Effect of the running system on the filling of thin section castings

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Synopsis
A new cylindrical casting has been designed to test the validity of data obtained with the fluidity strip casting in an earlier part of the collaborative research project on thin section castings. The cylindrical castings have cores of different diameter so that wall thicknesses of 2, 3 or 4 mm can be produced. A variety of running systems can be utilized. This report describes the methodology behind the design and presents some initial results for both grey and ductile iron castings.

First indications are that grey cast irons are relatively insensitive to the running system when making thin sections. However, further work is required using different mould/core combinations, coatings and different CE values to find out whether improved mould filling can be obtained while keeping pouring temperatures as low as possible.

Ductile irons are very sensitive to the running system and only castings of poor quality have so far been obtained. Further work to look at fill rates and surface tension effects is required if high integrity castings are to be produced.

Introduction
There has been increasing demand in recent years for strong, lightweight components in order to save both material and energy. This has led to the development of new casting processes for the production of thin sections iron castings particularly for applications in the automotive sector. Examples include the "FM thin walled casting process" (1, 2, 3) and the "CLA process" (4). However, both of these are low pressure techniques requiring investment in plant and equipment. It was obvious that there was a need for a systematic study of the production of thin section high integrity grey and ductile iron in sand moulds using conventional casting methods. The BCIRA Collaborative Research Programme has been directed towards at least partly fulfilling this need.

The present programme of work at BCIRA is concentrating primarily upon foundry problems associated with the production of thin section iron castings. To date fluidity strip castings have been used to generate data for grey and ductile cast irons in sections from 8 to 0.5 mm. Fluidity lengths have been determined (5) over a range of pouring temperatures using different moulding systems. It was also shown that the effect of pouring temperature on fluidity was less significant in the thinner sections (<3 mm). Thus, it is likely that surface tension effects are more influential than superheat in thin sections.

Attention in the project has now moved towards the application of the fluidity strip data to real castings, commencing with fairly simple shapes.

This report describes work on the development of cylindrical test casting design and reports the initial results obtained.

Test casting design
In recent years much research has been directed towards controlling the way in which molten metal enters the mould, to ensure that it does so in a non-turbulent manner (6, 7). This has always been important in alloys prone to the formation of surface oxide films, such as aluminium alloys and ductile iron, so as to ensure that the films do not become entrapped in the casting where they can be detrimental to properties. However in thin sections it assumes even greater importance because of the need to avoid cold laps and mis-

![Diagram of mould design with different gating orientations](image)

**Fig. 1** Schematic diagram of the mould design with the different gating orientations shown in a to d.
Table 1: Chemical compositions of grey and ductile iron melts

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*C.E. includes 0.195% Si added as metal stream inoculant

runs. Hence it was felt that an understanding of the effect of different running systems in filling thin sections would be of considerable practical importance.

A cored cylindrical test casting (120 mm outside diameter, 230 mm high) was chosen as a suitable casting design. It fulfilled the following requirements:

a) Castings having wall thicknesses in the range 2-4 mm could be made easily by varying the core diameter.
b) The metal flow pattern and degree of filling could be readily assessed.
c) The pattern will enable measurements of dimensional variations to be made.
d) Variables such as metal pouring temperature, chemical composition, mould core material combinations and the effect of different mould/core coatings could all be evaluated, with reference to a well defined base condition.
e) A boxless mould configuration offered the greatest flexibility in terms of the running system whilst remaining relatively simple to assemble.
f) The design enabled the casting to be made in the horizontal or vertical orientations with side, top or bottom filling via a slot gate.
g) It was decided for simplicity to avoid any changes in section size within the testing casting.

Fig. 1 shows a schematic diagram of the mould design with the different gating positions shown in a to d. Different wall thicknesses were obtained by using three different cores of 116, 114 and 112 mm diameter to give 2, 3 and 4 mm wall thicknesses. The core prints were common to each orientation and to each core to improve reproducibility.

The running system was designed to ensure that the speed of metal flow into the mould was always similar and less than 0.5 m/s. A common runner and slot gate design was used and the sprue top and base were always the same. The intention was that the speed of metal flow was controlled by the size of the base of the sprue which would act as a choke. It was anticipated that metal flow speed would be similar for each configuration. An offset pouring basin provided a consistent metal head height (ferrostatic pressure).

Fig. 2: The effect of pouring configuration on the percentage fill of 2mm wall grey iron cylinders.

Fig. 3: The effect of pouring configuration on the percentage fill of 3mm wall grey iron cylinders.
Preliminary casting trials

Initial work has been completed using grey and ductile irons of the same chemical compositions as in the previous work with fluidity strips. Three different wall thicknesses have been cast. An ester cured alkaline phenolic resin bonded sand system has been used with CO₂ hardened sodium silicate bonded sand cores so that the results could be compared with the earlier work. Four grey iron and four ductile iron melts have been carried out, one for each mould configuration. A range of pouring temperatures was used between 1430 and 1300°C. The chemical compositions of the melts are given in Table 1.

