Addressing Tooling and Casting Requirements at the Design Stage

Whitepaper

Bhaskar Sinha

Contents

Abstract

Several of the tooling and casting requirements of a part can be addressed at the design stage. If these requirements are not addressed at the design stage, lot of time is spent in design iteration when the design reaches the die caster. These design issues lead to increase in time and cost of production leading to delay in time to market and reduced profits for the organization. The features present in the design determine the total cost and the complexity of the tool. Designers should be aware of the cost of features added to the part and should try to reduce cost wherever possible.

Some of the features that affect cost, tool life and castability are wall thickness, rib parameters, dimensions of bosses, holes, sharp corners, draft angle, fillet radii, engraving, finishing, tolerances, material, quantity of produced parts, to name a few.

This paper discusses various issues related to casting and tooling that can be addressed at the design stage to save valuable time and cost.

Introduction

There are several guidelines for designers to ensure the die cast component is successfully manufactured. Adhering to these guidelines ensures the die cast component is cost effective with required dimensional accuracy, surface finish, quality and meets the functional requirements [1].

Some of these design guidelines have been discussed in the sections below and the way to adhere to these guidelines using automated process at the design stage have been discussed.

Casting Guidelines

This section lists some of the common casting guidelines followed by the casting industry.

Wall Thickness

Thick sections require more cooling time and hence increases the cycle time [1]. Thick section cause porosity, increase in the weight of the part which in turn affects efficiency and adds to material cost. Thin sections cool faster than the thick sections. This may block the metal from flowing to other parts of the model [2].

Sudden change in thickness causes problems associated with abrupt solidification which increases the turbulence and entrapped gas [2] causing stress and porosity in the part.

Wall thickness should be kept uniform. As per NADCA guidelines, range of wall thickness should be 2 times the thinnest wall section. Recommended wall thickness for aluminum casting is 3.5 mm [1].

Mold Wall thickness

Mold wall thickness is important aspect in die casting. If the tool is too thin and elongated, stresses develop in the tool. Also, special material is required for such areas in the tool. The part in the tool needs regular replacement so serviceability of the tool should be taken into account [2].

Ribs

Ribs can be added to thin walled castings to increase part strength. In addition, these ribs provide an ideal location for ejector pins and assist in metal flow. Ribs should have fillets at the top and the base to eliminate sharp corners [1].

Bosses

Bosses are projections for supporting an attachment or fastener or where a part such as a bearing on some mating part is to be applied or supported. Bosses are cored to avoid thick sections in the part and prevent porosity and sink marks on the opposite surface. For large bosses, ribs are added to provide strength [3].

Draft Angle

Draft is the taper given to cores and cavity for easy removal of the casting. The draft angle will depend on the type of the surface, the depth of draw and the material [1].

Depth (mm)	Draft Angle (degrees)
2.5	6
25	1.9
127	0.85

Table 1: Standard draft tolerances for draft on inside surfaces, outside surfaces and holes achievable under normal production conditions [1].

Holes

Holes have different functions; metal savers, clearance, functional or locating. Metal savers are used to reduce weight of the part, maintain uniform wall thickness, ensure smooth metal flow during injection and enhance tool life. As per NADCA guidelines, for cored holes, minimum hole diameter should be 6.0 mm and should be parallel to the direction of the draw. For holes with diameter less than 12.5 mm, the ratio of core length to diameter should be less than 4. For holes with diameter greater than 12.5, the length to diameter ratio should not exceed 10 [1].

Fillets and Sharp corners

Sharp edges, corners and sudden thickness variations should be avoided in die-casting parts. Sharp corners are undesirable because they become a localized point of heat and stress built-up in the die steel, which can cause die cracking and early failure. Fillets should be added to sharp edges and corners [4].

Lettering

Lettering and other identification marks in a die cast components are either depressed or raised features. Raised lettering is preferred over depressed because it requires lesser die- cost and die maintenance as compared to depressed lettering [1].

Applying Casting Guidelines at Design Stage

The above mentioned casting guidelines can be applied at the design stage by using automated CAD integrated tools available in the market.

