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Effect of Shape Variation on Feeding Efficiency for Local Exothermic-Insulating Sleeve

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Abstract. Exothermic- insulating sleeves are used to increase the yield in foundry practice. Function of the sleeve is predominant to enhance the effective casting modulus by increasing feeding efficiency. This is represented by a modulus extension factor (MEF) and shrinkage porosity of the casting. The use of an exothermic - insulating sleeve as a substitute for sand feeder can increase efficiency by up to 60%. However, exothermic-insulating sleeve in use today is imported and has limited range of shapes and sizes so that the cast steel products is limited. The research is intended to produce a variety of shapes and know about the effect of that to casting yield of C8000 cast steel. For this research the exothermic-insulating sleeve make use local and imported resource material. The research starts with the study of shape variations which are widely applied. The constant modulus will be used as a basic for the further design of the sleeve. Molten metal is poured for trials with and without the test sample (the casting) which is followed by feeder cooling rate measurement to find the value of modulus extension factor (MEF). To analyze the effect of efficiency other testing plate test is applied involving shrinkage cavity visual testing, and yield calculations. These results show that the dome - shape performed the best efficiency in the holding time, temperature above the solidus temperature (above 1360 °C) for 360 second, the shape of the cavity shrinkage apparently, highest MEF (2,02 times larger than sand riser), 90% in yield. These results which performed was accepted for exothermic-insulating properties of Indian standard.

INTRODUCTION

Feeding efficiency also called volumetric feed efficiency defined as volume of metal fed to the casting divided by the casting volume [1]. There are several factors which affecting these efficiency. First is the using of sleeve, Feedersleeves are a well-established tool in the steel foundry industry for minimizing feeder size, and hence minimizing the volume of metal melted and poured [2]. By evaluating the effect to the solidification time, the exothermic-insulating become the most effective caused by the lower net heat loss relative with exothermic and also insulating sleeve.

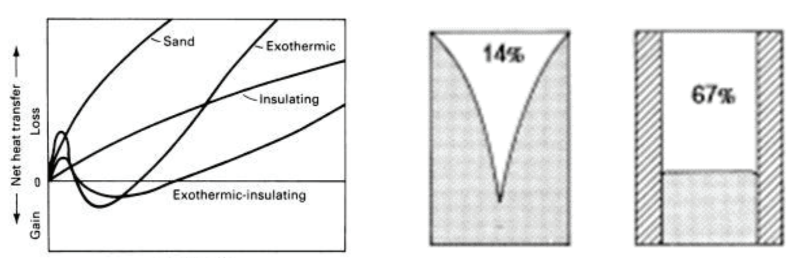

FIGURE 1. Net heat loss from a variety of feeder and effect from sleeve using to increase the efficiency

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Second is the effect of the shape, chwrorinov rules said that despite local variations in the rate of freezing, the influence of casting geometry is chiefly of importance in determining the overall solidification time. Once this is known, feeder heads can be designed to maintain the supply of feed metal throughout freezing. The ideal is to be able to predict the solidification time irrespective of the shape of the casting. A notable step in this direction was taken with the discovery of the Chworinov Rule, which postulates that the total freezing time of any casting is a direct function of the ratio of its volume to its surface area (V/A). The overall solidification time for a given volume of metal is thus found to be greatest when the ratio V/A is a maximum, i.e. in the case of a sphere, becoming progressively less for cylinders, bars and plates. Determination of the V/A ratio or of some analogous factor can thus be applied to the estimation of relative freezing times of feeder heads and the casting sections they are intended to feed, as well as giving guidance as to the best shape for a feeder head. It is the Chworinov rule which provides the basis for those later approaches to the feeding problem which use a shape factor or ‘modulus’ as the criterion of total freezing time [3].

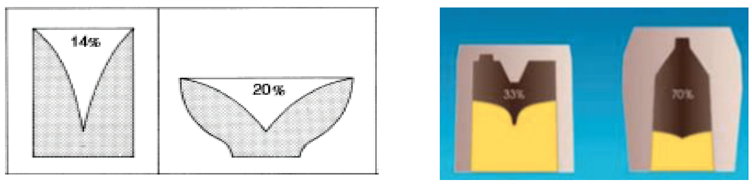


FIGURE 2. Effect of shape variation to feeder efficiency

By kind of these reasons this experiment will investigate the optimum efficiency between a dome shape and cylinders as exothermic-insulating shape and sand riser, involving value of Modulus Extension Factor (MEF), and finally casting yield (%) as standardized by Indian standard.

