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INCREASING THE ACCURACY OF A MULTI CHANNEL FLUIDITY TEST MOULD

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ABSTRACT

The accuracy of a multi-channel straight strip fluidity test mould was increased tremendously by simple adjustments in design and by the introduction of a filter. The percentage error in the 4 mm thick strip was reduced from 35% in the original mould to 4% in the modified mould. Optical examination shows that using deep channels lead to secondary flow in the shallow channels. Fluidity in all channels generally increases after the modification of the original mould.

INTRODUCTION

A main advantage of the casting process is its ability to produce components with very intricate and complex shapes. Fluidity has been defined as the length through which a metal or alloy flows in some standard test channel before being arrested by solidification [1,2,3]. The fluidity so defined is independent of viscosity [1]. Casting fluidity is the ability of the molten metal to flow and fill the mold cavities. It is defined as the distance to which the metal can flow in a given test mold before it is stopped by progress of solidification. Fluidity is a complex parameter that is affected by many parameters such as properties of the molten metal and the mold, pouring conditions, presence of solid particles in the melt and their characteristics, and mode of solidification [14]. It is important to reduce the influence of variables that are difficult to control in the experiment to improve the reproducibility of the measured fluidity [10]. Fluidity is mainly a complex technological property and it depends upon many factors [11]; The existing fluidity tests involved the measurement of length of the liquid metal until it was solidified; either in a spiral mold [10] or in a vacuum test [12] Timelli et al. [13] found out that pouring temperature and superheat affect the fluidity of Al alloy. The higher the fluidity of a metal/alloy the more intricate and complex the shape that it can be used to produce.

The basic functions of fluidity testing [4] are:

(1) Determination (based on fluidity values) of the best alloy out of otherwise equally suitably alloys for the production of specific casting.
(2) Serving as a means of quality control on the foundry floor and more recently
(3) Study of fundamental mechanism of flow arrest, which should be useful for future alloy design.

FLUIDITY TESTING

For a fluidity test to be meaningful [4]:

The dimensions of the channel must be such that (a) the metal/alloy flows an appreciable distance in the channel and (b) the metal/alloy does not run the entire length of the channel. For optimum reproducibility of test results (a) the force exerted upon the metal at the point of entry to the flow channel must be constant. (b) No other variable force should be upon the metal during its period of flow. (c) The conditions of heat transfer must be constant from test to test.

FLUIDITY TESTS

Fluidity tests may be classified into single or multiple channel tests depending on the number of channels in the mould. Based on the configuration of their test channels, each of the groups may be sub divided into spiral and straight channel tests. Tests in which vacuum was employed to generate a pressure difference along the channel are classified as vacuum test. Vacuum test has been of single channel type.

Sand moulded multi-channel fluidity test mould such as that used in this work, produces results that are much easier to relate to real casting situations than the usually more accurate vacuum tests. The results are more reproducible and are less sensitive to levelling errors than the spiral tests and possess the unique advantage over all the other tests in that if the flow length through each channel is reported separately, then the results can be extrapolated to give the fluidity in sections of different moduli [5]. Also, the minimum modulus of a channel through which the metal will run can be determined.

FACTORS INFLUENCING FLUIDITY RESULTS

The factors that affect fluidity are mould properties, "Metal properties and process variables. The mould properties are determined by the materials of which the mould and its coating are made, as well as by the method of producing the mould and of application of the mould coating.

The greater the chilling power of the mould and the higher the drag effect on the liquid metal the less the fluidity in such mould.

The metal or alloy properties that affect fluidity are [6] the inherent and extraneous properties. The inherent properties are functions of composition and/or casting temperature. Since this paper is addressing reproducibility of fluidity test results not fluidity, only the extraneous properties are discussed.

Extraneous properties are [6] those properties that affect melt quality. Gas content has only very small effect on fluidity [6,7,8]. Solid oxide film at the liquid surface reduces fluidity while liquid oxide films improve fluidity [6]. Impurity elements that are only slightly soluble tend to affect fluidity more than the readily soluble elements.

Turbulence (usually due to incorrect gating) reduces fluidity. A narrow channel dimension increases backpressure due to surface tension and reduces modulus, hence it reduces fluidity. However, it has been reported [9] that a slight change in pressure head does not affect fluidity and that using a low pressure head and keeping the metal level in the sprue constant assures high reproducibility of results.

EXPERIMENTRAL METHODS

Production of Fluidity Mould

The design of the mould pattern is illustrated by Figure1. The pattern was machined from rolled aluminum sheets. An offset weir pouring basin was produced as a sand core from a wooden pattern. A hole of the same diameter as the sprue entrance diameter was cut in the weir of the basin.

