Usage Of An Integrated CAD/CAE/CAM System In Foundries

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Abstract

In today's competitive age foundries are required to be more active, efficient. They need to respond fast. While CAD/CAE/CAM software can greatly enhance productivity, quality assurance and casting yield, their penetration in small/medium foundries and engineering companies has been poor. This paper reviews how CAD/CAE/CAM assists in designing, modelling, simulating, analyzing and improving cast products over electronic networks – providing a glimpse of the way castings will be designed in future. Key developments in computer-aided product design, casting design, simulation, rapid tooling, intelligent advisory systems and internet-based collaboration are reviewed, supported by relevant vendor information. According to the concept of concurrent engineering (CE), a CAD/CAE/CAM integrated system can shorten the cycle of casting design and manufacture, and result in the production of high quality castings in a shorter time. The lead-time of castings is shortened greatly. The use of CAD/CAE/CAM software greatly improves the speed and accuracy of decision-making in individual tasks involved in casting development for a new application.

1. Introduction

The ability of fluid to assume the shape of its container is exploited by casting processes, which involve melting and pouring liquid metal into a sand or metal mould and allowing it to solidify, yielding a shape close to that of the desired product. Metal casting continues to be the preferred process for intricate shapes of any size and weight with varying wall thickness and internal features. Nearly 70 million tons of cast components worth more than $100 billion are produced annually for automobile, industrial machinery, municipal fittings and many other sectors, by over 33,300 foundries worldwide. An even large number of companies are involved in designing, machining, testing and assembling cast components and in related activities such as tool making and material supply. This vital industry is facing many challenges today. On one hand, metal casters have to meet the rising expectations of customers in terms of quality assurance, shorter lead time, smaller lot size and competitive pricing. On the other hand, foundries are severely outpaced by the rapid technological and management changes taking place in other manufacturing sectors. One example is the increasing use of NC machines for finishing operations, which require dimensionally stable castings with uniform surface hardness to prevent damage to cutting tools. Another example is the adoption of Just-In-Time philosophy by assemblers to reduce their inventory costs, which requires foundries to deliver on-time. Increasing pressure from regulatory bodies in terms of energy conservation, environment protection and operational safety is of additional concern. This means that in order to survive, foundries have to offer dimensionally stable and sound castings and ensure reliable on-time delivery. To achieve customer satisfaction without sacrificing profitability, foundry engineers need to precisely model and control the casting process to obtain the desired quality and optimize the yield without repetitive and time consuming shop floor trials.

2. DFM for Foundries

Design revisions are expensive and time consuming. Yet, these are inevitable because product designers have limited knowledge about casting processes and have no means to evaluate the influence of design features on casting cost, quality and productivity. Problems appear much later, at the tooling or manufacturing stage, when it is much more expensive to incorporate changes than at the design stage. Progressive engineering companies therefore rely on design review committees, which include tooling and casting engineers, to suggest early modifications to a product design for ease of manufacture. An integrated CAD/CAE/CAM system simulates the way casting engineers decide the casting process, parting line, cores, mold box, feeders, gating system and mold layout, and analyzes each decision to suggest how the design could be modified to improve quality as well as reduce tooling and manufacturing costs. The system also facilitates electronic exchange of information between product, tooling and casting engineers, thus improving the level of communication between them.

However, casting engineers only produce what product engineers design. Product designers mainly focus on product function – creating an optimal shape to withstand operating stresses – aided by excellent Finite Element Analysis software available for this purpose. They are largely unaware of the casting processes, their capabilities and limitations. This results in either over design (for example, unnecessary thick ribs leading to heavier castings) or under design (for example, inadequate fillet radius leading to casting defects). Often a product design causes severe problems at the casting stage, and the foundry may request the customer to either modify the design or pay a higher price to offset the costs of tooling and modification, increased scrap and additional operations such as heat treatment and machining. Significant design modifications at this stage could mean additional burden of redoing the tooling and planning the process again, besides losing the time and resources already spent on these activities.