EXPERIMENTAL SETUP

There are several testing, which has to do for investigating the feeder efficiency involving plate test and solidification test. The efficiency also called volumetric feed efficiency obtained by calculating percent feed metal supplied to the casting relative to a sand feeder [4]. Another test which required for determining the effect of exothermic-insulating shaped variation as chworinov said is solidification test. This test should be done to know the value of modulus extension factor (MEF).

FIGURE 3. Kind of test which should be taken by exothermic-insulating sleeve (Indian standard)

Shape and modulus

The dome shape/H-sleeve ($Ø_1$ 39 mm, $Ø_2$ 60 mm × h= 67,93 mm) and cylinders shape/H-sleeve (Ø54 mm × h= 84 mm) taken from literature [5] have a same modulus which is 1 cm and 15 mm in thickness . The value of the modulus is calculated by mathematical and simulated by using solid cast 8.4 simulator. Moreover the value of thickness also taken from other experiment which done by foseco.

FIGURE 4. Dome feeder (a), dome *sleeve* (b), cylinders feeder (c) and cylinders sleeve (d)

Casting material

Creusabro steel which also called C8000 become a material for determining feeding efficiency. C8000 is low alloy carbon steel which has liquidus temperature about (1480-1500)°C and about (1360-1440) °C of solidus temperature based on the CE value. In additional C8000 categorized as short freezing range [6]. As a short freezing range material, in the solidification process, the dendrite length will be directly proportional to the equilibrium freezing range and inversely proportional to the average temperature gradient in the two-phase region. In simple term a chance for getting a sound casting is easier than other alloy which categorized as long freezing ranges.

Solidification test

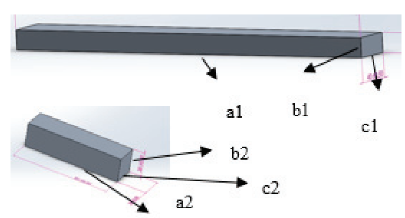
As told before solidification test should be taken in identifying the MEF value of the *sleeve*. The test will be taken in feeder cavity which have been set with thermocouple detector to record the solidification time which shown by thermal gradient per second. The minimum value of MEF is 1,60 for exothermic-insulating sleeve which have up to 150 mm in diameter [7].

Plate test

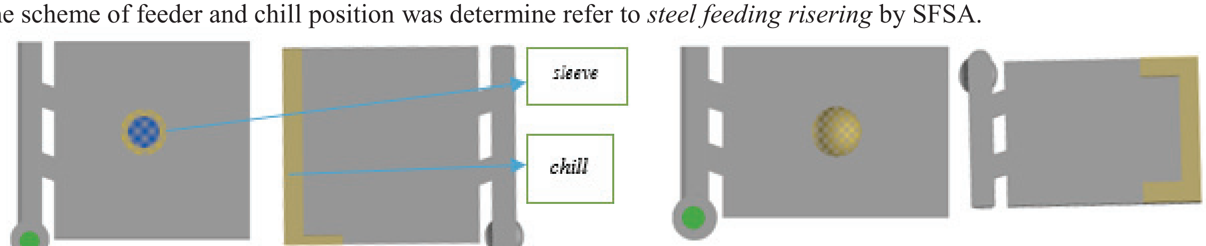
Assuming the shrinkage total is 4,5%, The plate test dimension is 400x400x22 mm for cylinder sleeve and cylinder sand feeder, dome-sleeve have 400x300x22 mm in dimension. Will be kept in constant condition:

Chill material : St 37
Chill thickness : 20 mm
Hydraulic height (mould height) : 200 mm
Mould : greensand
Pouring temperature : 1600 °C± 50° C
Feeder top cover : 7 mm silica sand cover

shape	Dimension (mm)					
	a1	a2	b1	b2	c1	c2
H-sleeve	400	100	20	20	40	20
Dome sleeve	300	80	20	20	40	20



