WEB BASED PRELIMINARY PROCESS PLANNING OF CAST COMPONENTS

R. G. CHOUGULE
Research Scholar,
Mechanical Engineering Department,
Indian Institute of Technology, Powai, Mumbai, India.

Dr. B RAVI
Associate Professor,
Mechanical Engineering Department,
Indian Institute of Technology, Powai, Mumbai, India.

E-mail: chougule@me.iitb.ac.in
bravi@me.iitb.ac.in

ABSTRACT:
This paper presents a virtual foundry environment that can be accessed over Internet by design and manufacturing engineers, for preliminary process planning of cast components. The plans are automatically generated by case based reasoning using the nearest neighbor algorithm. An interactive facility is also provided for handling entirely new cases that do not have matching cases in the database. The methodology has been implemented in a virtual foundry environment called WebICE (Web based Integrated Casting Engineering). The databases are created using Casting Data Markup Language based on the XML standard.

Key Words: Casting, Case based reasoning, Internet, Process planning, Virtual factory, XML

1. INTRODUCTION

Metal casting – one of the most widely used manufacturing processes – involves a large number of interdependent and interacting process variables. Designing process-friendly cast components that lead to reduction in total costs, defects and lead-time is a challenging task. This requires extensive knowledge of various casting processes including their capabilities and limitations. Since product designers may have limited experience with casting processes, there is a need for communication with casting engineers to predict and prevent potential manufacturing problems at the design stage itself. Traditional means of communication however, are inadequate to handle the time, distance and cultural barriers that may exist between the design and manufacturing engineers. These barriers can be overcome by web-based collaborative engineering of cast products.

One of the key tasks that can be taken up is preliminary process planning, which greatly affects tooling development and other downstream activities. The link between design and production, that is, However, process planning which determines methods by which parts are manufactured economically and competitively from initial stages (raw
material) to finished stages (Zhang et al, 1994) is not bridged up. The current investigation is on the preliminary casting process planning which is mainly concerned with decisions regarding the methods, steps and major process parameters (type of mold or core sand, pouring temperature, etc.).

This paper presents a systematic approach to preliminary process planning of cast components by collaborative engineering between design and manufacturing engineers over Internet. The following section summarizes previous work in process planning, especially for castings, and the methodologies employed for the purpose. The proposed approach, based on case based reasoning is presented next. The details of the web-based implementation and results are discussed at the end.

2. LITERATURE REVIEW

Process planning has been a major area of research, but mainly for machining domain. There are mainly two approaches: generative and variant process planning. These have been implemented using knowledge-based systems, fuzzy logic, neural network, genetic algorithm and case based reasoning (Meziane et al, 2000). The latest work reports the use of a new methodology called case based reasoning (CBR). This involves retrieving old solutions (cases) that match the new case from the design description (Watson, 1999). The best matching candidate is then chosen and adapted to fit the description of the new design and verified for consistency to obtain the new solution. The CBR approach has been used for process planning of prismatic components (Marefat et al, 1997). Another machining process planner has been developed using CBR (Chang et al, 2000). Lei developed Cold Forging Process Planning (CFPP) system using case based reasoning (Lei et al, 2001). Yang used CBR approach for developing PROCASE, a case based process-planning system for machining of rotational parts (Yang et al, 1996).

A number of software packages are commercially available today for casting design and simulation, as well as for foundry production management (inventory control, material planning, scheduling, etc.). However, there is very limited technical literature on process planning of castings compared to machining domain. Even available literature mostly focuses on casting process selection, which is the first step towards process planning. In an earlier work, Sirilertworakul developed a knowledge base for alloy and process selection for casting (Sirilertworakul et al, 1993). Darwish developed a preliminary casting process selection expert system (PCPSES) using Rule Master, a software package for developing expert systems (Darwish et al, 1996). Er developed a knowledge-based expert system for process selection for cast components (Er et al, 1996). Akarte used Analytical Hierarchy Process methodology for casting process selection (Akarte et al, 1999). This was later extended to product-process-producer compatibility evaluation (Akarte, 2002). Ajmal developed an interactive computer aided process planning and estimating system for foundry application (Ajmal 1988).

This work uses the web-based framework WebICE (Web based Integrated Casting Engineering) developed in an earlier investigation. The WebICE facilitates web-based creation, updating and exchange of casting project data. The project data is stored in Casting Data Markup Language (CDML), defined based on the XML standard (Ravi, 2002). The CDML consists of two parts: CDML tree and data blocks. The CDML tree represents the hierarchical relationship between different types of information essential for collaboration between the product, tooling and foundry engineer, whereas the data blocks
are used for storing the actual project data. The hierarchical tree structure enables easy identification of required information. A library function offers alternative options for the set of field values in a data block. The library database contains several data block files corresponding to a particular CDML data block. Any of these can be selected and its values can be copied to the corresponding data block. This eliminates manual input and thereby the possibility of human errors. The WebICE framework thus enables web-based collaborative engineering between product designers and foundry engineers.

3. PRELIMINARY CASTING PROCESS PLANNING SYSTEM

A virtual foundry environment has been created to model foundry-related information, by extending the WebICE framework described earlier. The foundry resources like machines, along with their specifications and relevant process parameters can be created and visualized, as shown in Fig. 1 and Fig. 2. In this virtual foundry environment, a semi generative approach has been developed for preliminary casting process planning. For this purpose, a case based reasoning methodology using the nearest neighbor algorithm, has been adapted. This involves retrieving a similar (previous) case from the case base (previous projects) depending on part attributes related to material, geometry and production. For this purpose, the user specifies the weights for part attributes and corresponding attribute values. Based on this, process plan of a similar previous case is retrieved and adapted for the new case (or project). In the absence of a similar case, an interactive facility to develop the process plan is also provided for handling new cases. In this interactive facility, process plan is developed from the library of options for individual activities. This overall approach is shown in Fig. 3 and explained next.