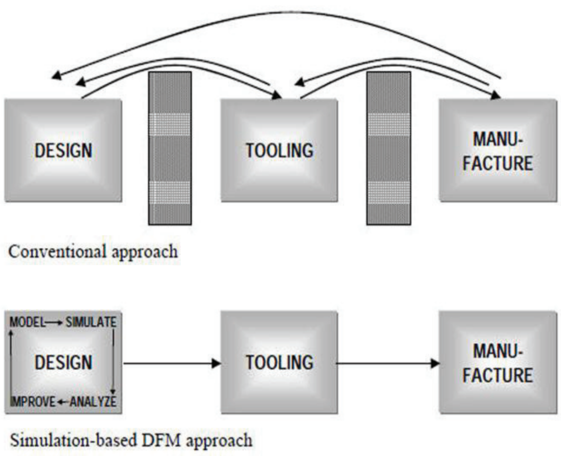

Figure 1.Conventional vs. DFM approach for Castings

If the ratio of benefit to cost is considered, then it is immediately apparent that dramatic saving of resources can be achieved by predicting potential problems at the design stage itself, and preventing them through suitable changes to product features. This approach is termed Design for Manufacture.

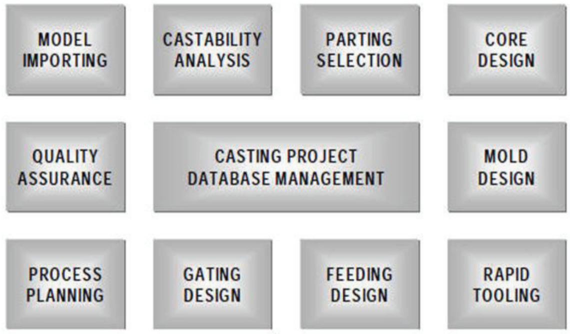

Figure 2. Elements of Casting Project

In the case of cast products, a typical DFM iteration involves modelling the part, designing the casting features (including parting, cores, mold, feeders and gating system), creating a solid model of the entire casting, generating the FEM mesh, specifying the boundary conditions such as heat transfer coefficients and temperature dependent properties of metal and mold, performing the simulation, interpreting the results and deciding further modifications to the design of either the part or the tooling. A number of such design-simulate-analyze iterations are required to optimize the casting design, which could take several days. Thus simulation-based DFM of cast products calls for an in-depth knowledge of the process, as well as significant time and effort for design improvements.

3. Solid Modeling

Engineers in every automobile company today use a range of software tools for design and analysis. The first step is Computer-Aided Design or CAD, in which a solid geometric model of the component is created on a computer.

Transferring the geometric information from human mind to a computer is perhaps the most involved step, and can often take several days for an intricate shape such as a six-cylinder engine block. However, once the part model is created, it can be used for many different applications.

Computer-Aided Engineering or CAE analysis (simulation of stress, strain, heat transfer, vibration, fatigue and fracture) based on Finite Element Method (FEM) is widely used to optimize the functionality and weight of the component. After the part design is finalized, it is sent to a Computer-Aided Manufacturing or CAM program to plan the CNC cutter paths and simulate the machining operation. The part model is also required for accurate and automatic calculation of geometric properties (volume, weight, centre of gravity, etc.) and as input for casting simulation programs. A number of solid modelling systems are available today (Table 1).

Table 1. Solid Modeling (3D CAD) Systems

System	Developer
AutoCAD	AutoDesk
AutoDesk Inventor	AutoDesk
CATIA	Dassault System
CREO	Parametric Technology Corporation
NX	Siemens PLM Software
Solid Edge	Siemens PLM Software
SolidWorks	SolidWorks Corporation

4. CAE – Casting Analysis and Simulation

Casting design involves converting the part design to the tooling design: orientation in the mold, parting line, application of draft and allowances, feeding and gating systems, core boxes and other elements. Simulation includes mold filling and casting solidification, useful for optimizing the design of gating and feeding systems respectively. Casting model is the main input for simulation.

