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SOME OBSERVATIONS ON THE APPEARANCE, GROWTH AND FIXATION OF GAS BUBBLE IN LIQUID STEEL SOLIDIFYING IN GREEN SAND MOULD

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Certain phenomena concerning appearance, growth and fixation of gas bubble in solidifying steel have been studied by creating an atmosphere in a glass tube, similar to that existing in mould cavity. The models suggested for liq. steel at 1600° and solidifying steel are respectively glycerin and mixture of salol and azobenzol (93/7), which is transparent and solidifies at room temp. Physical morphology of gas defects is also discussed.

INTRODUCTION

The physical process of blow hole formation may be divided into three stages viz formation of a supplementary pressure of gas at the metal-mould interface, appearance of a bubble in the pore of the moulding sand and its penetration into the liquid metal and fixation during solidification of molten metal. In the present paper the appearance, growth and fixation of gas bubble in the liquid steel solidifying in the green sand mould is studied with the help of a transparent model suggested for liquid steel at 1600°. The apparatus essentially consists of a specially designed glass-tube, two water manometers of 500 mm, gas cylinder for supplying gas, and a transparent model.

Design of Tube. In order to study the appearance of bubble in the liquid, in an atmosphere which is excepted to exist in the mould cavity during casting of steel, special glass tube of 40 mm inner dia. With perforated bottom, is designed. This glass tube has three outlets and one inlet. The inlet, P, is connected with the gas cylinder which supplies Oxygen; the outlet, M, is connected with the water manometer of 500 mm (M1), which is used to measure the gas pressure above the liquid. The most important part of this tube is another tube of 5 mm dia. which makes a perfect seal with the perforated bottom, and its other end is connected with the water manometer (M2). This manometer measures the pressure of the bubble when it appears at the liquid mould interface.

Selection of the Transparent Model. The liquid steel is opaque. It is, therefore, not possible to observe different stages of formation and development of gas bubble in the liquid steel. This difficulty is resolved by suggesting a transparent model of approximately the same physical properties as those of the liquid steel at the casting temperature (1600°). For this purpose, physical characteristics of many viscous organic liquids were studied and it was decided to use pure glycerin as the transparent model for liquid steel, since (i) pure glycerin has the same viscosity as that of steel at 1600° (i.e., 1499 centi-poises at 25°), (ii) glycerin is a transparent liquid and when a bubble of the gas appears in it, the light reflects from the spherical surface, so different stages in appearance and development of bubble can be photographed with good measure of success. But pure glycerin has also some limitations e.g. (a) some of the physical characteristics. e.g. Sp.gr., metallostatic and metallodynamic pressure are different from those of steel, and (b) the pure glycerin does not solidify at room temprature with the passage of the time. Therefore, it cannot be used for studying fixation of bubble. This difficulty is overcome by suggesting mixture of salol 93% and azobenzol 7% used by Ribonavich and Sapsski[1] for studying the penetration of bubble. The mixture of salol and azobenzol (93/7) is transparent molten mixture which crystallises at room temperature and is selected after considering physical and chemical properties of many organic chemicals which have viscosity, surface tension and solidifying around the room temperature. It crystallising properties make an interesting study of the behaviour of bubble solids.

Procedure. The apparatus comprises the tube of 40 mm dia fixed in the stand and inlet "P" is connected with gas cylinder which is regulated with the stopper S.M. connec-

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ted with water manometer (500 mm) M1, used to measure the gas pressure above the surface of liquid. The sample of moulding sand is prepared and placed at the perforated bottom of the tube. Then 5 mm tube is passed through the inlet "0" upto the surface of introduced sample, which will act as the glycerin-sand interface, then glycerin is poured in tube and cork is fixed in the inlet "0". The other end of the tube "T" is connected with the manometer M2 which measures gas pressure at glycerin-sand interface. The oxygen-gas cylinder is then opened and its stopper is fixed at reliable level. The gas enters in the tube and filters through the sample introduced after being equally distributed by the perforated plate fixed at the bottom of the tube. The stopper of the gas cylinder is regulated in such a way that only one bubble at one time leaves the sand-glycerin surface. The pressure of gas at glycerin-mould interface is also kept within the range of the pressure created by the gases ejected by the green sand mould cavity during casting of steel. When approximately the same conditions are created in the tube, which are supposed to exist in the mould cavity e.g. the glycerin acts transparent model for steel at 1600° glycerin sample interface behaves as steel mould interface; the pressure at glycerin sample interface is the same as that of the gases ejected from the mould surface during casting of steel in green sand mould. The column of glycerin will then act as column of liquid steel in contact with a portion of the green sand mould ejecting gases. Different phenomena are studied under these conditions.