Assessment of castings

An initial assessment of the effect of running systems was achieved by a visual examination of the cast cylinders to determine the approximate degree of fill and to detect any macroscopic defects such as cold laps, mis-run etc. In addition, a percentage fill was calculated for each casting.

Results

Grey Irons

In general, the 4 mm wall cylinders were successfully filled even at the lower pouring temperature (1310°C) regardless of gating configuration. The metal had then flowed a distance of 188 mm (circumference) from the in-gate. For the 2 and 3 mm cases, the horizontal bottom gated (HBG) configuration consistently yielded the worst results, with the vertical bottom gated (VGB) configuration next and both top poured systems being about the same, as shown in Figs. 2 and 3. It is likely that the metal temperature as it enters the cylinder will be lower in both the bottom gated systems than in the top run castings since the metal has further to run, and this may explain the poorer results. Some beneficial effect of increasing pouring temperature is apparent in the 2 mm and 3 mm cylinders, as shown in Figs. 2 and 3.

Ductile Irons

The 4 and 3 mm castings were all generally filled at each of the pouring temperatures as shown in Figs. 5 and 6. The horizontally bottom gated (HBG) configuration yielded the worst results in the 2 and 3 mm sections (this is particularly striking in the 3 mm case, Fig. 5). However, in the case of all the ductile iron cylinders, the cylinders were of poor quality even when completely filled. Flow lines were apparent, with evidence of sand burn on and of cold laps associated with oxide films. A detail of one such defect is shown in Fig. 7.

Discussion

There are many foundries that are routinely producing grey and ductile iron castings with wall thicknesses of 4 or 5 mm and published work indicates that engine blocks are consistently being produced with wall thicknesses as low...
as 3.5 mm. It is likely however that these wall thicknesses are not produced over large running distances, but rather are close to areas of heavier section which can provide a source both of heat and of liquid metal to the thinner sections. The present work is aimed therefore at producing thin walled castings which are thin over an appreciable area by conventional low cost moulding and mould filling methods. The use of vacuum or pressure assisted filling has not been considered. The aim has also been to define the minimum pouring temperature which can be used since it is felt that foundries may be using unnecessarily high pouring temperatures which is expensive in energy terms and can also exacerbate problems such as gas defects in castings.

The present work on grey irons has confirmed that 3-4 mm wall castings may be achieved at relatively low pouring temperatures. The actual lower limit of pouring temperature will depend on thickness and could be affected by CE. This is being further examined.

However, for a grey iron with a CE of 4.05 a full 3 mm casting was poured at a temperature of 1360°C. Full 4 mm castings were consistently produced at a pouring temperature of 1320°C.

The work completed to date on the ductile iron cylinders has demonstrated that much more attention will need to be focused on control of the mould filling if high integrity castings are to be produced. The fill rate will need to be controlled in order to find a balance between overcoming the surface tension forces that will resist filling of the mould whilst maintaining a laminar front to the liquid metal (i.e. no surface turbulence). It may be that the use of coatings to alter the wetting between the molten metal and the mould walls will be useful here.

Future work

In the case of grey irons work will concentrate upon improving the integrity of the 2 and 3 mm wall castings at lower pouring temperatures through the use of coatings, different mould and core combinations and through mould venting.

Improvements in the quality of the ductile iron cylinders will require increased control of fill rates in the mould cavity through the running system design. In addition the use of coatings to alter wettability will be studied.

One of the main problems that foundries producing thin wall castings face is control over dimensional accuracy. Problems associated with consistent core placement are common. Although work in this area does not form part of the present programme, different mould and core materials will be used which will begin to generate data about attainable dimensional consistencies in sand moulds.

In addition, work to assess the effect of carbon equivalent on fluidity in thin sections will be reported shortly. This work will be complementary to that carried out by Evans and is aimed at establishing whether the same principals apply in very thin sections as Evans found in the fluidity spiral.

Practical implications

1. Initial results obtained using the cylinder casting design indicate that grey irons are relatively insensitive to running systems. The ductile iron cylinders cast were consistently of poorer quality compared with the grey iron ones and contained cold laps and oxide film defects. Much more attention will need to be paid to the flow of the metal into the mould if good quality thin wall ductile iron castings are to be produced.

2. The earlier work on fluidity strips has been confirmed since flow distances of 188 mm have been achieved in 4 mm sections in both grey and ductile irons at a pouring temperature of 1320°C.

3. The pattern for a thin walled cylinder (2 to 4 mm) will enable the effect of variables such as pouring temperature, composition, mould/core combinations, and mould coatings to be assessed in a systematic manner.

References


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March 1995 BCIRA TECHNOLOGY