The aim of simulation of casting solidification is to:

- Predict the pattern of solidification, indicating where shrinkage cavities and associated defects may arise.
- Simulate solidification with the casting in various positions, so that the optimum position may be selected.
- Calculate the volumes and weights of all the different materials in the solid model.
- Provide a choice of quality levels, allowing, for example, the highlighting or ignoring of micro-porosity.
- Perform over a range of metals, including steel, white iron, grey iron and ductile iron and non-ferrous metals.

Some of the well-known casting simulation systems currently available to foundry engineers are listed in Table 2.

Table 2. Casting Simulation Systems

System	Developer
AutoCAST	Advanced Reasoning Technologies Pvt. Ltd.
FLOW-3D	Flow Science Inc.
MAGMASoft	MAGMA System
Pro/CAST	ESI System
PASSAGE/PowerCAST	Technalysis System
SOLIDCast	Casting Simulation System

The procedure for carrying out a casting solidification simulation program analysis is listed below:

- Using the casting drawing, determine model scale and element size.
- Make the solid model of the casting.
- Make the solid model of the proposed production method with feeders, chills, insulators etc. Use the program's own feeder-size calculator if required.
- Carry out thermal analysis to establish the order of solidification.
- Carry out solidification simulation to a set quality standard, for the selected alloy incorporating shrinkage percentage, ingate effects, etc. this results in the model being changed to the predicted final shape of the casting showing size, shape and location of shrinkage cavities in castings and feeders.
- Examine the predicted shrinkage by viewing and plotting of 3D 'X-rays' and selection of the model in 2D slices or 3D sections and relating

predicted defects to solidification contours and required quality standards.

- If the predicted defects do not meet the required quality standard, develop an improved production method and repeat the procedures. These trial-and-error sampling procedures can be carried out very rapidly, allowing the casting engineer to indulge in any number of "what-if experiments".

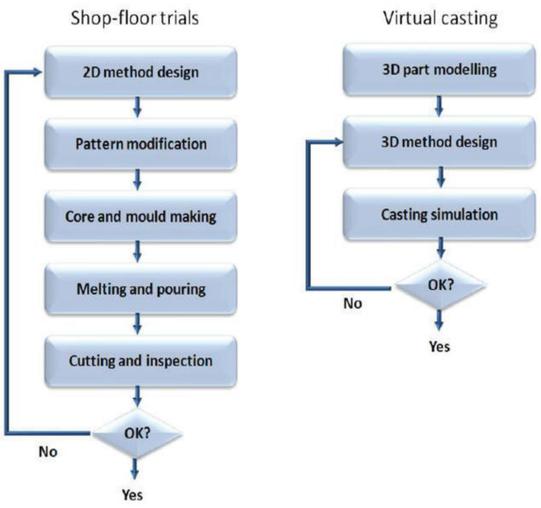

Figure 3. Comparison of conventional approach and integrated CAD/CAE/CAM approach

5. The Realisation of CAM

On the basis of the data of the 3D solid modelling and final method optimisation of castings, tool for castings (pattern or die) can be manufactured rapidly using manufacturing module of any popular CAD/CAM system like Pro/ENGINEER CAD/CAM software of PTC, Unigraphics NX CAD/CAM software of Siemens, SOLIDWORKS CAD/CAM software of Solidworks, etc. the operation table of machining including the machining parameters, cutters, cutter path, etc. is listed, and the NC (numerical control) cutting procedures and the CL (cutter locate) data files are also created. Furthermore, due to the use of module of an NC-check, the cutter path in machining is checked and the instantaneous machining process can be visualized. The CL data file of each NC cutting procedure is revised until a satisfactory result is reached. The CAM is realized as soon as these data files are post-processed and transferred into the NC machine code.

6. Concurrent Engineering

CAD (Computer Aided Design)/CAM (Computer Aided Manufacturing)/CAE (Computer Aided Engineering)/CAI (Computer Aided Inspection)/CAPP (Computer Aided Production Planning) and many other activities can go simultaneously after preparation of 3D model. This saves lot of time in various activities.

