Abstract

Die-casting is a fast, versatile and cost-effective manufacturing process for producing complex-shape metal components by injecting liquid metal at a high pressure in a steel mold called a die. Die-castings are among the highest volume, mass-produced items manufactured by the metalworking industry, and they can be found in thousands of consumer, commercial and industrial products. The die-casting process typically uses a non-ferrous alloy, such as aluminum and zinc, which is melted in the furnace and then injected into the die; the die is installed on a die-casting machine.

A die, or mold as it is sometimes called, is an essential requirement for manufacturing parts with the die-casting process. The die-casting die is said to be the back-bone of die-casting process, and greatly influences the cost, rate of production and quality of the parts produced. Designing a die for die-casting is a non-trivial and time consuming process that requires vast technical know-how and experience of a die designer. A die-designer has to go through a number of steps, all of which involve critical decision making, taking into account multiple factors, such as part material, production and delivery requirements, process requirements, die-design knowledge, and industry best practices. The non-triviality of the die-design activities further increases manifold in case of a multi-cavity die, which are commonly used in the industry.

Current practices prevalent in the die-casting industry are to use general mold or die-design applications. Available systems do not provide die-casting specific knowledge-based support for the user at various stages of crucial decision making, lack in the level of automation, and do not explicitly address multi-cavity die-casting die-design. The above mentioned deficiencies in the available systems result in high dependency on a die-casting expert, higher number of iterations, longer lead time, and
lack of consistency in the die-casting die-design. What makes the situation even worse is the lack of experts in the field available to the industry. The die-casting industry therefore needs computer-aided systems for die-casting die-design that provides a good level of automation, uses process information, applies die-design knowledge and industry best practices, is less dependent on the user, and also addresses the design of multi-cavity dies.

The thesis presents computer-aided systems related to design of multi-cavity die-casting dies, namely (i) computer-aided system for cavity layout design for a multi-cavity die-casting die, (ii) computer-aided system for core, cavity and side-core design for a multi-cavity die-casting die, (iii) computer-aided system for gating design for a multi-cavity die-casting die, and (iv) computer-aided system for multi-cavity die-casting die-design. Presented systems address major issues encountered in the computer-aided design of multi-cavity die-casting dies. Some of the major issues that not only effect die-design but its manufacturing too are: determination of number of cavities, design of the cavity, multi-cavity layout design, core and cavity design, side-core design, and gating system design. The proposed systems depend upon the databases of die-casting machines, die-casting materials, standard die-bases, and apply die-design knowledge. Besides providing knowledge-based support in a semi-automated manner at different stages of the die-casting die-design, the developed systems provide enough flexibility enabling the user to provide his/her choice interactively for decision support.

The first system, namely computer-aided system for cavity layout design for a multi-cavity die-casting die generates a CAD model of the cavity layout for a multi-cavity die-casting die in a semi-automated manner. The system determines applicable shrinkage and draft allowances for a part taking into account a number of factors related to part material, part geometry and its application. Subsequently, it applies the
allowances to the part CAD model, thereby eliminating lengthy procedures of calculations and subsequent modification of the CAD model.

The system also determines optimal, but a feasible number of cavities, decides their placement, and orientation to generate a CAD model of the die layout. First, the number of cavities is determined considering different factors like delivery date, production cost, machine constraints and part geometric limitations. Second, it uses die-design knowledge to decide the placement and orientation of the cavities in the die-base taking into account a number of factors, such as die-cast part material and geometry, number of undercuts and their position, feeding system, manufacturing resource considerations, well-established rules, and industry best practices. The system determines feasible layouts for orientation and placement of cavities, and selects the one which has the minimum die-base size. The system is validated by the industry case studies.

The second system, namely computer-aided system for core, cavity and side-core design for a multi-cavity die-casting die creates CAD models of the core, cavity and side-cores for a multi-cavity die in a semi-automated manner. The system makes use of the cavity layout design generated by the first system. The user only needs to interactively select the parting line edges and shut-off surfaces on CAD model of the part. The system automates most of the activities for generating core, cavity and side-cores for a multi-cavity die-casting die, resulting in significant saving in time and effort of the user. Results for industrial case study parts are presented.

The third system, namely computer-aided system for gating design for a multi-cavity die-casting die generates a CAD model of the gating system elements for a multi-cavity die in a semi-automated manner. The system takes into account various factors,
such as part material, filling requirements of the cavities, and industry best practices to determine the parameters of the gating system elements in a semi-automated manner. The gating system elements that it considers are gate, gate-runner, runner, overflow well and biscuit. The gating parameters are then used to generate CAD models of the gating system elements with the help of a gating feature library. Since the design of a gating system for a multi-cavity die requires user input at some stages, the system provides basic design rules and guidelines based on the industry best practices to facilitate the user. The system is validated by performing filling simulation and taking expert opinion for industrial case studies.

Lastly, an integrated computer-aided system for multi-cavity die-casting die-design is presented which takes part product model as input and generates CAD models of core, cavity, side-cores, and gating system elements in a semi-automated manner. The system, named Multi Cavity Die Designer integrates above mentioned three systems and handles major activities of the multi-cavity die-casting design in a computer-aided environment. The system works as an add-on application for SolidWorks software and depends upon the databases of die-casting machines, die-casting materials, standard die-bases, and applies die-design knowledge. A major advantage of such an integrated system is seamless flow of information from one die-design system to the other. Furthermore, developing the system on the platform of a commonly used CAD system has the advantages that CAD models of the die components can be directly used to design other essential systems, such as ejection and cooling. The CAD models of the die components can be further used for their manufacturing.

The developed systems have been tried on a number of industrial die-casting parts and results have been found to be on the lines of those obtained from the industry.
The results of industrial case study parts are presented in the thesis to demonstrate the effectiveness and capability of the developed systems. The developed systems would be useful in achieving the objectives of automated design of a die-casting die instantiating from the product (or CAD) model of a die-cast part. The systems therefore attempt to bridge the crucial gap of the design of a die to realize design-manufacturing integration of the die-casting process.