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Optimized Design and Manufacturing of Tooling by Concurrent Engineering

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In today's competitive age Industries are required to be more active, efficient. They need to respond fast. More and more competition calls for the fast response to buyer. In this quest maintaining quality is also a key issue. To meet this effective resource utilisation, optimised design and manufacturing of product is required. Compared with the traditional sequential design method, concurrent engineering is a systematic approach to integrate concurrent design of products and their related processes. One of the key factors to successfully implement concurrent engineering is information technology. In order to design a product and its manufacturing process simultaneously, information on product features, manufacturing requirements, and customer demands must be processed while the design is concurrently going on. There is an increased understanding of the importance of the correct decisions being made at the conceptual design and development stages that involve many complex evaluation and decision-making tasks. CAD engineers, CAE engineers and CAM engineers can work concurrently and the integration of CAD/CAM/CAE can be realized. This theory has been successfully applied to design and manufacturing of investment casting die and the results are obtained in terms of optimization and lead time reduction.

Keywords: Concurrent Engineering, Sequential Engineering, Investment casting

1. Introduction

The manufacturing environment has dramatically changed in the last few years. Worldwide competition among manufacturers and the development of new manufacturing technologies have contributed to today's competitive situations in manufacturing industries. Such competition has stimulated rapid changes in manufacturing industries, causing a significant shift in how products are designed, manufactured, and delivered. Customers demand products of higher quality, lower price, and better performance in an ever-shorter delivery time. As an example, in the mid-1960s the Chevrolet Impala was the best selling car in the USA, and the platform on which it was based was selling 1.5 million units a year; in 1991 the best selling car was the Honda Accord, and the platform on which it was based was selling 400,000 units a year. Despite the increase in the market size the number of units per model has decreased by a factor of 4. Companies are required to produce more and more new products, and at the same time reduce the time to market these products .

The first attempt made by Western companies to respond to this faster changing environment was to shorten their response time, pushing their development processes to move faster, but kept on doing the same things. Product design was asked to reduce the time to deliver the blueprints, and so was process engineering to design the process and manufacturing to produce.

Strong efforts were made to help each function to meet the goal of shortening its lead time, particularly where Western companies felt to be stronger on new technologies; and particularly on computer technologies: CAD, CAE, CAM and CIM. Sophisticated automation has been introduced, but in most cases results were disappointing. The main reason is that these technologies have been utilized just to speed up the process, not to change it. The need for a new development process then became clear and concurrent engineering (CE) has emerged as an effective answer to this need.

2. Need for Optimisation

Optimisation is the process of finding the best way of using your resources, at the same time not violating any of the constraints that are imposed. By "best" we usually mean highest profit, or lowest cost. For example, even after spending significant resources i.e. man-hours, materials, machine overheads and energy etc for casting development, one of the following situations may arise during regular production:
(a) **Under design**: resulting in high percentage of defective castings. This usually happens when the number or size of feeders and gating elements are inadequate, or their placement is incorrect.
(b) **Over design**: leading to acceptable quality level, but poor yield and thereby higher cost. In this case, the number and/or size of feeders and gating elements are much higher than their respective optimal values.

Foundries try to reduce rejections by experimenting with process parameters (like alloy composition, mold coating, and pouring temperature). When these measures are ineffective, then methods design (gating and feeding) is modified. When even this is not effective, then tooling design (part orientation, parting line, cores and cavity layout) is modified. The effect of any change in tooling, methods or process parameters is ascertained by pouring and inspecting test castings. Studies show that replacing shop-floor trials by concurrent engineering and computer simulation saves time, provides a better insight, and helps in reducing the rejections.

3. Concurrent Engineering

Competition forcing changes in the way product designers and manufacturing engineers develop products. In conventional product development, conceptual design, detailed design, process planning, prototype manufacturing, and testing are considered as sequential processes. Compared with the traditional sequential method, concurrent engineering is a systematic approach to integrate the concurrent design of products and their related processes. Concurrent engineering is intended to stimulate product designers/developers to consider all elements of the product life cycle in the early stage of product development.