Phenomena Studies: The experiments are carried out for studying the following phenomena: (i) appearance of gas bubble, (ii) factors influencing the growth of bubble, i.e. column of moulding sand cloumn of glycerin, pressure inside the bubble, degree of fineness of moulding sand and grade of ramming, and (iii) fixation of gas bubble.

Appearance of Gas Bubble. In order to study the stages in the appearance and completion of gas bubble the samples of 40 mm dia and 50 mm height are prepared from sands of compositions given in Table 1. These samples are prepared in the glass tube of 40mm dia. and 50mm height and grade of ramming is kept beween Dietert No: 55-60 for each sample. One of these samples is introduced in the tube gently and fixed on the perforated bottom of the tube, upto 100 mm height above the surface of the sample.

The apparatus is then fixed as is Fig.1. The gas clyinder is opened and gas bubbles are allowed to pass through the glycerin. The regulator of gas cylinder is fixed at such a point that only one bubble passed through the glycerin column. The gas pressure at sand glycerin interface is measured by the manometer M2 and is kept at 150 mm of Water. As soon as the bubbles appear at sand glycerin inter-

Table 1. Composition of different types of sand used.

Ingredient	Moulding sand	Core sand
Natural sand %	92	–
SiO_2%	–	75
Bentonite %	6	–
Molasses	–	25
Fuel oil	2	–
Sand grain shape	irregular	Rounded

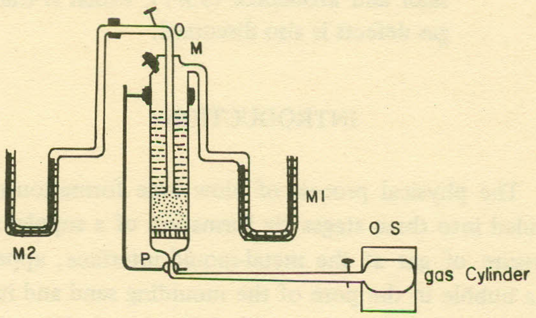

Fig. 1. The apparatns used for studying the appearance, growth and fixation of bubble.

face, different, stages of its appearance are noted.

Growth of Gas Bubbles. In order to study the influence of any factor on the velocity of bubble penetration in glycerin at room temperature, only one factor will be varied while other factors are kept constant. For studying the influence of the height of column of moulding sand of the velocity of bubble penetration, the test samples 40, 60, 80, 100 and 120 mm and dia. 40 mm each are prepared from the moulding sands with different composition (Table 1). Each of these test samples is introduced in the tube and column of glycerin for each sample fixed at 100 mm. As soon as bubble appears in the glycerin, the time taken by the bubble to travel from the sand-glycerin interface upto upper surface of glycerin is recorded by chronometer. The velocity of bubble penetration is then calculated. The influence of height of column of glycerin vis-a-vis velocity of bubble penetration is observed by increasing the height of column of glycerin to 40, 80, 120 and 160 mm and recording the time taken by the bubble to travel from the sand-glycerin interface upto the upper surface of glycerin, in each case. The experiment is repeated with test samples of the other sands (Table 1).

In case of gas pressure at sand-glycerin interface, the stopper of the gas cylinder is regulated properly and gas pressure is measured by the manometer M1. The time taken by the bubble to penetrate through glycerin, from sand-glycerin interface to upper surface of glycerin is recorded.

Test samples to study the influence of fineness of sand on the velocity of bubble penetration are prepared by drying the sand in open air (and not with the help of gas flame because in this case high heat of the flame will burn out some ingredients of the moulding sand). After crushing in muller the sand is screened in the electric sieve with the meshes 0.63, 0.32, 0.2, and 0.1 mm. water (i.e 2 ml for 25 gms. of sand) is then added to the sand of each grade of fineness so that it can attain the sufficient plasticity to make the test samples. The test samples of 20 mm and 40 mm heights and 40 mm. dia. with the grade of ramming from 10-20 Dietert No: were prepared and velocity of bubble penetration measured for each sample.

