COST 526

"Automatic Process Optimization in Materials Technology"

(APOMAT)

Half-Year Report

1. Reporting Period	**1.7.2003 – 31.12.2003**
Project title Project leader Organization Main collaborators involved	Form Final properties of Components to Mould and process Design in Metal Injection Moulding Prof. Jean-Claude GELIN LMA/ENSMM 24, chemin de l'Epitaphe 2500 Besançon FRANCE Dr T. Barriere, Dr. A. Lejeune, G. Ayad LMA/ENSMM, 24, chemin de l'Epitaphe 2500 Besançon, FRANCE Prof. LIU Baosheng, Southwest Jiaotong University, 610031 Chengdu, China

2. Funding Situation		
Amount of money received specifically for COST		0 kEuros
Other resources partially used for the project	Optimat Project	40 kEuros

3. International Collaboration (Mentioning the group and type of work done in collaboration in the reporting period)
Participation of the Working Group Meeting in Krakow + project progress report YES

4. Industry participation (Mentioning the name of companies and work done in collaboration in the whole project)

5. Meetings, visits, exchange of scientists, short-term scientific missions	**Location, date**
Work Group meeting Exchange of scientists	Krakow, November 26-30, 2003 Mr. CHENG Zhiqiang performed a 6 month period in Besancon under the cotuterial direction of Prof. Gelin and Prof. Liu

6. Progress in the reporting period

(Not exceeding 3 pages, including tables and figures)

HYR2: Project F2: From final properties of components to mould and process design in metal injection molding.

Summary: According to the updated work plan of the project, the last developments consist in the comparison of two strategies concerning optimization methods (genetic algorithm, surfaces responses) for the process optimization concerning various parts (tensile and wheel components) in their injection stage of the MIM

1 Definition of the general strategy for optimization in MIM

The proposed optimization strategy has been applied successfully in MIM. The injection of a tensile test specimen has been studied. The preliminarily selected process parameters, according to the process requirements, are indicated in table 1.

Process	and material parameters	Factor fields (2 levels)
A	Viscosity Law	Experimental Data // Newtonien Law
B	Injection Pressure	[1 - 16 MPa]
C	Melt Temperature	[90 - 220 °C]
D	Mold Temperature	[30 - 50 °C]
E	Powder Volume Fraction	[0,4 - 0,7]
F	Interaction coefficient	[0,001 - 0,007]
G	Powder Density	[1 - 8 g/cm3]
H	Binder Density	[0,5 - 2,5 g/cm3]

Table 1: The overall optimization strategy for the injection stage in MIM

A fractional design of the experiments (DOE) [3] based on a TAGUCHI method [2] has been applied. It is found that the most sensitive parameters are: powder volume fraction, interaction coefficient, powder and binder densities.

2 Objective function

The proposed objective function takes into account the effects of geometry in mould cavity and the minimization of powder segregation in injection molding. It is expressed as:

$$f(x) = \left(\frac{1}{N} \sum_{i=1}^{N} \frac{\left| F_{S\,i} - F_{S_0} \right|}{F_{S_0}} \right)$$

3 Optimization Methods

First method:

The proposed method for optimisation firstly consists to the generation of a response surface by the MSLA method [1] associated with the cost function. The minimum is then obtained through by a genetic algorithm.

Second method:

The optimizer has been coupled directly with the metallic injection molding software. The method used by the optimizer is based on a genetic algorithm ”GENOCOPIII”[4].

Comparative test:

a) The injection of a tensile test specimen has been studied in order to compare the both method. This optimization has been performed with 2 or 4 parameters. Admissible ranges for the selected process parameters are given in table 2.

Optimization with 2 parameters:	
Powder volume fraction	0.4 – 0.7
Binder density	0.5 – 2 $g.cm^{-3}$
Optimization with 4 parameters:	
Powder volume fraction	0.4 – 0.7
Binder density	0.5 – 2 $g.cm^{-3}$
Powder density	1 – 8 $g.cm^{-3}$
Interaction coefficient	0.001 – 0.007 $Pa.s.m^{-2}$

Table 2: Admissible range used for the optimization strategies.

Comparison of the two methods in terms of the optimal values is given in table 3. Method 1 is less expensive than method 2 in CPU time, while method 2 is more accurate. However, better results can be obtained with method 1 by increasing the point numbers for the discretization of field domains.

Method 1: Surface response with 4 point numbers		Method 2: Genetic algorithm	
Optimal values (Optimization with 2 parameters)			
Powder volume fraction	0.52	Powder volume fraction	0.54
Binder density	1.47$g.cm^{-3}$	Binder density	1.29$g.cm^{-3}$
Optimal values (Optimization with 4 parameters)			
Powder volume fraction	0.56	Powder volume fraction	0.50
Binder density	1.43 $g.cm^{-3}$	Binder density	2.33 $g.cm^{-3}$
Powder density	1.65 $g.cm^{-3}$	Powder density	2.34 $g.cm^{-3}$
Interaction coefficient	0.0045 $Pa.s.m^{-2}$	Interaction coefficient	0.0027 $Pa.s.m^{-2}$

Table 3: Comparison of optimal values with the both optimization methods

b) The second case, to be optimized with 4 parameters, is the injection of a wheel specimen in order ... methods, see figure 1. Admissible ranges for the se... e given in table 2. The results of optimization are gi...

