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Gating System Design For 0.67hp Gasoline Generator Piston

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Abstract- The design of gating system is key in the production of various engine components. It serves as basis for determining quantity of materials to be used in the manufacture of components during sand casting. The 0.67Hp gasoline generator piston designed to withstand stress and temperature conditions that the generator will be subjected to during operation was manufactured from the assemblage of gating system components. In order to produce effective generator piston the gating system design parameters such as weight of casting, thickness of casting, pattern length, runner size, sprue size and pouring time were designed to be 0.128kg, 4.805mm, 54.86mm, 492.31mm^2, 122mm^2 and 11.88s respectively. The gating system calculations were used to produce wood pattern, sprue size, runners and mould cavity. From the result obtained it showed that the developed piston was devoid of casting defects. The experimental generator piston produced from the application of the gating system worked effectively in a 0.67Hp generator set.

Keywords: Gating system design, engine, casting and sandcasting

Özet- Kapı sistemi tasarımı, çeşitli motor bileşenlerinin üretiminde kilit öneme sahiptir. Kum dökümü sırasında bileşenlerin üretiminde kullanılacak malzeme miktarının belirlenmesine temel teşkil eder. İşletme sırasında jeneratörün maruz kalacağı stres ve sıcaklık koşullarına dayanacak şekilde tasarlanmış 0.67Hp benzinli jeneratör pistonu, geçit sistemi bileşenlerinin montajından imal edilmiştir. Etkili jeneratör pistonu üretmek için, döküm ağırlığı, döküm kalınlığı, desen uzunluğu, koşucu boyutu, ladin boyutu ve dökme süresi gibi geçit sistemi tasarım parametreleri 0.128kg, 4.805mm, 54.86mm, 492.31mm2, 122mm2 olacak şekilde tasarlanmıştır. ve sırasıyla 11.88'ler. Izgara sistemi hesaplamaları, ahşap desen, ladin boyutu, raylar ve kalıp boşluğu üretmek için kullanıldı. Elde edilen sonuçtan, gelişmiş pistonun döküm kusurlarından yoksun olduğunu gösterdi. Izgara sisteminin uygulanmasından üretilen deneysel jeneratör pistonu, 0.67Hp'lik bir jeneratör setinde etkili bir şekilde çalıştı.

Anahtar Kelimeler: Kapı sistemi tasarımı, motor, döküm ve kumlama

1. Introduction

The gating system design parameters of sand casting influence castings of various components [1]. The system comprises of sprue, runners, ingates area, pattern size and mould cavity which are series of flow passages that give rise to molten metal flow from the pouring basin to the formation of cast in the cavity. An effective gating system design will ensure proper determination of the weight of castings, runner sizes, sprue height and ingate areas. A casting free of defects, minimization of degradation of metal quality and shrinkage porosity are attributed to detailed and effective design of gating system. In sandcasting carried out by [2], runner size was determined to be 62cm^2 from a casting weight of 4.952kg, ingate area of 52cm^2 and sprue height of 300mm. The determined levels considered in the study are 45cm^2, 55cm^2 and 62cm^2. An optimal runner size level of 52.13cm^2 was determined using Taguchi Orthogonal array design. It concluded that selection of appropriate runner sizes affect the quality of the casting.

Runners are connected channels that convey the molten metal to different parts of the mould. A well designed running system can regulate the speed of the molten metal, avoid shrinkage and minimize turbulence [2]. The determination of runner size in the design and construction of a gating system in the sand casting of aluminium silicon components was carried out by [3]. The study utilized the dimensions of the designed pattern in calculating the weight of the cast piston which was known to be 0.939kg. The determined weight of the piston was used to determine the pouring rate, pouring time and choke area of the gating system. The runner size was determined to be 1426.564mm^2 from a non-ferrous gating ratio of 1:4:4 for choke area: runner size: ingate area respectively. The result showed quality casting devoid of any defect.

The knowledge of melting temperature of metals and alloy is necessary to estimate their corresponding pouring temperature into the gating system. [4]. Pouring temperature is an important process parameter that affects the gating system in the casting of aluminium alloy [5]. It has been noticed that melting and pouring temperatures directly and indirectly affects mechanical properties of aluminium alloy cast materials [6].

The effect of pouring temperature on the gating system used in the production of A713 aluminium alloy component using investment casting was carried out by [7]. The study revealed that an increase in the pouring temperature and the well structured gating system brought about elimination of porosity and shrinkage from the developed component as well as increase of mechanical properties like hardness and tensile strength of the aluminium alloy. A temperature of 750^{0}C was noticed to be optimal in the casting of the aluminium alloy components. Also, [8] did a study on the importance of pouring temperature on the gating system components in the manufacture of hypoeutectic aluminium silicon alloy piston.