Method of identifying wall thickness related issues

Every CAD modeler has a measure functionality to determine the distance between two selected points. This tool is used frequently by many organizations to determine the wall thickness at a given section. However, there are various issues encountered using this tool [5]. To address these issues, several wall thickness technologies are available [2,6,5]. Using these automated wall thickness technologies, 3D wall thickness of the model can be easily computed. Figure 1 shows one such tool used to compute thick or thin walls and variations in wall thickness [5].

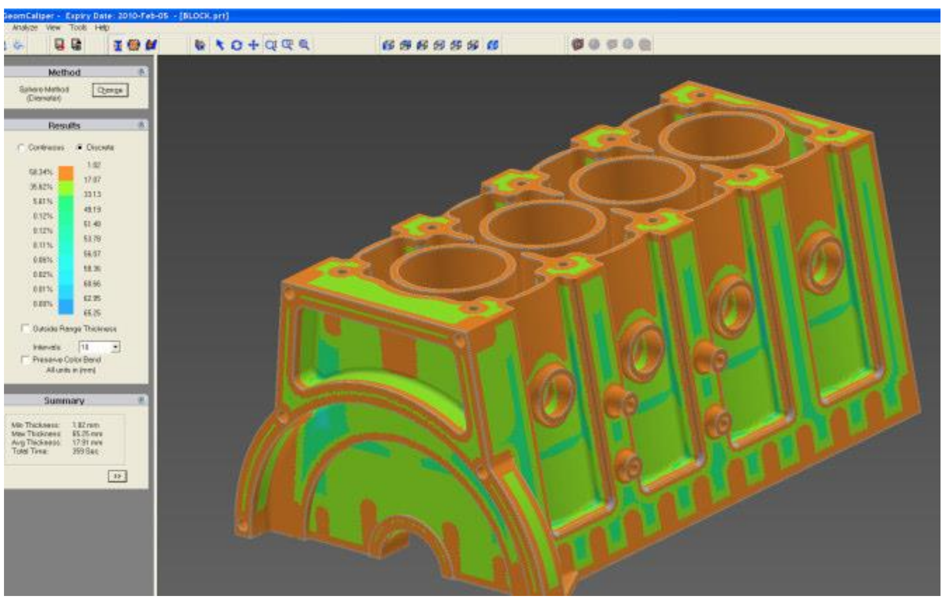

Figure 1: Wall thickness analysis using sphere method [5] on engine block using GeomCaliper [7].

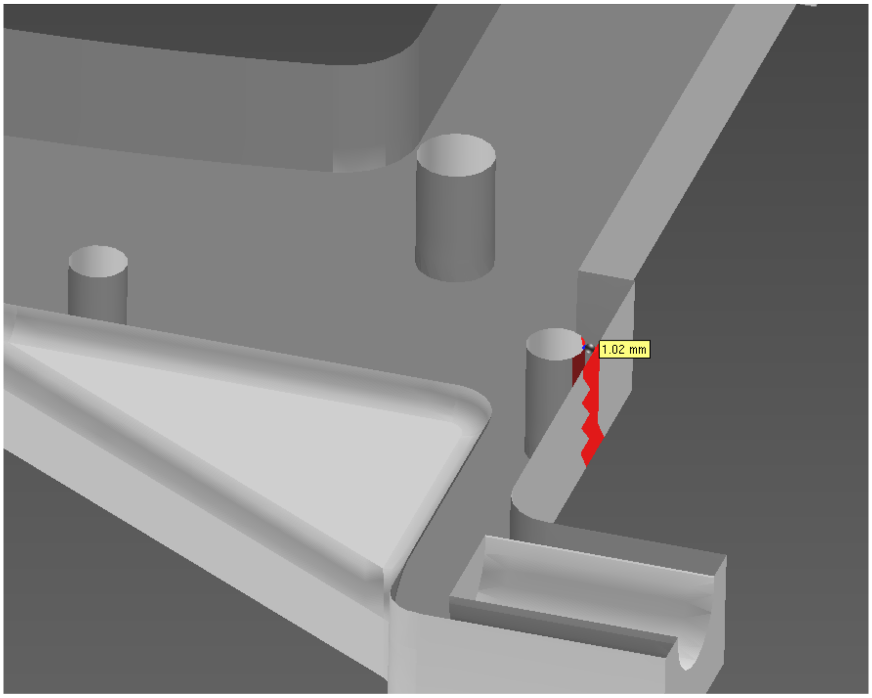

Figure 2: Automatically identify thin regions in engine block using GeomCaliper [7].

