Intelligent Manufacturing Process Tool For Plastic Injection Molding

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Abstract

This paper presents an overview of ongoing research aimed at the development of a Computer-Based Intelligent Manufacturing Process Tool, at the University of Louisiana at Lafayette. The Manufacturing Process Tool is a computer program, which would help the manufacturer in solving problems associated with Injection Molding. These problems include long process set up time, non-optimized cycle time, and poor control of the molding process. The Manufacturing Process Tool would eventually help the machine operator (who need not be an expert) in setting up, optimizing, and controlling the Injection Molding Process; thus maximizing the production rate on that particular Injection Molding machine.

Introduction

Plastic Injection Molding is the world's most common method of producing complex commercial plastic parts with excellent dimensional tolerance. According to the C-mold design guide, 32% by weight of all plastics processed go through Injection Molding machines, making Plastic Injection Molding one of the most important manufacturing processes[2]. It is seen that the final molded part quality is chiefly dependent on the type of material, mold design and the molding process settings. Once the material and the mold to be used are specified, the part quality basically depends on the molding process. The molding process is quite complex involving many variable process parameters like pressure, temperature and time settings. These process parameters have to be optimally set in order to improve part quality and maximize the production capacity of the Injection Molding machine. Educated and experienced individuals are required to set up and optimize such a complex process. These individuals control the molding process on a trial and error basis, which is usually time consuming. This method of controlling the molding process relies heavily on operator intuition and a few "rules of thumb," which the operator develops over a period of time while working with different materials, pressures, temperatures and time settings.

This paper presents an outline of ongoing research at the University of Louisiana at Lafayette involving the development of Intelligent Knowledge-Based Engineering Modules (IKEM) for the Injection Molding process. IKEM has different modules, namely: Parsing, Mold Design, Cycle Time and the Manufacturing module, which are linked to each other. This paper mainly concentrates on the Manufacturing module, which involves the development of an Intelligent Manufacturing Process Tool called "The Optimizer." Figure 1 and 2 show the transfer of data between the different modules of IKEM.

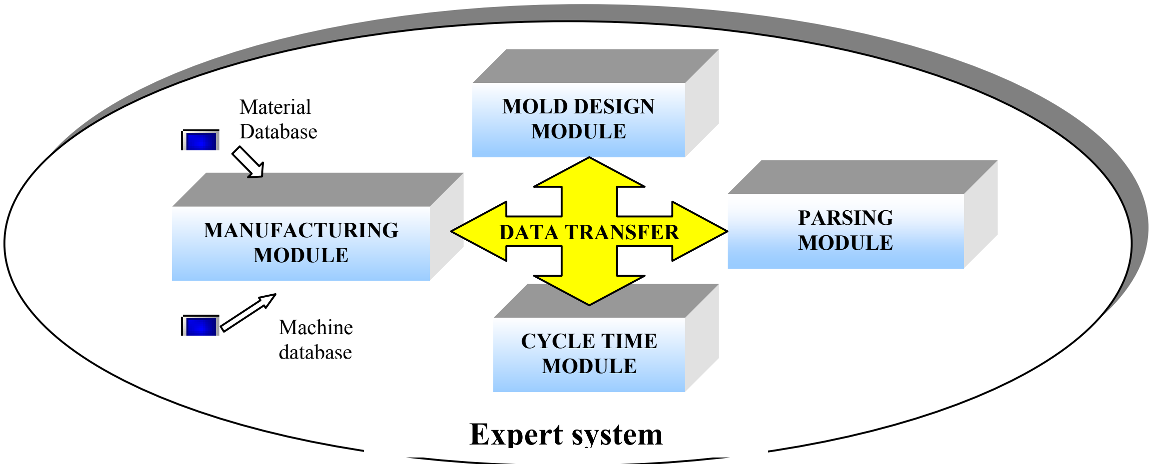

Figure 1.Intelligent Knowledge Base Engineering Modules For Plastic Injection Molding