The scheme of feeder and chill position was determine refer to *steel feeding risering* by SFSA.



a b

FIGURE 5. Plate test casting design for cylinders sleeve and cylinders feeder (a) and for dome sleeve (b)

RESULT AND DISCUSSION

SOLIDIFICATION PROCESS

Temperature Gradient

The solidification process taken in these conditions :

TABLE 1. Actual C8000 composition

C	Si	Mn	Cr
0,27	0,81	0,829	0,98
Mo	S	Ni	P
0,202	0,003	0,30	0,01

Pouring temperature (°C) : 1628
Pouring time (second) : 11

The effect of shape variation to temperature gradients in solidification process have been shown below :

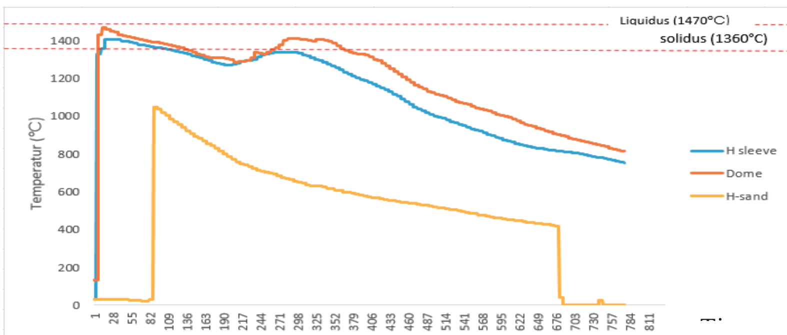


FIGURE 6. Temperature gradients from several feeder in same solidification process

Based on fig. 4, the graphic can give other specific information about thermal properties.

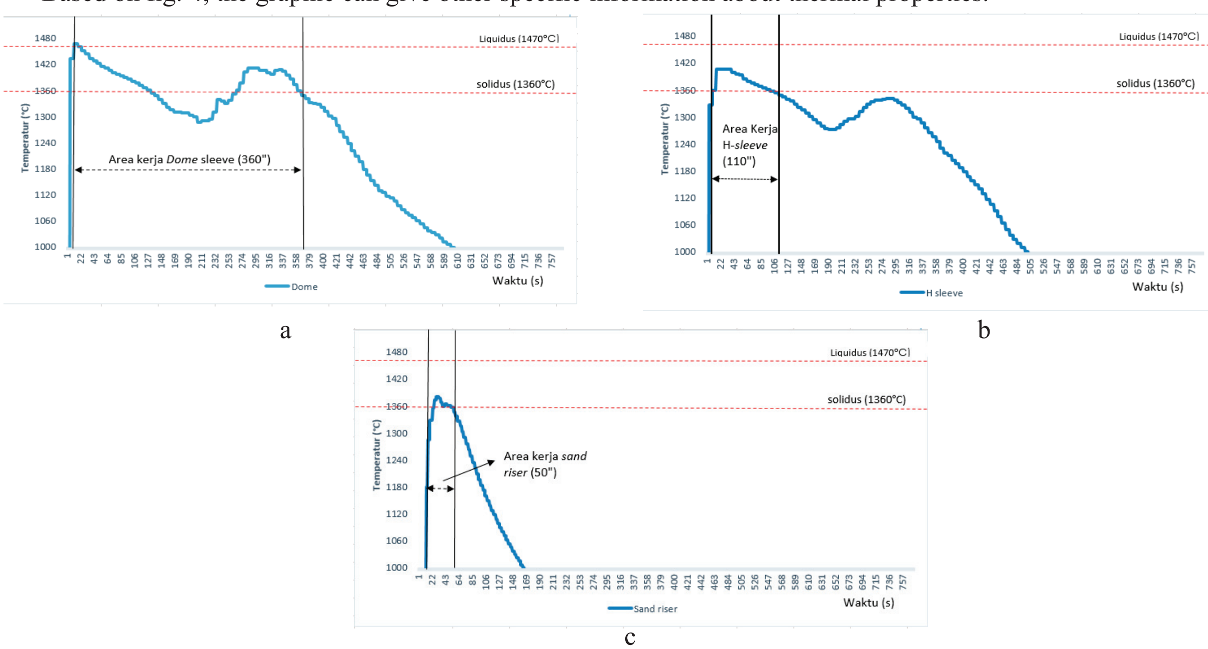


FIGURE 7. Cooling rate and effect from dome-sleeve (a), h-sleeve (b), and sand feeder (c) to hold temperature.

