumped. At start up, the liquid inside the pump will start rotating together with the impeller. The liquid experience the actions of the centrifugal force. It flows into the pump housing on the circumference of the impeller and then by the way of the delivery opening into the delivery pipeline. Note that the pump housing does not have the same shape. The mechanical seal has a spring loaded. The spring loaded components consists of two faces one stationary and another rotating and is located on the engine shaft between the impeller and the rear casing. It is designed to prevent water from seeping into and damaging the engine.

Pumps designed for work in harsh environments require a seal that is more abrasion resistant that pumps designed for regular household use. Casting can also be referred to as Founding or Foundry. It is the process whereby a molten metal is poured into the mould cavity and the end product casting. Some defects are typical only for some particular casting processes, for instance, many defects occur in sand casting as a result of interaction between the sand mold and the molten metal. Defect found primarily in sand casting are gas cavities, rough surface areas, shift of the two halves of the mold, or shift of the core (Groover, 2006). Cast alloys material grades usually have high transverse rupture strength, low coefficient of friction and excellent resistance to corrosion as in pump impellers (Pandey et al, 2015).

2. Materials and Methods

This project was carried out at The Federal University of Technology, Akure, Yaba College of Technology and Federal Institute of Industrial Research, Oshodi; all in Nigeria. The approach used in carrying out this research included:

- Identification of two pump components to be cast, which are impeller and the housing;
- Preparation of pattern in wood of these components.
- The pattern was then used to make a mould in the foundry shop to cast the component using grey cast iron.
- The cast pieces was machined to dimensions vis-à-vis the imported types; and;
- Performance evaluation was carried out in the areas of hardness, tensile strength and impact strength.

2.1 Pattern Making

A pattern is defined as a model of a casting, constructed in such a way that it can be used to forming an impression in moulding sand (Jain, 2014). In casting the pump housing and impeller, the pattern used to cast the components was produced. The following equipment, machines and materials were used for the pattern production, Wood lathe; planning/thickness machine, ripping and cross cutting machine, drilling/Milling/band saw machines, set of hammers and mallet, chisel, pincers, nails of various sizes, and wood (mahogany), P.38 (Body fillers) glue, sand papers etc. Patterns in sand casting are used to form the mold cavity. One major requirement is that patterns must be oversized to account for shrinkage in cooling and solidification, and to provide enough metal for the subsequence machining operation(s).

The patterns are made of solid and well seasoned mahogany wood. Mahogany wood is preferred for the pattern because;

- Moisture will not be readily absorbed;
- The impression of the sand will be sharper and more tune to pattern;
- Less wear and erosion will accrue from repeated use; and
- Usually much more care and planning will be given a pattern made of expensive hard wood.

The sand used for the moulding of the pump housing and impeller was blended in the sand mixer with bentonite, wood dust, water and others as desired in their correct proportions (Bentonite-3.5%, Water 3.5%; Wood dust 4.2%). The bentonite clays help develops the strength and plasticity for moulding. Samples of the sand mix were taken to the sand laboratory test for the following properties which are essential for a good and quality casting; Moisture content – to ensure that the moisture content does not exceed 4.2%; Permeability test and Green/dry strength.

The cores for the castings were made by using the CO_2 process. In this process sodium silicate (Na_2SiO_3) was used as the binder with the synthetic sand. After proper mixing in core sand mixer, the mixed core sand was rammed into the prepared core boxes. But before it is removed from the core boxes, CO_2 gas was passed into the core generally through a series of vent made earlier with a vent wire. The sodium silicate (Na_2SiO_3) then set by the reaction;

$$Na_2SiO_3 + CO_2 = Na_2CO_3 + SiO_2$$

The CO_2 process was chosen among the rest because it does not require expensive baking, and the cores fully hardened before it is removed from the core box. The floor moulding sand casting process was used for the making of the pump housing and that of impeller. It involves the following steps;

