CFD Simulation of a Continuous Casting Process for EN19 Billet in application of reduction in Shrinkage Porosity

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Abstract

The objective of this paper is to find an optimum temperature range in which no shrinkage porosity is found in continuous casting of EN19 made of billet. Billet is one of the most important components in application of making TMT bar, Connecting rod. The current rejection rate due to shrinkage porosity is 1.58 %. So, process parameters affecting Shrinkage Porosity were identified. Other parameters affecting were also discussed in detail in so, in order to achieve the required objective of minimizing Shrinkage Porosity, simulation of temperature at which billet is manufactured (the most affecting parameter for Shrinkage Porosity defect) is done using ANSYS FLUENT software, which is a powerful tool for analyzing material flow. The validation of the simulated range will be taken and experimented in the industry.

Keywords: Continuous Casting, Continuous Casting Defect, Shrinkage Porosity, Simulation, ANSYS FLUENT, CFD

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1. INTRODUCTION :

In continuous casting process the hot liquid metal from ladle is poured into the tundish and from the tundish the liquid metal goes into the mould through the SEN, the first solidification starts in the mould at the metal/mould interface and from there the semi-solid material goes into the caster and with different cooling condition and rolling operations finally the liquid material is solidified and cut into different shapes such as blooms, billets. The Continuous Casting process starts from the tundish till the final solidified material is obtained and as the liquid metal is fed continuously from the tundish so it is called continuous casting process and is mainly used for casting the steel material.

Prior to the introduction of continuous casting in the 1950s, steel was poured into stationary molds to form ingots. Since then, "continuous casting" has evolved to achieve improved yield, quality, productivity and cost efficiency. It allows lower-cost production of metal sections with better quality, due to the inherently lower costs of continuous, standardized production of a product, as well as providing increased control over the process through automation.[24]

Classification of Continuous Casting:

The two type of casting machines used for continuous and semi continuous castings are:

a) ***Horizontal Continuous Casting****:* In this type of continuous casting, these are widely used for manufacture of copper based alloys, especially higher diameter rods, strips & tubes.

Advantages: The main advantage of horizontal process is high value of production for higher size of rods, strips & tubes homogeneity of alloying elements and large dendritic grain structure. Fast die change, Lower cost, ease of operation.

Disadvantages: Higher diameter rod, billets, slab is not possible due to complexity of machine.[25]

b) Vertical Continuous Casting: in this type of continuous casting machine for casting in the shape of rods, strips & tubes directly from molten metal by mold and gravity continuous product manufacture.

Advantages: Very high production rates with mechanical properties are improved; friction is very less between die surface and work piece due to self-gravity of molten metal, Vertical Continuous casting machines are best suited for Wire rod industry for casting copper rod or copper alloy rod.

Disadvantages: Large space requirement for setup, cost of product higher.[25]

2. MATERIAL SPECIFICATION :

The material used in forging of connecting rod is EN19 (DIN-42CrMo4)

	Elements (%)	**Lower limit**	**Higher limit**
Constituents of EN19	C	0.38	0.45
	Mn	0.5	0.8
	Si	0.15	0.35
	Cr	0.9	1.2
	Mo	0.15	0.25
	S	-	0.035
	P	-	0.035
	Hardness (BHN)	260	300
	Tensile strength (N/mm^2)	865	1005

Table 1: Material Specification [26]

3. NUMERICAL SIMULATION USING ANSYS FLUENT:

ANSYS FLUENT is a Computational Flow Dynamics (CFD) based process simulation system designed to analyse for flow of molten metal and temperature of operation. It is also used dynamic analysis. It will be useful to know about the flow of molten metal in mould after simulation.

In this paper, the casting problem of Shrinkage Porosity which occurs a lot in billets manufacturing is analysed and an optimum temp range is found at which continuous casting of work piece may give completely filled cavity. The material used is as said above EN19.