3.1 Case Representation

The case-base is composed of cases, which are in predefined structures of WebICE framework. A case is composed of two major parts: problem description and solution. The problem description refers to attributes in the case that are required to describe the problem. These attributes and corresponding values are stored in PRODUCT node of CDML tree. The problem solution refers to the process plan. Here the information handling for the process plan is explained in detail.
For convenient handling of preliminary process planning information, it is divided hierarchically into activities, methods and steps. Different activities that are involved in the casting process are classified into:

- Pre-casting: sand preparation, core making and mold making.
- Casting: melting, holding and pouring.
- Post-casting: shakeout, cleaning and fettling.

After fettling, further steps may include heat treatment and machining, if required and in-house facility is available. Later on, it is painted, packed and transported to the customer. All the above different activities are stored under PROCESS node of CDML tree. The casting process planning information is stored under the child nodes PRE_CASTING, CASTING and POST_CASTING, which in turn contain information regarding different activities in the sub-nodes; for example PRE_CASTING node stores the information about the pre-casting activities viz: CORE_SAND_PREP, CORE_MAKING, CORE_DRESSING, MOLDING_SAND_PREP and MOLD_MAKING as shown in Fig. 4(a).

Each individual activity consists of several steps. These steps depend upon the method employed. For example, cores can be prepared by oil sand, hot box or cold box method, each with different steps. This information is systematically stored in library. It can be easily browsed by clicking the corresponding node of the CDML tree and then library function associated with that node as shown in Fig 4(b). Apart from different steps for performing each activity, library provides a framework for handling data regarding the time and frequency for each step. The user can browse through it by clicking the function View_Options and the data from the library can be copied to data block associated with corresponding node (activity) by clicking the function Copy_Options while performing the process planning interactively.
3.2 Case Retrieval

One of the biggest issues in case based reasoning is the retrieval of appropriate case, involving search and matching. The most popular retrieval algorithms are nearest neighbor matching, inductive indexing and knowledge based indexing. In our work nearest neighbor algorithm has been used for the retrieval purpose. Nearest neighbor algorithm is best suited if the matching function is good (values of all attributes specified) and cases are few. It involves specifying values for the attributes for new castings along with the weight corresponding to attribute. Different attributes that have been identified for retrieving case include:

- Casting material
- Geometric attributes: maximum casting length, casting weight, minimum and maximum wall thickness, core hole diameter, shape complexity
- Quality attributes: surface roughness, tolerance and maximum void size
- Production attributes: Order quantity, production rate, sample lead-time, and production lead-time.

Based on the attribute values and weights specified, a similarity coefficient for the problem (new project) is determined using the equation,

\[ \text{Similarity coefficient} = \sum_{i=1}^{n} A_i \times W_i \]

Where,
- \( A \) - Attributes
- \( W \) - Importance weighing of attribute \( i \),
- \( n \) - Number of attributes,
- \( i \) - Individual attribute from 1 to \( n \),
Similarly, similarity coefficients have been determined for each casting project in the case base (previous cases) using weights specified and corresponding attribute value of the project. Based on these similarity coefficients, the nearest three cases have been identified. In addition, similarity indices have been determined to express similarity by normalizing similarity coefficients of previous cases to the similarity coefficient of new problem on the scale 0 to 1 in which 1 indicates the best match.

\[
\text{Similarity Index} = \frac{SC_P}{SC_N} \quad \text{for } SC_P / SC_N \leq 1
\]

\[
= 1-(SC_P \cdot SC_N / SC_N) \quad \text{for } SC_P / SC_N > 1
\]

Where, \( SC_P \) = Similarity coefficient of previous case

\( SC_N \) = Similarity coefficient of new project (problem)

In addition, material compatibility and process compatibilities are also verified for retrieval purpose. It involves identifying the possible processes for the problem (new project) by comparing the attribute values with compatibility data of different processes stored in the library and only those cases (old projects) for which process and material have been matched are considered for retrieval. This methodology for the preliminary casting process planning is shown in the Fig. 5.
Once the case or cases that are to be used for deriving the solutions are known, the next step is to adapt the solution from the selected case to the problem at hand. If the current problem is nearly same as that which has already been solved, then old solution can be used directly and no adaptation is needed. However, if it is not the case, then the solution can be adapted by some local adjustment. In the absence of suitable case in the case-base, an interactive facility has been provided generating the process plan. In this process plan is generated for each activity from the libraries corresponding to each activity (node). From the libraries suitable method can be chosen and corresponding file can be copied using Copy_Options function.

After case adaptation and modification, the new case forms a part of case-base for future reference.

4. CONCLUSION

A semi-generative process planning approach has been developed for preliminary process planning of cast components. This is implemented in a web-based framework, which can be assessed by design and manufacturing engineers working in different locations. This helps in collaborative product-process development of cast components in which problems associated with manufacturing the component in the foundry can be revealed at early stages of design. This feedback assists designer in changing the design at early stages thereby reducing the cycle time and cost associated with the product development.

REFERENCES:


Industrial Engineering Conference, Greece.