The test samples of 40 mm. dia. and 40 mm height with different grades of ramming i.e. 20-25, 30-35, 40-45, 50-55 and 60-65 Dietert No: from each sand sample were prepared and velocity of bubble penetration measured for each of them.

Fixation of Bubble. The fixation of bubble is studied with the help of another model i.e. 93% salol and 7% azobenzol and followed as above. The transparent crystals are formed on the wells of the tube and the free surface of this liquid.

INTERPRETATION OF RESULTS

The Fig. 2 (a-d) illustrates different stages in the formation and development of gas bubble. Fig.2 (a) represents the appearance of gas bubble from the pore of the moulding sand. At this time, the pressure of the gas is greater than the sum of atmospheric pressure, pressure induced by the liquid on the sand liquid interface and surface tension of glycerin. Fig 2 (b) illustrates the gas bubble which appears in the pore, develops by the pressure of the gas, and when this pressure is sufficiently high, the bubble separates from the sand-glycerin interface Fig. 2 (c) Fig. 2 (d) represents the complete formation of the bubble monving to the upper surface of the liquid.

The experiments conducted with the transparent model suggested for liquid steel and relation drawn between velocity of bubble penetration and some variables have shown that for moulding sands (Table 1), the velocity of bubble penetration in glycerin at 25° increases with increase in gas pressure at sand-glycerin interface, decreases with increase in height of glycerin column and grade of

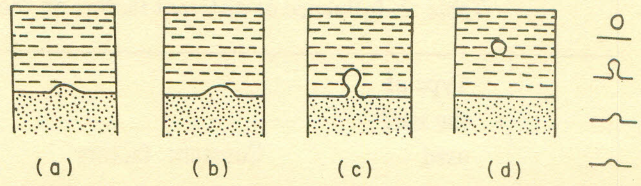

Fig. 2. Differential stages of formation and development of bubble

ramming, and is negligibly influenced by height of the column of sand while it increases upto certain limit by decrease in the grade of fineness of sand and then decreases with further increase in size of the grains.

In liquid state the bubble penetrates and goes straight through the liquid. As solidification starts small crystals collect at the wall of the tube and bubble settles below hard layer formed on the liquid. With the passage of time "hard layer" on the liquid is thickened and small crystals formed while proceeding towards the central axis of the tube when bubble finds difficulty in passing through this mushy viscous material. As the solidification completes the path of the bubble, it is blockened by the crystals and fixed itself in the branches on the extremeties of dendrities.

DISCUSSION

The experiments carried out with the transparent model suggested for liquid steel at 1600° have shown that the bubble appearing from the pore of the moulding sand in liquid steel in an atmosphere similar to that existing in mould cavity during the casting of steel, thereby completing the process in four stages. viz. Appearance, growth, separation (from mould surface) and completion of bubble.

By applying the results of the transparent models on the liquid steel at 1600°, it is concluded that the velocity of bubble penetration in the liquid steel increases with increase in the gas pressure at sand-steel interface, and decreases with the increase in the height of steel column. The grade of ramming of moulding sand is negligibly influenced by the height of the sand coloumn, while it increases upto a certain limit by decrease in the grade of fineness of sand and then decreases by further increase in the size of the grains.

The studies concerning the phenomena of fixation of bubble have cleared the physical mechanism of blow hole formation in steel solidifying in the green sand mould. As solidification starts a thin "hard layer" is formed on the steel. The bubble proceeding rapidly settles under the thin layer and forms "Sub-Cutaneous" blow hole. If the pressure of the bubble very high, it breaks the thin hard

Table 2. Influence of different factors on the velocity of bubble penetration in glycerin at 20°.

