Developing a Prototype of Case-based System Utilizing Fuzzy Sets to Detect Faults of Injection Molding Process

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Abstract: The purpose of this research is to develop a case-based system for detecting faults of injection molding machine by utilizing the information retrieved from troubleshooting guidelines. It is also reduced the system downtime. Case-based fault detection system guides users to detect their failure through the retrieval procedure. It utilizes fuzzy sets based on the relationship between parameters of the process, part, and mold to define the weight of features which is important for occurrence the faults. In this paper, a case-based system is also utilized the occurrence weights of features to capture the problems in injection molding processes and to recommend the way of fixing these faults.

Keywords: Fault detection, failure diagnosis, case-based reasoning, fuzzy logic, injection molding machine

1. Introduction

Extracting and utilizing new knowledge from the given product information to improve a new product is aimed at many types of research in the last decade i.e. using a rule-based system for the reasoning about product information [1]. Fault detection systems (FDS) can be developed with the help of several approaches, depending on a type of knowledge needed in each particular case. Some of these techniques are artificial neural networks, expert systems or case-based reasoning (CBR) compared in [2]. The FDS based on these techniques are distinguished from each other by problem-solving, data acquisition and their complexity level. Maintenance time should be kept as short as possible to meet the high-performance output demands, especially for an automated production system. When a system’s fault is detected, finding a solution for repairing and replacing parts needs the maintenance strategy. The maintenance downtime process is characterized by maintenance delay, access, diagnosis, logistics, repair or replacement and finally checkout [2]. The time of each activity within this process should be kept as short as possible to loose minimal total downtime. In order to reduce the downtime, diagnosing the occurred failures is the main step, on which we focus in this paper. CBR is one of the appropriate techniques which help us to find the solution for a given problem and is applied in different domains [3]. A comparison of the properties of the surveyed artificial intelligence methods shows that CBR can find the similar cases by using the previous similar problems [4], [5] and [6].

In this paper, we developed the prototype of fault detection using fuzzy CBR by focusing on the application scenario of injection molding machine. Injection molding is a cyclic process that contains clamping, injection, cooling, and ejection to produce plastic parts. For achieving a higher quality of products, three main points should be considered: a) type of materials; b) process setting parameters (e.g. temperature); c) basic parts of injection molding machine [7].

The structure of this paper is as follows: in the second section, we give an overview of a fault detection system considering the types of fault and failures. In the third section, the injection molding machine and its processes are explained. Case-based reasoning, fuzzy sets and fault diagnosis is discussed in section four. Finally, section five explains conclusion and a future work.

2. Fault Detection System in Injection Molding Machine

FDS is a monitoring system which can identify the occurrence of the faults in machinery, recognize their types and locations. Fault detection and diagnosis play a serious role in engineering systems, which is enhancment of production quality and reduction of costs for testing. Modern fault detection systems distinguish several types of problems. “Fault is an unpermitted deviation of at least one characteristic property (feature) of the system from the acceptable, usual, standard condition” [8].

Fault detection is the accepted term for recognition of any degraded settings or inactive status of a system, plant or its operational parts. Fault-diagnosis approaches use the analytic and heuristic signs. Hence they must be provided in a unified way like self assurance-numbers, membership functions of fuzzy sets or probability frequency function after a statistical evaluation over a while. Then either classification techniques may be employed, in case a learned pattern-based procedure is recommended to recognize appearing problems from symptom patterns or clusters. However, fault detection using CBR is applied in maintenance [2] with the goal to find the process parameters of injection molding machines [9], [10] but there is still more needs to do researchers in this field. In this paper, CBR considering fuzzy rules and sets is utilized for fault detecting of injection molding machine (IMM). It's a cyclic method of a high-speed mold filling followed by means of cooling and ejection. Step one to the injection molding is the clamping of the mold. The clamp is a component that holds a mold while the melted plastic is being injected. The pressing mold is kept under a pressure during the injected molten plastic is cooling. On the next step, the injection of the melted plastic is performed. The plastic stays within the mold, where it is being pressed until it will be cool and solid. The next step encompasses the holding period, which is ensuring that all cavities of the mold are full of melted plastic. After a holding period, the cooling phase starts and continues unless the plastic becomes strong within the mold. Subsequently, the mold is opened and a newly produced plastic part is ejected from it. Then the section is cleared from any residuals in the mold. IMM is likely one of the largest and rational forming approaches present for processing plastic substances [11].