Moulds were produced using AFS60 silica sand bonded with 'pepset' resin a 2-part urethane system, according to standard procedures. Whistle holes of 3mm diameter were drilled through the cope at the very end of the fluidity channels. These holes were loosely filled with fire resistant wool so that only gases could pass through and not liquid metal.

Mould Assembly

The drag was placed on supports and the height of the supports were adjusted until it was perfectly horizontal as read with a spirit level. The cope was located on the drag by aligning the location holes with those on the drag until a bolt could pass through each pair of holes. The nuts were then screwed on to the bolts tightly. This secured the two halve firmly together.

Melting and Pouring Practice

The *changes* were melted in day bonded graphite crucibles in an electromagnetic induction furnace (EMA). The *changes* were held at 700^{o}C for fifteen minutes to allow the melt to passively outgas and also ensure that the ***solid*** was totally dissolved in the liquid. The *changes* were then rapidly heated and poured into the fluidity mould at 750^{o}C. the metal was poured into the deeper side of the pouring basin.

Definition and Determination of Fluidity

Fluidity of the strips was defined as the length defined as the length the molted metal would flow in the strip channel if it were to advance with an interface perpendicular to the direction of flow and fill the cross-section of the channel completely throughout its length of flow. This length was measured with steel rule.

Fluidity Testing Using the Original Mould

Using the mould, melting and pouring practice described above, fluidity test was carried out on alloys with nominal silicon content as 0, 0.5, 1, 1.5, 2, 4, 6, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20 weight percent. The fluidity of each alloy were measured and is illustrated by Figure 2.

It was observed that in alloys with nominal silicon content between 10 and 20 wt % the fluidity in the 1mm deep channel was higher than the fluidity in the 2mm dep channel. This runs contrary to all known theory of fluidity. Optical inspection of the fluidity strips revealed the presence of rippled surfaces indicating that the flow of the alloys was stopped only to start flowing again. The flow of the alloy after first being arrested is termed secondary flow. All the phenomena described in this paragraph are due to back induced secondary flow. The back pressure was generated by the impact of flow on the mould wall at the end of the channel.

REPRODUCIBILITY TESTING AND MODIFICATION OF FLUIDITY MOULD

Three castings of the sane alloy (Al-796Si) were made from the original mould. The fluidity and the fluidity test strips were analyzed for reproducibility and the effect of back-pressure induced secondary flow. Based on the analysis, modification was made and the process was repeated until an acceptable level of reproducibility was attained. Modifications were made as follows.

(i) The whistle holes were not blocked with fire wool and a tubular cylindrical sand core with a hole of same diameter as the whistle holes was placed on each whistle hole to form an extension to a height level with the top of the basin. The aim of the change was to provide a path for the liquid metal to flow after hitting the end of the channel, thereby reducing any back pressure wave on the liquid metal in the channels.

(ii) The mould in (i) was modified by providing a radiused sprue inlet from the pouring basin. A plunger, made of graphite head and metal stem was used to plug the basin sprue entry so that nom metal could flow into the fluidity mould unless the plunger was removed. The plunger was preheated, and was only removed when the pouring basin was filled with liquid metal in order to ensure constant metal head during casting.

(iii) The mould in (ii) was further modified by blocking the 6 and 5mm deep channels so that liquid metal did not flow into them. The channels were bloc ked by sand cores.

A respectable degree of reproducibility was achieved after modification (iii) and the test was repeated using a hypereutectic Al-16%Si alloy.

(iv) The pattern (illustrated by Figure 1) was modified by milling off the first 4cm along the lengths of the 8, 6, and 5cm thick channels near to the cross runner. This was done so that these channels were totally blocked during moulding. Using this mould and modifying the technique by introducing a filter pouring cup containing an alumina lost foam filter (10 pores per linear inch (25.4 mm)) positioned just above the pouring basin, three castings were produced.

The results of these tests are summarized in Table 1.

RESULTS AND DISCUSSION

In order to get reproducible results all, the factors that control fluidity must be kept constant. Turbulence in particular must be avoided as much as possible. The fluidity test strips must be seen as castings in their own rights, and steps must be taken to see that they are castings of high integrity. The use of proper gating system for the alloys must therefore be ensured. The fluidity test mould used in this work was designed in line with the current idea on running systems for the production of high integrity light alloy castings.