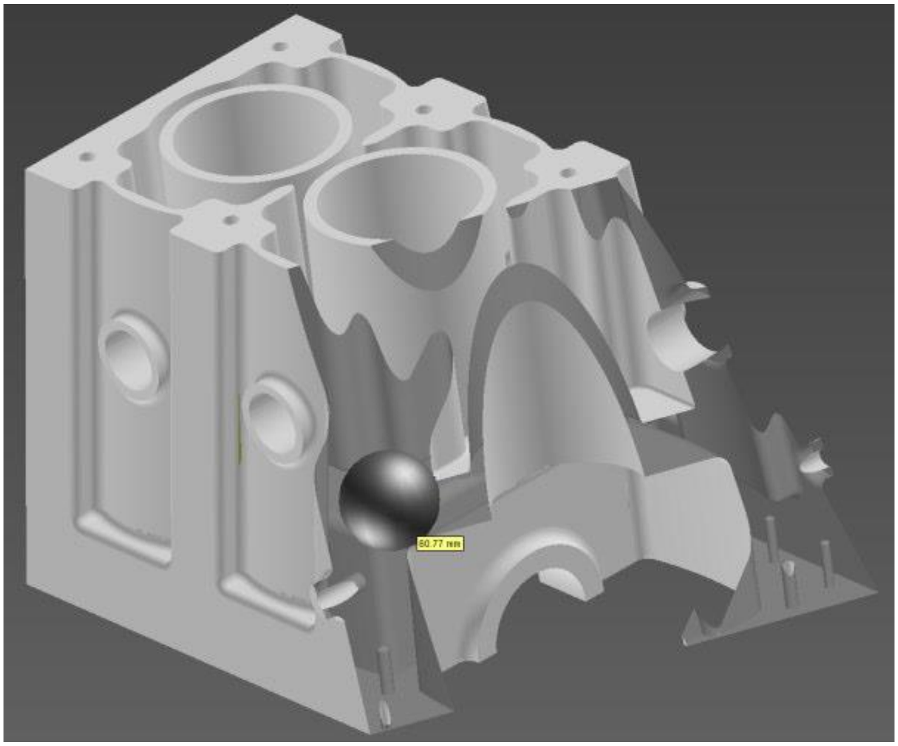

Figure 3 a: Thick region in casting

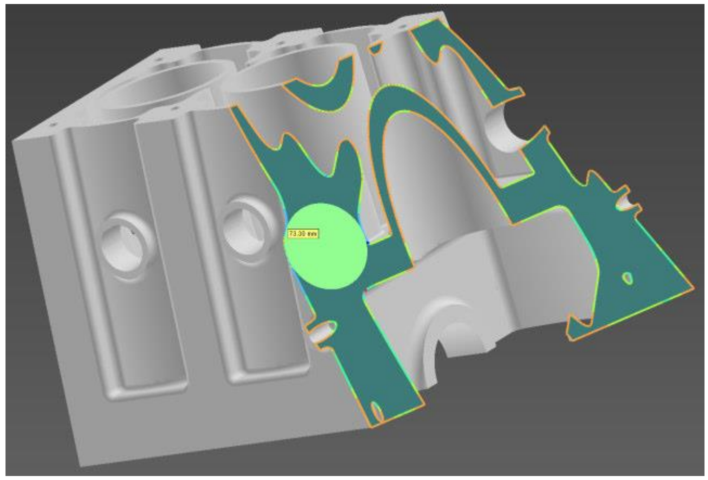

Figure 3 b: Automatic creation of section plane along the thick section and checking critical sections along the section plane

Figure 3: Checking thick sections in casting using GeomCaliper [7].

Mold Wall Thickness

Mold wall thickness can be derived by checking design features on the model. Figure 4 shows all instances where such problems occur. Ribs too close to each other, bosses very close to each other, bosses and ribs close to each other, bosses with deep narrow holes, ribs I bosses close to the wall causes problems related to mold wall thickness [1].