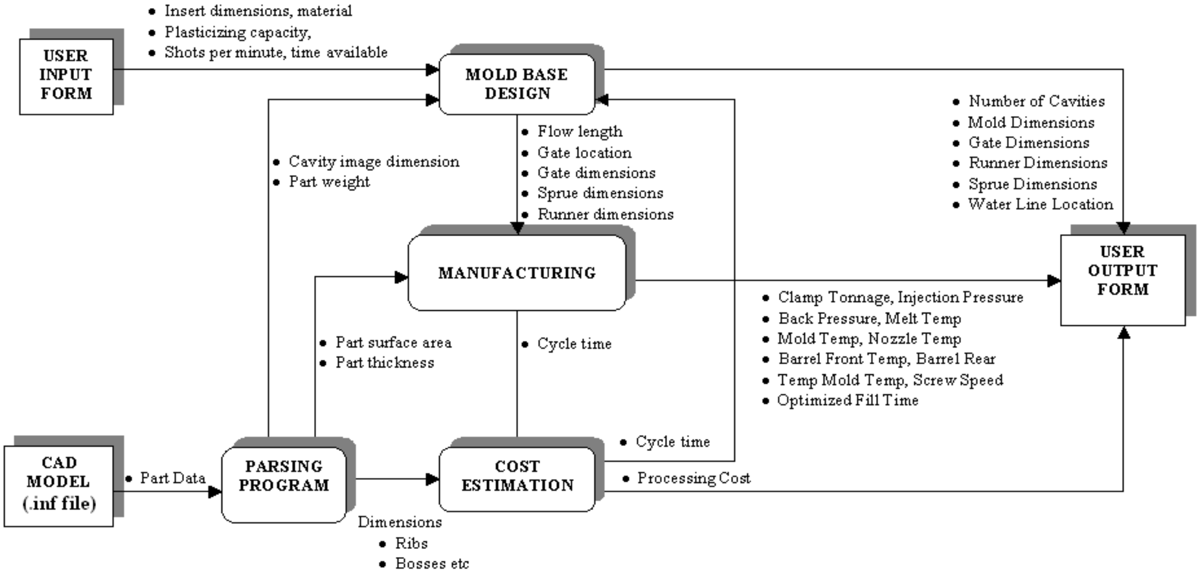

Figure 2. Data Flow Diagram

The Optimizer captures non-deterministic knowledge in the Injection Molding process from an expert in this field, and also uses deterministic knowledge available in the form of relations, look up tables, etc. The Optimizer is written in Visual Basic, and would assist the machine operator in setting up, optimizing and controlling the Injection Molding Process and thus maximize the production rate on that particular Injection Molding machine. As shown in Figure3, The Optimizer helps the manufacturer in the set up of the molding machine, by giving him the initial optimal process parameter values. These values could be later fine tuned for personal benefits by the operator using his intuition and guesswork.

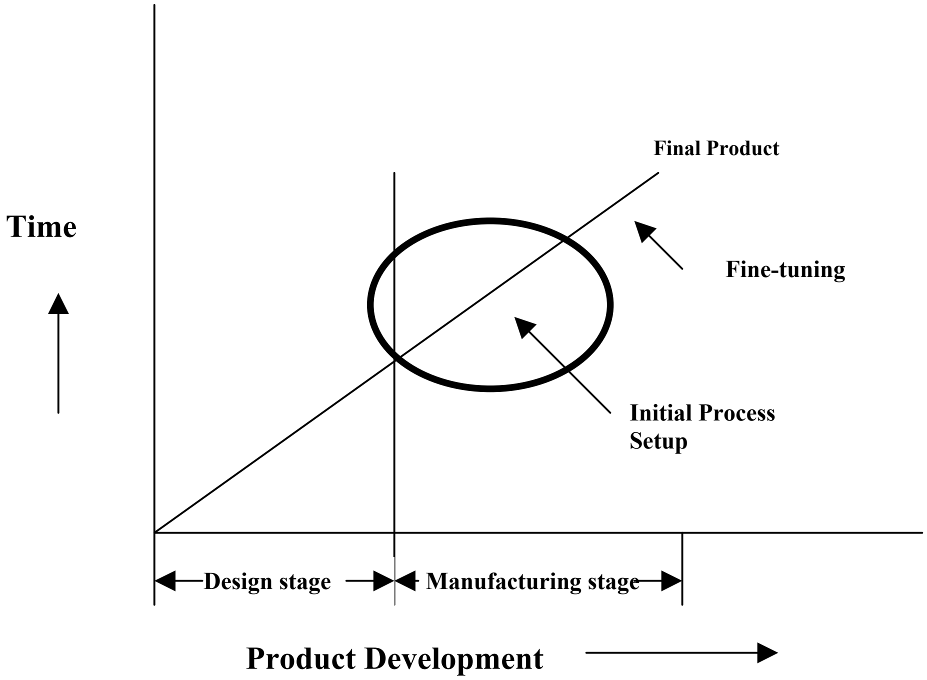

Figure 3. Product Development Vs Time

Knowledge-Based Engineering Modules

An expert system, or a knowledge-based system, is defined as "a model and associated procedure that exhibits, within a specific domain, a degree of expertise in problem solving that is comparable to that of a human expert[5]." Of the different kinds of expert systems available, which have their individual advantages and disadvantages, the "Rule Based" type of knowledge-based system is the one that is most commonly used. It basically consists of a knowledge base, containing a set of "IF-THEN" statements, called "rules."

