DESIGN AND FABRICATION OF A CENTRIFUGAL CASTING MACHINE

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ABSTRACT

The design and fabrication of a centrifugal casting machine was successfully carried out. The operation of the machine was based on the principle of centrifugal force. Suitable design theory, analysis and calculation were adopted carried out in the course of the work. The mold is bolted to the base plate which can rotate at moderate speeds thereby forcing the molten metal against the inner walls of the mold. This machine could be used to cast small engineering components. The centrifugal force on the machine was determined to be 3207.3N, while the required power on the machine was 854.7W. A test was carried out on the fabricated centrifugal casting machine with aluminum alloy and the machine was able to cast 6kg of aluminum alloy and the casting was successful.

INTRODUCTION

Casting by definition is the process of producing metal shapes by pouring molten metal into moulds of required form where it is allowed to solidify on cooling. The metal part formed as a result of this operation is called cast. Casting is as old as the Roman Empire. The roman craftsman started the art of casting by making two half mold, wedge them together and carefully pouring molten bronze into the mold cavity. This molten bronze solidifies on cooling and the cast removed from the mold. Within this method, they were able to make swords in large numbers. Casting hence has been a method by which important metal components are made in large quantity. [Allen, (1979)]

Today, casting is the sixth largest manufacturing industry in the whole world. Cast metal parts account more than 50% of the total weight of tractor and for more than 90% of an automobile engine. High precision castings are used in turbine vanes and blade in an aircraft jet engine. The reason for the widespread use of casting lies wholly in its economy and time factor. In terms of time, it is the quickest method producing components, as it fairly easily done. Economically, it is desirable as machine appears to be the most expensive method of producing an engineering component. Hence, without casting automobile, household appliances and machine tools would have become costlier. Method for making cast metal parts can be classified into three groups. The molding processes that use a permanent pattern and expendable mold, molding processes that use expendable pattern and expendable mold and the molding processes that use permanent mold. An expendable mold or pattern is the one that is used only once and discarded. The mold can be made of green-sand, core-sand, dry-sand, plaster of Paris or shell molding method using any of these, the same method is employed in the construction of the pattern and mold. [Brace *et al*, (1957)]

Centrifugal casting consists of producing castings by causing molten metal to solidify in rotating moulds. The speed of the rotation and metal pouring rate vary with the alloy, size 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 the basic principles involved. Centrifugal casting has greater reliability than static castings. They are relatively free from gas and shrinkage porosity. Many times, surface treatments such as case carburizing, flame hardening and nitriding have to be used when a wear resistant surface must be combined with a hard tough exterior surface. [Campbell, (1961)]

Centrifugal casting consists of a number of processes in which the centrifugal force set up by the rotation of a part of the casting is utilized to shape the casting, fill the mould and help solidify and strengthen the metal [Pavlovic, *et al* (2009)]. There is a difference between vertical centrifugal casting and horizontal centrifugal casting. The first mentioned process is essentially a pressure casting technique, employing rotation about a vertical axis. It produces good filling of the mould, high dimensional accuracy and a high strength of the cast metal. This method is used for casting of components that are too difficult to produce satisfactorily by static casting methods because their sections are too thin or for other reasons, e.g. gears, piston ring, impellers, propellers, bushings and railway wheels. Horizontal centrifugal casting is used mainly for making long hollow castings, such as pipes, gun barrels, sleeves, rods etc. Centrifugal casting process is industrially used for production of axially symmetrical components such as pipes, cylinder lining and rings. [Kaufman,(2004)]

For this type the mould rotates at high speed about a horizontal axis, the molten metal being fed into the interior of the mould and distributed around it by centrifugal action. Rotation is continued until solidification is completed. The external diameter of the casting corresponds to the internal diameter of the mould. The advantage of the centrifugal process is that it produces sounder and more uniform castings. The aim of the work is to design and construct a suitable centrifugal casting machine considering a standard design parameters and theory. [Flemings, (1974)]

DESIGN THEORY AND CALCULATIONS

The major components of a centrifugal casting machine all these components must be designed to ensure efficiency of performance. The motor shaft should be able to withstand applied loadings during operations. The turntable should be able to counterbalance the effect of imbalance associated forces with the mould during spinning action. To restore this imbalance to the axis of rotation, the turntable base diameter was designed to be larger than the mould base diameter. Some other essential design analysis of the vertical centrifugal force required by the machine, and power and torque generated by the spinning section of the machine were considered. [Ennor, (1967]

DESIGN ANALYSIS AND CALCULATIONS

Determination of the Speed of Driven Pulley

The speed of the driven pulley is determined by

$$N_2 = \frac{N_1 \times d_1}{d_2} \quad (1)$$

Where:

N_1 = Speed of the motor pulley (m/s);

N_2 = Speed of the driven pulley (rpm);

d_1 = Sheave diameter of motor pulley (mm);

d_2 = Sheave diameter of driven pulley (mm).