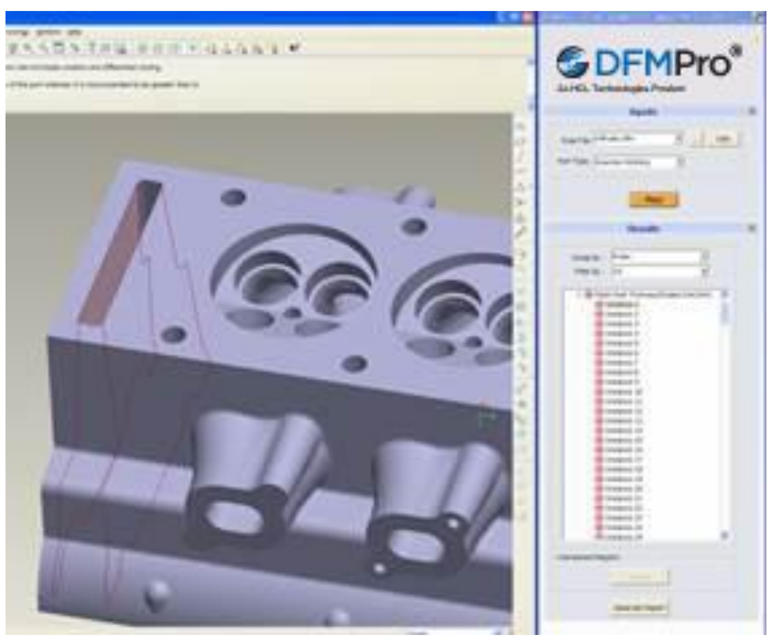

Figure 4: Checking Mold Wall thickness using DFMPro [8]

Ribs

Ribs are mainly incorporated into a die casting to structurally reinforce it, replacing heavy sections that would be otherwise necessary. To avoid sinks, ribs should not be much wider than the thickness of the casting wall and no higher than 4 times their thickness for complete filling. Ample draft (at least 2 degrees 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].

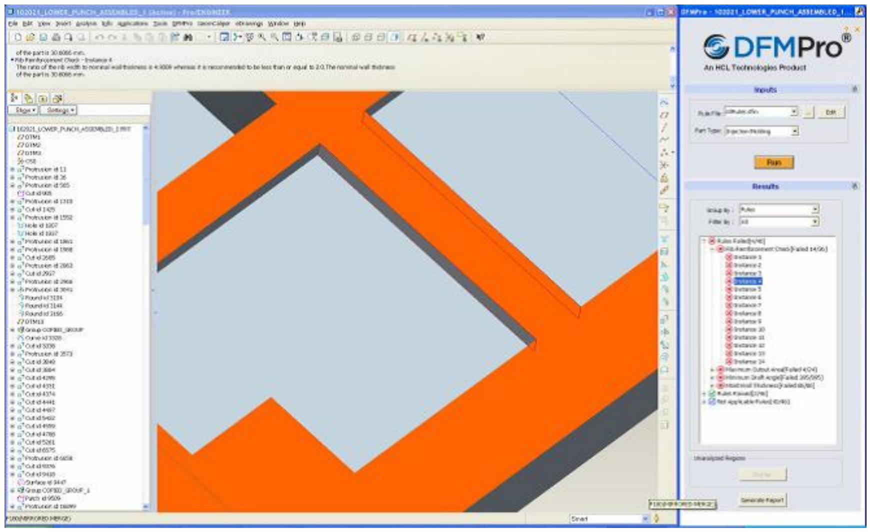

Figure 5: Wide ribs identified in design using DFMPro [8].

