Numerical simulation of centrifugal casting of pipes

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Abstract: -

In the centrifugal casting process the numerical model has been developed by the commercial simulation package flow 3D. The mass energy & momentum equation and free surface tracking taken additionally for the fast radial and slower horizontal moment of mould. The metal inflow is not steady state but time dependent also. The friction between mould & liquid taken special consideration with viscosity & turbulence of molten metal.

Using a high speed camera a experiments has been carried out with mould at controlled rotational speed the friction coefficient were obtained from above experiments for description between mould and molten metal were obtained. From the simulation model the influence of typical parameter such as melt inflow, mould movement melt temperature & cooling media.

On the wall thickness of casted pipe can be studies. A comparison between simulation result and actual process has been carried out.

Keywords*- Centrifugal Casting, simulation, molten metal*

Introduction: -

The iron water pipes and pipes for deep foundation are generally produced using horizontal centrifugal casting. In this process molten metal filled through open channel into fast rotating mould that is lightly tilted. The mould is water cooled at outside and cooling system in this process centrally distributed in a controlled movement. The simulation of the centrifugal casting is quite challenging & no description of its numerical simulation was found in literature. Some research paper describes the less complex vertical centrifugal casting process. The following phenomenon cannot be described for horizontal casting process besides mass energy momentum and surface tracking such as

- **(i)** Fast radial movement of mould
- **(ii)** Relatively slow but time dependent movement of mould in axial direction
- **(iii)** Time dependent inflow of iron along the channel

(iv) Friction between liquid and mould

(v) Turbulence and viscosity of molten metal cause's unfavourable relation between relatively thin wall thickness of tube & its overall length hindered the situation.

Hence it is possible to develop a valid model with 3D after overcoming instabilities and difficulties. In this work the basic principal of solution method is described and practical experiments are presented.

Simulation model: -

In the geometry of the model the mould is from tool steel and closing is formed cold box bounded silica sand and both parts are spinning and moving. The channel is fixed and open feeding channel is extended into the mould. Due to the significant heat from the outer side of the mould is water cooled and inner side contain air which has no heat loss.

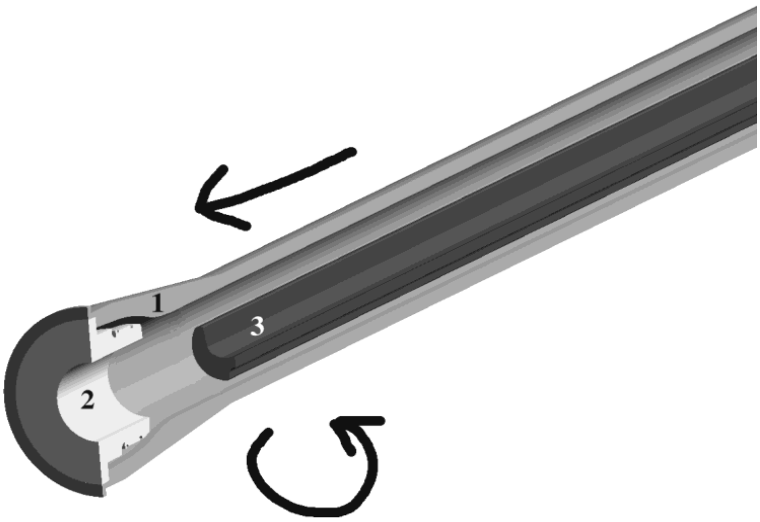

Figure-1 Vertical cut through the geometry of the model

The core of mould are cylindrical and most of the time for cylindrical coordinate system the melt flows the inner surface of the mould. The most of the unfavourable flow between neighbouring cells under 45 degree angles is avoided in comparisons with Cartesian coordinate system. The cylindrical mass is aligned to the mould for better computation is lightly tilted. Due to this the gravity vector also tilted in the axial direction and splits in two components. Due to cylindrical mesh so called non inertial reference frame model the 3D flow has to be induced that able to define the gravity vector.

The general moving model of 3D flow is used to describe the relatively slow but time dependent movement of mould. According to predefined motion the model shifted the assigned obstacles such as mould and core. In the conservation equation the additional source term according to loss of mass, momentum and energy are added at the mesh cell. This approach is not suitable for relatively fast spinning of mould and core due to time step increasing smaller with increasing speed. The Ospin model of software package flow 3D was used for rotational moment of mould & core.

Experiments: -

An electrical engine drives a horizontal cylindrical mould at a finely controlled revolution speed in the experimental setup. Constant speed or an angular velocity ramp at constant acceleration is provided by the control. A 300 mm section of an original 5 metre hot-work tool-steel mould with its original inner surface was used for the experiments. The sample mould features two covers on the front and back, one of which is transparent to allow viewing of the fluid inside.

Figure-2. Experimental setup for the spinning experiments

The experiments involved two different fluids: coloured water at room temperature and Rose's alloy (Bi, 50 wt-%; Pb, 25 wt-%; Sn, 25 wt-%; Sn, 25 wt-%; Sn, 25 wt-%; Sn, 25 wt-%; Sn, 25 wt-%; Sn, 25 wt-%; Sn, 25 wt-%; Sn, 25 A high-speed digital camera was used to photograph the behaviour of the fluid at varied revolution speeds and varying acceleration ramps from the front at 600 frames per second.