3.1 A 2D model of the tundish & mould of continuous casting process by ANSYS Design Modeler:

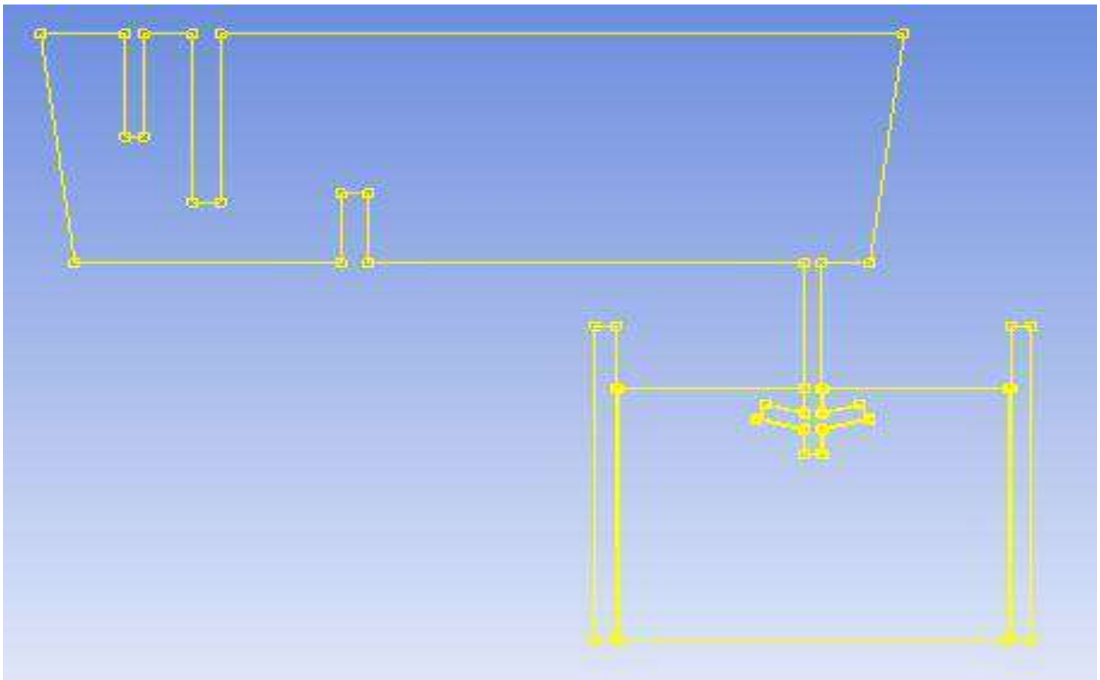


Figure 1: 2D sketch of tundish with mold in continuous casting machine

3.2 Preprocessor steps :

The geometry of tundish and mould in ANSYS Design Modeler are uploaded into ANSYS FLUENT in form of .agdb these input parameters include the material of the tundish, object meshing, temperature range, friction-coefficient, positioning of work piece etc.

The input Parameters and Boundary Condition parameters used are as follows:

Solver	Pressure Based
Time	**Steady and Transient**
Turbulent Model	**Standard k- ε model**
Material	**Liquid steel**
Operating pressure	**101325 pa**

Solid density	7400 kg/m3
Liquid density	7,000 kg/m3
Viscosity	0.005 kg/(m.s)
Solid conductivity	35 W/(K.m)
Liquid conductivity	42 (W/(K.m)
Specific heat	686 J/(kg.K)
Latent heat	271,000 J/kg
Solidus temperature	1703 K
Liquidus temperature	1743 K

