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Application of an integrated CAD/CAE/CAM system for die casting dies

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Abstract

According to the concept of concurrent engineering (CE), a CAD/CAE/CAM integrated system for die casting dies is established and applied in the primary stage. The platform of the Pro/ENGINEER CAD/CAM software, the MAGMASOFT simulation software and a primary expert system for the design of the die casting process are available to establish this integrated system. A primary expert system package including a series of empirical calculation equations and data for the design of technological scheme and dies of die casting has been developed by the authors. This integrated system has been applied successfully in the design and manufacture of die casting dies for aluminum and magnesium die castings, such as the water pump of the Santana sedan. The use of this integrated system can shorten the cycle of die design and manufacture, and result in the production of high quality die castings in a shorter time. The lead-time of die castings is shortened greatly.

Keywords: CAD/CAE/CAM integrated system; Die casting dies; Numerical simulation of metal flow and solidification

1. Introduction

The application of die castings is expanding continuously. The construction of die castings is becoming more complex and large-sized, and at the same time a shorter development cycle of new die casting products is required. How to produce high quality die castings in a shorter period with a lower cost has become an important and urgent task of die casting enterprises. Recently concurrent engineering (CE) has been introduced into die casting production, and the CAD/CAE/CAM integrated system of die casting dies has been established [1]. In the CE process, the first step is to create a 3D part database for use in all aspects of the production process. The next step is to design the die casting process, which includes the design of gating system, overflows and cooling channels and whole set of die casting dies. In order to avoid the defects in the casting, by means of the casting simulation software the numerical simulation of metal flow and solidification in the dies, i.e. the CAE, is performed. The database also provides the data which are needed in the generation of the cavity roughing and finishing CNC programs for die manufacturing by CAM, and is connected to the coordinate measuring machines (CMMs) for measuring [1,2]. Due to the use of a unitary database of 3D model in the whole period, all these steps can be performed simultaneously. The lead-time and whole cycle of design and manufacture can be shortened greatly [2]. Therefore, die casters have paid more and more attention to the CAD/CAE/CAM integrated system of dies, which embodies the CE concepts of modern advanced manufacturing technique.

2. Establishment of the CAD/CAE/CAM integrated system for die casting dies

The general scheme of CAD/CAE/CAM integrated system of die casting dies is shown as Fig. 1. A CAD/CAM software, a CAE simulation software and a die casting expert system are included in it.

Due to the complex shape of die castings, the large-scale CAD/CAM software is required for the 3D solid modeling and manufacturing. Now the widely used CAD/CAM software are Pro/ENGINEER CAD/CAM software of PTC, Unigraphics II CAD/CAM software of EDS, and IDEAS CAD/CAM software of SDRC, USA.

The principle of CAE simulation of castings is based on the solving of the equations in fluid dynamics and heat transfer (such as the continuity equation, the Navier–Stokes equation and the Fourier equation, etc.) by means of finite difference method (FDM) or finite element method (FEM). The velocity profile of the metal flow in the die cavity and the temperature distribution of the casting and die during the filling and solidification process can be obtained by calculation. Then the metal flow and solidification of die castings

