COMPUTER CALCULATION OF THE GATING SYSTEM

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ABSTRACT

The calculation of the gating system has been undertaken on a computer using the basic programme.

1. INTRODUCTION

During the design of the technological process of manufacture of Castings (ingots), there is a need to calculated the gating systems for the alloy concerned. This calculation is very tedious and is not always accurately done by hand or conventional means. This calculation is important especially in factories where castings are mass-produced. In this case, it is always necessary to choose and design the most optimal variant of the technological process that gives the most production efficiency and the economized time will be spent in increasing the productivity of the factory. Hence, computer calculation of the gating system for ferrous and non-ferrous metals and alloy is of great importance especially to a country like Nigeria where foundry practice is intensively developing.

The gating system is a combination of channels, carities and other elements of the casting mould, which are used to feed molten metal into a mould, fill in the moulds and feed up the casting with metal during solidification. The quality of castings depends so much on the accuracy of construction and calculation of the gating system. The gating system must guarantee the smooth transfer of metal to the mould's cavity and be able also to stop the different non-metallic inclusions (slags), in the melt from entering the mould's cavity. The transfer of metal and the regulation of its motion during the feeding of the mould can generate the necessary heat regime of cooling the casting which in its turn defines the structure and main operational properties of the casting. It is necessary to determine the position of casting in the mould during metal pouring, the place of metal pouring, to choose the type of the gating system, to determine the sizes of the casting mould, to choose the type of pouring cup, to make up the drawing of the casting with all technological design description which with all reference data will be the initial material for the calculation.

II. CALCULATION PROCEDDURES

The calculation of the gating systems means the calculation of the narrowest cross sectional areas and sixes of all elements of the gating system. The calculation is always started with the determination of the narrowest cross-section areas of the gating system As, after which all the other elements are determined. For closed gating system, the narrowest point is the cross-sectional area of the runners while for the open gating system, it is the bottom section of the sprue.

The cross-sectional area of the narrowest point of the gating system is calculated according to this formula:

$$As = \frac{10000\ M.N}{\rho\ \tau\mu\ \sqrt{2gHp}}\ Cm^2 \quad (1)$$

Where M is the mass of the casting in the mould, including side risers, Kg.
N is the number of castings in the mould (in closed gating system N= 1). p is the density of the molten metal, kg/m^3. t is the time of mould filling, second. u - is the dischrge coefficient of the gating system ($o < \mu < 1$).

g - is the acceleration due to gravity, m/sc.HP is the calculated static head of the metal, m. The time of mould filling is calculated with the help of the follwing expression:

$$\tau = C\sqrt[3]{m\ W}$$

Where, C is the coefficient that determines the type of alloy, the casting mould and the construction of the gating system (table 1). W is the wall thickness (predominant) of the casting, mm. The discharge coefficient is usually determined experimentally but occasionally u = 0.4 - 0.7. When pouring the metal through the sprue from a tilting ladle, the static head is calcualted by the following expression.

$$Hp = H_0 - \frac{p^2}{2_C} + H_1, \text{ m.}$$

Where, H_o is the vertical distance from the axis of the runners to the top edge of the cope flask (i.e. the height of the sprue),m. P is the distance from that edge to the metal level in the tilting ladle during metal pouring, m. H_1 is the height of the casting during metal pouring, m. If the pourin cup is at the side of the mould, then $H_1 = 0.1 \div 0.15$m, and if it is at the centre, then $H_1 \geq 0.4$ When pouring through the sprue cup $H_1 = 0$

The discharge coefficient characteriszes the total hydraulic loss and is usually choosen as $\mu = 0.3 \div 0.8$ ($\mu = 0.5$ in our case). For the open gating system, the narrowest point is the cross-sectional area of the bottom of the sprue which is determined as expresseed above. The calculation of the cross-sectional areas of the other elements is carried out by choosing the corresponding areas in table 2.

The cross-sectional area of the slag trap and runners are determined as follows:

$$Ast = Asp.\ T_1$$

$$\sum Arun. = Asp.\ T_2.$$

Where T_1 is the ratio of cross-sectional areas of the slag rap and sprue. T_2 is the total cross-sectional area of the runners and the sprue.

The sizes of the sprue are determined by the following relationship.

$$d_s p_T - = \sqrt{A_s p / \pi}$$

$$d_s p.\ b = d_s p.T + 0.01.Ho., \text{ cm}$$

Where dsp.T' d_sp.b are the diameters of the sprue at the top and bottom respectively. The sizes of the slag trap are determined after calculating its cross-sectional area. The width at the base is determined as:

$$W_S b = \sqrt{A_{ST}/1.25B}$$

Where B is the number of branches of the slag trap.

The top width WsT = 0.8 Asb. The height: h_2 = 1.4 Wsb. The determination of the sizes of the runners is carried out with the help of the following relationship.