The IKEM project deals with creating an expert system containing a set of IF-THEN rules collected from the human expert with the help of knowledge engineers. Two of the most important issues that are essential to the reliability of this rule-based type expert system are, the Knowledge Acquisition and Knowledge Representation.

Knowledge Acquisition

This is the initial approach wherein the knowledge engineers extract the rules from the human expert. This step is quite labor intensive, and has been considered the bottleneck in the expert system development process. Knowledge acquisition mainly depends on the skills of the knowledge engineer. His primary aim is to extract strategies or rules of thumb from the human expert(s) and transfer it to the knowledge base. Care has to be taken during the knowledge acquisition process, as it directly affects the knowledge representation scheme, later. It's seen that there are two basic types of Knowledge Acquisition:

1. Knowledge Acquisition directly from the human expert (non deterministic knowledge)
2. Knowledge Acquisition thorough previous cases, relations, look up tables (deterministic knowledge).

The Intelligent Manufacturing Tool being developed intends to capture non–deterministic knowledge which is gained by experience in the field, as well as more deterministic knowledge available in the form of relations, look up tables, etc.

A student knowledge engineer from the University of Louisiana at Lafayette has been working in conjunction with Ash Industries, Lafayette, which is primarily a Plastic Injection Molding plant. The knowledge engineer interviews the human expert at Ash Industry. He then organizes this extracted data in a logical fashion. This knowledge extracted from the expert is in the form of heuristics, or more precisely "rules of thumb." The expert develops these heuristics or rules of thumb intuitionally and from his prior experience in this field. These "rules of thumb" act as the guidelines, using which; the molding process is operated for the most optimal product quality.

A typical example of a set of "rules of thumb" or heuristics developed by the expert useful in the calculation of clamp tonnage is:

Rule 1: **IF** part wall thickness >= 0.04 inch
And material = crystalline
THEN clamp tonnage = 2.0 ton/ inch^2 *

Rule 2: **IF** part wall thickness < 0.04 inch
And material = crystalline
THEN clamp tonnage = 2.6 ton/inch^2

Rule 3: **IF** part wall thickness >= 0.04 inch
And material = amorphous
THEN clamp tonnage = 3.0 ton/inch^2

Rule 4: **IF** part wall thickness < 0.04 inch
And material = amorphous
THEN clamp tonnage =3.6 ton/inch^2

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* Inch^2 represents the cross sectional area of the total number of parts in the mold that are perpendicular to the nozzle of the injection molding machine.

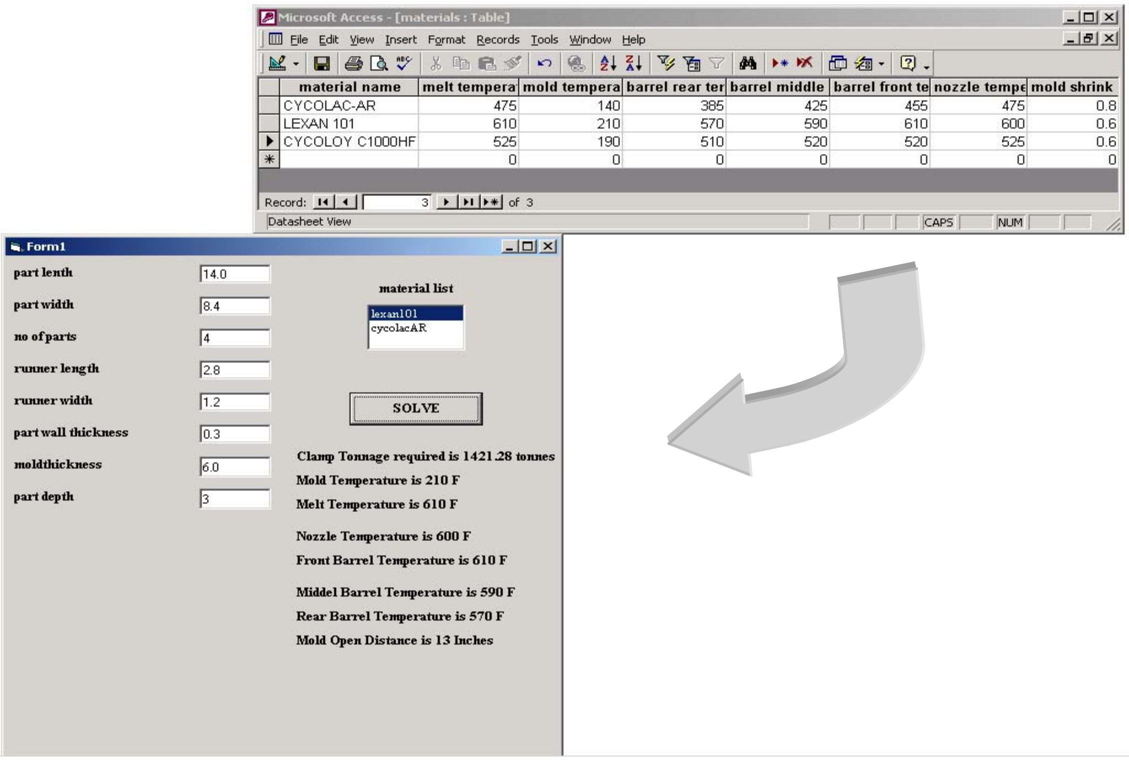
To this rule set we add a couple more rules, to determine whether the material selected is amorphous or crystalline. Using these six rules the expert system calculates the required clamp tonnage.