3. Fault Detection utilizing Case-based Reasoning

The benefits of the FDS founded on a CBR approach are that comparable cases could be obtained rapidly just by inputting a set of unusual levels (of symptom features) to make sure that the solution could be produced accordingly.

In this paper, based on the troubleshooting guides [12], [13], [14] and [15], twenty features in six categories are considered for injection molding processes which are temperature(f5,f6,f9,f16 and f17), pressure(f1, f2, f3, f4 and f14), time, speed(f7 and f8), gate size(f20), runner size(f19).

Fault diagnosis based on CBR could assist in dealing with ill-defined issues related to the diagnostic activities which have two main steps:

1) Fuzzy Sets and Feature Weight

Case indexing and defining the weights of features is the first step of case retrieval. In this research four fuzzy sets are identified for classifying the relationship between process parameters of injection molding and a bundle of a part and mold parameters which can be estimated as strong (S:0,7-0,9), medium (M:0,5-0,7), weak (W:0,3-0,5) and very weak (V:0,1-0,3). Table 1 shows the relationship between the parameters of pressure and a set of various part and mold parameters which are defined based on [16], [9] weight. The FO (Feature's Occurrence) column is defined based on the probability of occurrence of these features in all IMM's faults. The relationship of injection pressure(f1) and holding pressure(f3) is illustrated in Table 2. The fuzzy classification weights are calculated as follows:

$$w_{\mathrm{i}} = \frac{1}{n}\sum_{i=1}^{n}(FO_{\mathrm{i}} * PR_{\mathrm{i}}) \qquad (1)$$

where w_i is the fuzzy weight for the i^{th} feature, FO is the occurrence weight of feature, PR is the relationship between features and parameters and n is the number of parameters.

Table 1: Relationship between pressure, part and mold parameters of injection molding

Process Parameters	Part and mold parameters											W_i
	FO	Molding Material	Part size	Wall thickness	Part complexity	Part volume	Projected area	Runner type	Runner size	Gate type	Gate size	
F1	0,4	S	V	S	S	W	V	W	M	S	S	2,4
F3	0,2	S	S	S	S	M	S	W	M	S	S	1,5

2) Case Base and Retrieval

In this section, the prototype of FDS is explained, which is implemented based on the open source tool myCBR [17], [3]. At the first step, all attributes and instances are defined. Then, their weights are calculated by equation (1). Defining the case base is the third step which includes 15 most often appearing faults arising in different types of IMMs. Hence to provide better fault detection results and to identify more exact solutions for the IMMs of various vendors, the case base consists of the common injection molding faults and solutions. This allows to apply them not only to the machines of observed brands but also to all possible IMMs out of this research considering different default settings of IMM features. Each and every brand of IMMs is producing its machines established on its own technical design requirements. As a result, the machines of various manufacturers differ to each other in the default settings of IMM features as injection and clamping pressure, injection and screw rotation speed, clamping time etc. as they were set by the manufacturer while assembling. For instance, if a standard injection pressure for injection molding of a polypropylene for Machine A is 1200 bar and for Machine, B is 1000 bar, then it is impossible to classify them both to the same measurement group of injection pressure feature because of difference between these two values. For this reason, all features of diverse IMMs will be unified in a way of mapping their normal and abnormal feature values to the fuzzy alternatives, that would confirm the IMMs of various manufacturers and could be directly utilized in the FDS. The faults which are being researched for a development of this prototype were chosen from several injection molding scientific guidelines and troubleshooting guides of various manufacturers of IMMs [12], [13], [14] and [15]. These faults are caused due to abnormal states of one or several process parameters or features of the machines. In Table 2, three faults considering their causes are illustrated. This table is filled with L (Low), N (Normal-Standard) and H (High) which is the feature range of occurred fault.

Table 2. Fault examples

	Fault	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10	f11	f12	f13	f14	f15	f16	f17	f18	f19	f20
1	Sink Marks	N	N	L	N	H	H	L	N	N	L	L	N	L	L	L	N	N	N	N	N
2	Flow Lines	L	L	N	N	L	L	L	N	N	N	N	N	N	N	N	L	N	N	N	N
3	Excessive Flash	H	H	N	L	H	H	H	N	N	N	H	N	N	N	N	N	N	N	N	N

This mapping principle is applied to all of the features of IMMs and will be utilized by the user during filling of the query to detect the occurred fault which is the most similar case which is calculated by utilizing myCBR. The retrieved result of an example query is 77%, 72%, 62% and 60% for fault 10, fault 1, fault7 and fault 2 respectively. The most similar case is selected for reuse of its solution and it is an input of adaptation phase. Therefore the solution of the most similar fault should be reviewed by IMM worker. In this prototype null adaptation is used and it can be extended to develop adaptation mechanism in the future work.