- Leveling the moulding floor to avoid un-even surfaces;
- The bottom moulding board was then laid on the securely on the floor;
- The pattern (pump housing) is then positioned on the bottom board with the flask (moulding box) located properly to take the moulding sand;
- The parting powder (plumbago) are then sprinkled on the pattern;
- Then facing sand which was a fine and clean variety of sand are sieved over the stern with riddle;
- Backing sand was then shoveled into the flask over the facing sand and the whole rammed securely, using the peen rammer around edges and the boot as rammer over the pattern;
- After ramming a straight edge was drawn across the upper surface to remove excess sand;
- The drag was then turned to face up, tooled after which a parting powder (whiter powdery substance) is dusted over the sand and pattern;
- The same operation as that of drag was also performed for the cope flask;
- The in gates and the risers are formed and the chaplets and cores are positioned;
- The cope are then place on drag, and the mould is ready for pouring.

The above methods used for moulding for pump housing was also used for the impeller moulding. Prior to charging for melting, the scraps-(cast iron, textile scraps, engine block etc) are broken to sizes, screened to remove toxic and other dangerous items before charging into crucible lift-out (oil fired) furnace. The capacity of the furnace is 120kg of cast iron with a maximum attainable temperature of about 1560^{o}C. Pouring of the molten metal unto the assembled mould was done at a temperature of about 1380^{o}C. Portable optical pyrometer was used to measure the temperatures. The charge make ups are;

- 135kg of cast iron scraps;
- FeSi -0.58%
- FeMn -0.035% and
- Inoculants – 0.0045%

The molten metal in the mould remains for 24 hours, to allow the solidified metal to cool to the room temperature. This is because the final structure of a cast however, depends on its solidification history. The moulds are then broken, 24 hours after casting, to retrieve the pump housing and also the impeller. This process was carried out manually. The gates and risers were removed by cutting with hand and the use of grinder to finish up. Other rough places were smoothening and the final cleaning was done by the use of wire brush. Figs 2, 3 and 4 show the drawings of the impeller and pump housing to be cast.

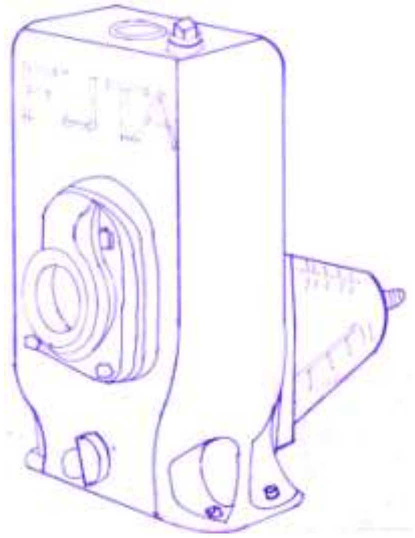

Fig. 2: Pump Housing to be cast

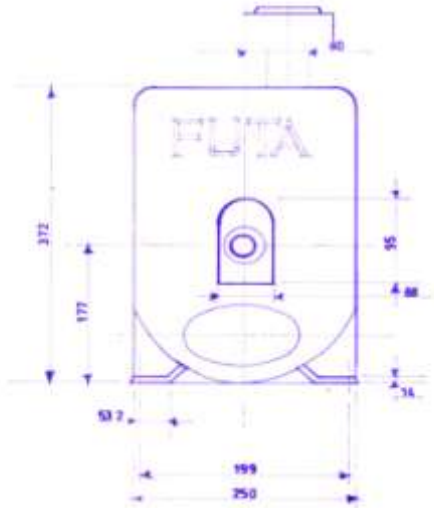

Fig.3: Dimension of the Pump Housing to be cast

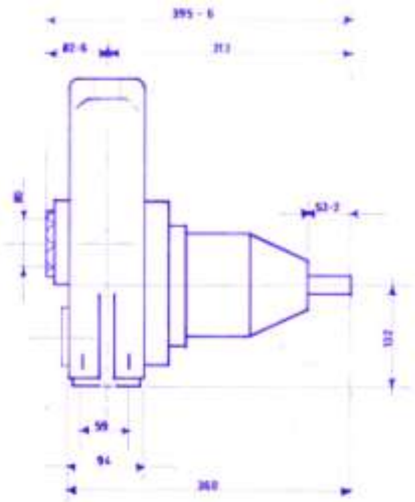

Fig. 4: Impeller to be cast

3. Results and Discussion

The solidified metal in the mould which has taken the shape of the impeller and the housing was knocked out. A fine surface finish was presented on close examination of the items, after cleaning. Since the final dimension has not been achieved, it is imperative therefore for the cast items to be taken for machining so as to achieve the proper dimensioning. The finished cast pump housing and cast impeller are shown in Figures 5, 6 and 7.