Type of the sand used	Constant factors	variable factors	Column of glycerin mm	Time taken Sec.	Vel. of bubble penetration mm/Sec.
	Height of col. of gl=100 mm	height of col. of sand. mm			
	Pressure of bubble=134-140 mm of H_2O.	40	100	2.6	38.46
moulding sand		60	100	2.75	36.36
	grade of ramming =50-60	180	100	2.75	36.36
	Dietert No.	100	100	2.75	36.36
	grade of fineness =0.02 mm	120	100	2.75	36.36
Height	height of col of gl=100 mm	height of col of sand			
	Pressure of bubble =100-115	40	100	3	33.3
column		60	100	2.5	40
	mm of H_2O	80	100	2.4	41.7
Core sand	grade of ramming =50-60				
	Dietert No	100	100	2.4	41.7
	Grade of fineness =0.02 mm	120	100	2.4	41.7
sand	height of col of gl=100 mm	height of col of sand mm			
	Pressure of bubble =100-115	40	100	2.4	41.7
Banking	mm H_2O	60	100	3	33.3
sand	grade of ramming =50-60	80	100	2.4	41.7
	Dietert No.	100	100	2.5	40.0
	Grade of fineness =0.02 mm	120	100	2.6	38.46
	height of col of sand =100mm	height of col of glycerin mm			
	pressure of bubble = 100 mm	40	40	1	40
Moulding sand	of H_2O	80	80	2.10	38.1

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		Grade of ramming =50-60 Dietert No.	120	120	3.20	37.5
		Grade of fineness =0.02 mm	160	160	4.2	38.1
		height of col of sand=100 mm	height of col of gly mm			
		Pressure of bubble = 100 mm of H_2O	40	40	0.6	66.67
	Core Sand	Grade of ramming = 50-60	80	80	1.3	61.54
Height of column of glycerin		Dietert No.	120	120	2	60.00
		Grade of fineness = 0.02 mm	160	160	3.6	47.2
		height of col of sand = 100 mm				
		Press. of bubble	40	40	1	40
	Backing Sand	= 100 mm of H_2O	80	80	1.9	42.1
		Grade of ramming = 50-60	120	120	3	40
		Dietert No.	160	160	4.5	35.5
		Grade of fineness = 0.02 mm				
		height of col of gl=100 mm	Press of bubble			
		height of col of sand = 100 mm	25	100	2	50
	Moulding Sand	Grade of ramming	50	100	1.9	52.7
		= 50-60 Dietert	90	100	1.8	55.56
		Grade of fineness	115	100	1.4	71.43
		=0.02 mm	175	100	1.1	91
			200	100	1	100
Pressure		height of col of gl. = 100 mm	Press. of bubble mm of H_2O			
of the			25	100	2	50
		height of col. of sand	50	100	1.8	55.56
bubble	Core sand	=100 mm	75	100	1.7	59
		Grade of ramming	100	100	1.5	66.7
		= 50-60 Dietert No.	125	100	1.4	71.43
		Grade of fineness = 0.02				

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		height of col of gl=100 mm	Press. of bubble mm of H_2O			
		height of col of sand	25	100	1.7	58.8
	Backing sand	=100 mm	50	100	1.6	62.5
		Grade of ramming =50-60 Dietert	75	100	1.4	71.43
		Grade of fineness	100	100	1.4	71.43
		0.02 mm	150	100	1.2	83.33
		height of col of glycerin = 100 mm	Grade of ramming Dietert No.			
	moulding sand	height of col of sand	20-25	100	1.9	52.7
		= 100 mm	30-35	100	2	50.0
		Pressure of bubble	40-45	100	2.63	38.0
Grade of ramming		100 mm of H_2O	50-55	100	2.75	46.4
		Grade of fineness = 0.02 mm	60-65	100	2.75	36.4
		height of col of gl	20-25	100	2	40.0
		= 100 mm	30-35	100	2.63	38.0
		height of col of sand	40-45	100	2.75	36.4
	Core Sand	=100 mm	50-55	100	3.0	33.3
		Grade of fineness = 0.02 mm				
		Pressure of bubble 100 mm H_2O	60-65	100	3.3	30
		height of col of gl = 100 mm	20-25	100	1.9	52.7
		height of col of sand = 100	30-35	100	2.0	50.0
	Backing sand	Press. of bubble = 100 mm	40-45	100	2.63	38.0
			50-55	100	2.75	36.4
		Grade of fineness =0.02 mm	60-65	100	2.8	35.7
		height of col of gl = 100 mm	Grade of fineness mm			
		height col of sand = 100	0.1	100	3.0	33.3
		Pressure of bubble	0.2	100	3.3	30.0
	Moulding sand	=100-120 mm H_2O				
		Grade of ramming	0.32	100	3.5	28.5
		= 50-55 Dietert No.	0.63	100	3.3	30

