# Applications of Expert Systems as a Tool For Decision Making in Metal Casting

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***Abstract-*** *Expert system is a computer program simulating decision making process to solve problem in a particular domain. These expert system mainly consists of knowledge base and inference mechanisms. Different systems need to be developed for various processes involved in production of casting starting from selection of manufacturing process for casting till the analysis of casting defects once it is produced. The role of the expert system is more important in foundry because most of its process are rich in rule of thumb and knowledge base. These expert systems utilizes current facts and knowledge contained in the knowledge base to establish additional facts or decisions and continues as a chain, until a fact specified as a goal is established or decision making is done. Expert system application is proposed in the selection of metal casting process, cost estimation, quality control and scheduling.*

***Keywords***- Expert system, Knowledge base, Cost estimation, quality control and scheduling

## I. INTRODUCTION

As computer technology is applied to more complex problems, traditional approaches are being superseded by other methods, that is, knowledge-based systems. This is particularly important when complex manufacturing and processing technologies are to be analyzed. One of the most complex production technologies is that of metal casting, which requires extensive knowledge of a number of demanding technical disciplines

Once the knowledge representation stage complete, the next step is to produce the program which will search through the data, matching the given parameters, and produce all the matching results. To do this, an expert system is needed which assists in decision making. The expert system is based on the one of the programming language and is made user friendly. The expert system is designed to allow users to perform searches through the use of frames, relations and actions.

Expert system methodology has been applied in the past to a number of problems of planning, design, diagnostics etc. However, the problems of metal casting have not been adequately addressed. These problems need to be attended in an integrated manner with knowledge from different domains and sources. Continued research in the last ten years has resulted in the emergence of new methodologies which will enable building of automated integrated design systems that will have the ability to handle the entire process.

Stand-alone expert systems doesn't serve much to the engineering community due to their limited applicability to narrow problem domains. Expert systems were found to be ideal for integrating different programs in a domain resulting in the development of decision support systems. Decision support systems integrate heuristic knowledge-based inference, description of scenarios and situations using a network of frames, objects or scripts, conventional programs and databases.

Application of the expert system is suggested for certain applications in foundry process such as selection of metal casting process, cost estimation, quality control and scheduling . The use of relations is the main search technique for this expert system and these relations are supported by rules and actions throughout the execution of the program.

## II. LITERATURE REVIEW

Unlike other computer information systems, the power of expert systems lies in the knowledge that they incorporate, as opposed to specific calculations or search methods. As these systems progressively penetrate the manufacturing environment, they represent an increasingly practical tool for foundrymen.

According to Niebel et al [1], metal casting has several distinct advantages: "The ability of a liquid to fill a complex shape; economy when a number of similar pieces are required; and a wide choice of alloys suitable for use in highly stressed parts, where light weight is important or where

corrosion may be a problem. Casting permits the engineer to place the metal where it is needed and remove it where it is excess. However, there are a variety of problems inherent in the metal casting process. These may include variations in dimensions caused by shrinkage, metal penetration into the mold, pinholes, and gaseous inclusions, which makes it complicated even for the most sophisticated foundrymen, despite years of experience."

Despite the complexity of the process, most engineers and scientists view metal casting as a simple process that is low in technology. In truth, the technological demands are so challenging that for many years it was easier to use art and informal rules-of-thumb to make castings.

Darwish et al [2] have presented an expert system for the selection of casting processes. The selection criteria are based on the production, design, manufacturing as well as trade-off attributes. The objective of the proposed system is to aid the designer in adequately selecting casting processes for the production of components.

Akarte et al [3] have given the requirements of a product, selecting the most suitable casting process is a multi-criteria decision making problem. These characteristics vary with the type of cast metal, leading to a large number of material dependent process-characteristics. They presented a systematic approach for evaluating product-process compatibility, which is useful for casting process selection and product design improvement. The criteria were assessed using linear weighing and fuzzy logic models, and their relative importance is determined using Analytical Hierarchy Process, to finally arrive at the product-process compatibility index.
An expert system will serve the purpose if properly designed taking into consideration all these parameters. Expert system not only will help in identifying cost associated with each metal casting process but also will help in ranking among the alternatives under consideration. It helps for cost estimation which is also one of the major criteria before finalizing the process.