It was noticed from the result of the study that an increase in pouring temperature leads to an increase in the molten metal flow in the gating system components.

The use of green sand in the gating system was discovered to be very effective in the production of mould for the manufacture of Silumin aluminium alloy pistons using sandcasting [9]. It showed that the pistons produced attained a wear rate of 0.00000123g/mm^2/min which was comparatively lower than that obtained in the engine component produced using the Centrifugal casting. Also, the use of green sand in producing aluminium alloy pistons was judged to be effective [10]. The result showed that the aluminium piston developed an optimal tensile strength of 82.59Mpa. Furthermore, the produced piston had a refined microstructure as a result of the reduced grain size of the green sand used.

The moulding sand used in sand casting aluminium alloy generator piston in this study is the green sand which comprises of silica sand mixed with 18 to 30% clay and 6 to 8% moisture content. The clay and water content ensured accurate bondness for the green sand particles. The green sand exhibited inherent characteristics such as cohesiveness, refractoriness, green strength, high permeability, collapsibility, chemical and thermal stability at high temperature [11]. In addition the green sand was used in this work because of its availability, high strength and relative low cost.

There are numerous process parameters that influence of sand casting and gating system .The listed following parameters are important variables in sandcasting. They are pouring temperature, pouring time, riser size, runner size, pouring speed, vibration time, vibration frequency, pouring rate, solidification time, green compressive strength, grain size, shear strength, number of ramming, amount of moisture and many more [11].

In sandcasting process, developing an accurate means of feeding molten metal into mould cavity has been a huge challenge especially when it involves castings of engine components like pistons, cylinder and engine blocks which have tendencies of withstanding high thermal stressses [12]. In order to ensure proper feeding of molten metal into mould cavity, a well designed gating system is highly required to be put in place. This study is aimed at designing gating system parameters that will be used in the development of a 0.67Hp gasoline generator piston.

2. Materials and methods

2.1 Design specifications of the Gating system

The specifications used in constructing a gating system for the sandcasting of the piston are
Density of aluminium =2500kg/m^3
Height of casting in the cope=20mm
Sprue height=100mm
Acceleration due to gravity=9.81kg/m^2
Coefficient of friction=0.8
Fluidity factor=1.4

2.2 Piston Pattern Design

In designing the piston pattern the dimensions of an original piston were obtained with the aid of Micrometer screw gauge and Vernier caliper [13]. The parts measured are External diameter of piston crown, Internal diameter of piston crown, external diameter of skirt, Internal diameter of skirt, Skirt height, Piston height, Pin hole diameter, pin hole thickness, pin hole length, oil groove width Pressure ring groove depth and Piston mass.

Also, standard machining and shrinkage allowances as stated in Tables 1 and 2 [14] were applied in the piston pattern design. The piston pattern design was made using Auto Computer Aided design. The piston pattern was done using wood.

Two solid cross section split wooden patterns were prepared to make impression mould cavities in which molten metal is poured into the mould box housing the sand to produce the castings.

Table 1: Standard of General Machine Allowance [14]

S/N	Type of Alloy	Size	Machining Allowance(mm)
I.	Cast iron	Large size(>1000mm)	10.00
		Medium size (<150mm)	3.00
II.	Cast steels	Large size (>1000mm)	12.00
		Medium size (<150mm)	4.30
III.	Aluminium	Large size(>1000mm)	5.00
		Medium size (<150mm)	1.50

Table 2: Typical Shrinkage Allowance for Casting Metals [14]

Type of Metal	Amount of Shrinkage (%)
Steel	2.00
Cast Iron	2.10
Zinc	2.60
Brasses	1.30-1.55
Bronzes	1.05-2.10
Aluminium	1.65
Aluminium alloys	1.30-1.60

In designing the piston pattern, the following components were included as prescribed by Tables 1 and 2 [14].