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Grade of fineness of sand		height of col of gl= 100 mm height of col of sand = 100 mm	0.1	100	3.3	30.0
	Core	Pressure of bubble	0.2	100	3.5	28.5
	Sand	20-120 mm of H_2O	0.32	100	4	25.0
		Grade of ramming	0.63	100	3.5	28.5
		50-55 Dietert No.				
		height of col of gl = 100 mm height of col of sand = 100 mm	0.1	100	3	33.3
		sand = 100 mm				
	Backing	Press. of bubble	0.2	100	3.5	28.50
	Sand	100-125 mm of H_2O	0.32	100	3.6	28.0
		Grade of ramming	0.63	100	3.3	30.0
		50-55 Dietert No.				

layer and surface blow hole appears. When the other coming bubbles attach with the first one, large quantity of gas collects under the hard layer and forms big gas hole or "Gas entrapment." In the "Mushy" state, the penetration of the bubble is retained due to the high viscosity of semisolidified steel. The path of the bubble proceeding through the viscous steel appears as "gas canal" after solidification and finally the fine bubbles which stick to the extremeties of dendrites appear as "Pin-hole."

CONCLUSION

Further elucidation of the relation between the rate of

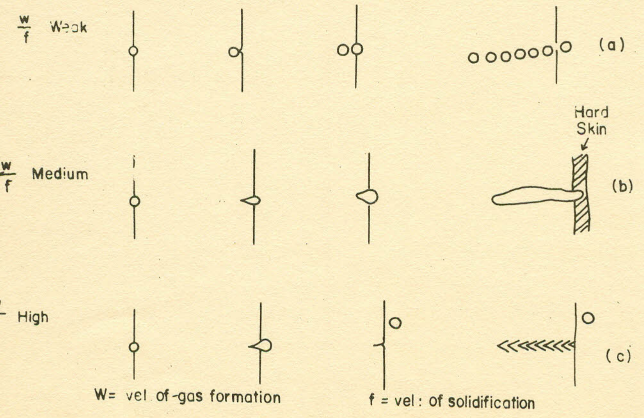

Fig. 3. Fixation of gas bubble in solidifying steel

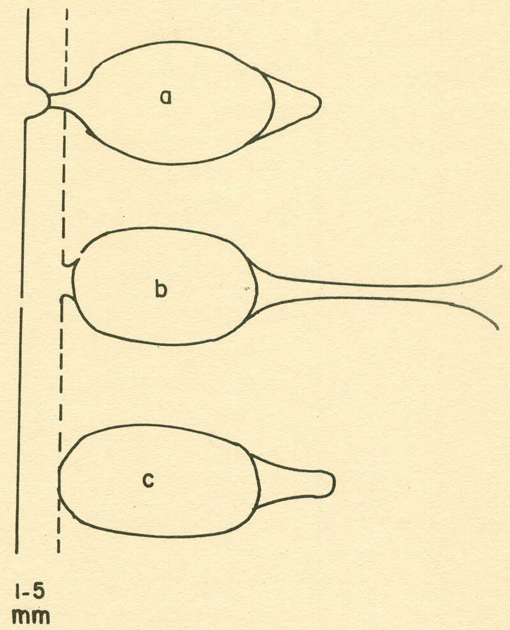

Fig. 4. a) Crater bubble with break through towards outside
b) Primary bubble with break through towards inside
c) Bubble without break through.

bubble growth and solidification is diagrammatically represented in Fig. 3 and 4. If the rate of bubble growth is lower than the rate of solidification, the bubble appears in globular form and the thin hard skin formed on the surface of casting is broken by the bubble, thus leaving a break-through towards outside (Fig.3 and 4a). If the rate of growth of bubble is equal to that of solidification, it creates a breakthrough towards inside. In this case the bubble finds difficulty in escaping because surface tension of steel gets hold of it. (Fig. 3 and 4b). When the rate of bubble growth is higher than that of solidification, the bubble disappears easily leaving a small cavity, which is without any breakthrough (fig. 3 and 4c). Further work on the effect of casting temperature on the appearance, growth and fixation of gas bubble is contemplated.

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