Patil et al [4] has revealed that in India many foundries have followed conventional and manual operations. Foundry industries suffer from poor quality and productivity due to large number of process parameters combined with lower penetration of automation and shortage of skilled worker. Mould shifting, sand inclusions, poor surface finish, shrinkage, porosity, cold shut and flash are common casting defects in casting. Since casting process involves complex interaction among various parameters and operations related to metal composition, method designs, melting, pouring, shake-out, fettling and machining and hence need to improve. It prescribed comprehensive review of work pertaining to process improvement techniques used for defect minimization in casting. There is a need for integration of these parameters into system.

T. Elbel et al [5] has mentioned that one of the powerful tool for defect analysis is an expert system. It is a computer programme based on the knowledge of experts for solving the quality of castings. They presented the expert system developed in the VSB-Technical University of Ostrava called 'ESWOD'. The ESWOD programme consists of three separate modules: identification, diagnosis / causes and prevention / remedy. The important aspect need to be considered at greater depth for identification of casting defects which needs further analysis separately before integration into system. Expert system is proposed to give recommendations for the selected problem.

Sury et al [6] have shown how to design design and build an expert system focused on special processes occurring in the production of aircraft engine parts manufactured by the investment casting. The construction of an expert system for technological processes in the foundry industries is determined by the class of problems. The way the complexity of the process, a multitude of physical and chemical reactions practically eliminate possibility to create a classical mathematical model for group of these processes. Knowledge base of the shown system is continuously updated collection of process parameters, with the greatest possible number of technological nodes. The purpose of this system is to reduce product defects occurring during the investment casting process. The expert system proposed for the sand casting process requires modification in the parameters related to the new process.

Yarlagadda et al [7] In their work on an artificial intelligent neural network system have developed to generate the process parameters for the pressure die casting process. The scope of their work was analysis of a physical model for the pressure die casting filling stage based on the governing equations of die cavity filling, and the collection of feasible casting data for the training of the network through the use of simulation package MELTFLOW and also from experts in the die casting industry. The neural network was developed using three different training algorithms; namely the error back-propagation algorithm, the momentum and adaptive learning algorithm, and the Levenberg–Mrquardt approximation algorithm. But interactive system will not only take us closer but also helps to establish facts for further studies .

Yue et al [8] have established concept of concurrent engineering (CE), a CAD/CAE/CAM integrated system for

die casting dies 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. 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. Such system can further be extended for estimation of cost of a casting using a typical method of casting.

Ahmet et al [9] have stressed on the fact that the solution of many casting problems requires the use of heuristics knowledge or expertise gained over many years. Analytical or algorithmic based computer programs can not readily deal with such an expert knowledge and its heuristics reasoning process. Computerised expert systems, however, can combine human expertise and the power of computers to solve specific metal casting problems. It dealt with a prototype casting defects control knowledge-based system was developed consisting of three separate modules: Defect Diagnosis for the identification of casting defects based on their physical forms; Defect Analyser for defect source identification of a given defect, followed by its causes analysis and specific preventive measures. In the present system few casting defects are considered. Some more defects need to be considered with similar approach.

## III. EXPERT SYSTEMS APPLICATION IN METAL CASTING

### i) Selection of metal casting process :

A knowledge-based expert system can be employed as a real-time expert advisor to assist manufacturers to select the most appropriate casting process for a given component without deviating norms for the required quality at each level. There is a need to formalize and quantify rules-of-thumb in such a way that modern computational applications can be developed to permit much of the "art" of metal casting to be transformed into a recognized science

This paper proposes one such application of an expert system approach for casting process selection. It also helps in deciding the most appropriate process by considering the weighted point average of each alternative. The expert system may be developed considering the parameters in the matrix and its interrelationships with the various metal casting process. In this, rules-of-thumb is proposed to be formalized and "quantified"

Table 1: Parameters affecting selection of metal casting process

| Parameters | Metal casting processes |
|---|---|
| Range of metals,<br>Dimensional Accuarcy,<br>Surface quality,<br>Unit weight,<br>Minimum section thickness,<br>Ease of casting complex design<br>Ease of design change in production<br>Fixed cost,<br>Variable cost,<br>Economic lot size | Sand casting<br>Die casting<br>Permanent casting<br>Investment casting<br>Centrifugal casting |

### ii) Cost estimation of metal casting process

Expert system need to be developed for each metal casting process to know the cost associated with it. The same can also be used to identify the variance if any. Material cost variance, labour cost variance, Manufacturing overhead variance. Based on the records, variance need to be further computed for subcategories from controlling point of view. It can further be reviewed to classify them into favorable and unfavorable. With proper strategy recommended by the proposed expert system costs can be kept under control. Same can be untilled for cost reduction. The proposed system will give its recommendation at intermediate stage and final stage while interacting with user. The choice will be made by the user by changing the weights for the parameter and comparing the responses given by the system for the purpose of formulation of strategy. The system designed is flexible. The following figure shows the cyclic process used in variance analysis.