Rule 5: **IF** mold shrink, linear flow rate** of the material < 12
THEN material = amorphous.

Rule 6: **IF** mold shrink, linear flow rate of the material >= 12
THEN material = crystalline.

Knowledge Representation

Knowledge Representation is the second stage of the knowledge engineering process, wherein the knowledge acquired is coded into the Knowledge Base. The heuristics obtained by the knowledge engineer from the human expert are represented in the knowledge base using IF-THEN rules so that conclusions can be drawn by the expert system. These IF-THEN rules are then coded in VISUAL BASIC. A separate material database is created in Microsoft Access and then linked with the Visual Basic program. This is shown in Figure 4.



material name	melt tempera	mold tempera	barrel rear ter	barrel middle	barrel front te	nozzle tempe	mold shrink
CYCOLAC-AR	475	140	385	425	455	475	0.8
LEXAN 101	610	210	570	590	610	600	0.6
CYCOLOY C1000HF	525	190	510	520	520	525	0.6
	0	0	0	0	0	0	0

Record: 3 of 3

part lenth: 14.0
part width: 8.4
no of parts: 4
runner length: 2.8
runner width: 1.2
part wall thickness: 0.3
moldthickness: 6.0
part depth: 3

material list: lexan101, cycolacAR

Clamp Tonnage required is 1421.28 tonnes
Mold Temperature is 210 F
Melt Temperature is 610 F
Nozzle Temperature is 600 F
Front Barrel Temperature is 610 F
Middel Barrel Temperature is 590 F
Rear Barrel Temperature is 570 F
Mold Open Distance is 13 Inches

Figure 4. Access to Visual Basic Linkage

** Mold shrink, linear flow rate obtained from the material database.

The Outputs

The Optimizer gives out the most optimized values of different parameters affecting the Injection Molding process, which have to be controlled in order to ensure that a high quality part is produced in the most economical way. The outputs of The Optimizer could be confined to four different categories, namely: the Temperature, Pressure, and Time And Distance. Each of these outputs are represented in Figure 5 and discussed in detail below.

Temperature:

Approximately 80% of the plastic products produced today are made of thermoplastics. Thermoplastics could be defined as " plastic materials which, when heated, undergoes physical change[1]."

The different types of thermoplastics are:

- Amorphous materials, " which basically soften as the temperature is increased and get softer and softer as more heat is absorbed, until they degrade[1]."
- Crystalline materials, " these don't have a softening stage but they stay firm until they are heated to a particular point at which they start to melt and later degrade if more heat is added[1]. "