3.1 Concurrent Engineering vs. Sequential Engineering

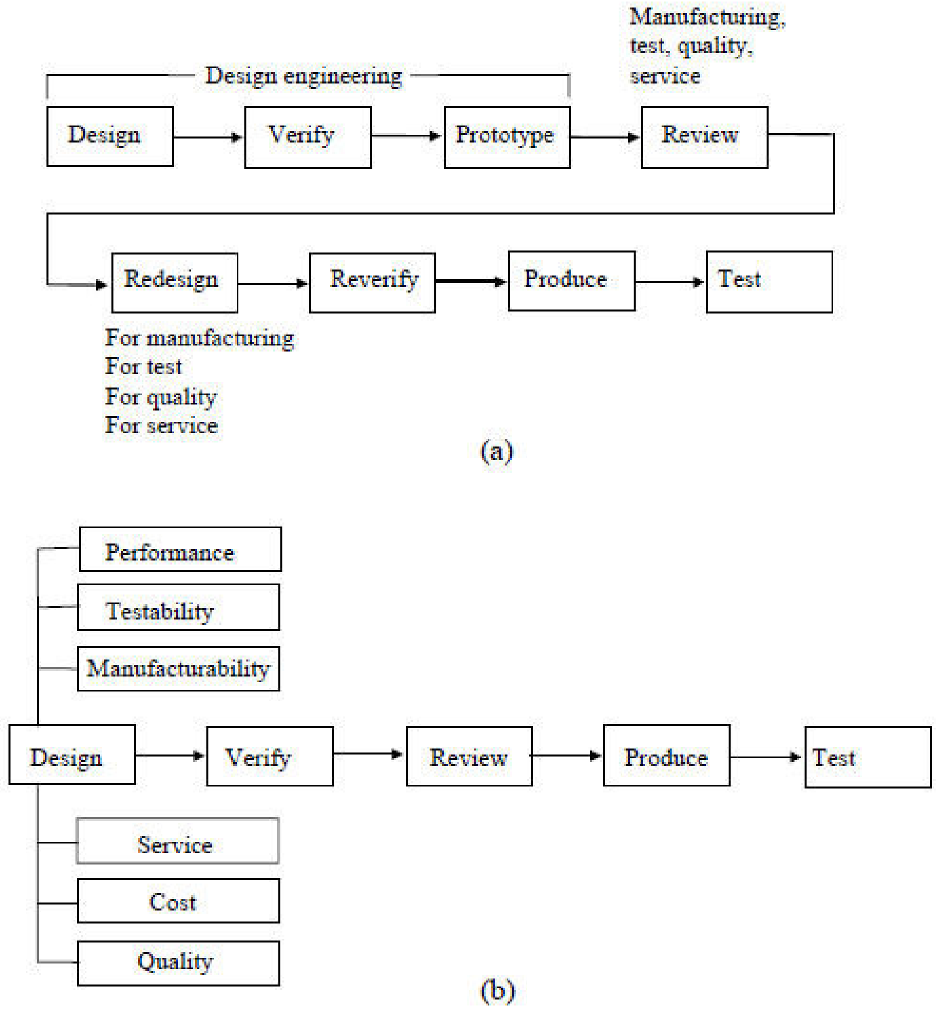


Figure 1. (a) Flow diagram of the serial engineering organization and (b) flow diagram of CE organisation

A flow diagram of the serial engineering organization is shown in Figure 1(a). In serial engineering, the various functions such as design, manufacturing, and customer service are separated. The information in serial engineering flows in succession from phase to phase. In sequential engineering a department starts working only when the preceding one has finished, and, once a department has finished working on a project.

On the contrary, in CE all functional areas are integrated within the design process. A flow diagram of CE is shown in Figure 1(b). The decision making process in a CE environment differs from sequential engineering in that at every stage decisions are taken considering the constraints and the objectives of all stages of the product life cycle, thus taking at the product design level issues that are usually addressed much later, thus giving the possibility to achieve a better overall solution. The integration of other functional areas within the design process helps to discover hard to solve problems at the design stage. Thus, when the final design is verified, it is already manufacturable, testable, serviceable, and of high quality. The most distinguishing feature of CE is the multidisciplinary, cross-functional team approach. Product development costs range between 5% and 15% of total costs, but decisions taken at this stage affect 60–95% of total costs. Therefore it is at the product development stage that the most relevant savings can be achieved.

4. Establishment of Concurrent Engineering for Investment Casting Dies

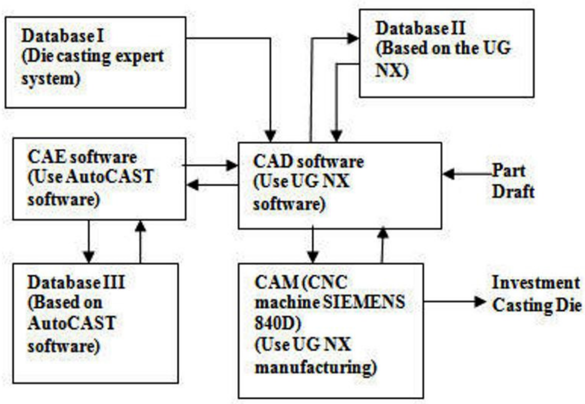


Figure 2. Integrated CAD/CAE/CAM systems for investment casting die

The general scheme of CAD/CAE/CAM integrated system of investment casting dies is shown in figure 2. In this paper the platform of the UG NX CAD/CAM software, the AutoCAST simulation software, and a primary expert system for the design of investment casting process are used to establish the CAD/CAE/CAM integrated system of investment casting dies.

