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EXPERT SYSTEM TO ASSIST IN SETTING OF MICRO INJECTION MACHINES

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Abstract: *Micro-injection moulding is a complex processing technology with many parameters to control. Micro-injection part defects are difficult to evaluate because of its qualitative nature. This makes difficult to choose the correct parameter combination derived from the analysis of the part defects. An intelligent decision making system has been developed. This system is based on fuzzy logic techniques, and it is oriented to advice in the machine setting. The system guides to the operator to establish the priority of intervention, and the magnitude of change needed over the Micro-injection parameters. Micro-injection tests have shown the effectiveness of the developed system. Considerable time reduction has been achieved in the machine setting.*
Key words: *Micro-injection, Moulding, Fuzzy, Expert, Polymers*

1. INTRODUCTION

Micro-injection moulding is one of the main manufacturing methods for mass production of polymer parts due to: its productivity, its accuracy to reproduce geometrical details, its excellent repeatability, and its versatility in part shape.

Despite its many favourable advantages, the Micro-injection moulding has a significant challenge, the complex interaction among high number of variables, (material variables, mould design variables, part design variables, and processing variables).

Numerous methods have been proposed to overcome the process disadvantages to improve some of the Micro-injected parts features. Methods such as: Design of Experiments (DOE) (Sha et al., 2007), statistical modelling, and expert systems.

DOE limitation is the non-existence of some qualitative relation between the improvement of the part quality (defects decrease, specially the qualitative ones) in each cycle, with the intervention on the parameters. This limitation mainly is explained due to the fact that the variable influences on qualitative features of injected parts is usually opposite, making it, very difficult to reproduce it, in a precise DOE model.

Statistical models were proposed to analyse the effects of injection parameters on the features obtained for specific parts (Lu & Khim, 2001). These techniques have the same limitation than DOE techniques and additionally the difficulty to handle qualitative variables.

Expert systems were developed to solve such difficulties.

Among the techniques used are: Genetic Algorithms (Alam & Kamal, 2005), and Neural Networks (Keniga et al., 2001). They have been used to optimise injection parameters, in order to control the part quality, employing a previous training phase for the system. These techniques were also combined to optimise process parameters (Changyu et al., 2007).

Expert Systems based on Fuzzy Logic (FL) offer the ability to manage a great number of qualitative part features without the need of an initial training phase. FL is suitable for qualitative variables as it has been demonstrated in previous developments (Tzafestas & Rigatos, 2000; Devillez et al., 2004; Chena et al., 2008, Chaves M.L. et al, 2010). The approach in this research is based on the use of FL. The system developed is supported by the operator's qualitative inspection of the part. The system evaluates this input and guides the operator to make correct modifications on the injection parameters. The FL limitation of adaptation to any polymeric material, and machine type were overcome with the system capacity to take as a start point, the specific machine and polymeric material recommendations and even taking into account the specific part geometry.

2. EXPERT SYSTEM KNOWLEDGE DATA

The knowledge base employed in the development of the system consisted in a combination of inputs from related literature review, results obtained from simulation (CAE system), and results derived from injection tests. Such results provide enough information to predict defect evolution related to process parameter changes.

2.1 Technical literature review

32 defect types with their causes and their possible ways to correction were classified. In experimental phase of this work, 5 defects were considered as the more critical defects to evaluate the part quality: sink marks, flash, short shots and fragility. These defects are implemented in the developed expert system.

2.2 Simulations

Simulations were conducted on small plastic parts with different shape features (Fig.1.).

The defect cause, and the action for correction reviewed in the literature were validated with these simulations. Additional conclusions about the relationship between the defect occurrence and process parameters were also identified.

2.3 Injection tests

Injection tests were done varying only one parameter each time. Starting with the ideal conditions and evaluating the part quality changes (defect occurrence and defect intensity variation).

The defect intensity variation was evaluated by defining a quantifiable concept, the "defect level". The percentage of part surface affected and the observed "defect intensity" allowed to convert a qualitative feature into a quantifiable magnitude.