The speed of the driven pulley is determined from Eq. (1) to be 388.7 rpm

Determination of the belt speed

The speed of the belt is determined by the relation

$$Bs = \frac{\pi \times d_1 \times N_2}{1000} \quad (2)$$

Where:

Bs = Speed of belt.

The speed of the belt is determined using Eq. (2) to be 57.64m/min

Determination of belt Length

The length of the belt of the centrifugal casting machine is determined by

$$L = 2c + \frac{\pi}{2}(d_2 + d_1) + \frac{(d_2 - d_1)^2}{4c} \quad (3)$$

Where:

L = effective outside length (mm);

C = Distance between the two pulleys (mm).

The length of the belt is determined from Eq. (3) to be 941mm

Determination of the angular velocity of the driven pulley

The angular velocity of the driven pulley is given by

$$\omega = \frac{2 \times \pi \times N}{60} \quad (4)$$

Where:

ω = angular speed of rotating disc (rads^{-1});

N = speed of driven pulley (rpm).

The angular velocity of the driven pulley is determined from Eq. (4) to be 40.7 rads^{-1}

Determination of the Angular Velocity of the Turntable

The angular velocity of the turntable is determined by

$$S_D = \frac{\pi \times d_p \times N_2}{60} \quad (5)$$

Where:

S_D = Angular velocity of the turntable (m/s);

D_p = Diameter of the turntable (mm).

The angular velocity of the turntable is determined from Eq. (5) to be 1.425 m/s

Determination of the centrifugal force on the machine

The centrifugal force on the machine is given by

$$F = Mr\omega^2 \quad (6)$$

Where:

F = Centrifugal force on the machine (N);

M = Total mass of the rotating disc (kg);

r = Radius of the disc (mm);

ω = angular speed of rotating disc (rpm)

The centrifugal force of the machine is determined from Eq. (6) to be 3207.3N

Determination of the torque generated by the machine

The torque generated by the machine is determined by

$$T = F \times r_D \tag{7}$$

Where:

T = Torque generated (Nm);

r_D = Radius of rotating disc (m).

Using Eq. (7) above, the torque generated by the machine is determined to be 21.00Nm

Determination of the required power by the machine

The required power by the centrifugal machine is determined by the relation

$$P = \frac{2 \times \pi N_2 \times T}{60} \tag{8}$$

Where:

P = the required power (W)

From Eq. (8), the required power by the machine is determined to be 854.7W

Determination of the diameter of the shaft

The shaft diameter is determined by

$M_b = 0.3855$ $M_t = 0.057$ $K_t = 1.5$ $K_b = 2.0$

$$d^3 = \frac{16}{\pi T}\sqrt{(K_b M_b)^2 + (K_t T_t)^2} \tag{9}$$

Where:

M_t = belt torque moment (Nm);

M_b = Bending moment (Nm);

d = Shaft diameter (mm);

K_b = Shock and fatigue factor applied to bending moment;

K_t = Shock and fatigue factor applied to torsional moment.

The shaft diameter of the machine is determined using Eq. (9) to be 38.2mm

Determination of bearing life

The bearing life of the machine is determined by

$$L = \frac{10^6 \times L_{10}}{60 \times \pi} \tag{10}$$

Where:

L = bearing life (million revolutions);

L_{10} = A factor chosen from the bearing table corresponding to the shaft diameter 38.2mm [Flinn, (1963)]

The bearing life is determined from Eq. (10) to be 14.749076million of revolutions

RESULTS AND DISCUSSIONS

Casting operation using vertical centrifugal casting machine is quite different from other methods of casting process. The electric motor was plugged to the main power supply empowering the rotational effects of the motor. This rotational effect is transferred to the shaft assembly via the belt drive linked to both driven pulley and the motor pulley. This propelled the mould to rotate about its own axis at speed 600rpm. The molten metal was then poured on the spinning mould via the sprue. The spinning mould generated centrifugal action on the molten metal to position the metal within the mould. As the casting solidifies from the outside, the inner surface feeds the necessary molten metal to the reminder of the casting as required and the grain structure was created, ready for ejection. After pouring for a while the speed of the rotating mould was reduced to allow the molten metal to rotate freely on the wall of the mould. The machine was able to cast 6kg of aluminum alloy products.

CONCLUSION

This research project led to the design and construction of axial load vertical centrifugal casting machine which is made up mould, shaft, belt, bearing, motor and the wheel, basically used for casting cylindrical components. These components include: short hollow pipes and cylindrical containers covered at one end. However, this machine could also be used to produce some other cylindrical casting, such as cylindrical linings depending on the mould configuration. The mould spinning speed depends on the casting desired.

This vertical centrifugal casting machine could be used for the production of larger and smaller cylindrical casting machine. A test was carried out on the fabricated centrifugal casting machine with aluminum alloy and the machine was able to cast 6kg of aluminum alloy and the casting was successful.

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