The 8mm and the 6mm deep channels were filled for all the conditions and alloys investigated, thus these fingers are not much use in respect of obtaining the fluidity of any of the alloys. In evaluating the results, the result obtained by introducing risers at the end of the channels (involving melt number BSA-7-1 to BSA-7-6) is preferred to that obtained for the unmodified mould (involving melt number BSA-7-1 to BSA-7-3) despite the higher accuracy of the latter. This is because in fluidity testing of melts BSA-7-4 to BSA-7-6, the fluidity consistently increased with increasing channel depth, while in the other set the fluidity in the 1mm thick strip is higher than that in the 2mm finger. This indicates there is less interaction between the flows in the different channels of the modified mould (with only the addition of risers) than in the unmodified mould. The fluidity of the 1mm and 2mm channels are particularly important because they are more relevant to the casting of thin wall components, fluidity of alloys is more important in casting of thin wall components than it is in the casting of thicker components.

The fluidity of the alloys in the 0.5mm thick channels are not used for analysis. This is because the alloys do not flow a considerable distance in this channel. It is possible that in most cases the liquid metal was frozen solid on coming in contact with the sand mould.

It is seen from the results that with each modification the results get better. Thus, by the minimization of the interaction between the flow in the channels and the elimination of fronts of temporary arrest, the error in fluidity value in the 4mm thick strip was reduced from 34.7% to a minimum of 4.0% for the Al-7R% Si alloy. The fluidity also increased from an average of about 370mm to 410mm. the castings made using Al-16%Sialloy, is clearly indicative of the decrease in the interactions between flow in the channels. In the unmodified mould the Al-16%Si alloy, displayed clear indications of fronts of temporary arrest and ripples was observed. However, on casting the alloy in the modified mould, neither a front of temporary arrest nor ripple was observed. The fluidity of the 3mm thick strip also increased from 268mm in the unmodified mould to 419 mm in the modified moulds. Similar increase was obtained in all the channels.

On blocking the 8mm thick channel, so that liquid metal could not flow into it, a respectable degree of reproducibility was attained for Al-4%Si alloy. For each strip, the error was less than 10%. This is quite commendable considering that Al-4%Si alloy is one of the less fluid alloys, and in fluidity testing, alloys with low fluidity tend to have higher error in fluidity. Also, there is the additional advantage of increasing the fluidity length. The fluidity increased from 87 mm in the unmodified mould to 157 mm in the mould that was the final stage of the modified mould.

CONCLUSION

The sand moulded multiple channel straight strip fluidity test mould can be made to produce results with less than 10% error in strips varying in thickness from 4mm to 1mm. this has been achieved by reducing the turbulence and minimizing the interaction of flow in channels. This modification also leads to a general increase in fluidity of the alloys.

REFERENCES

[1] Flemings M.C., Conrad H.F. and Taylor H.F., 1959 'Aluminum alloys fluidity test', TAFS, 67, 496-S07.

[2] Campbell J., 1991, Castings, pub. Butterworth Heinemann. 82-84

[3] Ragone D.V., Adams C.M. and Taylor H.F., 1956, 'Some factors affecting fluidity of metals' TAFS, 64, 640-652.

[4] Clark, K.L., 1945/46, 'Fluidity testing of foundry alloys', Institute of British foundrymen, 39, paper no. B47 A52-A63.

[5] Campbell J., 1994, 'Review of fluidity concepts in casting'., Cast Metals, 7, 55-60.

[6] Kondic V., 1950, 'Effect of liquid metal properties on the casting fluidity of alloys', proceedings of the Institute of British Foundrymen, 43, 152.

[7] Flemimgs M.C., Mollard F.R., and Taylor, H.F., 1961 'Mold variables influence om fluidity of aluminum', TAFS, 69, 566-576.

[8] Kondic V., 1956, 'Fluidity testing developments', Foundry Trade Journal, 100, 31-34.

[9] Tiryakioglu M., Askeland D.R., and Ramsay C.W., 1994, 'Fluidity of A319 and A356: an expjherimental design approach; TAFS, 102, 17-22.

[10] Di Sabatino, M., Syvertsen, F., Arnberg, L. and Nordmark, A., 2005. An improved method for fluidity measurement by gravity casting of spirals in sand moulds. *International Journal of Cast Metals Research*, *18*(1), pp.59-62.

[11] Di Sabatino, M., Arnberg, L., Brusethaug, S. and Apelian, D., 2006. Fluidity evaluation methods for Al–Mg–Si alloys. *International Journal of Cast Metals Research*, *19*(2), pp.94-97.

