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TECHNOLOGY ADAPTATION: DESIGN OF A CENTRIFUGAL CASTING HEAD.

Adesina, A. S. and Adegbite, D. A.
Department of Metallurgical Engineering
Kwara State Polytechnic, Ilorin, Nigeria
E-mail: adeflocy@gmail.com

ABSTRACT
The concept of centrifugal casting of metals is presented as a means of improving the soundness of metallic articles. The major principle of the process is enumerated. Main components of a centrifugal machine are highlighted and the conditions of exploitation and design of the mould are enumerated. Mould design for casting of ∅50 – 250mm cast articles are discussed based on appropriate design parameters.
Key words: *Design, Casting, Centrifugal, Mould, Axis of Rotation.*

INTRODUCTION
Today, casting is the sixth largest manufacturing industry in the whole world. Cast metal parts account for more than 50% of the total weight of tractor and more than 90% of an automobile engine. The reason for the wide spread use of castings lies wholly in its economy and time factor. In terms of time, it is the quickest method for producing components, as it is fairly easily done (Adedipe and Abolarin, 2011). The main tendency of progress in metal casting consist in improving the quality and dimensional accuracy of casting; reducing metal consumption; i. e. aiming at manufacturing articles with very high working properties (Mikhailov, 1989).The general influences which determines the soundness, density and chilling properties of cast metals and alloys are determined by chemical composition and the mode of manufacture, and they may be grouped under the followings (Longden, 1954):
a) The chemical basis and the influence of gases, impurities and alloying elements on structure;
b) The influence of various qualities and volumes of mould materials on structure;
c) Pressure influences exerted by gravity, atmosphere and mechanical force.

Developments in chemical readjustments of melt and melt regimes in furnaces is giving way to obtain alloys of any specified chemical compositional range. So, the focus is on thermal conditions which determine the cooling and solidification periods of molten metal, and consequently the metal structure (Adesina, 2001). Efforts so far made toward achieving this are application of denser in moulds, which encourages a progressive order of solidification of the metal; addition of iron fillings to improve the heat conductivity of moulds. These causes an increase in the density of the metal, and whether this is achieved by metal or mould influences, registers as an improvement in general properties of the metal. In essence, the higher the conductivity of mould materials and improved/enhanced force of mould cavity filling greatly improves the soundness of castings. This study is on the issue of metallic mould and relevance of application of an extra force in aiding mould filling with molten metal. One

Corresponding Author: Adesina, A. S.

of the main technological means of achieving the double edge is through centrifugal casting (Adesina, 2010). Castings produced in permanent moulds and dies by gravity feed, or pressure feed are considerably influenced by the nature of the mould material. Centrifugal casting processes confer on the casting soundness and density above that obtained by any other cast metal process. In most cases, the mould consists of materials of high heat conductivity value, usually a metal or a metal carrying a thin layer of refractory (Stepanov, et al, 1983). Centrifugal casting initially refers more specifically to the forces used to distribute molten metal in the mould rather than a specific moulding process. However, moulds for centrifugal casting are usually specially designed and therefore considered as a process (Heine, et al, 1976). Centrifugal casting consists of producing castings by causing molten metal to solidify in rotating moulds. The speed of rotation and metal pouring rate vary with the alloy and shape being cast. The idea of employing centrifugal force to make castings had been known for a long time, it was A. G. Eckhart's original patent of 1809 which revealed understanding of the basic principles involved. Centrifugal casting has greater reliability than static castings. They are relatively free from gas and shrinkage porosity (Campbell, 1961).