The interface point in the figure is denoted by red arrows because the contrast of high-speed movies is low in principle and significantly worse in a printed paper. During acceleration, the metal goes through three phases (i) it forms a wedge-shaped surface along the cylinder (ii) the free surface decays and a curtain forms (iii) when the angular velocity is high enough, the looping condition is satisfied, the curtain vanishes, and the metal becomes stable along the mould's inner surface. This behaviour is mostly determined by the melt's viscosity and the mould's surface state. Figure 4 depicts two simulations with variable surface roughness; in one, the melt is unstable and produces a curtain, while in the other, the melt spins steadily.

In a second experiment, the engine and gear system were spun at a 90-degree angle to use a section of the mould as a turntable. Instead of Rose's alloy, liquid cast iron could be used in this configuration. Meaningful input parameters for the simulation of certain industrial pipes were discovered using the knowledge gathered from the studies.

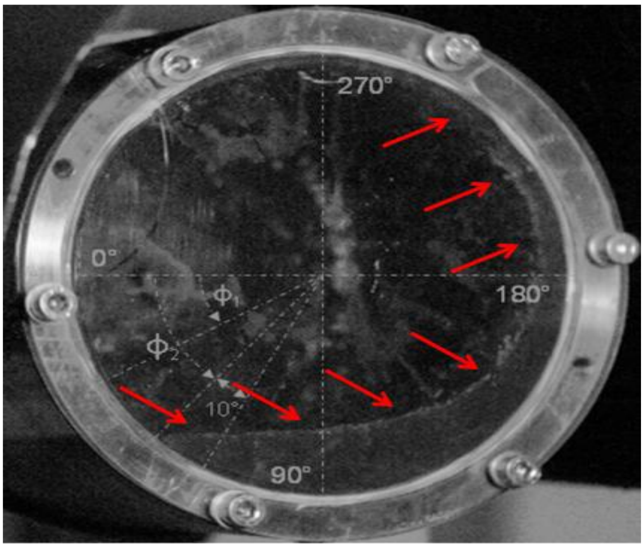

Figure 3. Shape of the free surface of the Rose’s alloy at a selected revolution speed

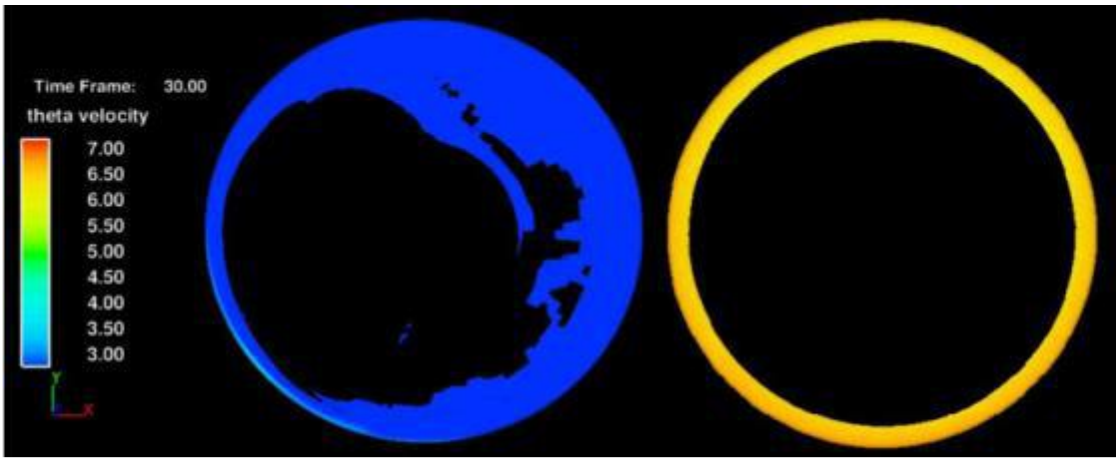

Figure 4. The simulation with low surface roughness (left) shows an unstable melt curtain, the simulation with an appropriate surface roughness (right) shows a stable melt following the looping condition.

The finished pipes' wall thickness should be as consistent as feasible. As a result, the anticipated wall thickness of a pipe along its whole length is the most interesting simulation result. The position of each fluid cell, its size, and fill fraction were read out from Flow 3D for each individual simulation with precise production settings in order to compute the wall-thickness along the length. The shape of the pipe might vary greatly depending on the production factors. Figure 6 depicts the wall thickness of numerous pipes as a function of their length.

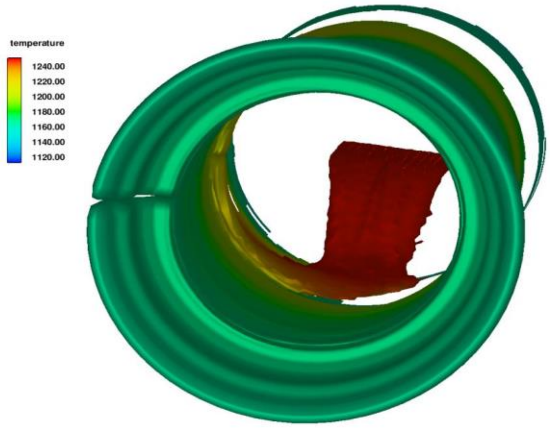

Figure 5. Simulated temperature distribution during filling of a pipe in a front view. The hot inflowing melt (in red colour) is distributed along the inner tube-shaped steel mould due its rotation.

Conclusions: -

- Flow3D may be used to replicate the De-Lavaud process, taking advantage of the software's diverse modelling features.
- The calculation time which is too long are common for all pipes.
- The influence of the key process parameters can be replicated in the simulation in comparison to reality.
- Each process parameter can be adjusted in simulation, and the impact on wall thickness can be investigated.
- Within the somewhat coarse grid size, computed wall thickness matches standard pipe measurements.

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