

Intelligent Mold Design Tool For Plastic Injection Molding

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Abstract

Plastic Injection molding is one of the most popular manufacturing processes for making thermoplastic products, and mold design is a key aspect of the process. Design of molds requires knowledge, expertise and most importantly experience in the field. When one of these is lacking, selection of an appropriate mold for manufacturing a plastic component is done on a trial-and-error basis. This increases the cost of production and introduces inconsistencies in the design.

This paper describes the development of an intelligent mold design tool. The tool captures knowledge about the mold design process and represents the knowledge in logical fashion. The knowledge acquired will be deterministic and non-deterministic information about the mold design process. Once developed the mold design tool will guide the user in selecting an appropriate mold for his plastic part based on various client specifications.

Introduction

The plastic injection molding process demands knowledge, expertise and, most important, experience for its successful implementation. Often it is the molding parameters that control the efficiency of the process. Effectively controlling and optimizing these parameters during the manufacturing process can achieve consistency, which takes the form of part quality and part cost.

The level of experience of the manufacturer(s) determines how effectively the process parameters are controlled. This sometimes leads to inconsistency introduced by human error. There is also the case where there is inexperience, shortage of time, resources and little scope for innovation. Knowledge-based engineering provides a feasible solution to all these problems by creating what is called an “intelligent model” of the problem.

IKEM

Intelligent Knowledge based Engineering modules for the plastic injection molding process (IKEM) is a software technology that is a step ahead of the concurrent engineering and CAD/CAM systems. It integrates current knowledge about the design and manufacturing processes and helps to reduce several man-hours by reducing engineering changes in the design phase of product development by giving users instruction about various design aspects. The system will be used for injection molding design, design iterations, and process integration. The current process consists of many manual computations, CAD graphical constructions, and experience attained from previous projects. Once the engineer completes the design, it will be evaluated for performance.

The IKEM project has been divided into three major modules.

1. The cost estimation module
2. The mold design module
3. The Manufacturing module

Input to the IKEM system is of two forms. Input in the form of a CAD model (Pro-E file) and input given at the User Interface form. Figure 1 illustrates the kind of input that goes into each module and the output given to the user.

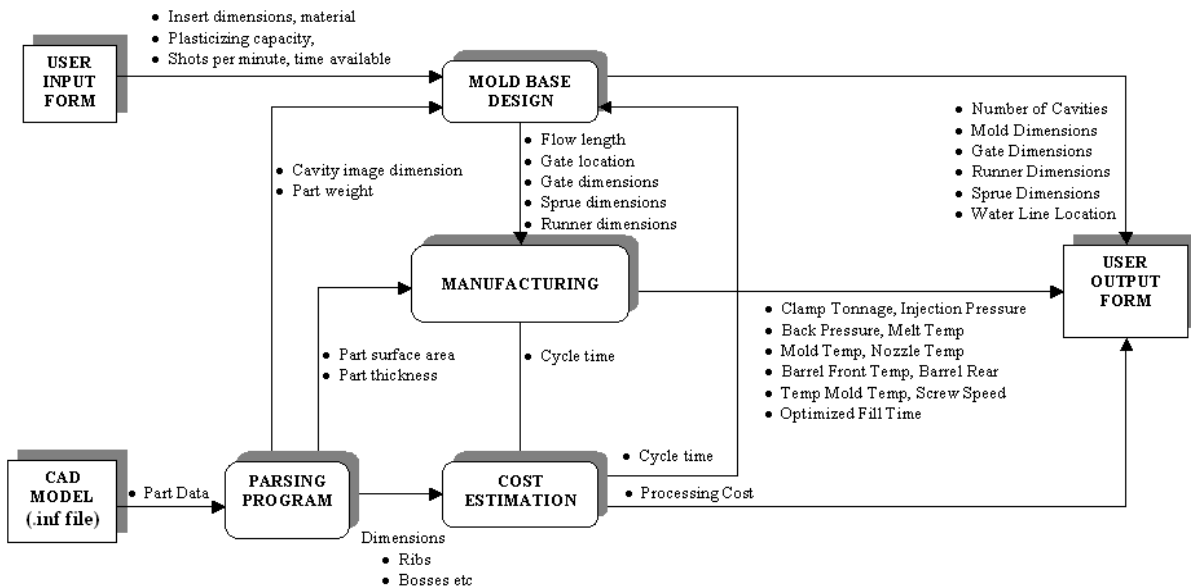


Figure 1. Organization of the IKEM Project

Intelligent Mold Design Tool

The mold design tool in its basic form is a Visual Basic application taking input from a text file that contains information about the part and a User Input form. The text file contains information about the part geometry parsed from a Pro/E information file. The input is used to estimate the dimensions of mold and various other features.