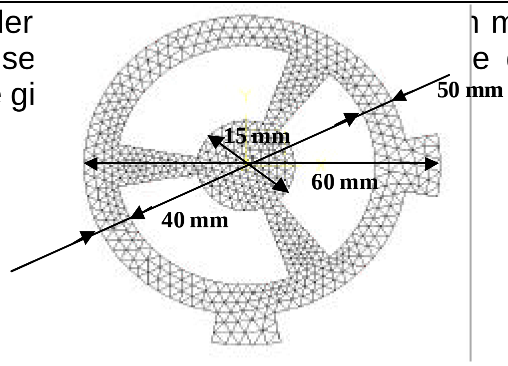

Figure 1:Mesh and geometry used for the tensile specimen (nb. nodes: 1679, nb. element 1040).

Method 1: Surface response with 4 point numbers		Method 2: Genetic algorithm	
Optimal values			
Powder volume fraction	0.56	Powder volume fraction	0.50
Binder density	1.43 g.cm^{-3}	Binder density	2.33 g.cm^{-3}
Powder density	1.65 g.cm^{-3}	Powder density	2.34 g.cm^{-3}
Interaction coefficient	0.0045 Pa.s.m^{-2}	Interaction coefficient	0.0027 Pa.s.m^{-2}

Table 4: Comparison of optimal values with the 2 optimization methods

The comparison of the both methods concerning the optimal values is given in table 4. Method 1 is less expensive in CPU time but method 2 is more accurate.

4 Segregation results.

The powder volume fraction for the tensile tests and wheel tests injected with the optimal values is plotted in figure 2 a) and b). In the both cases the segregation phenomenon is reduced, a relatively homogeneous repartition of the solid volume fraction is obtained.

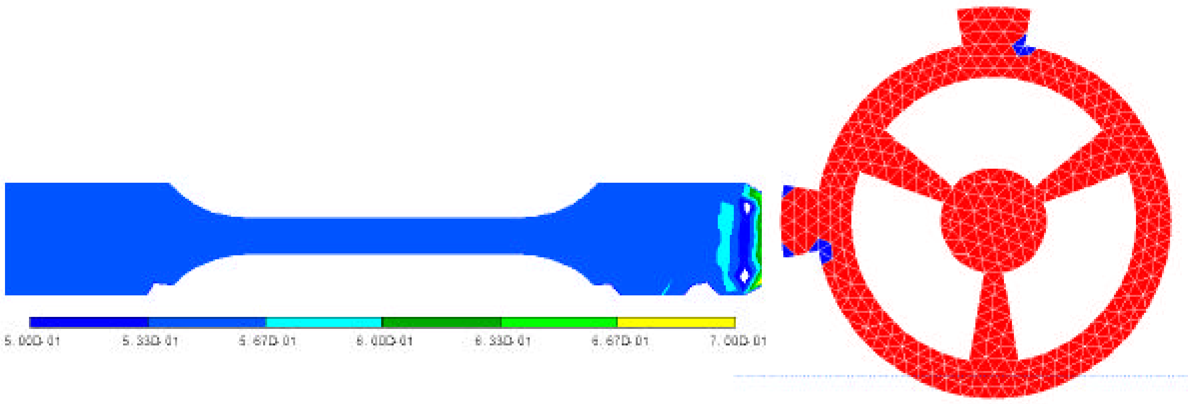

Figure 3 a) and b) Repartition of the solid volume fraction with the optimal values resulting from the optimization strategy.

References :
[1] : T.Belytschko et al., Meshless methods : an overview and recent developments,

Comput. Methods Appl. Mech Engrg. 139 (1996) 3-47.
[2] : P.Scimmerling et al., Pratique des plans d'expérience, Lavoisier & Doc, 1998
[3] : M. Pillet, "*Les Plans d'Expériences par la Méthode TAGUCHI*", Les Editions d'Organization, ISBN 2-70-812031-X, 1997.
[4]:Michalewicz_ Z__ Genetic Algorithms_ Numerical Optimization_ and Constraints_ Proceedings of theSixth ICGA_ Morgan Kaufmann_ 1995 p 151-157.

7. List of publications

a) Published

J.C. Gelin, T. Barriere, B. Liu, Mould design methods by experiment and numerical simulation in metal injection molding, J. of Engineering Manufacture, Part B, Vol. 126, 2002, pp. 1533-1547.

T. Barriere, B. Liu, J.C. Gelin, Determination of the optimal parameters in metal injection molding from experiments and numerical modeling, J. of Materials Processing and Technology, Vol. 143-144, 2003, pp. 636-644.

J.C. Gelin, G. Ayad, T. Barriere, A. Lejeune, Analysis and finite element modeling of powder segregation occurring in metal injection molding of stainless steels, PM^2TEC conference, USA, Las Vegas, 2003.

b) Submitted for publications

c) In preparation

J.C. Gelin*, T. Barriere, G. Ayad, A. Lejeune, Optimization of the Injection Stage in MIM Based on a Surface Response Approach. PIM 2004, An International Conference on the Powder Injection Molding of Metals, Ceramics, and Carbides, March 21-24, 2004, Penn State, USA, in preparation.

G. Ayad, A. Lejeune, T. Barriere, J.C. Gelin, Optimization of powder segregation occuring in metal injection molding of stainless steels, 7th ESAFORM Conference, April 28-30 2004, Trondheim, Norway, in preparation.

G. Ayad, A. Lejeune, T. Barriere, J.C. Gelin,, An optimization strategy for the determination of material and process parameters to avoid segregation defects during metal injection molding. NUMIFORM 2004, 8th International Conference on Numerical Methods in Industrial Forming Processes, 13-17 Juin 2004, Columbus, Ohio, USA, in preparation.