

Rapid Development of Industrial Castings Using Computer Simulation

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Conducting trials on foundry shop-floor is iterative, thus time consuming and results in huge wastage of resources. Casting Simulation is a well-established technology that enables virtual trials on computer systems. These virtual trials help in developing new cast products faster, more economically, and with better quality assurance. In this paper, casting simulation for an industrial stainless steel part is described. This helped in a better insight of casting solidification, leading to an optimal methoding plan in a much shorter time, resulting in faster product development.

Keywords: Casting simulation, Metal solidification, Vector Element Method.

Casting Simulation

Simulation offers clear economic benefits in industrial manufacturing processes, including casting. Numerical simulation of thermal and mechanical behaviour of castings permits designers to create robust and economical products, while also optimising process parameters for ensuring consistent quality. Casting simulation is rapidly penetrating the Indian industry as foundry engineers realise its benefits in terms of lower rejection, higher yield, faster development and better customer satisfaction. Solidification simulation of sand casting processes have proved useful in identifying and eliminating defects such as shrinkage, crack, hot tears, misruns and cold shuts. Early detection of these defects by performing virtual trials using simulation helps in minimising actual shop-floor trials and in faster and economical product development^[1].

Laws of conservation of mass, momentum and energy are applied to simulate the physical behaviour of solidification process. Based on continuum mechanics, governing partial differential equations are formulated, and solved numerically. Finite Element Method (FEM), Finite Difference Method (FDM), Finite Volume Method (FVM), and Boundary Element Method (BEM) have been employed by many researchers to numerically solve the governing differential equations with suitable boundary conditions. The interfacial heat transfer influences the solidification process and is incorporated by employing a suitable heat transfer coefficient at metal-mould interface. An alternative approach

to solidification simulation is by vector methods^[2,3]. These are based on determining the direction of the largest thermal gradient at any point inside the casting, which is given by the vector sum of flux vectors in all directions from that point. The Vector Element Method (VEM) does not involve the complexities of other numerical methods yet provides robust and reliable results^[1,2,4].

Casting Simulation Software

Casting simulation using an integrated software like AutoCAST(www.autocast.co.in) is basically a two-step procedure. The first step is importing a 3D model of cast part (created in any CAD programme), followed by methods design (mould cavities, cores, feeding and gating system). The second step is simulating the mould filling and casting solidification to predict defects, if any. The methods design is modified and verified by simulation till the desired quality is obtained at the best possible yield. The steps are described in more detail here.

The methods design starts from selection of materials and process parameters, as well as the mesh size of voxels (volume elements). Orientation of the part in mould is decided followed by selection of an appropriate mould-box size and parting plane. This is followed by identifying the hollow regions to be made by core. Core and core print design are performed next. After completion of mould design, casting solidification (without any feeders) is simulated to visualise the solidification pattern and the

formation of hot spot regions. The hot spots indicate the locations where feeder(s) should be connected. A feeder can be designed by clicking the preferred location, and then altering the types, shape and size of the feeder suggested by the programme. Multiple feeders can be placed following the same procedure. Feed-aids: chills, insulating and exothermic sleeves and covers can also be designed, modelled and simulated in AutoCAST. The effect of feeding system on casting solidification can be viewed to assess the effectiveness of the feeders and accordingly feeder design can be modified. Isothermal contours and thermal gradients can be visualised using the feed path generation options. The location and extent of shrinkage porosity can be computed and displayed. Based on the shrinkage prediction and yield computations, the optimal

Part Import and Thickness Visualisation: The part was modelled in SolidWorks, converted to STL format file, and imported into AutoCAST. Thickness visualisation is performed to validate the design and understand the part geometry (Fig. 1).

Identification of Hollow Regions and Core Design: Hollow regions can be easily identified by selecting the openings (hole boundaries) and clicking on the inside of the surface. Software then automatically generates the core geometry and models the core prints (Fig. 2).