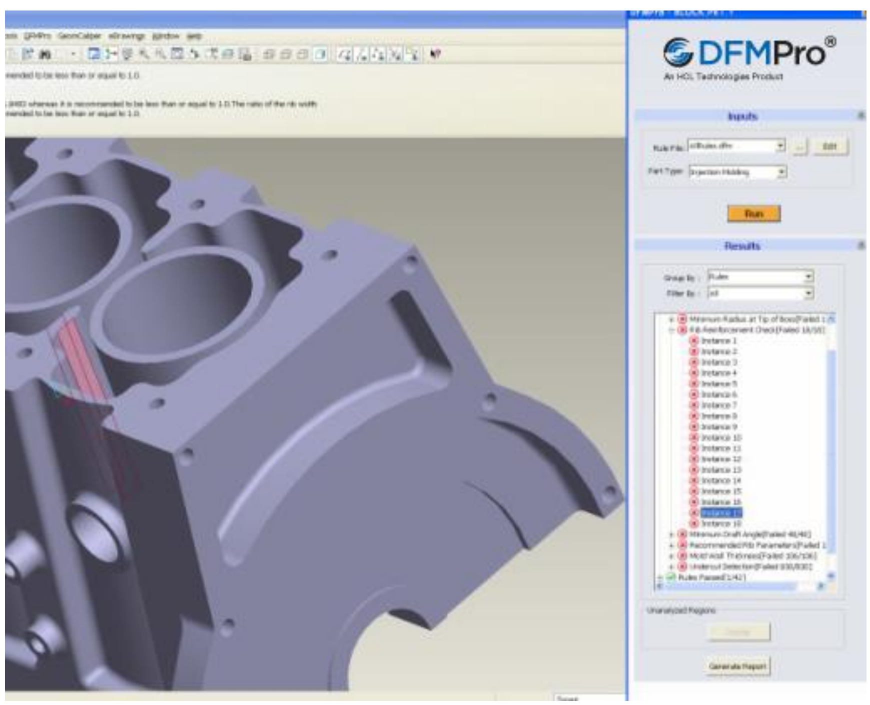

Figure 6: DFMPro used to identify ribs with high height to nominal thickness [8].

Bosses

The height to diameter ratio of the boss is recommended to be below 1. For ratios greater than 1, ribs should be used to improve filling. Distance between bosses should be 6.5 mm to minimize porosity [1].

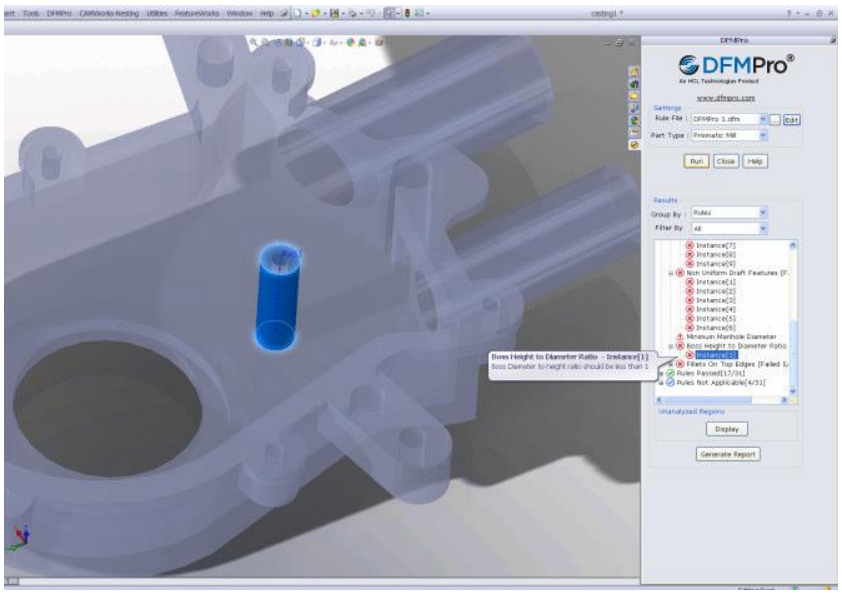

Figure 7: Using DFMPro, boss identified in design which has a height to diameter ratio of more than 1.0 [8].

