1996

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Recommended Citation

Er, A., Sweeney, E., Kondic, V., (1996) Knowledge-Based System for Casting Process Selection, American Foundry Society (AFS) *Transactions*, Vol. 104, pp. 363-370.

Knowledge-Based System for Casting Process Selection

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ABSTRACT

Design of casting entails the knowledge of various interacting factors that are unique to casting process, and, quite often, product designers do not have the required foundry-specific knowledge. Casting designers normally have to liaise with casting experts in order to ensure the product designed is castable and the optimum casting method is selected. This two-way communication results in long design lead times, and lack of it can easily lead to incorrect casting design. A computer-based system at the discretion of a design engineer can, however, alleviate this problem and enhance the prospect of casting design for manufacture. This paper proposes a knowledge-based expert system approach to assist casting product designers in selecting the most suitable casting process for specified casting design requirements, during the design phase of product manufacture. A prototype expert system has been developed, based on production rules knowledge representation technique. The proposed system consists of a number of autonomous but interconnected levels, each dealing with a specific group of factors, namely, casting alloy, shape and complexity parameters, accuracy requirements and comparative costs, based on production quantity. The user interface has been so designed to allow the user to have a clear view of how casting design parameters affect the selection of various casting processes at each level; if necessary, the appropriate design changes can be made to facilitate the castability of the product being designed, or to suit the design to a preferred casting method.

INTRODUCTION

In casting manufacture, there are many complex problems that can not be readily solved using conventional algorithmic techniques alone. Their solution often relies on the use of empirical knowledge or expertise gained over many years. Although algorithmic-based conventional computer programs can process and manipulate data to yield solutions, they cannot readily deal with human knowledge of experience and its heuristic reasoning procedures. Moreover, experience knowledge and experts, themselves, are scarce, and can be difficult and expensive to obtain. Computerized expert systems, however, can solve specific foundry problems that cannot otherwise be solved using conventional computer programs, and where human expertise is not readily accessible.

An expert system (ES), also known as a knowledge-based system (KBS), is essentially a computer program with "intelligent" characteristics, which simulates the thought process of human experts to solve complex problems in a specific domain. A KBS basically consists of three major components: the *knowledge base*, the *inference engine* and the *user interface*. The knowledge base contains the knowledge needed for the solution of a particular problem. This knowledge may be in the form of rules, heuristics or problem-solving know-how, representing the knowledge of experts in a specific problem domain. The knowledge in the knowledge base is structured and represented in a form that can be understood by computer, using a variety of representation techniques, such as *production* or *IF-THEN* rules, *semantic nets*, and *frames.* The inference engine is the mechanism used by the KBS to reason with the knowledge, and contains mechanism, strategies and controls to manipulate and apply the knowledge in the knowledge base.

The user interface part enables interaction of the system with the user. It includes screen displays, a consultation strategy and an explanation component. In addition, expert systems provide interfaces for system developers, as well as for communication with external programs, such as data bases, spreadsheets and similar software.

Developments of expert system software tools, in recent years, have facilitated the use of KBS in a range of manufacturing domains, including production management, process planning, fault diagnosis and process control. A number of KBS developments for solving various casting problems have been reported, including casting design, process and alloy selection, casting defects diagnosis and their prevention, design of mould-filling and feeding systems in investment castings and process monitoring.

Selection of the correct casting process is an important part of casting design and manufacture. Basically, casting processes can be classified into three main or primary methods, based on materials used for mould construction, namely, sand, metal and ceramic. A number of different technical variants have been developed in each primary method. Different casting methods offer different technical and cost advantages, and selection of an appropriate method requires a sound understanding of the interactions between casting design constraints, required product properties, technical limitations of individual casting methods, available casting production tooling and the overall cost determining factors. A tool that could identify the optimum method of manufacturing castings to meet specified requirements would, therefore, be of great value to the designer, as well as to the manufacturer of castings.

This paper discusses the development and use of such a tool, namely, a casting process selection KBS. The development work, reported here, is still being continued; thus, the KBS features reported in the paper are confined to the current state of its development.

KBS DEVELOPMENT

Provided that the correct development tool is employed, the construction of knowledge-based systems does not necessitate skilled software programmers, but a certain amount of computer literacy is required, as is the case with most application software programs. In-house development of foundry-specific expert systems should, thus, be within the capacity of most foundries. Developing a successful KBS, however, necessities a well-planned development process. It is important that a systematic approach be adopted, from the identification of problem domain, through the construction of the knowledge base and, finally, to the implementation of the system.

The end product of the knowledge coding, along with the design of menu-driven user/system interface and consultation dialogue, was a casting process selector (CPS) knowledge-based system.

CPS STRUCTURE AND FEATURES

In CPS, the complex casting process selection problem is divided into modular levels. Each level has its own sub-knowledge base, dealing with a specific part of the overall process selection problem, thus making its development, as well as its application, simpler and more effective. The system's knowledge base consists of four separate, but interconnected, knowledge bases (KB) or levels.

The approach is based on eliminating inappropriate methods at each of the four stages (or levels) of the system, namely, alloy suitability (KB 1), the complexity of a casting shape and other design features (KB 2), suitability of required dimensional tolerances and surface finish (KB 3), and production costs, currently limited to economical total production quantity (KB 4). The optimum process is recommended at the end of level 4.

The system takes the user through each of the four levels, in turn, asking the appropriate questions at each stage. The answers or data input by the user can be modified at any stage, so that the effect of changes in particular parameters on the system's conclusion can be explored.

POTENTIAL BENEFITS

Casting designers often have only an elementary knowledge of casting technology. They have to refer to experts to ensure that the product they are designing is castable and complies with certain technical and economic limitations of specific casting processes. A lack of availability of casting experts or insufficient expert support during design stage is likely to result in not only an incorrectly designed product, but also in a substantially longer design lead time and, thus, adversely affect costs of design and manufacture.

The emphasis on concurrent or simultaneous engineering, in recent years, stresses the importance of timely interaction of product designers with process experts. However, a knowledge-based system, such as CPS, can provide potential uses for casting product designers, both at preliminary and detailed design stages. The designer can consult the system to obtain advice on the optimum casting process for a particular design, or, for a given preferred casting process, the system can simply evaluate the castability or suitability of the design for that particular method.

It is also envisaged that foundries can make direct use of such a KBS as a support tool to help casting engineers quickly assess the suitability of a new design or inquiry for a preconceived or preferred casting method. Such a tool can be extremely useful, particularly in helping less-experienced foundry engineers to make decisions, when experts or experienced staff are not readily available. Furthermore, KBS of this nature can be used as a training or educational tool across the foundry industry, as well as in academia.

CONCLUSIONS

Based on a systematic methodology, a prototype knowledge-based system for casting process selection has been successfully developed. The system is based on production rules knowledge representation technique, and, for ease of use and a more effective application, a modular knowledge-based structure has been adopted. The system, in its present form, consists of four interconnected levels, each dealing with a specific group of casting process-determining factors, namely, casting alloy, casting shape features, casting accuracy requirements and, finally, cost comparison, based on production quantity.

This system can be of potential benefit to casting product designers, as well as foundry engineers, in identifying the most suitable casting process for a given specific design and for assessing a given design for a preferred casting process. However, for the system to be fully applicable, further development work is being undertaken.

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