Dome-sleeve can make molten metal held at a working area (above 1360°C) as long as 360 second, better than H-sleeve which can be held as long as 110 second, and sand riser which just hold as long as 50 second. These phenomena come because several factors. First is surface area. With the constant modulus, The surface area of dome sleeve is smaller than cylinder sleeve, it’s meant the solidification from dome sleeve will longer than cylinder relative to the higher modulus. Second is the surface cover condition. All of the surface of dome shape which covered by sleeve can minimize the heat loss from metal when the solidification process happened. Hence the solidification time from dome-sleeve will longer than cylinder sleeve.

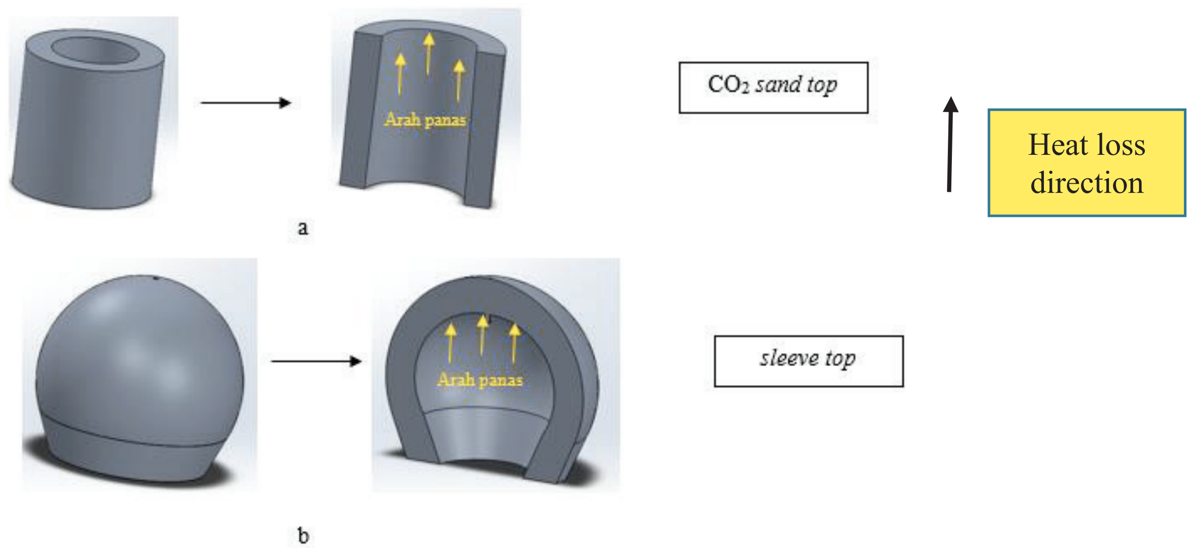


FIGURE 8. Illustrations about correlation between top condition to heat loss

Modulus extension factor (MEF)

The value of MEF is determined from solidification time sand feeder module/sleeve feeder module, the result from the solidification time is below :

$$\text{MEF H-}\textit{sleeve} = \frac{Modul\ Sand\ Riser}{Modul\ \text{H}-sleeve} = \frac{1.77}{1.07} = \mathbf{1.63}$$

$$\text{MEF } \textit{Dome-sleeve} = \frac{Modul\ Sand\ Riser}{Modul\ Dome-sleeve} = \frac{1{,}78}{0{,}88} = \mathbf{2{,}02}$$

Based on that result, showing that MEF parallel with temperature gradient and proved that shape have an effect on how to increase solidification time by increasing MEF value.