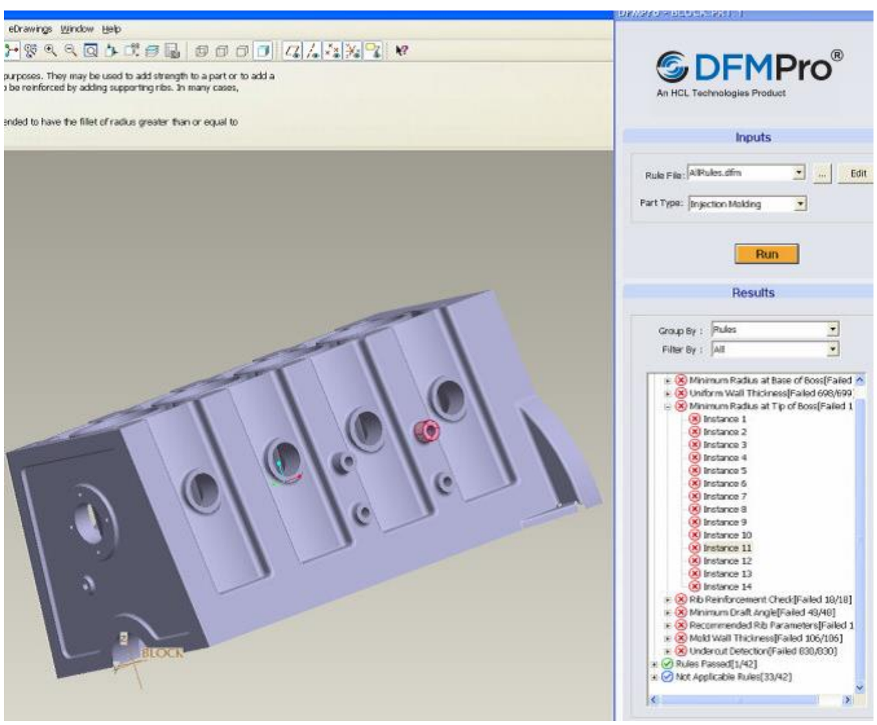

Figure 8: Bosses with insufficient or missing fillets at the tip and base identified [8].

Draft angle check

From the point of increasing the tool life, appropriate draft angle should be provided. Features with reverse draft should be avoided [4].

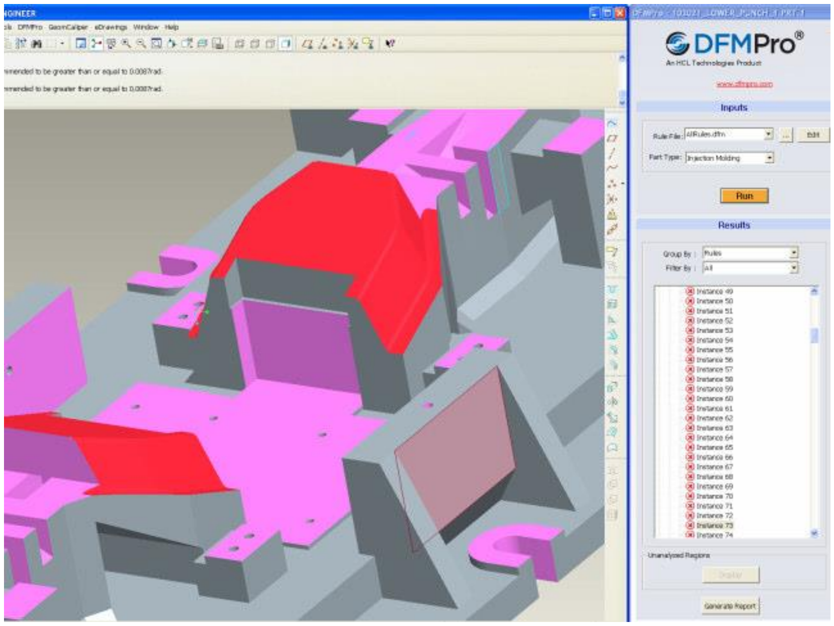

Figure 9: Identifying all areas in a casting which require draft using DFMPro [8].