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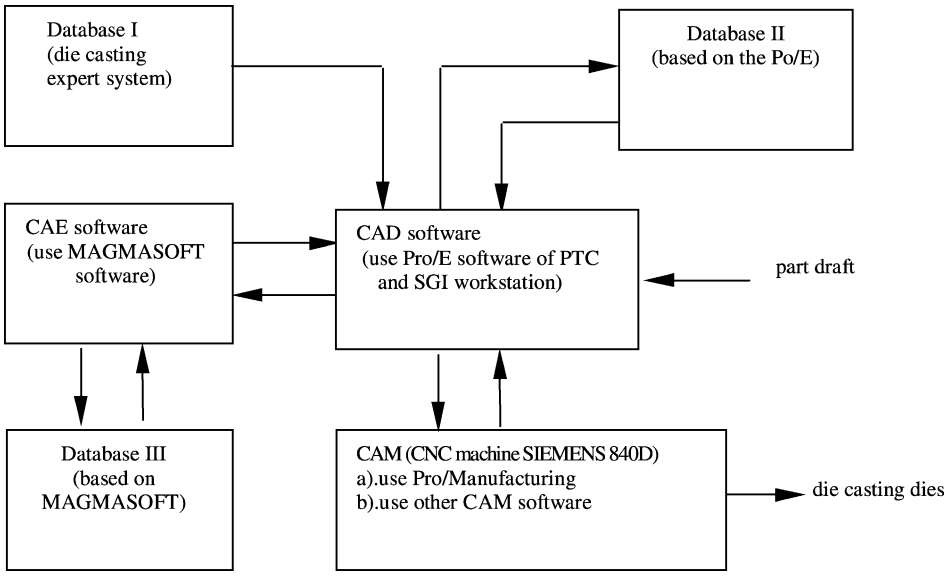

Fig. 1. The general scheme of CAD/CAE/CAM integrated system of die casting dies.

are simulated with the use of CAE simulation software. The casting simulation software packages now available are CAP of EKK, FLOW-3D of Flow Science, Pro/CAST of UES, USA, and MAGMASOFT of Magma, Germany, etc. [3].

In this paper the platform of the Pro/ENGINEER CAD/CAM software, the MAGMASOFT simulation software, and a primary expert system for the design of die casting process are used to establish the CAD/CAE/CAM integrated system of die casting dies, this system is applied for the die castings of a water pump of aluminum alloy and a housing cover of magnesium alloy [4,5].

3. Application of the CAD/CAE/CAM integrated system for die casting dies

3.1. CAD modeling and design of technological scheme and dies

First the 3D solid modeling of a part is created, then the 3D modeling of the die casting including the information of machining allowance, shrinkage and taper is formed by using the Pro/ENGINEER CAD/CAM software (shown as Fig. 2). The data of machining allowance, shrinkage and taper are chosen from Database II in accordance with the accuracy and surface rating of the parts, the structure of the parts and the type of alloy.

By means of a primary expert system package for the design of the technological scheme of die casting process, which was developed by the authors, the process parameters of die casting such as the injection pressure, plunger speed, gate velocity and filling time, etc. are selected suitably, and checked by empirical calculation equations in accordance with the type of alloy, and the wall thickness and structure of the casting. The technological scheme of die casting process including the gating system, overflows and cooling channels is also designed, and the projected area of the cavity and the thermal balance of dies are calculated and checked. Then the die casting machine is selected. In database I are stored the information of various normalized component parts of dies and some empirical data of die design such as the thickness of inlays, the distance from the cavity to the outer surface of the die, etc. With the use of database I in the expert system, finally the 3D solid modeling of the whole set of die casting dies, including cover and ejector moulds, cores, gating system, overflows and cooling channels, etc. are all completed (shown in Fig. 3). Then all these modeling data are translated into data files.

The shape of the die casting of the water pump is comparatively complex. It includes an involute outline, a groove with varied height, a distorted transition region connecting different transverse sections with a sphere-like arch, etc. All these are difficult for modeling.

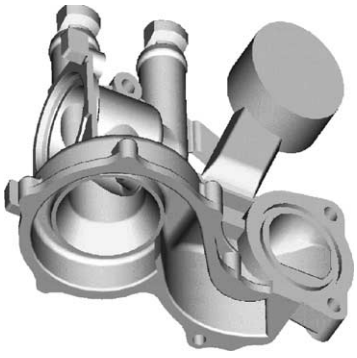

Fig. 2. The 3D solid model of water pump.

