Study of Heat Transfer Phenomenon in the Ladle for Reduction of Skull

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***Abstract*— A ladle is a component used for carrying the molten metal in the casting process. The basic ladle design can therefore include many variations that improve the usage of the ladle for specific tasks. This study is concerned to minimize heat loss of the ladle for reduction of skull and analysis the effect on heat transfer and skull formation of insulating material. This study is concerned to minimize heat loss of the ladle for reduction of skull and analysis the effect on heat transfer and skull formation of insulating material.**

Keywords— ladle; skull; insulating material;skull formation

I. INTRODUCTION

Ladle is used for transfer molten metal to one place to another. In industries casting ladle, transfer ladle and treatment ladle are used. Common shape of the ladle is vertical cone shape but other shape is available due to the requirement of industries. Ladle size is depending upon the capacity of the molten metal. When molten metal enter in the ladle the temperature is more than 1200°C. Ladle directly contact with ambient temperature so due to this temperature variation heat transfer takes place. Temperature of molten metal is reduced due to heat transfer. When the temperature drop occurs in the ladle solidified material produced inside boundary of ladle. This solidified material is called skull. Skull formation is low if heat transfer in the ladle is minimum. Insulation material is provided at outside surface of the ladle to reduce the skull formation. Insulation material is use to minimize the heat transfer through walls. Three different high insulation materials are studied to minimize the skull formation in the ladle. Molten metal temperature is very high so high temperature insulation material used. In this paper it focused on ceramic fiber, felt insulation and fiber paper insulations material. The effect of skull formation on this insulations material was studied. Generally ladle material is graphite and insulation is provided at outside surface of the ladle. Skull formation occurs in the ladle is shown in figure.

Fig. 1. Skullformation in the ladle

1.1 Ceramic fiber insulation

Ceramic fiber is manufactured by blending and melting alumina and silica at temperature of 1800-2000°C.Main advantages of ceramic fiber insulation is given below. Light weight; lower heat storage; thermal shock resistance; low installation cost; low maintenance cost; high temperature stability up to 1400°C. Different density of ceramic fiber is available due to the requirement of process.

TABLE I THERMAL PROPERTY OF CERAMIC FIBER INSULATION

Density	96 kg/m^3
Thermal conductivity at 400 °C	0.125 W/m K
Thermal conductivity at 600 °C	0.14 W/m K
Specific heat at 200 °C	980 J/ kg K

1.2 Felt insulation

Felt insulation designed for resistance. Felt insulation is high temperature insulation. It has high temperature stability up to 1300 °C. Thermal property of felt insulation is given below

TABLE II THERMAL PROPERTY OF FELT INSULATION

Density	96 kg/ m^3
Specific heat at 200 °C	1480 J /kg K
Specific heat at 600 °C	1540 J /kg K
Thermal conductivity at 200 °C	0.12 W/m K
Thermal conductivity at 600 °C	0.19 W/ m K

1.3 Fiber paper insulation

Fiber paper insulation is manufactured by using non woven technology. It has high uniform structure and low heat storage capacity. The main advantages of fiber paper

insulation are high temperature stability up to 1260°C; low heat storage; light weight; resiliency; thermal shock resistance; easy to wrap and cut; contains no asbestos; flexibility in use. Fiber paper insulation used in ladle & tundish insulation; thermal & electrical insulation; expansion joint packing; piping and asbestos paper replacement.

TABLE III. THERMAL PROPERTY OF FIBER PAPER INSULATION

Density	96 kg/m^3
Specific heat at 1093°C	1130 J /kg C
Thermal conductivity at 200°C	0.06 W/m K
Thermal conductivity at 400°C	0.10 W/m K

II. MATERIALS AND METHODS

2.1 Modeling of ladle

i. Draw the ladle geometry

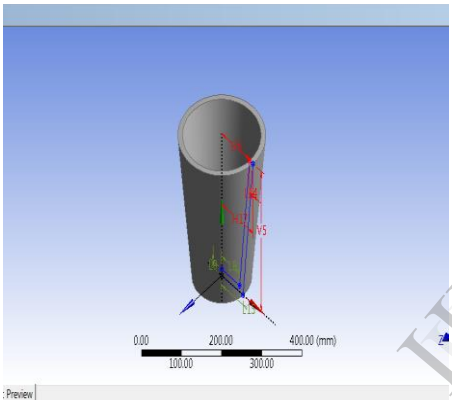

Fig 2. Modeling of ladle

ii. Add cast iron property and initial temperature

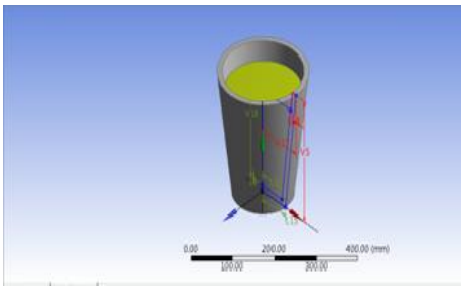

Fig 3. Add material property in the ladle geometry

iii. Generate mesh

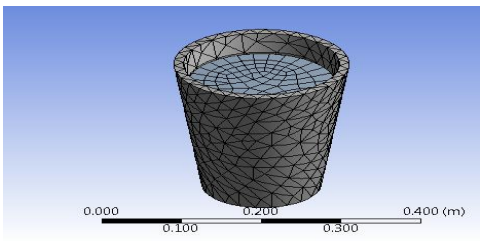

Fig 4 Mesh generation

iv. Apply boundary and solve the problem.