PLATE TEST

Shrinkage appearance

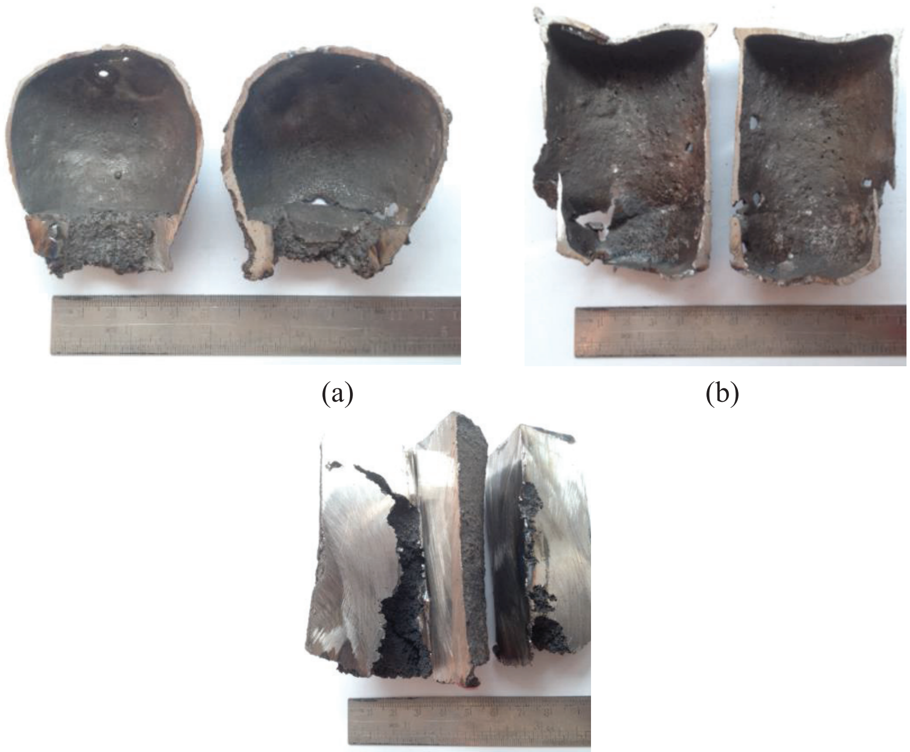
TABLE 2. Actual C8000 composition

C	Si	Mn	Cr
0,27	0,94	0,93	1,05
Mo	S	Ni	P
0,09	0,007	0,30	0,01

Pouring temperature (°C) : 1568 (H-sand), 1567 (dome sleeve)

Pouring time (second) : 11 (H-sleeve), 10 (H-sand) 9 (dome sleeve)

The result showed that the dome-sleeve and H-sleeve have the better feeding than sand riser, showing by the shrinkage appearance which smooth (columnar zone), different with sand riser which have equiaxed zone in the center of the feeder (dendritic). The condition happen caused by the sleeve effect which can make the liquid metal prevent to be solid quickly. So the feeding process going to be effective.



(a) (b)

(c)

FIGURE 9. Shrinkage appearance at the feeder from the plate test result

Casting yield/volumetric feeding efficiency

By looking the shrinkage appearance data, it simpler to says that the dome sleeve and H-sleeve/cylinder sleeve will have greater efficiency than sand riser. The result of the casting yield is below:

TABLE 3. efficiency data

feeder type	theoritical feeder weight (kg)	Actual feeder weight (kg)	effieciency (%)
H	1,67	0,206	88
H sand riser	1,67	1.347	19
dome	1,13	0,109	90

Dome-sleeve have a greater efficiency than H-sleeve, it's parallel with the solidification time result involving the MEF value and holding effect.

CONCLUSION

The exothermic-insulating shape variation gives an effect to the feeding efficiency caused by the modulus extension factor value, holding temperature effect and also heat transfer from each shape. The effect obtained from the solidification testing and plate testing. Showing that with the constant modulus and thickness the dome sleeve Dome-sleeve can make molten metal held at working area (above 1360°C) as long as 360 second, better than H-sleeve which can be held as long as 110 second, and *sand riser* which just hold as long as 50 second, greater MEF with 2,02 than 1,63 cylinder MEF which also accepted Indian standard minimum MEF. The final effect is shown with the efficiency testing by using plate testing, the yield is increased until 90% by dome sleeve, greater than cylinder sleeve which have 88% and sand riser which only 19%.

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