Die Casting Process

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***Abstract*— Design and manufacturing are two very fundamental engineering processes in mechanical related fields. Traditionally design has been a manual process separated from manufacturing but concept of Concurrent Engineering with Design For Manufacture (DFM) and Design For Assembly (DFA) not only coupled both these but also increased complexity of design and thus brought about the application of computers. The importance of the order of the die filling is shown as is the role of flow separation from corners and even moderately curved surfaces. The data available clearly show that a large improvement on overall casting properties is achievable by reducing the defect content of the microstructure either by a more strict control of conventional processes or by the adoption of innovative techniques such as vacuum assisted high pressure diecasting.**

***Index Terms*- The sph methodology, design guidelines for design of die cast components, two dimensional numerical studies, two dimensional numerical studies,**

I. INTRODUCTION

High pressure die casting (HPDC) is an important process for manufacturing high volume and low cost components. Examples from the automotive industry include automatic transmission housings, piston heads and gear box components. In this process liquid metal (generally an aluminium alloy) is injected at high speed (around 50 to 100 m/s) and under very high pressures through complex gate and runner systems and into the die. The design of die casted components involve careful consideration of guidelines or rules like "section thickness should not vary much", "sharp corners should be avoided", "proper draft should be given", "fillet radii should be as large as possible", "material concentration should be avoided" and many more. These guidelines are very extensive and sometimes even conflicting which makes it difficult for a designer, who may not be a die casting expert, to take care of all these along with functional, feasibility, aesthetic requirements. Also a human is prone to make errors and the danger increases if number of requirements and guidelines is high. These errors if discovered at the manufacturing stage add cost and increase cycle time.

II. THE SPH METHODOLOGY

Smoothed particle hydrodynamics (SPH) is a Lagrangian method for modelling heat and mass flows. Materials are approximated by particles that are free to move around rather than by fixed grids or meshes. The governing partial differential equations are converted into equations of motion for these particles. The particles are really just moving interpolation points that carry with them (convect) physical properties, such as the mass of the fluid that the particle represents, its temperature, its enthalpy, its density and any other properties that are relevant, such as stress and strain history dependent rheology. The inter-particle forces are calculated by smoothing the information from
nearby particles in a way that ensures that the resultant particle motion is consistent with the motion of a corresponding real fluid, as determined by the Navier-Stokes equations.

The interpolation process is performed using a kernel to smooth information from the current set of disordered points (particles). In this way any smooth field quantity can be found from its discrete particle values. More formally, fluids and solids are discretised, with the properties of each of these elements associated with its centre, which is then interpreted as a particle. A particleUsing these interpolation formula and suitable finite difference approximations for second order derivatives, one is able to convert parabolic partial differential equations into ordinary differential equations for the motion of the particles and the rates of change of their properties. In particular, the SPH representation of the hydrodynamic governing equations can be built from the Navier-Stokes equations. For more comprehensive details, see Monaghan (1992), Cleary and Monaghan (1999) and Cleary, et al. (2000).

III. DESIGN GUIDELINES FOR DESIGN OF DIE CAST COMPONENTS

General design guidelines applicable to any design process and any casting process are applicable to the die casting also but as a different process it has some specific design considerations applicable only to it. The design guidelines both general and specific can be grouped based on the feature on which these are applicable. These groups are wall thickness based guidelines, ribs and bosses based guidelines, cored hole based guidelines, draft based guidelines and fillet radii based guidelines etc. Sources of these guidelines are [3] and [9].

3.1 Section/Wall Thickness Based Guidelines

Since the cost of casting increases with increase in weight, designer should try to use thinnest section that can meet strength, stiffness and other design requirements. Thin section cool quickly in the die. Hence it can be opened sooner than for thicker sections and the casting cycle time is reduced. The thin sections are likely to be smoother and have minimum surface porosity. But extremely thin sections do not allow the molten metal to fill the cavity and thus there is a limit to minimum allowable section thickness which should be taken. The thickness depends on surface area of the wall and must conform to the values shown in Table 1. It is also highly desirable to have sections of reasonably uniform thickness and if changes in section thickness is unavoidable then to have changes smooth and gradual.

3.2 Ribs Based Guidelines

Ribs are mainly incorporated into a die casting to reinforce it structurally replacing heavy sections that would be otherwise necessary. To avoids sinks, ribs should not be much wider than the thickness of the casting wall and no higher than 4 times their width for complete filling. Ample draft (at least 20 per side) must be given for easy ejection. If ribs are designed to cross, they should do at right angles as far as possible.

3.3 Boss Based Guidelines

Boss are projections, often quite shallow, though frequently quite deep and are usually provided where an attachment or fastening comes or where a part such as a bearing on some mating part is to be applied or supported. It is always desirable to avoid undue metal concentration at bosses, as then boss may be porous. Whenever possible bosses should be cored and ribs may be applied to stiffen the boss and the walls around it. Heavy bosses behind the surface cause visible sink on other side of the wall thus the boss should be moved away from the wall and connected to be wall with a short rib of the same thickness, as shown in fig 1.

3.4 Core Based Guidelines

The die casting process can accommodate the coming in holes into the body of the casting at right angles to the parting line. As a thumb rule it is often cheaper to drill or pierce than to core small holes, especially where depth does not exceed 3.0 mm. Optimum greatest depth of cored holes as related to diameter are shown in Table 2. Cores must also be drafted adequately to assure their longevity. Minimum draft requirements must conform to the values shown in Table 3. Lower limit on core diameter of 3.0 mm for aluminium and magnesium alloys and 1.5 mm for zinc alloys should be observed.