Literature Review

Design of molds is another stage of the injection molding process where the experience of an engineer largely helps automate the process and increase its efficiency. The issue that needs attention is the time that goes into designing the molds. Often, design engineers refer to tables and standard handbooks while designing a mold, which consumes lot of time. Also, a great deal of time goes into modeling components of the mold in standard CAD software. Different researchers have dealt with the issue of reducing the time it takes to design the mold in different ways. Koelsch and James [2] have employed group technology techniques to reduce the mold design time. A unique coding system that groups a class of injection molded parts, and the tooling required in injection molding is developed which is general and can be applied to other product lines. A software system to implement the coding system has also been developed. Attempts were also directed towards the automation of the mold design process by capturing experience and knowledge of engineers in the field. The development of a concurrent mold design system is one such approach that attempts to develop a systematic methodology for injection mold design processes in a concurrent engineering environment [3]. The objective of their research was to develop a mold development process that facilitates concurrent engineering-based practice, and to develop a knowledge-based design aid for injection molding mold design that accommodates manufacturability concerns, as well as product requirements.

Researchers have been trying to automate the mold design process either by capturing only the deterministic information on the mold design process or the non-deterministic information, in various ways. This research uniquely attempts to develop a mold design application that captures information in both forms; deterministic and non-deterministic.

Approach Adopted

In order to develop an intelligent mold design tool, the conventional method of designing molds is studied. The application developer and the design engineer work together in designing a mold for a particular plastic part. During this time, the approach adopted by the engineer to select the mold base is closely observed and aspects of the selection process that require his knowledge/experience are identified. Also, there will be times when the engineer will refer to tables and handbooks in order to standardize his selection process. This time consuming process is also recorded to incorporate it later in the application.

Formulating the problem for the application in terms of inputs and outputs is the next stage. This involves defining what information about the mold layout is most required for the user and also the minimum number of inputs that can be taken from him to give those outputs.

Based on the information gathered in the mold design exercise, the conventions followed by the engineer are transformed into if-then rules. Decision tables are used to account for all possible cases that arise when dealing with a particular aspect of the mold design process. The rules so framed are then organized into modules interacting with each other, using an application development environment. Finally the application is tested for its validity when it comes to designing molds for plastic parts manufactured in the industry.

Selection of Appropriate Mold Base

Typically, selection of appropriate mold base for manufacturing a plastic part involves

- ❑ *Estimating the number of cavities*
The number of cavities is decided depending on the number of parts required within a given time. There are also other issues like the plasticizing capacity of the machine, reject rate etc that affect the number of cavities to be present in the mold base.
- ❑ *Deciding on the presence of inserts and their dimensions*
Inserts facilitate the reusability of the mold base and therefore help in reducing cost of manufacturing. When it comes to selecting the dimensions and the number, a decision is made depending on the reusability of existing old inserts and cost of ordering new ones.
- ❑ *Determining the size and location of runners*
The runner size depends on the material being molded. Although there are other considerations material properties determines the channel size required for its flow. Location of runners mainly depends on the topology of runners being used. Though a circular runner system is always preferable, the branched runner system that avoids runner balancing is the one most widely used.
- ❑ *Determining the diameter of sprue*
The diameter of the sprue is decided based on the size of the mold, number of cavities, or the amount of plastic that is to be filled within a given time.
- ❑ *Locating gates*
Plastic enters the cavity at a point where it can uniformly fill the cavity. A gate can be located at any point on the perimeter of a circular cavity but has to enter at the midsection when it comes to filling rectangular cavities.