4.1 Solid Modelling

First the 3D solid modelling of a part is created, and then the 3D modelling of the investment casting including the information of machining allowance, shrinkage and taper is formed by using the UG NX CAD/CAM software (shown as figure 3). The data of machining allowance, shrinkage and taper are chosen from Database I in accordance with the accuracy and surface rating of the parts, the structure of the parts and the type of alloy.

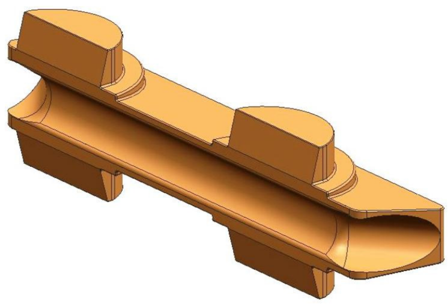


Figure 3. Solid Model of Automobile (Tractor) Part

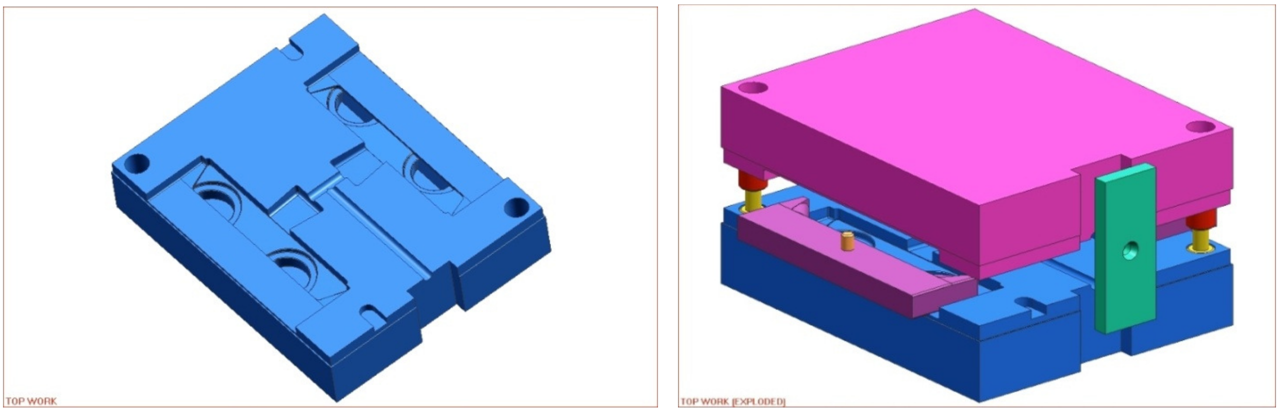
4.2 Design for Investment Casting Die

Standard parts and raw materials which will be used for manufacturing die are shown in table I. Die is designed for two cavities. So the production is increased at 50%.

Table 1. Die Components

Part Name	Material	Quantity
Std. Dowel	Hardened Steel	2
Std. Bush	Hardened Steel	2
Std. Dowel	Hardened Steel	2
Block	Aluminium	2
Injection Plate	Mild Steel	1
Core	Aluminium	2
Copper Block for Electrode	Copper	1
Std. Dowel	Hardened Steel	2

The parting line is the intersection of parting surface (the surface separating the die halves) of a casting die with the object or die cavity. The main objective of parting line is to split the component in such a way so as to reduce core and slides to absolute minimum. Here parting line is generated at centre line of the product. So the die is consisting of mainly two parts. Figure 4(a) shows method design details. Finally the 3D solid modelling of the whole set of investment casting dies, including cores, gating system, feeding system, injection plate, etc. are all completed as shown in figure 4(b).



(a) (b)
Figure 4. Multicavity Investment Casting Die

4.3 CAE – Casting Simulation and Analysis

The metal flow and solidification in the dies is simulated with the use of AutoCAST software. The simulation results of several technological schemes are analysed. The problems occurring in the metal flow and solidification can be observed directly through the simulation. The defects of shrinkage cavities and porosity are basically eliminated. The design of the investment casting process is optimized with the help of CAE simulation and analysis as shown in figure 5.