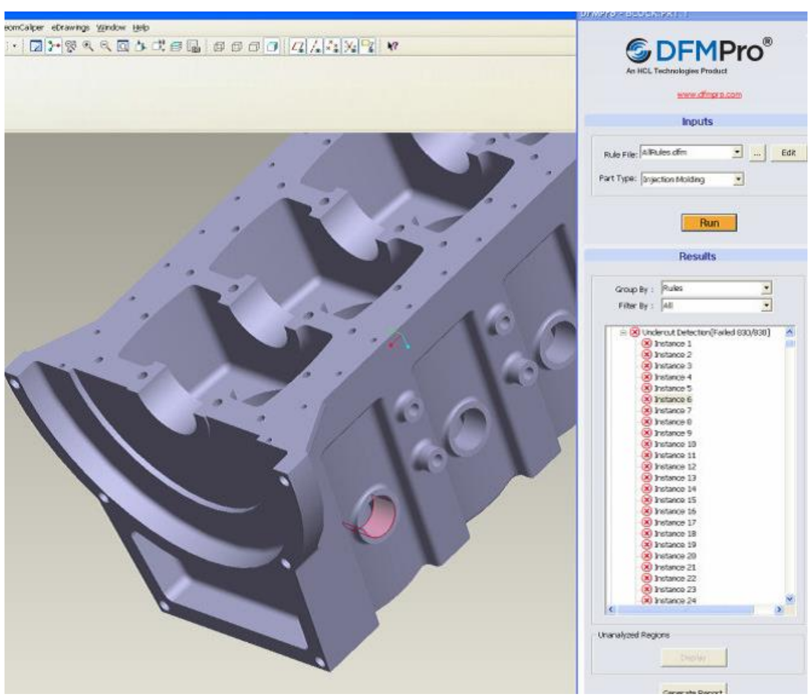

Figure 10: Undercuts identified in Engine block [8]

Holes

The hole depth to diameter ratio should be followed based on material used. Uniform wall thickness around holes should be maintained. Draft angle of holes should be minimized [1].

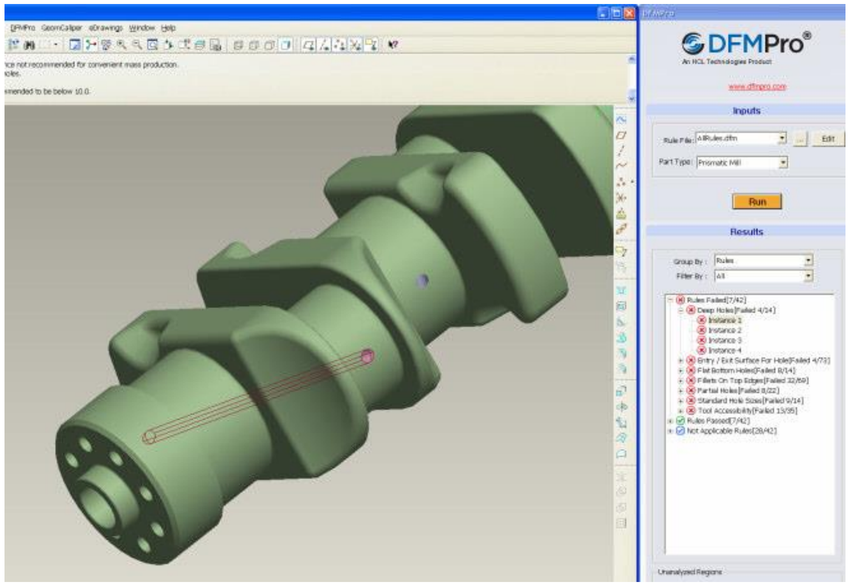

Figure 11: Hole depth to diameter ratio greater than permissible value identified in the model [8].

Fillets and sharp corners

All sharp corners and fillets with insufficient radii can be identified at the design stage and corrected. This will save downstream cost and time.