[12] Colak, M., Kayikci, R. and Dispinar, D., 2015. Influence of different cross sections on fluidity characteristics of A356. *Transactions of the Indian Institute of Metals*, *68*(2), pp.275-281.

[13] Timelli, G. and Caliari, D., 2017. Effect of superheat and oxide inclusions on the fluidity of A356 alloy. In *Materials Science Forum* (Vol. 884, pp. 71-80). Trans Tech Publications Ltd.

[14] Mirzadeh, H. and Niroumand, B., 2009. Fluidity of Al–Si semisolid slurries during rheocasting by a novel process. *Journal of Materials Processing Technology*, *209*(11), pp.4977-4982.

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Table 1: The errors in the average fluidity on subjecting the mould to different modifications.

		AVERAGE FLUIDITY/(cm)						
	Strip Thickness(cm)	5	4	3	2	1	0.5	
Melt no	Alloy composition							MODIFICATION
BS-7-1 to 7-3	Al-7%Si	*45.8	*37.7	*6.9	*2.9	*4.7	*1.2	Unmodified Mould
% Error in Average fluidity		*14.2	*34.7	*11.1	*32.3	*28.7	*3.8	
BS-7-4 to 7-6	Al-7%Si	*50.4	43.9	12.2	5.4	4.7	0.9	Risers Only
% Error in Average fluidity		0	21.1	30.3	40.1	4	44.4	
BS-7-7 to 7-9	Al-7%Si	*48.9	38.8	21.1	11.7	4.6	1	Risers,radiused basin outlet,& plugged sprue-outlet.
% Error in Average fluidity		N/A	0	3.3	4.1	18.8	31.4	Risers,radiused basin outlet,& plugged sprue-outlet,6&5 mm blocked
BS-4-1 to 4-3	Al-4%Si	N/A	27.6	15.7	8	3.6		Risers,radiused basin outlet,& plugged sprue-outlet,6&5 mm blocked,filtered
%Error in Average fluidity		N/A	5.2	7.7	6.1	9.2		

*The fluidity channel was filled in some of the castings.

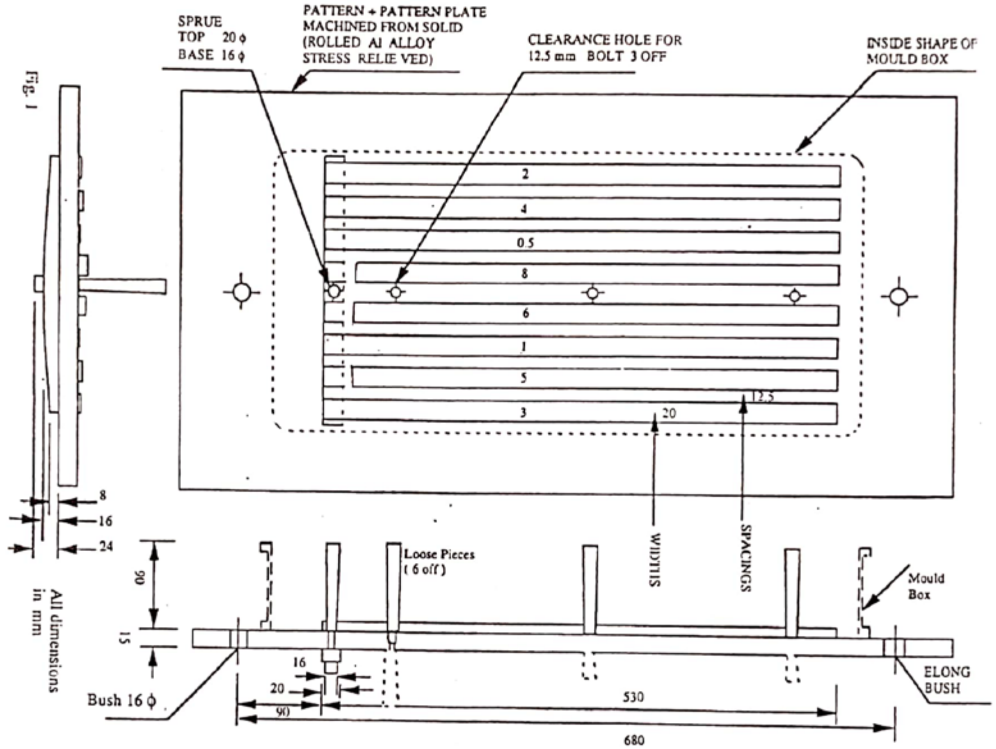

Figure 1: Pattern used to prepare the mold.