I. A shrinkage allowance of 1.60%.
II. Machine allowance of 1.5mm
III. A draft angle of about 1.8^0 was included so as to facilitate the easy removal from the mould after ramming

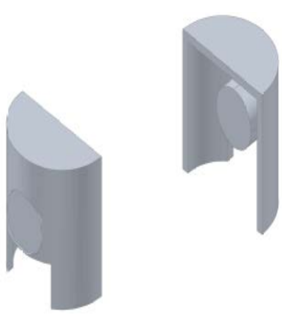


Fig. 1: Isometric View of the Pattern

2.3 Design of Runner size

The design of the gating system of the sand casting was carried out by determining the sizes of compoments such as sprue, runner size and ingate area. The gating system layout is shown in Fig. 2

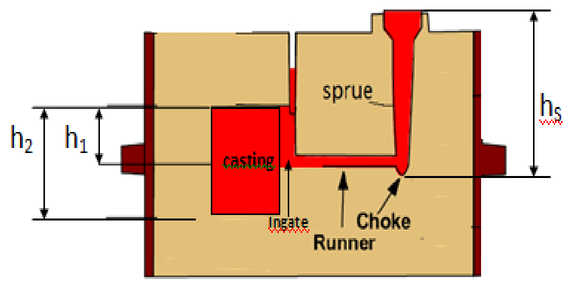


Fig. 2: Gating System Layout [15]

2.4 Determination of weight of casting

The weight of the casting was determined by applying equation 1

$$W_g = \rho \times V \quad (1)$$

Where ρ=density of aluminium
W_g=weight of casting
V=volume of casting

The volume of casting is calculated by subtracting the volume of core from the volume of the combination of the Pattern and sand core as shown in equation 2

$$V = \pi R_a^2 h_a - \pi R_o^2 h_o \quad (2)$$

where V=volume of the casting
R_a=radius of pattern
R_o=radius of sand core
h_a=height of pattern
h_o=height of sand core

$$volume\ of\ casting\ in\ mm^3 = \{\pi(23.8)^2 \times 54.864\} - \{\pi(22)^2 \times 50.06\} \quad (3)$$

The value of casting weight was determined by substituting for the volume of casting in equation 4

$$W_g = 2500 \times 51{,}216 \times 10^{-9} = 0.128 \quad (4)$$

2.6 Design for Choke sectional area

The choke area was determined using equation 7

$$A_k = \frac{W_g}{\rho t_i \mu \sqrt{(2gh_d)}} \quad (7)$$

where A_k=choke area
W_g=Casting weight
$\rho =$ density of molten metal (Aluminium base=2500kg/m^3)
$\mu =$ discharge coefficient (0.8)
g=acceleration due to gravity (9.8m/s^2)
t_i=pouring time

$$A_k = \frac{0.128\times10^9}{2500\times11.88\times0.8\times\sqrt{(2\times9.81\times96.35)}} = 122.24mm^2 \quad (8)$$

The runner size was determined using the gating ratio for non ferrous metal. The gating ratio is given as 1:4:4 for choke area: runner size: ingate area respectively

$$Runner\ size = 4 \times 122.24 = 492.31mm^2 \quad (9)$$

Also the total ingate area is 492.31mm^2

The determined runner size was necessary as it acted as a guide for the choice of runner sizes used in this study. The maximum runner size used in this study was 490mm^2

2.7 Determination of Pouring time

To Determine the pouring time of the sandcasting process, equation 10 was applied

$$t_i = S\sqrt[3]{(T_s W_g)} \quad (10)$$

where T_s=thickness of pattern
S=fluidity factor
W_g=weight of casting

For this study we used the gating ratio of non-pressurized gating system as given by [16]. The ratio is A_k: D: Ag to 1: 4:4.
Where A_k= choke area
D=runner size
A_g=ingate area
The size of the runner was estimated using equation 11

Runner size=choke area × 4 (11)

$$t_i = 1.4 \times \sqrt[3]{4.805 \times 128} = 11.88s \quad (12)$$

2.8 Determination of piston pattern sizes

In determining the piston pattern sizes, the dimensions of an original Tiger 950 piston were obtained. The dimensions are

1. External diameter of piston crown 44.85mm
2. Internal diameter of piston crown 41.54mm
3. External diameter of skirt 45.40mm
4. Internal diameter of skirt 42.20mm
5. Skirt height 42.72mm
6. Piston height 50.56mm
7. Pin hole diameter 10.50mm
8. Pin hole thickness 11.00mm
9. Pin hole length 21.50mm
10. Oil groove width 3.50mm
11. Pressure ring groove depth 3.50mm
12. Piston mass 0.505kg

The piston pattern was determined by adding machine and shrinkage allowances to the designed piston dimensions. The machine and shrinkage allowances are shown in Table 2.