The thickness (height) of the runner

$$h = 1.4Wsb/5, \text{ cm};\ h \leq 0.7\ Wc.$$

The total width b = Arun/h b = b/k. Where Wc is the wall thickness (Predominant) of the casting where the metal is poured. For closed gating system, the narrowest point is the total cross-sectional area of the runners, arun, which is calculated later Ast and Asp are chosen from table 2.

$$Ast = \sum Arun.\ N/T_2$$

$$Asp. = \sum Arun.\ N/T_2.$$

The rest of the sizes are calculated as for open gating system. Now that the main calculation has been undertaken, the discharge coeffiecient can be calculated as follows:

$$\mu_2 = 1/\sqrt{+ k1\ (\underline{Ai})^2 + K_2\ (\underline{Ai})^2 + \ldots\ldots Ki\ (\underline{Ai})^2} = 1/\sqrt{1 + \sum C}$$
$$\qquad\qquad A_1 \qquad\quad A_2 \qquad\quad A_i$$

Where K_1, K_2, K_3 ..... K_i and A_1, A_2, .. A_i are the coefficients of resistance and cross-sectional areas of all sections of the gating system respectively. For gating system with three elements, the calculation is carried out as follows:

For the sprue: h_1 $(0.1+0.03H_0/d_s p.d)$ $(Arun./A_s p)^2$

For the slag trap: $h_2 = (2B+0.03\ Lst./WsT)\ (\sum Arun./Ast)^2$

For the runners: $h_3 = 1.5\ K + 0.05\ L_{run}.k.\ \frac{b+h}{2.b.h}$

where L_{ST}, $L_{run.}$ are the lengths of the slag trap and runners respectively.

If $/\mu_1 - \mu_2/ = \xi$ and $\xi = 0.01$, then the calculation of the gating system is correct. If not, then we assume that $\mu = \mu_1 + \mu^2/_2$ and the whole calculation is repeated.

Is the given accuracy for the determination of the discharge coefficient. The calculation of the gating system when metal is poured from a stopper ladle is carried out by other methods. The bottom cross-sectional are of the sprue (the narrowest point) is determined by the following equation.

$$Asp = \frac{10000\ M.N.}{\rho\ \tau\ \mu 1\sqrt{2g.0.8.\ (H_3+H_4+H_5)}}$$

Where H_3 is the distance from the top of the casting to the top of the mould in the pouring position, m. H_4 is the distance from the top of the mould to the bottom of the pouring cup, m.

H_5 is the static head of the metal in the pouring cup at the end of pouring, m. the area of the hole of the refractory funnel of the ladle is determined as:

$$Ah = \frac{Asp\ .\ \mu_1\sqrt{0.8(H_2+H_4+H_5)}}{\sqrt{0.95\ H_6}}$$

Where H_6 is the static head of the metal at the beginning of metal pouring, m.

The diameter of the hole of the funnel is calculated as: $d_f = d\sqrt{A_h/\pi}$ after this, a standard ladle is choosen according to this standard Series: 30, 35, 40, 45,.....65, 70. The diameter of the sprue of an open gating system is equal to:

$$Asp = \frac{\mu_k A_h.\ H_6}{\mu_1\sqrt{0.8\ (H_3+H_4+H_5)}}$$

$\mu_k = 0.95$ is the discharge coefficient of liquid metal from the ladle. The calculation of the other sizes of the gating system is undertaken by choosen the ratio of the corresponding areas. The side of the slag trap (in form of a square) is determined by the following equation:

$$a = \sqrt{A_k}$$

The sizes of the runners are determined as:

$h = 0.7\ Wc.$

$\sum b = Arun./h \rightarrow b \pm \sum b/k.$

The calculation of the resistance coefficients is carried out with the help of the following relationship:

For the sprue: $h_1 = (0.1+0.03\ H_o/dsp.b)(\sum Arun./A\ sp)^2$

For the slag trap: $h_2 = (2B+0.3\ Lc/W)(\sum Arun.Ac)^2$

For the runners: $h_3 = 1.5\ K + 0.05\ Lrun\ K.\ \frac{b+h}{2b.h}$

The discharge coefficient is calculated as for open gating system.

III. CONCLUSION

The suggested computer calculation of the gating can be adopted in Nigerian Foundries and will result in improved quality of the castings as rejects will be drasitically reduced.