Fig. 1: Variance Analysis cycle

### iii) Quality control in metal casting process

Expert system need to be developed for each metal casting process for controlling the quality at each stage of production. More focus is given on controlling the defects of the casting as revealed in the literature. But considering the steps involved in metal casting process integrated expert system is proposed to be developed to take care of all the parameters which affect the quality of casting. Continued improvements in the control of casting quality is a significant problem for many foundries. The number of variables that affect casting integrity implies that the prevention of such defects is possible, though not necessarily easy. The utilization of statistical process control techniques can substantially change the level of rejection due to these defects.

The foundryman is faced with the task of identifying the cause of the casting defect and then selecting the best method to deal with it. If an experienced, knowledgeable foundryman is not available, time and money may be lost while the foundry attempts to find a solution to the problem associated with defect. Hence, an expert system is proposed to identify, analyze defects and advise the best way to eliminate these defects. Defects can arise from a multiplicity of causes, which can be difficult to sort out, trace, and correct. Because much foundry practice has, in the past, relied on rules-of-thumb, defect analysis has also frequently followed this approach. Hybrid expert system is proposed for logical choice to defect analysis.

The architecture [10] of proposed expert system as shown in figure below includes integration of knowledge base module with various other elements of the system including client interaction.

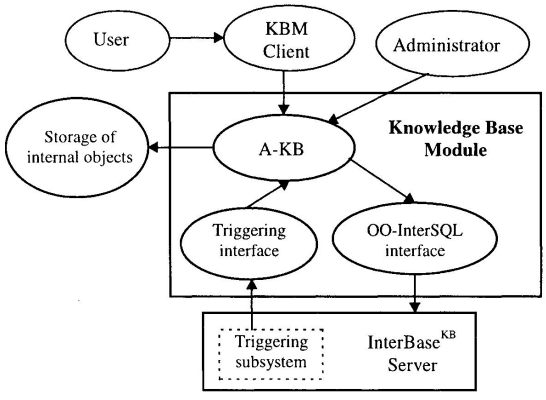


Fig. 2: The architecture of an expert system

**iv) Scheduling in metal casting process**

Scheduling [11] determines the timing of production, that is, exactly when and in what sequence the work will be performed. This shop floor scheduling, often referred to as dispatching, has long been studied in the literature. However, with particular regard to the jobshop manufacturing environment that characterizes many foundries, the dispatching problem becomes inordinately complex. Although the classical definition of expert systems infers a strictly heuristic approach to problem-solving, increasingly expert systems are incorporating decision support system modules as well. The inclusion of algorithms serves to enhance the capabilities of the expert system, which prove to be particularly useful for scheduling problems. These hybrid systems, provide a logical extension to either the decision support system approach or the expert system. They frequently allow for the choice between algorithmic models and expert heuristics, depending upon the specific characteristics of the problem. These hybrid systems in scheduling permit both approaches to the problem, with each approach addressing the appropriate portion.

## IV. CONCLUSION

The expert system provides access to reliable data in real time, eliminates errors and delays generated by humans and helps to select the appropriate metal casting process for a given component based on its relative ranking.

The expert system provides access to feedback from downstream processing and operational data and to establish an effective mechanism for the use of data for the purpose of cost estimation and cost control. It also helps to analyze variance and suggest suitable remedial action if required.

The expert system supports the inference and decision-making based on the results of the analysis and knowledge base and it allows you to control processes aimed at stabilizing parameters, eliminating or reducing of variability and controlling quality.

With respect to scheduling, the hybrid system frequently utilizes the heuristic processing component to determine a limited number of feasible solutions for a explosive problem. The algorithmically based decision support system component is then utilized to derive an optimal solution within this limited search space.

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