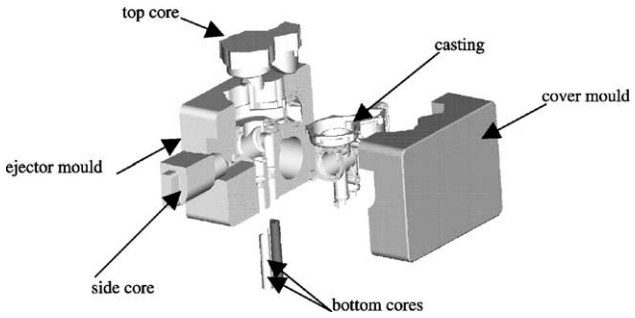

Fig. 3. The 3D solid model of die casting dies of die casting water pump in open state.

3.2. CAE simulation and analysis

The die casting of water pump is produced in an IP 550 horizontal die casting machine. There are two types of defects occurring in this casting: air holes and porosity. The metal flow and solidification in the dies is simulated with the use of MAGMASOFT software. The simulation results of several technological scheme are analyzed. The problems occurring in the metal flow and solidification can be observed directly through the simulation. In the original scheme the gating system of the water pump causes the splash of liquid metal and air entrapment during filling (shown in Fig. 4). This results in the occurrence of air holes and oxide inclusions. Then the design of the gating system is revised and the process parameters are also regulated, which reduces these defects notably (shown in Fig. 5). In addition, the original scheme often leads to porosity at the hot spot of die castings (shown in Fig. 6). Therefore, in the revised scheme the transition point from the slow shot to plunger acceleration is adjusted suitably, and the pressure build-up time is also shortened, in order that the high pressure can be transferred to the liquid metal at the hot spots in time before the gate solidifies. Thus, the defects of porosity are basically eliminated. The complex shape of the water pump casting

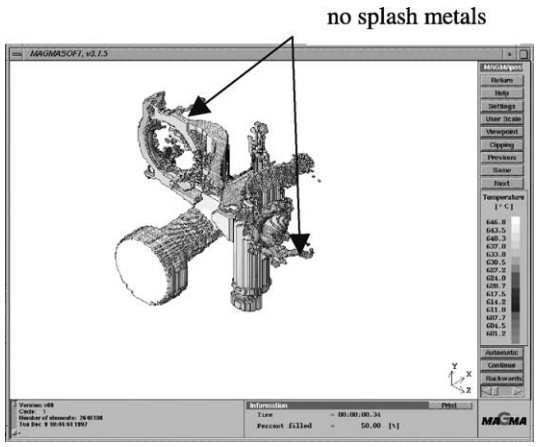

Fig. 5. The simulation of metal flow of water pump die casting in the revised technological scheme (50% filling).

and its wall unevenness make the defects of porosity and air entrapment easy to occur, but the demand for the sealing of a die casting of a water pump is very high, and the casting has to pass through a hydraulic pressure test without any leakage. The design of the die casting process is optimized with the help of CAE simulation and analysis, and the percentage of qualified products of die casting is raised greatly in a shorter time.

3.3. The realization of CAM

On the basis of the data of the 3D solid modeling of the cavities of die casting dies, with the use of the Pro/MANUFACTURING module of the Pro/ENGINEER CAD/CAM software, the 3D solid modeling of blank figures of the inlays are created first. Then the operation table of the 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

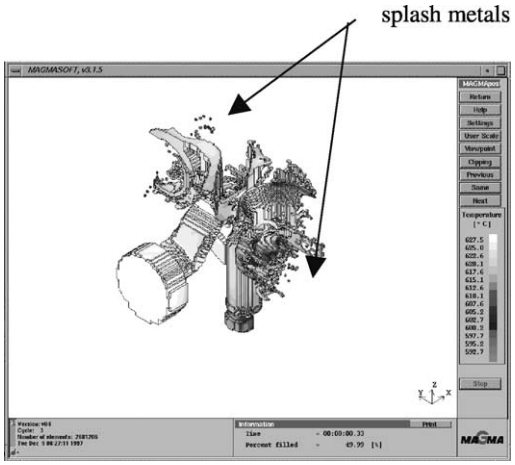

Fig. 4. The simulation of metal flow of water pump die casting in the original technological scheme (50% filling).