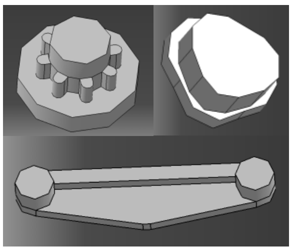

Fig. 1. Parts simulated and injected (Dims: 3mm)

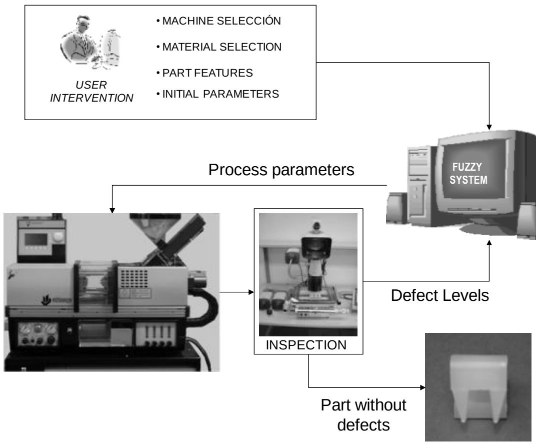

Fig. 2. Workflow of the system

The injection tests allowed having a validation of the theoretical relationships between injection defects, causes, corrective actions, and process parameters.

3. FUZZY INFERENCE ENGINES

The developed expert system has four inference engines, one per each process parameter. The observed defect behaviour depends on the process parameter that is being changed.

4. EXPERT SYSTEM DESCRIPTION

The expert system development was carried out in Matlab. This application allows linking the created inference engines with subroutines (one subroutine for each defect). The expert system workflow is showed in Fig. 2 .

1. The user should introduce basic data related to: material, machine, and part features.
2. The membership functions are fitted in accordance to the moulding window,.
3. The user must do a classification for each part defect detected.
4. According to the defect occurrence and its defect intensity, the system internally calls to a specific subroutine and to its inference engine.
5. The inference engine applies the defined rules and proposes the changes for the injection parameters.
6. A new iteration, with the new parameter combination, should be run after 5 to 10 injection shots. These are the injection shots needed to stabilise the machine. Then a new inspection should be performed.

The complete sequence should be repeated until desired part quality is reached.

5. EXPERT SYSTEM VALIDATION

More than 100 tests were carried out, to validate the system. A Babyplast Micro-injection machine was employed for the tests. Two polymer grades were injected: Polypropylene ISPLEN PC47AVC and Polyethylene REPSOL PE017. The objective was to make the tests representative from the perspective of the material.

The validation was conducted in two phases. Firstly, a set of tests were carried out in where the operator did not use the expert system. The parameter values were set according to the injected material and machine range. Secondly, more validation tests were done by setting an erroneous combination of injection parameters to analyse how the system would manage the problem and would fix the combination.

In this second set of tests, initially only one wrong parameter value was set. Later on these tests, more than one wrong value were adjusted. An average of 10 iterations was required to reach the correct tuning of the injection process. The number of iterations to reach the optimal combination of parameter values was significantly increased up to 20 iterations when more than one parameter was wrong.

The same test procedure was repeated employing the expert system. The number of needed iterations was significantly reduced. When one wrong parameter was set, only four iterations were required to reach the correct tuning of the injection process. Very promising results were also obtained in the case of tests with more than one wrong parameter. It can be concluded that a 40% of reduction in the average number of iterations was achieved by using the fuzzy inference engine.

6. CONCLUSIONS

A fuzzy expert system has been developed and tested for the Micro-injection process. The goal is to assist to the operator of a Micro-Injection moulding machine, to correct four typical injection defects. The system was designed to be used at shop-floor level to determine the optimal process parameters interactively with an operator, causing a significant reduction in setting time and production cost.

The expert system integrates data from the operator's skill, theoretical knowledge, material and machine recommendations, and experimental relationships derived from tests, to establish the fuzzy membership functions. These functions are adapted to the qualitative-defect behaviour, which makes this research more innovative.

This system was validated for two polymeric material types, and with only one machine, this situation could produce some limitations to achieve the same efficiency of the system. Nowadays, more validation tests are been developed employing other polymeric materials, machines and injection parts with different geometrical shapes.

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