Depending on the direction of axis of rotation of the mould is differentiated horizontal and vertical foundry centrifugal machines. Machines with horizontal axis of rotation are used for producing cylindrical pipe products of diameter 50-1500mm and length up to 5000mm. Products/castings, in which the diameter is bigger than its height, such as rings, gears and shaped castings are produced on machines with vertical axis of rotation (Fig.1) (Lipniski, et al, 1986). The main objective of this paper is to establish the fact that centrifugal casting machine operating on vertical axis of rotation could be adapted, designed and constructed for the purpose of laboratory use. This could be used for teaching students the principle of centrifugal casting. The main components of a centrifugal casting machine are: frame, spindle/shaft, mould/die, housing, guard, cooling system, pneumatic- and electrical controls (Saphronov, 1985). The mould, which is the main working component, the receptacle into which hot molten metal is poured to acquire the predetermined configuration and shape is the focus of this paper. Moulds for centrifugal casting are prepared from cast iron or steel, in which die wall thickness is taken as 1.5-2 times bigger than wall thickness of casting (Lipniski, et al, 1986, Kakutani, 1989). The moulds under working conditions are often cooled by compressed air or water, and their inner /working surface are coated with oils for ease of casting ejection.

DESIGN THOERY AND ANALYSIS

Centrifugal casting employs metallic materials as mould. They are preheated or pre-cooled to $\sim 300^oC$, i.e. cyclic temperature regime. The intensity of heat exchange between a casting and mould is 3-5 times that of a sand mould, because of which castings have a denser fine-grained structures and higher properties. This is especially important for aluminium and magnesium alloys (Mikhailov, 1989). Molten metal fills in the mould, solidifies and cools partially in the field of centrifugal forces, which exceeds many times the force of gravity. The field of force is created by rotating the casting mould. An essential factor for controlling the process is the speed/frequency of the mould rotation. It can be found from the equation (Stepanov, et al, 1983):

$$\mathbf{F_c = K\,F_g} \quad \text{eq. (1)}$$

where: $\mathbf{F_c}$ - centrifugal force
$\mathbf{F_g}$ - force of gravity
$\mathbf{K}$ - gravitational coefficient;

but $\mathbf{F_c = m.\omega^2 r}$ eq. (2)

$$\boldsymbol{\omega = 2\pi n/60} \quad \text{eq. (3)}$$

and $\mathbf{F_g = m.g}$ eq. (4)

∴ Rotational frequency of a die(mould):

$$\mathbf{n} = \frac{30\sqrt{kg/r}}{\pi} \quad \text{eq. (5)}$$

where: $\mathbf{r}$ – inside radius of the casting surface;
coefficient $\mathbf{K}$ = 3.3 – 300 depending on process conditions.

One of the main advantages of this method is the directional solidification of metal. During centrifugal casting operation of paramount importance is the appropriate selection of speed of mould rotation, since on it is dependent the character of the resulting grain structure, spread of slag inclusions, gases and shrinkage porosity (Saphronov, 1985). Other means of calculating the required speed of rotation with a value, close to practical evaluation is given by Konstantinov's empirical formula:

$$\mathbf{n} = \frac{5520}{\sqrt{\rho r}} \quad \text{eq. (6)}$$

where: $\mathbf{n}$ – rotational frequency of mould, rev/min;
$\mathbf{r}$ – inside radius of the casting surface, cm;
$\boldsymbol{\rho}$ - density of the casting, g/m^3.

The general mechanism of operation of the centrifugal machine is shown in figure 1. On it is shown: the main working component of the system is the mould, i. e. the centrifugal casting head. This is the metallic die mounted together with die/mould plate 2 and attached to spindle 3, rotating together under the belt drive of the powered electric motor 4. The mould design depends also on regime of production; unit, serial and mass production (Yudin, et al, 1972). The present design is for short castings of diameters within 50 – 250mm. Hence, moulds of different diameters within the size range are produced. The mould-2 is to be mounted on mould plate 1, Figure3, which itself is mounted on the console end of the spindle of the centrifugal machine. On the mould plate is provided circumferential four holes through 90^o and each set at a distance of 10mm displaced at 45^o to a previous set towards the centre, Figure2. Into these holes may the dies of different sizes be attached for casting different sizes of articles up to maximum of the internal diameter of the biggest die, 200mm, and a minimum of the internal diameter of the smallest die, 50mm. These are held together firmly for rigidity during spinning. Inner surface of the mould is made with a draft of 1 – 3^o, with a smaller value for bigger casting diameter. For casting diameters bigger than 300mm, draft is not included, since castings are easily ejected due to formation of clearance caused by shrinkage. Cover lid 4 is fastened to mould by bolt 3 at a minimum of two points. In order to avoid molten metal coming in contact with the cover, bolt fastening is fitted last at the mould edge as depicted in figure 3.