Table 1: input Parameters and Boundary Condition parameters

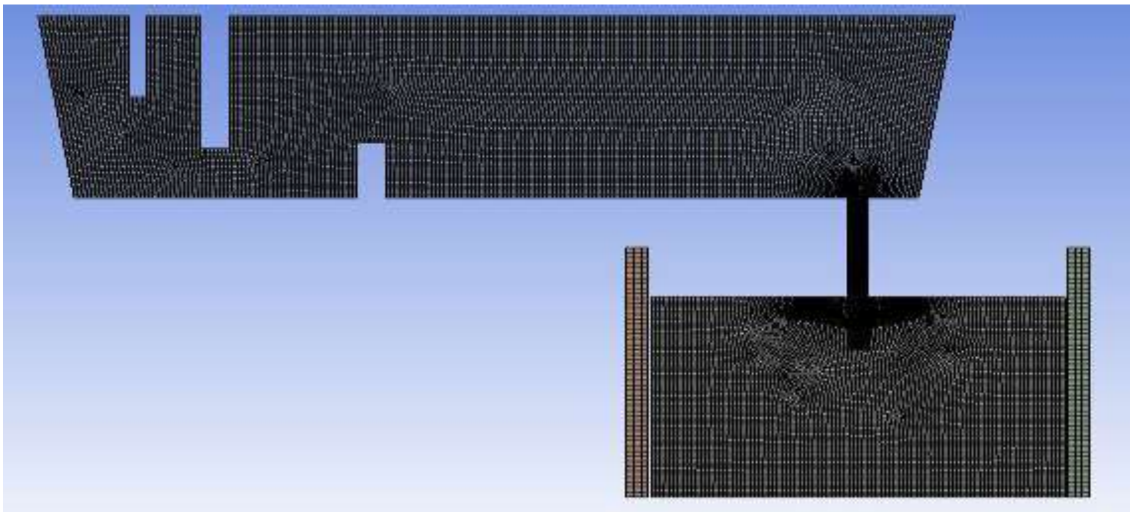


Figure 2: Meshing of geometry

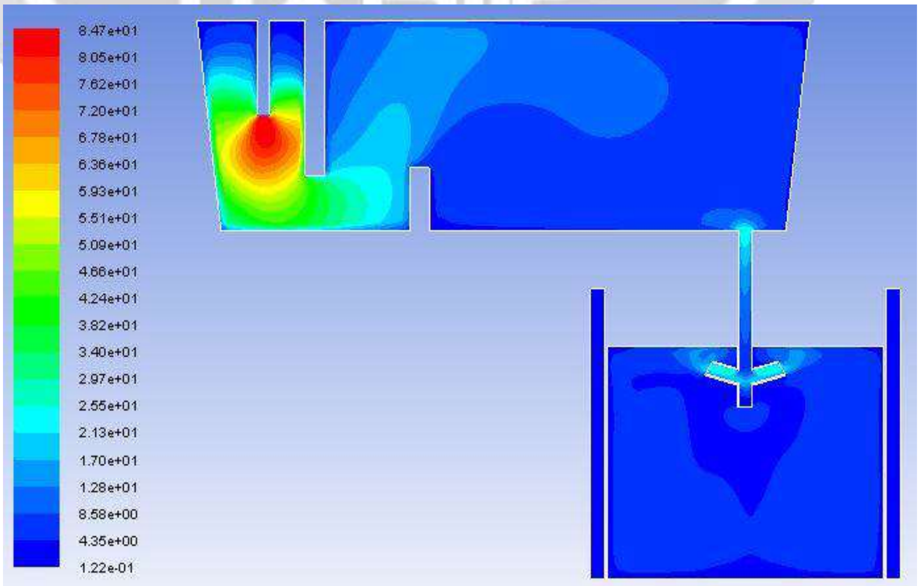
3.3 Simulator steps :