3.5 Fillet Radii Based Guidelines

Sharp internal corners in a die casting are to be avoided as when the casting shrinks, induced stresses are concentrated at sharp corners instead of being distributed through the surrounding mass thus making the parts weaker at such corners. The abrupt change in metal flow direction during injection can cause subsurface porosity at corner to weaken this area further. Sharp edges on dies are also prone to premature erosion die to hot spot at corners. Therefore radii and fillets should be as generous as possible and should be around 1.5 times wall thickness for both internal and external radii fig 2.

3.6 Draft Based Guidelines

The sidewalls of die casting and other features perpendicular to the parting line must be tapered/drafted as much as possible to facilitate removal from the die. Draft angle should be large as without it even the slightest depression in the drafted surface of the die will prevent ejection without causing drag marks in the surface of the casting. Draft angle also depends on the alloys and varies inversely with wall depth as shown in Table 4.

IV. TWO DIMENSIONAL NUMERICAL STUDIES

In this section, 2D SPH simulations of the isothermal filling of a couple of very simple dies are presented. The liquid metal begins in a 10 mm wide shot sleeve and is pushed into an asymmetrical 10:1 convergent runner and through a narrow constriction called the gate by a piston on the left of Figure 1. This constriction increases the fluid pressure and accelerates it from the piston speed of around 3 m/s up to around 50 m/s when it enters the gate before jetting into the die. The gate width used here is 1 mm. Figure 1 shows an initially rectangular body of fluid being deformed as it enters the constricting region. It is shaded according to its velocity. At t=1.7 ms (Figure 1a) the deformation is still small and the velocity of the metal front has only increased to 5 m/s.

By t=5.1 ms (Figure 1b) the leading material has passed through the gate and has accelerated to 43 m/s.

Note that the asymmetric shape of the shot sleeve gives the fluid a net downward motion as it enters the gate. The jet reflects upwards from the lower wall of the gate and enters the die with a net upward component of velocity and therefore does not travel directly along the wall and allows the opportunity for air to become trapped underneath.

The simulations presented in this section demonstrate that the flow in the shot sleeve, runner and gate is important to the filling process and needs to be modelled properly. Modelling just the die with a user specified inflow condition on the gate is inadequate because of the strong effect of the runner geometry on the fluid velocity profile within the gate region and therefore the filling of regions of the die near the gate. The effect of the runner system declines with decreasing proximity to the gate.

Three basic die geometries with gently increasing complexity are used in this first set of simulations:

1. A rectangular die 10 mm high and 20 or 50 mm long;
2. A C shaped die corresponding to a 2 mm strip around the left, top and right sides of a 10 mm high and 25 mm long rectangle;
3. Similar to 2 but with an insert added into the top section of the die.

In all cases the density of the material was chosen to be that of water =1000 kg$m$-3 so that we could validate the simulations using water analogue experiments. The characteristic length scale was chosen to be the gate width L=1 mm and the characteristic velocity to be the velocity through the gate of around V=50m/s. The viscosity was then chosen to give Reynolds numbers (Re) of 500. A resolution of 90 particles were used across the shot sleeve. Cleary, et al (2000) examined the effects of Reynolds number on die filling for these cavities and found that the filling process is relatively invariant with Re. They also examined the effect of higher resolution on the SPH predictions and showed that the essential features of the high resolution results were well reproduced at these lower resolutions.

V. MATCHING SCORE OF GEARS

Matching scores of gears consolidate the evidence presented by multiple biometric sources and typically provide better detection performance compared to systems based on a single biometric modality. Although information fusion can be performed at various levels, integration at the matching score level is the most common approach due to the ease in accessing and combining the scores generated by different matchers. Since the matching scores output by the various modalities are heterogeneous, score normalization is needed to transform these scores into a common domain, prior to combining them.

VI. SUMMARY AND CONCLUSIONS

Several aspects of modelling the high pressure die casting process using Smoothed Particle Hydrodynamics have been described. Two dimensional isothermal modelling of very simple geometries demonstrated that the filling was not a uniform front fill. The order of fill was found to be strongly dependent on the die geometry with back filling being responsible for filling much of the thin wall sections. Flow separation of corners provides significant opportunities for porosity formation. The capacity of numerical simulation to easily examine the effect of changes in gate and runner geometry on filling pattern was demonstrated.

REFERENCES

[1] Bedworth David D., Henderson, Mark R., Worfe Philip M.; "*Computer Integrated Design and Manufacturing*", McGraw Hill Inc, 1991.

[2] Boothroyd Geoffrey, Dewhurst Peter, Knight Winston; *"Product Design for Manufacture and Assembly"*, Marcel DekkerInc,1994.

[3] Bralla James G., *"Handbook of Product Design for Manufacturing"*, McGraw Hill Book Company, 1986.

[4] Durkin John; *"Expert System Design and Development"*, Macmillan Publishing Company, 1994.

[5] Marek Clarence T., *"Fundamentals in the Production and Design of Casting"*, John Willy and Sons Inc, 1961.

[6] Patterson Dan W.; *"Introduction to Artificial Intelligence and Expert Systems"*, Prentice-Hall of India Private Limited 1990.

[7] Technical Report, *"Die casting product design"*, The Die casting Society of India.

[8] Pham D.T., *"Artificial Intelligence in Design"*, Springer Verlar, 1991.

[9] Cleary, P.W. (1998a). SPH Technical Note #29, CSIRO Division of Mathematical and Information Sciences, *Technical Report CMIS 1998/166*.

[10] Cleary, P.W. (1998b). *Applied Mathematical Modelling*, **22**, 981–993.

[11] Cleary, P.W., Ha, J., & Ahuja, V. (2000). *Int. J. Cast Metals Res*, **12**, 335–355.

[12] Research Paper on Modelling the High Pressure Die Casting Process Using SPH byPaul W. Cleary and Joseph.