CONCLUSION AND RECOMMENDATION

The design of centrifugal casting head – the mould is an attempt to demonstrate the ability to develop and produce teaching aid technologies. It shall be further used for experimental research into the centrifugal influences on improving technological properties of castings. The present work is still an ongoing project, to be completed with the construction of a whole centrifugal casting machine.

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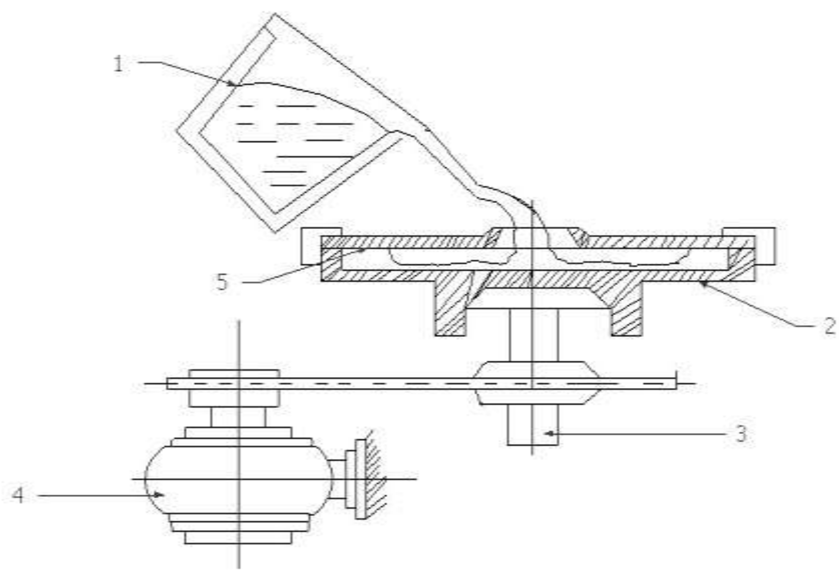

Fig.1 Centrifugal casting operation on vertical axis of rotation.

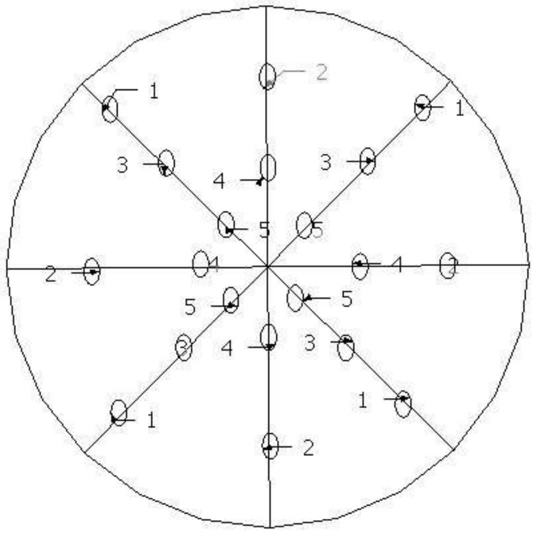

Fig. 2 Mould plate, D = Ø 300mm.

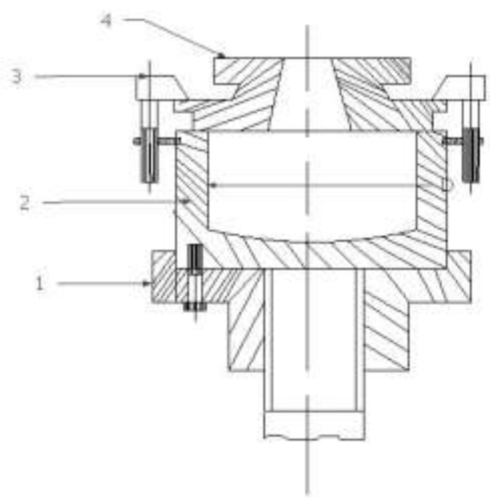

Fig. 3: Method of mounting mould with lid.