Solidification Simulation and Hot Spot Visualisation: Casting solidification simulation is performed to identify hot spot regions. These will solidify at the last and may manifest in shrinkage porosity defects, if feed metal does

not reach these regions. Therefore, feeders must be placed as close to the hotspots as permissible by the casting geometry. Casting solidification can be visualised and animated in both 3D (see-through) and 2D (cross-sections). The probable shrinkage porosity locations are displayed as red dots (Fig. 3).

Feeder Design and Simulation:

Based on the computation of hotspots, feeder design is carried out by clicking on the part surface, and tuning the feeder design parameters suggested by the programme. Feedaids can also be modelled and their effect on casting solidification can be visualised. By quick iterations, various feeder layouts can be evaluated by tracking the quality and yield (Fig. 4). Each iteration

of a new methods layout, solidification simulation and visualisation of results takes less than one hour.

Gating Design and Filling Simulation: Gating layout can be developed by identifying the gate locations, connecting the gate location by adding runners and then connecting the runners to sprue. The programme suggests the dimensions of the various channels, which can be changed by the user. The 3D model of the entire gating system is then automatically generated and displayed. The filling time is estimated and the gating system can be altered for a specific filling time (Fig. 5).

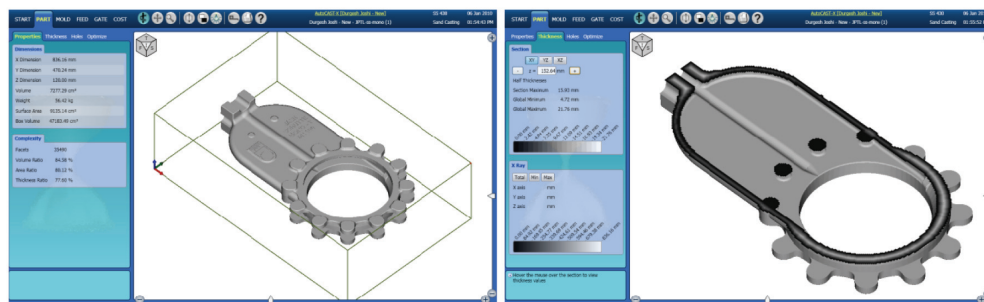


Fig. 1: Part import and thickness visualisation.

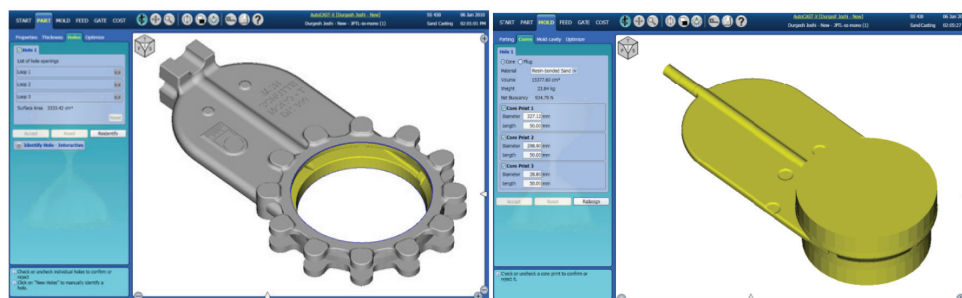


Fig. 2: Identifying hollow regions and core design.

feeder layout can be obtained. For a target quality level, the feeder optimisation can also be automated. In a similar manner, various gating design elements are designed and modelled. It is also possible to automatically optimise the gating sizes for a user-specified fill time of mould cavity.

Simulation of Valve Body

In this section, casting simulation of Jash-Schutte, Mono-T-300 valve body in stainless steel (SS-430) is performed using the above methodology. The various steps are as follows.