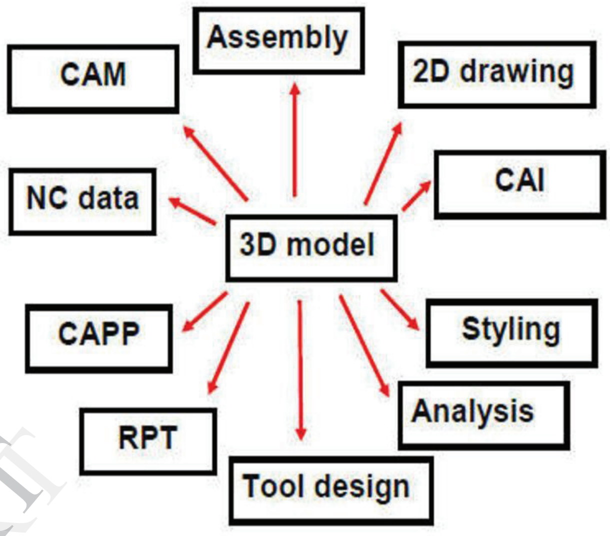

Figure 4. Application of Concurrent Engineering

7. Benefits

An integrated CAD/CAE/CAM system enable product engineers to design more cost-effective parts through a better appreciation of the problems faced by casting engineers. It will also improve the level of communication between product, tooling and foundry engineers, leading to better and faster decision-making. Proper implementation of CAD/CAE/CAM system in a foundry gives both immediate and long-term benefits. Immediate benefits include shorter lead time, higher productivity and lower rejections. Long term benefits include better image, higher confidence and stronger partnerships.

1) Immediate: Computer-aided casting design and tooling production enable achieving high internal quality and dimensional control, lowering the occurrence of defects. This is critical for new orders especially large castings and expensive for difficult to machine metals where the cost of rejection is high. Also, with increasing use of Just-In-Time philosophy, quality assurance has become a key issue with customers. Defective castings discovered at the machining stage upset their carefully synchronized production and assembly schedules. Lead-time reduction is important, since it is often said that in future, there will be only two types of foundries: fast ones and dead ones.

2) Long-term: An integrated CAD/CAE/CAM system gives a new competitive edge to a foundry – important for continuous growth and increased profitability. This system enhances the image of foundry, which helps in getting new customers who prefer such suppliers. Computer-aided design, manufacture and information management enable better control and faster decisions, leading to an increased confidence level in the foundry. The system also enables foundries to initiate meaningful dialogues with their customers for arriving at a fair pricing or for reducing the costs by lowering casting weight, tooling development time and production costs; without affecting the profit margins. All these bring more business, enable successful execution of challenging orders and add value to the castings.

8. Concluding Remarks and Future Works

The increasing frequency of new product introductions is putting pressure on component suppliers to reduce their lead time from order to supply. This is most apparent in the case of automobile components. In the early 80s, new car models were introduced every 3-4 years, which is now down to 10-12 months. The paper showed how an integrated CAD/CAE/CAM systems can automate casting design, modelling, simulation, analysis and suggestions for improvement while allowing the user ultimate control over all decisions. Most integrated CAD/CAE/CAM systems usually pay back for themselves within a year. While it is of great use to casting engineers in better and faster decision-making, greater benefits will be achieved by analysing cast products at the design stage itself and preventing potential problems through suitable changes to part features. In addition, product engineers, tool makers and casting engineers will be able to share relevant information with each other over electronic networks, thereby avoiding confusion and errors and significantly reducing the non-productive time for completing a casting project.

Though some Indian foundries have now understood the importance of integrated CAD/CAE/CAM system as an integral part of their operations, but it is not like Germany and USA where this system is fully penetrated. A large number of CAD/CAE/CAM engineers and consultants will be required to fill the gap.

In future, this system will increasingly use internet to provide software training, upgrading, license management and technical support. Presently machining process is required in cast components to get the desired dimensional tolerance and surface finish. Also this is a challenge to develop such a system that by incorporating it in a foundry we can get ready to fit cast components that do not require secondary manufacturing process machining for getting required dimensional tolerance and surface finish in cast component

9. References

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