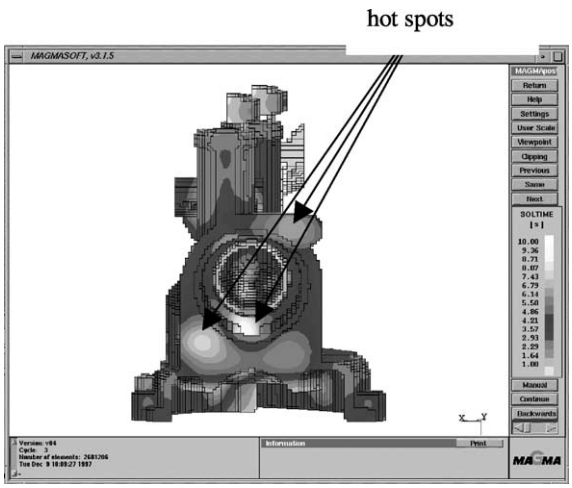

Fig. 6. The hot spot of the water pump die casting according to the original technological scheme (80% solidified).

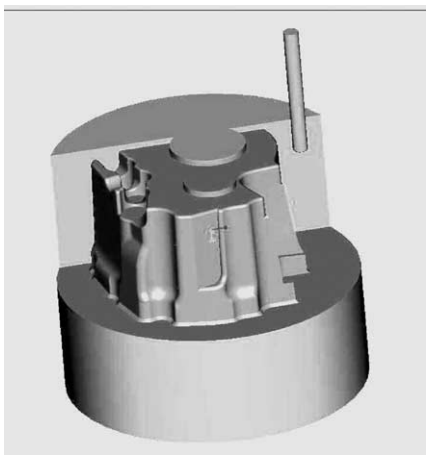

Fig. 7. The cutting path in the machining of inlay of die casting die of housing cover.

also created. Furthermore due to the use of the 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 inlay of die casting dies of housing cover is shown in Fig. 7.

4. Results of the application of integrated system

As mentioned above, with the help of the Pro/ENGINEER CAD/CAM software and a primary expert system package, the 3D solid modeling of die casting and the design of technological scheme of die casting process are created. Next the simulation and analysis of metal flow and solidification in dies are performed with the use of the MAGMASOFT software; the technological scheme and process parameters of die 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 moulds and cores are created, and the CAM of whole set of dies are completed on the CNC machines. Due to the use of a unitary database of the 3D model over the whole period, some steps may be performed simultaneously, and the design and manufacturing cycle of the dies can be shortened obviously.

The technological scheme and process parameters of die casting process are revised and further optimized by using the CAE simulation, and the quality of the die castings improved greatly in a shorter time. For example, due to the use of CAE simulation, the percentage of qualified products of die castings of the above-mentioned water pump is raised from 60 to 90% in a shorter time.

Another example is a magnesium die casting of a gearbox housing of a sedan. The CAE simulation results show the unevenness of the temperature distribution in the die cavity. The thermal balance and temperature distribution of the dies are improved with the regulation of process parameters such as gate velocity, flow rates of cooling media, etc. and the occurrence of cracks is reduced greatly. Because the percentage of qualified products of die castings can be raised greatly in a shorter time, the whole lead-time of die castings is also shortened greatly.

5. Conclusions

The established CAD/CAE/CAM integrated system of die casting dies has been used successfully in the design and manufacture of die casting dies of sedan parts such as a water pump, a gearbox housing, etc. The cycle of design and manufacture of die casting dies are shortened obviously. The process parameters and technological scheme of die castings can be optimized with the help of CAE simulation. This results in the production of die castings of consistently high quality in a shorter time, and the lead-time is shortened greatly. However, further research and development has to be undertaken for this integrated system, especially for the part of the expert system. More cases of die castings that are produced successfully in production have to be analyzed, and their information will be also included in the expert system. This will help to perfect the expert system.

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