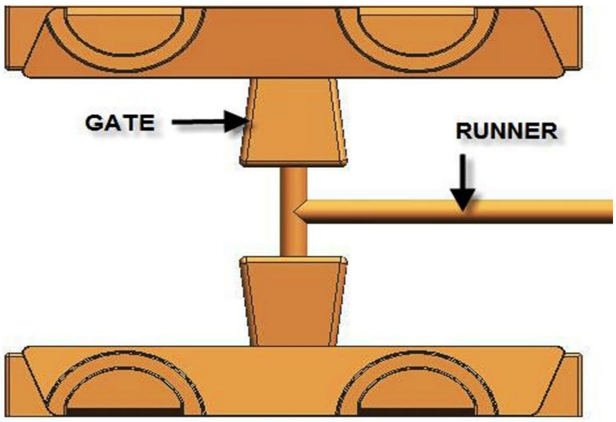
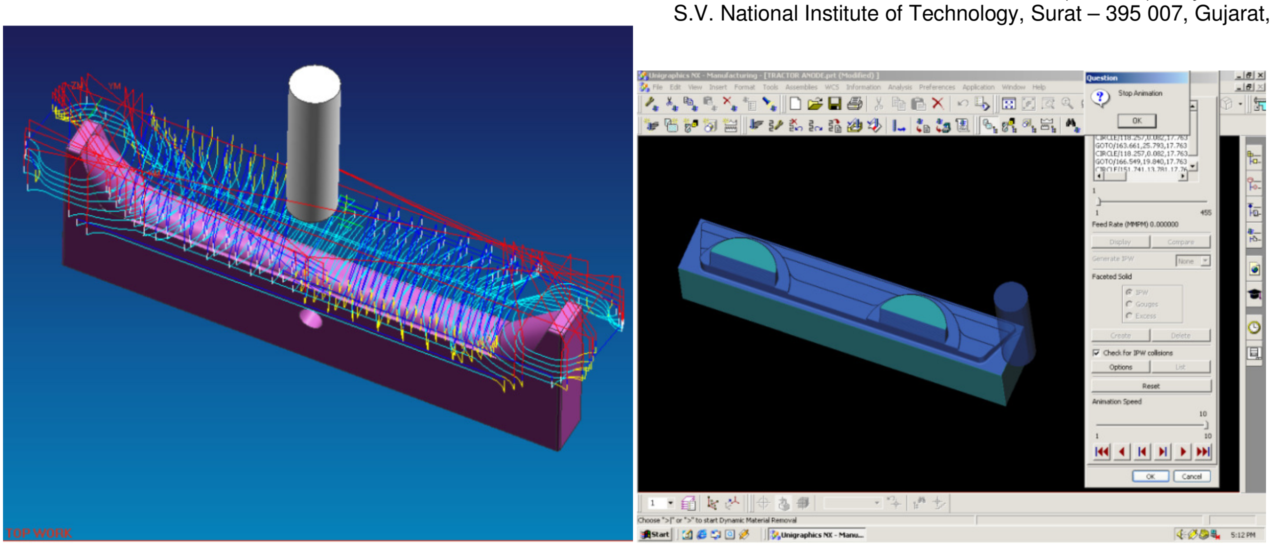


Figure 5. Optimisation of casting method design

4.4 CAM for Die

On the basis of the data of the 3D solid modelling of the cavities of investment casting dies, with the use of the MANUFACTURING module of the UG NX CAD/CAM software, 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. The cutter path in the machining of the core and the electrode for Electric Discharge Machine for machining die cavity is shown in figure 6 (a) and (b) respectively.



(a) (b)

Figure 6. (a) Toolpath verification for core and (b) Toolpath verification for electrode for EDM

5. Benefits

With the help of the UG NX CAD/CAM software and a primary expert system package, the 3D solid modeling of investment casting and the design of technological scheme of investment casting process are created. Next the simulation and analysis of metal flow and solidification in dies are performed with the use of the AutoCAST software; the technological scheme and process parameters of investment casting are also revised and optimized. Then the 3D solid modeling of whole set of dies is completed. Finally the CAM machining data of the complex surface of dies and cores are created and the CAM of whole set of performed simultaneously, and the design and manufacturing cycle of the dies can be shortened obviously. The method design and process parameters of investment casting process are revised and further optimized by using the CAE simulation, and the quality of the investment castings improved greatly in a shorter time.

6. Conclusion

Optimisation plays vital role in business. It is an effort towards making the things run smoothly with efficient utilisation of available resources. Optimisation is the philosophy of life. When applied to the engineering sector, that too to foundry it saves unnecessary wastage of resources. This leads to the noticeable savings in terms of cost. Concurrent engineering, an integrated CAD/CAE/CAM system of investment casting dies can be used successfully in the design and manufacturing of investment casting dies of parts such as automobile components, machine tool components, etc. The cycle of design and manufacturing of investment casting dies are shortened obviously. The process parameters and technological scheme of investment castings can be optimized with the help of CAE simulation. This results in the production of investment castings of consistently high quality in a shorter time, and the lead-time is shortened greatly.

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