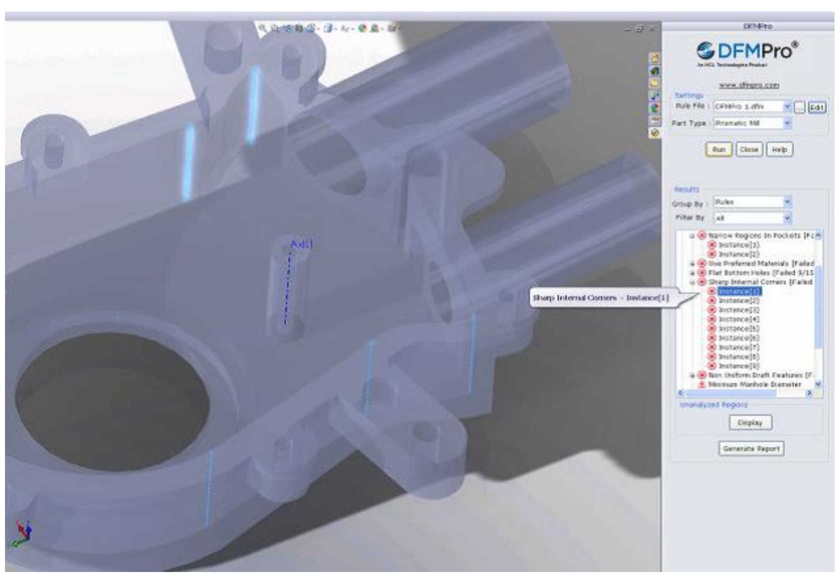

Figure 12: Sharp corners highlighted in design [8].

Conclusion

There are many design guidelines available for casting. If these guidelines are enforced at the design stage, there are several benefits like improved quality of cast part, improved tool life, cost reduction and faster time to market. The above paper discussed some of the guidelines and how automated tools integrated within the CAD environment can help achieve the objectives of the casting industry.

Scope for future work

The results obtained in the paper were achieved using tools like GeomCaliper [7] and DFMPro [8]. DFMPro uses feature recognition technology [9] which can extract manufacturing features from the CAD design. This technology can even operate on imported models. Currently, DFMPro uses feature recognition to extract manufacturing features from the design and apply the manufacturability guidelines to these features. The concept can be extended to use these manufacturing features to estimate the cost of the casting right at the design stage.

Acknowledgements

I sincerely thank my colleagues Yogiraj Dama and Rahul Rajadhyaksha for providing me all the support needed in compiling this paper. I would also thank Geometric Ltd. for permitting me to take my time off for writing this paper.

References

1. NADCA Product Specification Standards for Die Castings, 2009, 7th Edition, NADCA Publication #402
2. A Visualization Tool for Mechanical Design, S.C. Lu, A.B. Rebello, D.H. Cui, R. Yagel, R.A. Miller, G.L. Kinzel, Center of Die Casting, Dept of Computer and Information Science, The Ohio State University
3. Expert System for DFM of Die Cast Components; A. Chawla, K. Ravi Raju and Amit Gupta; Department of Mechanical Engineering, IIT Delhi
4. Computer Aided Manufacturability Analysis of Die-cast Parts, J. Madan, P.V.M. Rao, T.K. Kundra, IIT Delhi
5. Efficient Wall Thickness Analysis Methods for Optimal Design of Casting Parts; Bhaskar Sinha;
6. Voxel-based Thickness Analysis of Intricate Objects; K. Subburaj, Sandeep Patil and B. Ravi; Department of Mechanical Engineering, Indian Institute of Technology, Bombay, India
7. GeomCaliper addon product integrated with ProIENGINEER, CATIA V5, HCL Technologies Ltd http://geomcaliper.geometricglobal.com/
8. DFMPro addon product integrated with ProIENGINEER, SolidWorks and Standalone, HCL Technologies Ltd, http://dfmpro.geometricglobal.com/
9. Feature Recognition Technology, HCL Technologies Ltd, http://feature.geometricglobal.com/

About Author

Bhaskar Sinha is a product leader with experience in software product management, marketing, sales and engineering. His area of expertise includes aligning product vision with company vision, identifying market needs, assessing gaps and fulfilling those through enhancement / rationalization of existing portfolio or creation of new products / technologies.

About HCL Technologies

HCL Technologies is a leading services company that covers the entire gamut of technology solutions and services including infrastructure management, application development, BPO and engineering and R&D services. Over the years, HCL Technologies has demonstrated remarkable growth inspite of economic downturn and is emerging as one of only eight 21st century listed technology companies in the world to cross $1bn in net profit, $5bn in revenue and $15bn in market capitalization.

As a $6 billion global company, HCL Technologies brings IT and engineering services expertise under one roof to solve complex business problems for its clients. Leveraging extensive global off-shore infrastructure and a network of offices in 31 countries, HCL provides holistic, multi-service delivery in industries such as financial services, manufacturing, consumer services, public services and healthcare.