Fig. 5: Finished cast pump housing front view.

Fig. 6: Finished cast pump housing back view

Fig. 7: Finished cast impeller

4. Performance Evaluation

In evaluating the performance of the cast impeller and housing it is necessary to first consider the physical soundness of these castings in relation to the known defects that could affect their performance in service. Some of the defects are:

- Surface Imperfection: Surfaces of casting are sometimes rough or pebbly because of the moulding sand is too coarse, or the pouring temperature of the metal is too high. Sometimes penetration of metal between and around sand grains is a serious problem.
- Other defects like; moulding defects, gas porosity, external hot tears, cold cracks and warpages, incomplete feeding, infused chills and chaplets, were all taken care off during the production process of the above mentioned projects.

Subjecting the locally produced impeller and pump housing to some test vis-avis the imported one, we were able to evaluate their performances. Some of the common evaluation tests used are as follows:

Visual examination: On physical examination of the various configurations of the cast pieces, in terms of dimensions, weight, surface finishes and others, there was no visible difference between both the local and imported impeller and pump housing. It means that if the performance is based on only this examination alone it would has scored 100%.

Hardness test: Hardness if often a measure of acceptability of castings. It is determined by measuring resistance of a metal to deformation by penetration with a steel ball or indenter's hardness reflects ductility and tensile strength of sound metal with reasonable accuracy. In the test carried out the hardness numbers (BHN) for both housing respectively. From the result above it shows that there is no significant difference in their hardness (tensile strength) which means they can both perform under the same condition.

Dynamic balancing: The cast impeller was dynamically balanced as a rule because impellers are exposed to transverse forces (normal to the machine centre line) and axial forces (parallel to the machine centre line). Here the impeller was fixed into a rotary machine in a rotary machine and allowed to rotate as when in operation. During rotation, area that has a higher weight concentration will be shown and marked electronically. Gradual removal of this weight will be done until an equilibrium position is attained. When the impeller manufactured replaces the imported one in the existing housing. It fitted well and all their configurations were in place. The expected volume discharge was attained.

Dimensional Stability: This is an extremely critical requirement to evaluate the performance of an item. This is done by subjecting the new casting into proper dimensional control; vis-a-vis the original one (imported). Here the castings from the corresponding patterns are measured in a layout room to be sure that they conform to the blue print specifications. The result obtained after the various dimensional checks leave no one in doubt that the performances of the locally produced items cannot be questioned.

Magnetic powder inspection: The magnetic powder is dusted over the surface of the castings that have been magnetized. These powder particles will collect at any crack or discontinuity on or near the surface. But from the test carried out, the castings are free from airline crack in the surface, which could be located to determine the internal cracks or voids, ring test or vibration test was carried out to determine the soundness of the castings by the quality of the ring it produce. The result also shows that there is no internal crack present.

Impact test: The resistance of the castings to impact is determined. The result was then compared with the equivalent one in the existing manual. During the test a notched specimen from the sample taken from the casting material was fractured by a single blow from a heavy hammer, the energy required being a measure of the resistance to impact. In this case it was 150J compared to 168J in the equivalent pump manual. This shows that the material developed can perform under the same condition with standard in the manual.

5. Conclusion

The various tests and the practical foundry work carried out to cast pump housing and impeller shows that it is possible to cast all component parts of pumps housing and impellers with a locally available materials which is presently an imported parts in developing countries like Nigeria and Ghana. It is therefore suggested that some of the component parts of our vehicles, machine tools, some component parts of our industrial machines and so on, should be manufactured locally. By this singular act we shall be developing our industrial base in developing countries. Encouragement should also be made to our foundry experts and researchers to be involved in the design and casting of some these components so that there will be a little dependence on the foreign parts.

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