5. Conclusion

This paper presented the results of a research student project that applies fuzzy sets in CBR as a methodology and utilizes the myCBR tool to develop a fault detection prototype. It makes two contributions. First, it describes the injection molding machine and fault detection system. The faults and main important features of these fault's occurrence are defined and analyzed based on the troubleshooting guidelines. Additionally, fuzzy case-based reasoning considers fuzzy rules and sets. The retrieval testing and evaluation of the prototype of FDS shows that it can be utilized in injection molding machine for fault detection. Although the current prototype as a CBR system has a useful function, namely it could be extended in a way of collecting more specific cases containing faults of a certain product of particular IMM and hence enriching a case base. Another aspect for extension is the implementation of the adaptation rules to specify the recommended solutions. Finally, for evaluating of the retrieval phase, the similarity measurement could be enhanced based on the specific cases and real test results.

References

[1] M. Dornhöfer, M. Fathi and A. Holand, "Applying Rules for Representing and Reasoning of Objective Product Use Information Exemplarily for Injection Molding Machines," in *ICIEIS 2011, Part II, CCIS 252*, A. Abd Manaf et al. (Eds.), 2011.

[2] Y.-T. Tsai, "Applying a case-based reasoning method for fault diagnosis during maintenance," *Proc. IMechE Vol. 223 Part C: J. Mechanical Engineering Science,* pp. 2431-2441, 2009.

[3] K. Bach and K.-D. Althoff, "Developing Case-Based Reasoning Applications Using myCBR 3," in *Case-Based Reasoning Research and Development*, pp. 17-31, 2013.

[4] A. Aamodt and E. Plaza, "Case-based reasoning: Foundational issues, methodological variations, and system approaches," *AI Communications,* pp. 7(1), 39–59, 1994.

[5] R. López and e. al., "Retrieval, reuse, revision, and retention in case-based reasoning," *The Knowledge Engineering Review,* vol. 20, no. 3, pp. 215-240, 2005.

[6] M. M. Richter and R. Weber, Case-Based Reasoning: A Textbook, Springer, 2013.

[7] V. Goodship, Practical Guide to Injection Moulding, UK: Repra Technology and ARBURG Limited, 2004.

[8] R. Isermann, Fault-Diagnosis Systems, Verlag Berlin Heidelberg: Springer, 2006.

[9] S. L. Mok and C. K. Kwong, "Application of artificial neural network and fuzzy logic in a cased-based system for initial process parameter setting of injection molding," *Inteligent Manufacturing, 13,* pp. 165-176, 2002.

[10] K. Shelesh-Nejad and E. Siores, "An Intelligent System for Plastic Injection Molding Process Design," *Materials Processing Technology,* pp. 458-462, 1997.

[11] D. V. Rosato and M. Rosato, Injection Molding Handbook, Springer, 2000.

[12] MMM, "Mold Masters Milacron LLC – Troubleshooting Guide," 2011. http://www.moldmasters.com/media/documents/HRUM-EN-XX-LTR-V14.pdf.

[13] PPL, "Pentagon Plastics LTD – Troubleshooting Guide," 2015. http://www.pentagonplastics.co.uk/wp-content/uploads/2015/03/Trouble-Shooting-for Injection-Moulding-2014.pdf.

[14] RT, "Routsis Training - Scientific Molding Pocket Guide / IM Reference Guide," 2016. http://www.traininteractive.com/download/pdf/routsis_injection_molding_reference.pdf.

[15] ECC, "EASTMAN CHEMICAL COMPANY – Troubleshooting Guide," 2012. http://www.eastman.com/Literature_Center/P/PPD407.pdf.

[16] Y. K. Lau, Basic Injection Molding Trouble Shooting Guides, Hong Kong: Hong Kong Plastics Technology Centre, 1996.

[17] A. Stahl and T. R. Roth-Berghofer, "Rapid prototyping of CBR Applications with the Open Source Tool myCBR," in *ECCBR 08*, Berlin, Heidelberg, 2008.