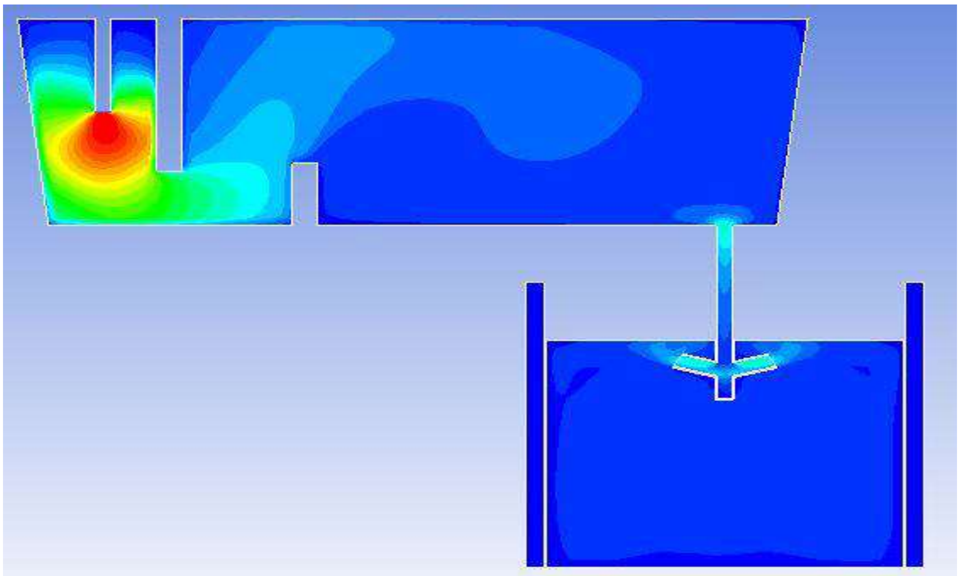
After the meshing is completed the model is imported to FLUENT software and firstly the mesh and mesh quality were checked and if the meshing is not good then error will be shown and simulation will not be access further.

3.4 Post-Processor :

The results of the simulation are seen in the post-processor along with some other options as well. Even animation of all steps combined as full process can be seen.

4. RESULTS AND DISCUSSION :





The dam and weir reduces the turbulent intensity near the SEN area which can been seen from the above figure.

Slag is entering in the mould region and from the literature review study (10-15) % inclusion can be removed from the mould by using the casting powder which is sprayed on the mold which attracts the slag.

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Cases	Time
Without dam and weir	31 sec
With curve dam and weir	68 sec
With rectangular dam and weir	120 sec

Table 2: RTD for different Cases

5. EXPERIMENT FOR VALIDATION OF SIMULATION RESULT

After finding the temperature range from the simulation, validation is necessary for the results so 15 experiments at different 15 temperatures has to be carried out.

Step 1:- molten metal poured into mold 100 x 100 mm with tundish shroud.

Step 2:- Melting of molten metal into induction furnace continuous casting temperature ranges i.e. from 1510°C-1550°C and approx. 15 different ranges of temperature.

Step 4:- Visual Inspection and Ultrasonic Inspection is carried out after completion of billet manufacturing.

Temperature (^{0}C)	Output (after Inspection)
1510	No Shrinkage Porosity Found
1513	No Shrinkage Porosity Found
1516	No Shrinkage Porosity Found
1518	No Shrinkage Porosity Found
1520	No Shrinkage Porosity Found
1523	No Shrinkage Porosity Found
1526	No Shrinkage Porosity Found
1528	No Shrinkage Porosity Found
1530	No Shrinkage Porosity Found
1533	No Shrinkage Porosity Found
1536	No Shrinkage Porosity Found
1538	No Shrinkage Porosity Found
1540	No Shrinkage Porosity Found
1543	No Shrinkage Porosity Found
1550	No Shrinkage Porosity Found

6. CONCLUSION :

A computational fluid dynamic (CFD) study is conceded on the continuous casting process to achieve the desired objective. A Standard turbulent *k*- model is used for the CFD analysis. In this simulation, a tundish with and without the rectangular and a curve dam and weir. Critical temperature range of molten metal in 1510^{0}C-1550^{0}C with no shrinkage porosity. When casting speed increases solidification time of casting is lower so, practice of industry casting speed nearer to 1.2m/s.

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