- *Determining the size and location of water lines*
Water lines are located at standard distances from each other and from any wall in the mold. The convention is not to locate a waterline within one diameter range on the mold wall.

- *Deciding mold dimensions based on above conclusions*
Based on all the above decisions the approximate mold dimensions can be estimated and rounded off to the nearest catalog number. Considering all the above aspects before even modeling the mold base reduces the cost and time that go into redesigning.

Formulation of the Problem

Based on issues that require human knowledge/experience, and aspects of mold design that consume time referring to tables, data sheets etc., the problem for developing the application is defined as shown in Figure 2.

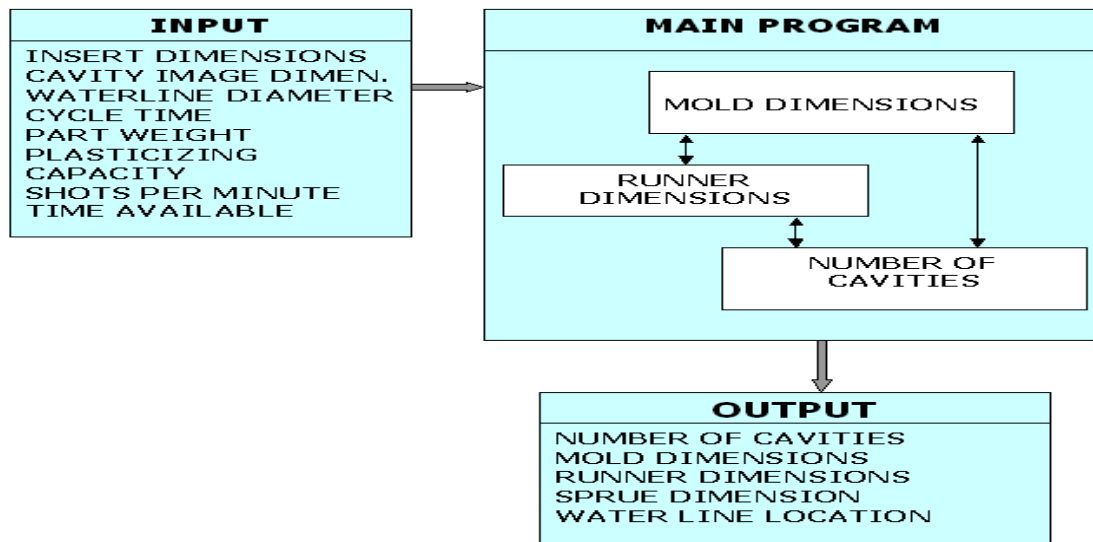


Figure 2. Organization of the Mold Design Module.

While most of the input, like the number of cavities, cavity image dimensions, cycle time are based on the client specifications, other input like the plasticizing capacity, shots per minute etc., can be obtained from the machine specifications. The output of the application contains mold dimensions and other information, which clearly helps in selecting the standard mold base from catalogs. Apart from the input and output, the Figure 2 also shows the various modules that produce the final output.

Framing rules

At this stage, the expert's knowledge is represented in the form of multiple If-Then statements. The rules may be representations of both qualitative and quantitative knowledge. By qualitative knowledge, we mean deterministic information about a problem that can be solved computationally. By quantitative we mean information that is not deterministic, but merely followed as a rule based on previous cases where the rule has worked. A typical rule is illustrated below:

```
If Material = "Acetal" And
  RunnerLength <= 3 And
  RunnerLength > 0 Then
  RunnerDia =0.062
EndIf
```

When framing the rules it is important that we represent the information in a compact way while avoiding redundancy, incompleteness and inconsistency. Decision tables help take care of all the above concerns by checking for redundancy and comprehensive expression of the problem statement. As an example, in the process of selecting an appropriate mold base, the size of mold base depends on the number of cavities and inserts. To ensure that all possible combinations of cavities and inserts have been considered we use a decision table and subsequently use the decision table to frame rules. Table1 shows more than one case where the mold dimensions are the same.