IV

NOMENCLATURE

Asp.	=	Cross-sectional area of the spre, Cm^2.
Ast.	=	Cross-sectional area of the slag trap, Cm^2
∑Arun	=	Total Cross-sectional area of the runners, Cm^2
M	=	Mass of the casting, kg.
N	=	Number of castings in the mould.
p	=	The density of the molten metal, kg/m^3.
τ	=	Filling time, sec.
μ_1	=	Given discharge coefficient.
μ_2	=	Calculated -11-
Hp	=	Calculated static head of metal, m.
S	=	Coefficient for the calculation of filling time.
Wc	=	The wall thickness of the casting, m.
Ho	=	The height of the sprue, m.
H_1	=	The distance from the top of the mould to the level of the metal in atilating ladle, m.
p	=	The distance from the axis of the runners to the top of the casting,m.
h_1	=	The height of casting during pouring, m.
dsp.b	=	Bottom diameter of the sprue, m.
dsp.t	=	Top -11- , m.
h	=	The height of the runners, cm.
∑b	=	Total width of the runners, cm.
Wc	=	Thickness of casting where the runners are connected, cm.
asl.b	=	The upper base of the trapezoidal section of the slag trap.
asl.b	=	The bottom base -11- -11-, cm.
a	=	The height/width of the square section of the slag trap, cm.
K	=	The numbers of runners, Quantity.
C_1	=	The total resistance coefficient of the sprue,
C_2	=	The total resistance coefficient of the slag trap.
C_3	=	-11- -11- runners,
Lc	=	The length of the slag trap, cm.
Lrun	=	The length of the runner, cm.
B	=	The number of branches of the slag trap.
ξ	=	Given accuracy for thecalculation of the discharge coefficient.
∑Ast/Asp	=	Ratio of Cross-sectional areas of the slag trap and sprue.
∑Arun/Asp	=	Ratio of the cross-sectional areas of the runners and sprue.
H_5	=	Static head of the metal at the end of metal pouring, m.
H_6	=	Static head of the metal at the beginning of metal pouring, m.
H_3	=	The distance from the top of the casting to the top of the mould, m.
H_4	=	The distance from the top of the mould to the bottom of the stopper ladle, m.
A_h	=	The area of the hole in the refractory funnel of the ladle, cm.
dh	=	The diameter of the funnel, cm.
		The read cycle.
		The type of the pouring ladle tilting stopper
C_2	=	The height of the section of the slag trap.

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No.	Alloy	Type of gating System		
		Top	Side	Bottom
1.	Carbon steel and low alloyed	1.5	1.4	1.3
2.	Alloyed Stell	-	0.8	0.7
3.	Irons	2	1.8	1.6
4.	Alluminium Alloys	2.6	2.4	2.2
5.	Magnesium Alloys	-	-	2
6.	Bronze and Brass	-	1.8	1.7

Table 1 : The Values of C for different gating Systems.

Alloy	Open System		Closed System	
	Ast/Asp	Arun/Asp	Ast/Asp	Arun/Asp
Irons	1.2	1.5	1.1	1.2
Steels	1	2	-	-
Ala Cu alloys	2	3	-	-
Mg alloy	3	4	-	-

Table 2 : The relationsjip between the Cross-sectional areas of elements of the gating System.

The volumeof the ladle	At the beginning of pouring, H6, m	At the end of pouringH_5, m.
0.5	0.52	0.20
1	0.75	0.28
4	1.1	0.33
6	1.25	0.38
10	1.35	0.39
16	1.55	0.41
20	1.7	0.43

Table 3: Possible heads of metal in a stopper ladle

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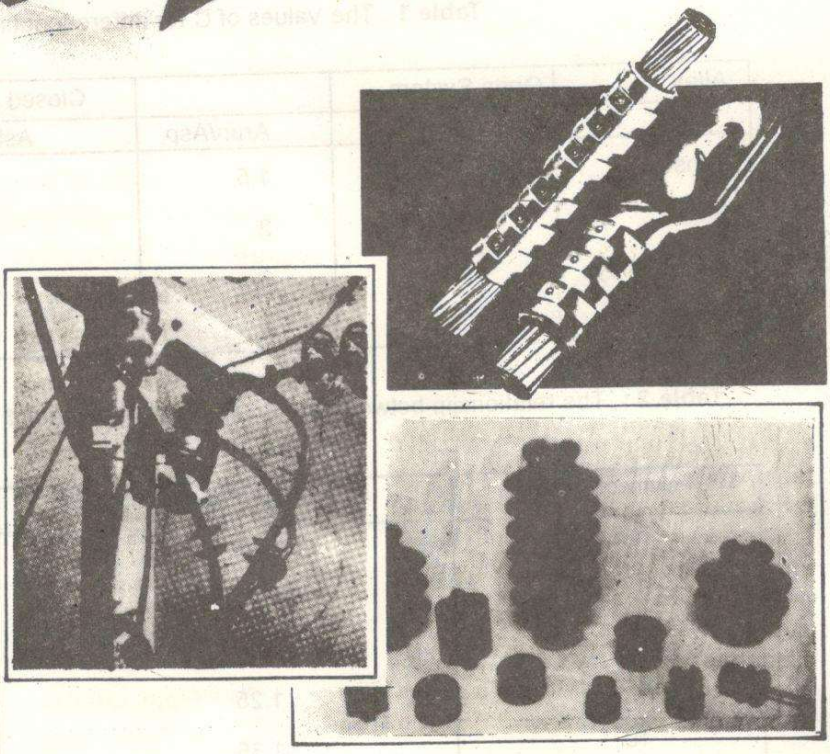
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