$$External\ diameter{:}\ 44 + 1.5 + 1.5 + (1.6\% \times 47) = 47.752mm \quad (13)$$

$$Total\ length{:}\ 51 + 1.5 + 1.5 + (1.6\% \times 54) = 54.864mm \quad (14)$$

$$Thichness{:}\ 3.23 + 1.5 + (1.6\% \times 4.73) = 4.805mm \quad (15)$$

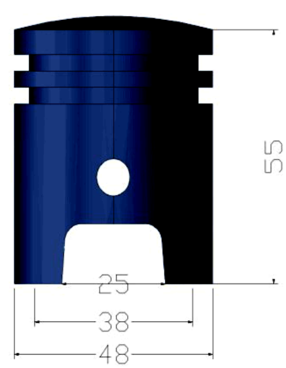
3. Results and discussion

The calculations obtained were used to produce engineering graphic models of the gating system and pattern. Autodesk Auto-CAD 16 software was applied in modeling the gating system and the pattern as shown in Figures. 3 and 4 respectively. The values of the gating system components are shown in Table 3.

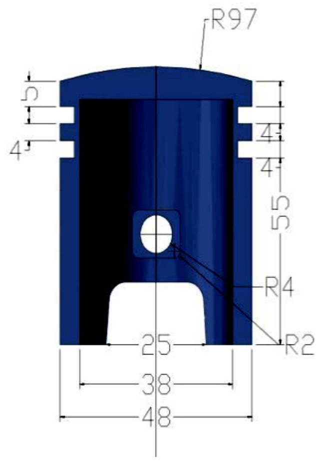
The obtained dimensions were used to create isometric drawing of the wooden pattern as shown in Fig. 3.

Table 3: Presentation of design parameters for the gating design

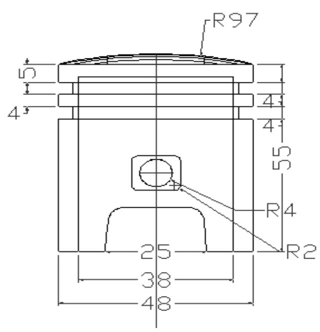
S/N	Parameter	values
1	Pattern length	54.864mm
2	Pattern Thickness	4.805mm
3	Weight of casting	0.128kg
4	Pouring time	11.88secs
5	Runner size	492.31mm^2
6	Metal head	96.35mm
7	Choke area	122mm^2



(a)



(b)



(c)

Fig. 3 (a): Split Pattern Internal View (b) External view (c) Wireframe design

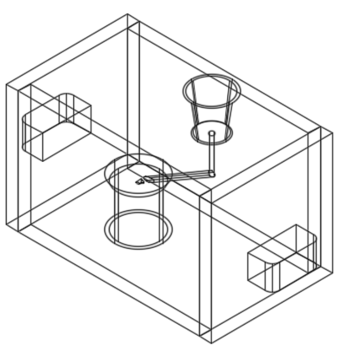


Fig. 4: First angle isometric drawing of the gating system

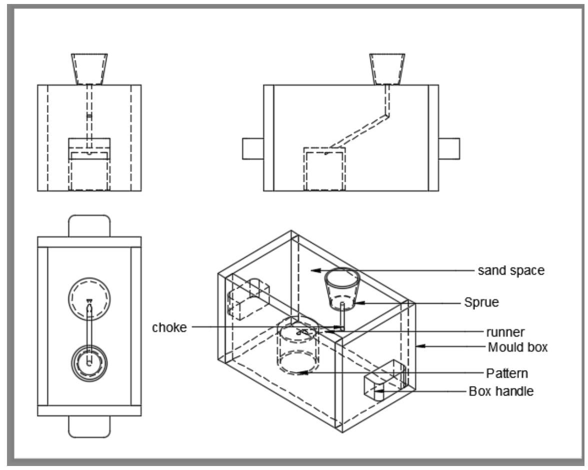


Fig. 5: Isometric drawing of the gating system

4. Conclusion

This study was actually carried out to bridge the gap between the manufacture of engine components using reverse engineering approach and the embankment of a local detailed design. The developed gating system was used to produce 0.67Hp gasoline generator pistons using green sand mould and a determined gating gating ratio of 1:4:4 usually used for engine components. The mould cavity was prepared to readily accept the molten metal when poured helped in reducing the number of wasteful casting. The mould cavity has the core made of green sand well placed in it to create an internal cavity for the piston. The molten metal was scooped out from the crucible on the furnace with the aid of a ladle and introduced into the prepared gating system through the pouring basin to the runner before entering the casting cavity. The result from this study showed that a properly designed gating system produced casting that are devoid of defects.The determined gating system design parameters where found to be within the recommended range of values for sand casting gating design parameters.

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