Number Of Cavities (1,2,4)	1	1	1	2	2	2	4	4	4
Number Of Inserts (1,2,4)	1	2	4	1	2	4	1	2	4
Mold Dimensions	A	*	*	A	B	*	A	B	C

Table 1. Sample Decision Table

Case A:
MoldWidth = (InsertWidth + 2)
MoldLength = (InsertLength + 2)
MoldThickness = InsertThickness

Case B:
MoldWidth = (2* InsertWidth + 3.5)
MoldLength = (InsertLength + 2)
MoldThickness = InsertThickness

Case C:
MoldWidth = (2*InsertWidth + 3.5)
MoldLength = (2* InsertLength+ 3)
MoldThickness = InsertThickness

Figure 3. Mold Dimensions for various combinations of Inserts and Cavities

The case where the number of cavities is one and the number of inserts is one has the same mold dimensions as the case where the number of cavities is two and four. The three cases can be reduced to one single rule:

```
If NumberOfInserts=1 Then
    MoldWidth = (InsertWidth + 2)
    MoldLength = (InsertLength + 2)
    MoldThickness = InsertThickness
EndIf
```

The rules are arranged in modular fashion using a standard programming language for the sake of convenience and clarity. Each module generates a set of outputs, which would be inputs for other modules.

Testing the application

The intelligent mold design application is validated using various test cases. For each case the part information, mold information and the machine information are varied and a human expert validates the results of feeding this info into the application. Table 2 shows one such test case where the part requires two cavities and there are no inserts present. The application gives the approximate mold dimensions, runner dimension, sprue dimension and runner length based on the cavity image dimensions and other information.

Input	
Number of Inserts	0
Insert Length	0
Insert Width	0
Insert Thickness	0
Cavity Image Length	2.02
Cavity Image width	3.28
Cavity Image depth	0.5
Waterline Dia	0.25
Number of parts to be produced	1000
Time Available	6
Cycle time	26
Reject Rate	0.1
Shots per minute	2.3
Material	ABS
Output	Program output
Number of cavities	2
Mold Length	10.06
Mold width	4.02
Mold Thickness	1.125
Runner Dia	0.109
Runner Length	1.5
Big end sprue bush dia	0.218

Table 2. Typical test case showing program input and output.

The mold dimensions obtained are very close to a typical human expert design for the test case but do not suggest explicitly the use of a standard mold base, like a specific mold from the D-M-E mold base catalog. The mold dimensions are however useful in selecting appropriate mold base from the mold catalogs. The runner dimensions are based on the material being used and therefore are limited to a specific range of shot size.

Summary

This paper presents the approach adopted towards developing an intelligent mold design application that performs mold base selection based on user input. The knowledge acquisition process is done by first designing a mold base in close consultation with an industry expert and also by collecting deterministic information from hand books and data sheets. The collected information, which can be both qualitative and quantitative knowledge about the mold selection process, is represented in the form of rules arranged in different modules. Decision tables are used to reduce the size of rule base and make the rule base comprehensive in the problem domain. The application developed using the rules in different modules is then tested for its validity when it comes to selecting appropriate mold bases for plastic parts manufactured in the industry

References

1. Chambers T. L., Parkinson A. R., 1998, "Knowledge Representation and Conversion of Hybrid Expert Systems." Transactions of the ASME, v 120, pp 468-474
2. Koelsch, James R., 1999, "Software boosts mold design efficiency " Molding Systems, v 57, n 3, p 16-23.
3. Lee, Rong-Shean, Chen, Yuh-Min, Lee, Chang-Zou, 1997 "Development of a concurrent mold design system: A knowledge-based approach", Computer Integrated Manufacturing Systems, v 10, n 4, p 287-307
4. Steadman Sally, Pell Kynric M, 1995, " Expert systems in engineering design: An application for injection molding of plastic parts" Journal of Intelligent Manufacturing, v6, p 347-353.
5. Fernandez A., Castany J., Serraller F., Javierre C., 1997, "CAD/CAE assistant for the design of molds and prototypes for injection of thermoplastics "Information Technological, v 8, p 117-124.
6. Douglas M Bryce, 1997, "Plastic injection molding -Material selection and product design", v 2, pp 1-48.
7. Douglas M Bryce, 1997, "Plastic injection molding-Mold design fundamentals", v2, pp 1-120.

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