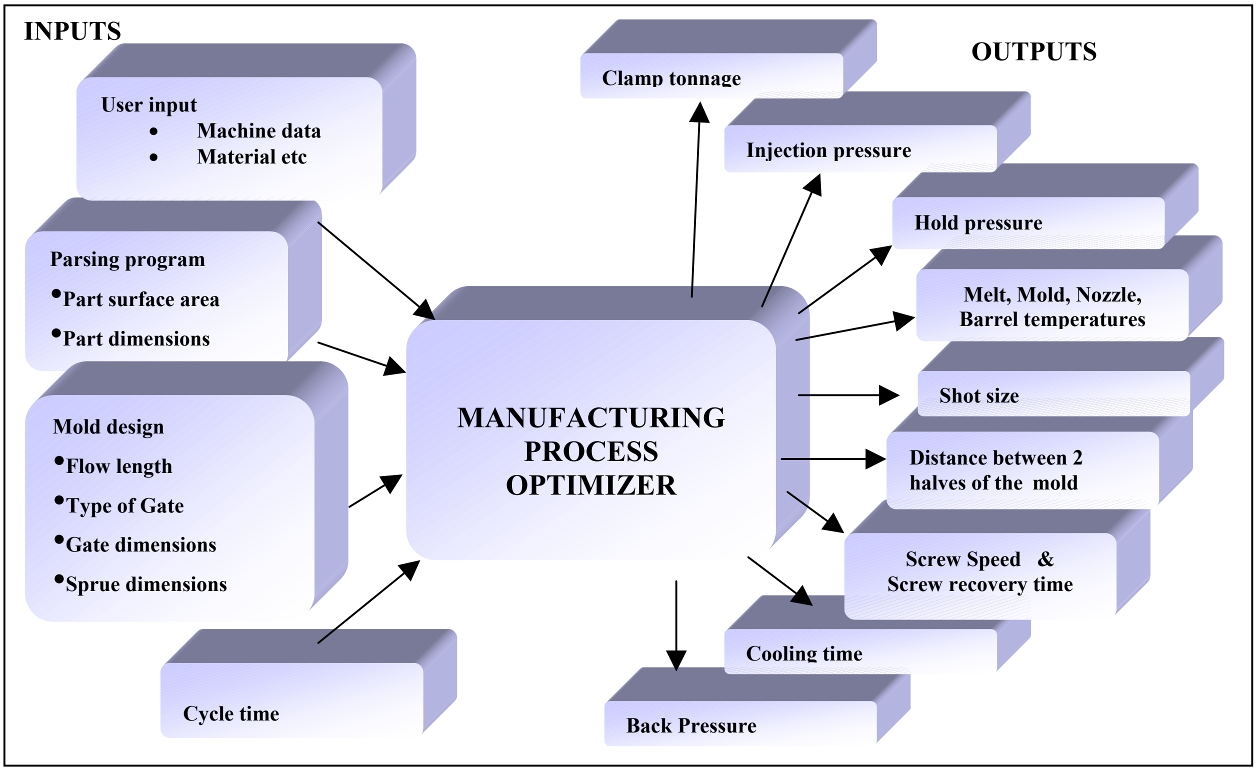


Figure 5. The Optimizer.

Considering the differences in the properties of amorphous and crystalline materials, we set the different temperatures in the Injection Molding machine.

1. Melt temperature: The temperature to which plastic material has to be heated before it is injected into the mold. Optimizing the melt temperature results in controlling the flow rate of the material, material degradation, brittleness and flashing.
2. Barrel temperatures: The different temperatures to be set at the rear, middle and the front end of the barrel of the injection-molding machine.
3. Nozzle temperature: The temperature set at the machine nozzle, which is right in front of the heating zone (barrel) of the plastic.
4. Mold temperature: The temperature at which the injection mold has to be set to obtain a plastic part of high quality with a lower cycle time. The optimized mold temperature helps in obtaining reduced cycle time and better part quality having a glossy finish, less warp and less shrinkage.

Pressure:

There are various pressures to be optimized in the Injection-Molding machine.

1. Clamp Pressure: The amount of pressure to hold the injection mold tightly against the injection pressure. The optimal clamp pressure prevents the mold from flashing due to less clamp tonnage. It even saves energy and the mold from collapsing due to high clamp tonnage.
2. Injection Pressure: The amount of pressure required to produce the initial filling (95%) of the mold cavity. The optimized injection pressure helps to attain a part of high quality, less shrinkage, less warp, and that is easy to eject.
3. Holding Pressure: The second stage of the injection pressure, and usually fills up the remaining 5% of the mold cavity. It is usually needed to hold the plastic in the mold, from flowing back into the barrel.
4. Back Pressure: The pressure exerted by the plastic on the screw spindle. Optimized backpressure helps in obtaining a part of better density and fewer voids.

Time:

- Cooling time: It is the amount of time required by the plastic part in the mold cavity to solidify and get ejected safely. The optimized cooling time helps in achieving better cycle time.

Distance:

- Mold open distance: The distance for the mold halves to open apart in order to eject the part safely. Optimal mold open distance is necessary for better cycle time.

Conclusion

The Manufacturing Process Tool, which has been discussed in this paper, is being developed at the University of Louisiana at Lafayette. When completed this Tool will be able to give the initial optimal process parameter values, which are crucial to start off the injection molding process. These values could be later fine tuned for personal benefits by the operator using his intuition and guesswork.

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Mr. Bill Best is currently working as a plant manager at Ash Industries in Lafayette, LA. He is an expert in the field of injection molding having an experience of more than 40 years in this field.