v. Compare with insulation and without insulation result.

2.2 Grid independence test

Grid independence test is use for compare the best result and selecting the element size of node. Simulation work begins with mesh generation so , here change in mesh element size and check the temperature difference with default mesh size.

TABLE IV. THERMAL PROPERTY OF FIBER PAPER INSULATION

Element size	Nodes	Elements	Temperature
5	583619	213859	1174.5
7	240043	83238	1174.5
9	122254	44490	1174.4

III. RESULTS AND DISCUSSIONS

When the molten cast iron metal enters into the ladle at that time temperature of the cast iron is 1250°C. Skull is produce below 1200°C in the ladle. Skull formation in without insulation and with insulation after 120 second is given below.

3.1 Ceramic fiber insulation result

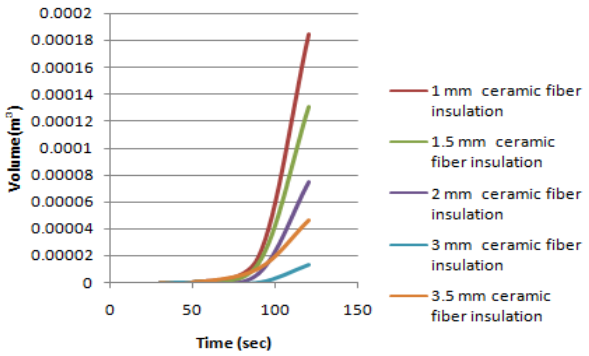

Fig 5 skull in ceramic fiber insulation

Figure 5 compare the skull formation in different ceramic fiber insulation material thickness. It is seen that maximum skull produced in 1 mm ceramic fiber insulation and minimum skull produced in 3 mm insulation thickness. Skull formation in the ladle increased after 3 mm thickness of insulation. Skull produced in the ladle at 3.5 mm insulation thickness lower than 2 mm insulation thickness. Skull volume increased with respect to time.

3.2 Felt insulation result

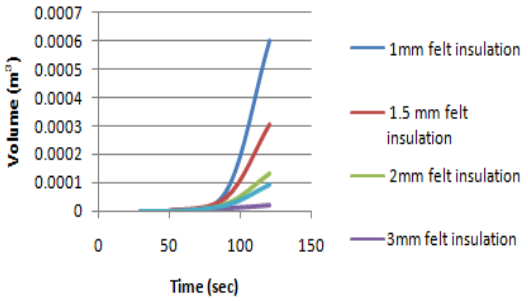

Fig 6 skull in felt insulation

Figure 6 shows the skull formation in the ladle while using felt insulation. Skull formation in the ladle increased after 3 mm thickness of insulation.

3.3 Fiber paper insulation result

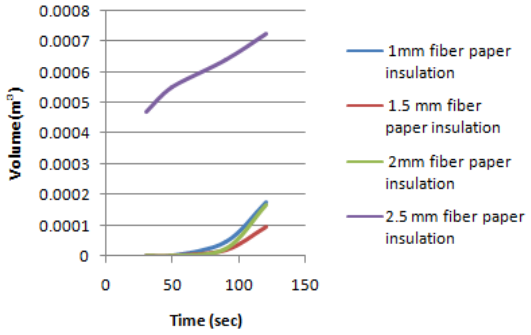

Fig 7 skull in fiber paper insulation

In figure 7 shown skull formation in the fiber paper insulation. When the ladle transfer time is 30 second and 50 second skull was produced. Minimum skull produced at 1.5 mm thickness of finer paper insulation. Skull formation in the ladle increased after 1.5 mm fiber paper insulation.

IV. CONCLUSION

Skull was produced after 30 second in without insulation of ladle. Skull was not produced up to 50 second in insulation ladle. Three insulation materials were compared to analysis the skull formation. Maximum skull was produced in 1.5 mm fiber paper insulation after 120 second. Minimum skull was produced in 3 mm ceramic fiber insulation after 120 second. Skull formation in 3 mm ceramic fiber insulation was 65% less than 1.5 mm fiber paper insulation. Skull formation in 3 mm felt insulation was 8 % less than 1.5 mm fiber paper insulation.

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