A Computational System for Process Design of Injection Moulding: Combining a Blackboard-Based Expert System and a Case-Based Reasoning Approach

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Process design of injection moulding involves the selection of the injection moulding machine, mould design, production scheduling, cost estimation, and determination of injection moulding parameters. An expert system approach has been used to derive the process solution for injection moulding over the past few years. However, this approach is found to be incapable of determining the injection moulding parameters owing to the fragile nature of the knowledge for setting the moulding parameters. In addition, the existing expert systems for process design lack proper architecture for organising heterogeneous knowledge sources. In this paper, the combination of a blackboard-based expert system and a case-based reasoning approach is introduced to eliminate the deficiency of the existing expert-system approach to process design, from which a computational system for the process design of injection moulding, named CSPD, has been developed. CSPD first derives the process solution including the selection of the injection moulding machine and the mould base, tooling cost, processing cost estimation, and production scheduling based on the blackboard-based expert-system approach. It is then followed by the determination of the injection moulding parameters based on the case-based reasoning approach and the previously derived partial solution.

Keywords: Blackboard architecture; Case-based reasoning; Expert system; Process design of injection moulding

1. Introduction

Process design of injection moulding mainly involves selection of the injection moulding machine, mould design, cost estimation, production scheduling and the determination of injection moulding parameters. Traditionally, these activities are carried out by a team of experienced personnel, including a mould designer, a moulding engineer, a costing engineer and a production engineer, in a sequential manner after the completion of the part design. This could lead to the frequent redesign of the part owing to the lack of process information in the design stage. Nowadays, obtaining a process design solution in the design stage is one of the crucial factors for reducing the product development time and shortening the time-to-market.

Technological advances in artificial intelligence (AI) have boosted the development of computational systems for process design. Expert systems are popular AI techniques being employed to develop computational systems for process design. A variety of research work adopted the expert-system approach in process design. Farris and Knight [1] built an expert system for selecting the processing sequence in the early product design stage. Venkatchalam et al. [2] demonstrated how expert systems methodology could be used to make process selection decisions based on a set of design and production parameters to achieve cost-effective manufacture and to estimate processing cost based on the identified processes. An expert system approach has also been used in the process design of injection moulding including injection mould cost estimation [3,4], and injection mould design [5–7]. Process design of injection moulding normally involves different domains of expertise that may result in different types of knowledge representation existing in an expert system. However, the works described above were all based on the conventional architecture of expert systems which is incapable of managing a heterogeneous knowledge base in an expert system. In addition, these works do not indicate how the ill-defined knowledge about the determination of injection moulding parameters can be captured.

Traditionally, moulding personnel might make moulding trial runs in order to determine the proper moulding parameters for producing good quality parts. The time taken is, in many cases, dependent on the experience of the moulding personnel. Their experience probably exceeds their understanding of the technology and sometimes it is hard for them to explain the reason for the actions that they have taken. In addition, the experience...
is hard to codify and transfer to other moulding personnel. Since the nature of that heuristic knowledge and experience is fragile and not well structured, it is not acquired easily or represented well in an expert system. Simulation is another approach for determining moulding parameters. Various commercial simulation packages such as C-Flow from Advanced CAE Technology Inc. and MoldFlow from Moldflow Australia are available. However, owing to the complexity of the injection moulding process and difficulties in obtaining an accurate rheological description of the actual material being processed, a general comprehensive mathematical model giving a satisfactory picture of the process is not yet available.

2. Combining a Blackboard-Based Expert System and a Case-Based Reasoning Approach

The literature review shows that an effective architecture for expert systems is required to manage the heterogeneous knowledge base. Various strategies and architecture have been proposed to implement such a design procedure, where more than one domain expert is involved. One such popular architecture is the blackboard, which simulates the arising of contradictions and the arriving at compromises to resolve the contradictions, when experts representing different domains interact with each other to arrive at an acceptable solution. A detailed description of the blackboard architecture can be found in [8] and [9]. Blackboard architecture has been adopted in organising expert systems for concurrent engineering [10,11], part design [12,13], and handling engineering design data [14].

The literature review has also revealed that the search for other techniques which can capture the experience in setting injection moulding parameters is necessary. In this paper, a novel case-based reasoning (CBR) approach is described to derive the proper moulding parameters based on old solutions. Case-based reasoning can mean adapting old solutions to meet new demands, using old cases to explain new situations, and using old cases to assess new solutions. There are several benefits of applying CBR technology in the determination of injection moulding parameters. It allows the reasoner to propose solutions quickly, hence reducing the time needed to work them out. In addition, remembering previous experience is particularly useful for injection moulding, as previous experience helps to avoid the repetition of past mistakes. The learning process available with a CBR system enables it to become more efficient by increasing its recall of old solutions and by adapting them. Schank [15], and Riesbeck and Schank [16] pioneered the case-based reasoning technique as an alternative to the more traditional rule-based and model-based reasoning techniques. Case-based reasoning has been employed for a multitude of problems [17]: catering, recipe making, dispute mediation, criminal sentencing, process planning [18], etc. Some systems have been documented as design systems in the CBR literature [19].

A computational system for process design for injection moulding, named CSPD, has been developed by the authors based on the combination of a blackboard-based expert system and a case-based reasoning approach. In Section 3, the architecture of the CSPD is presented. This is followed by the description of its two major components – the blackboard-based expert system for process design (KPC), and the case-based reasoning system for process design (CBRS). An example of the CSPD is described in Section 6. Finally, discussions and conclusions are given.


Figure 1 shows the architecture of the CSPD, which mainly consists of four components – a user interface, a blackboard-based expert system for process design (KPC), a case-based reasoning system (CBRS), and a database. KPC is a complex expert system that involves multidisciplinary expert knowledge. It is used to generate a process solution including the selection of an injection moulding machine and a mould base, tooling and processing cost estimation, and production scheduling. CBRS is used to retrieve the previous cases and experience and tries to work out the setting of injection moulding parameters in a very short time. The database is used to store the information and data about the shop floor injection moulding machines, standard mould bases, and common thermoplastic materials. CSPD first derives the partial process solution based on the blackboard-based expert-system approach. The partial solution together with the part information are then read by the CBRS for case retrieval and adaptation from which the proper injection moulding parameters are recommended to the user, based on the case-based reasoning approach. Detailed descriptions of the KPC and CBRS will be provided in Sections 4 and 5, respectively.

4. Blackboard-Based Expert System for Process Design (KPC)

As mentioned in Section 2, blackboard architecture is adopted to develop the KPC in this research project, which mainly

![Fig. 1. System architecture of the CSPD.](image-url)