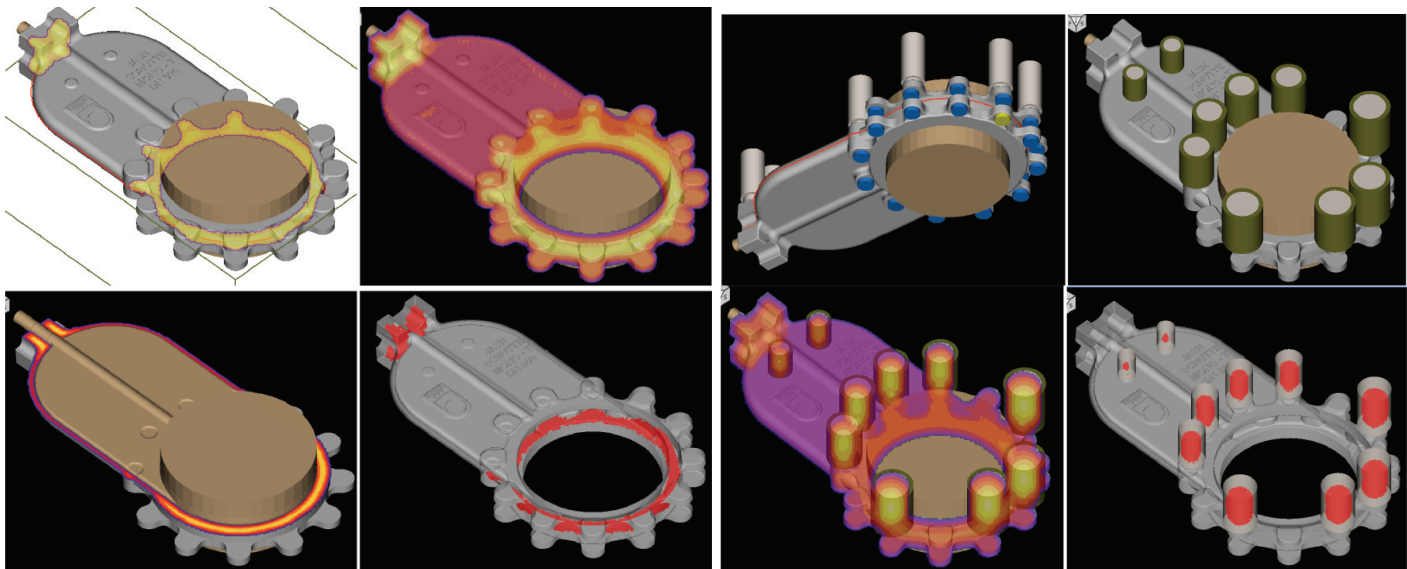


Fig. 3: Hotspot computation and visualisation of cooling.

Fig. 4: Feeder and feed-aids: modelling and simulation.

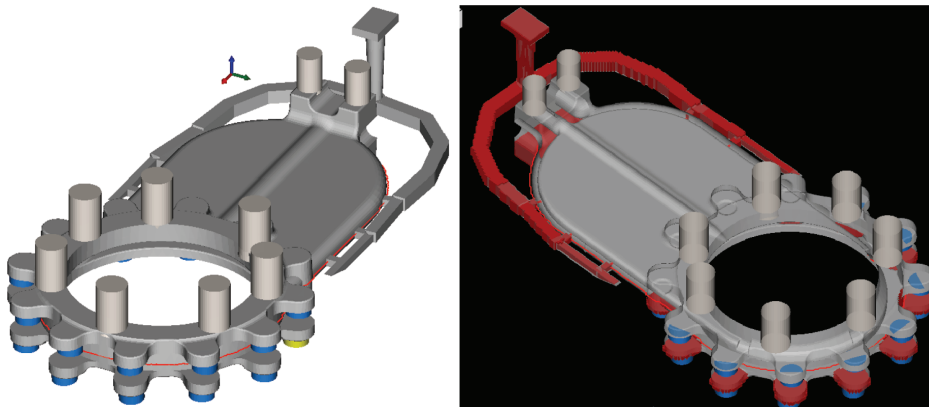


Fig. 5: Gating design and simulation.

Conclusion

By the application of casting simulation, the progressive solidification of molten metal can be visualised in an otherwise opaque mould. This insight can help in confidently evaluating and optimising the methods design. Such virtual trials reduce the number of physical trials, and help in faster product development, which is key to survival in the current global competitive market (Fig. 6).

References

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Fig. 6: Jash SS-Mono-300-T casting.