COST 526

"Automatic Process Optimization in Materials Technology"

(APOMAT)

Half-Year Report

1. Reporting Period	**1.1.2002 – 30.6.2002**
Project title	Form Final properties of Components to Mould and process Design in Metal Injection Moulding
Project leader Organization	Prof. Jean-Claude GELIN LMA/ENSMM 24, chemin de l'Epitaphe 2500 Besançon FRANCE
Main collaborators involved	Dr T. Barriere 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	0 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 Saint-Dié des Vosges + 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	Saint-Dié des Vosges, May 21-32, 2002 Mr. CHENG Zhiqiang performed a 6 month research period in Besancon under the cotutorial direction of Prof. Gelin and Prof. Liu

6. Progress in the reporting period
(Not exceeding 3 pages, including tables and figures)

HYR1: Project F2: From final properties of components to mould and process design in metal injection molding.

1 Definition of the process: Metal Injection Molding

Metal Injection Molding (MIM) is expected to be very efficient for manufacturing small and complex metallic components in large batch. Large amount of components with excellent mechanical properties and high geometrical accuracy may be obtained by this newly developed technology, under a cost much lower than traditional techniques [1]. See figure 1. The research on Metal Injection Molding (MIM) involves three main stages: the injection molding of a binder/powder mixture, the thermal or catalytic debinding to get a shaped part in porous metallic state, and the sintering to get the condensed part in pure metallic material [2-4].

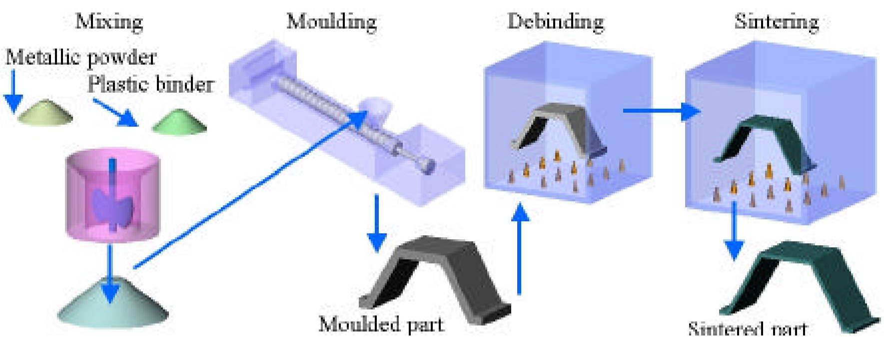

Figure 1: Description of the Metal Injection Molding process

The geometrical accuracy and mechanical properties of the final parts after sintering depend strongly on the choice of process parameters in the different stages. The determination and optimization of the process parameters have motivated numerous research works in molding and sintering stage, as it needs deep knowledge on different processes and accurate modeling techniques for each stage [5][6][7].

It is difficult to get sufficient knowledge to develop the optimal MIM process from only experiments. For this strong reason, both experimental research approaches to get the final parts and the development of reliable software with new efficient algorithms are carried out in our laboratory. A series of necessary equipments, including an injection molding machine controlled by computer, a debinding oven and a high-temperature sintering furnace, are organized in an easily adaptable manner. The necessary data acquisition systems for different physical quantities are also available. A five-cavity mould has been specially designed and realized to achieve the determination of process parameters in different stages and to facilitate the validation of mechanical properties. To reach this goal, cavities in the mould are designed in the forms of standard tensile and bending specimens. See figure 2.

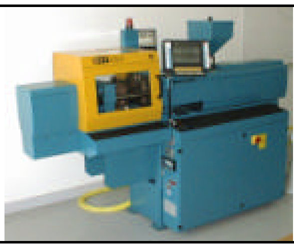	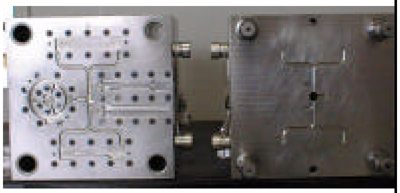	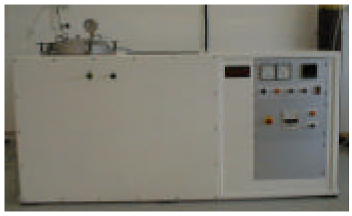
Injection machine	Mould used	Sintering furnace

Figure 2: Equipment installed and used in our lab.

From the viewpoint of developing a realistic simulation tool, a bi-phasic model based on mixture theory is adopted. To overcome the persistent difficulty of high computational cost for a model of the coupled bi-phasic flow, with the necessity to respect the mixture's incompressibility, a new efficient algorithm is proposed and developed. Then the reliable and easily performed simulations can be achieved [4][5][6]. The research work to determine the optimal process parameters by optimization in metal injection molding will be performed with all the facilities above mentioned. A example of comparison between numerical and experimental result is given figure 3.

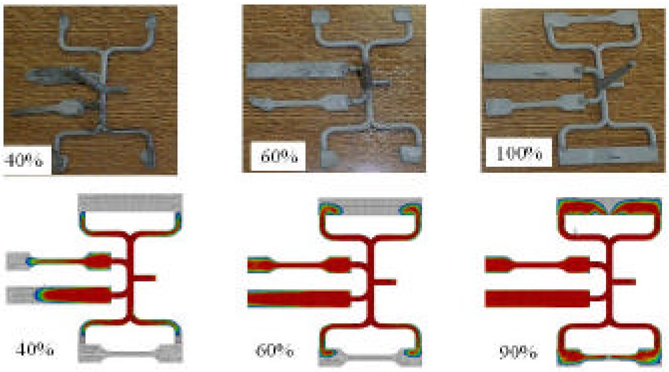

Figure 3: Comparison between numerical and experimental result for a multi-cavities mould

2. Preliminary design for QFs for the injection stage

It's necessary to take into account possible occurrence of injection defects during molding and sintering defects during sintering phase. For the molding stage it must be prevented:

- Injection defects (dead zones, welding lignes, …),
- Segregation (powder accumulation),
- Distortion after the packing and ejection stages.

For the sintering stage it's necessary to predict:

- Sintering defects (distortion, isotropic shrinkage),
- The errors in geometrical shape and size,
- The errors in terms of resultant physical and mechanical properties.

It's necessary to optimize the injection parameters: injection duration, injection pressure, feedstock temperature, mold temperature, packing pressure cycle and cooling ones with respect to time, as well as the parameters for mould design (cross section of the runners, number of mould gates, location of the gates and vents, effects of gravity…)

To optimize the sintering parameters is necessary to study heating rate and time, temperature cycle, atmosphere, friction, …

3. Optimization tools and strategy

Optimization toolbox

An optimization toolbox is under development to provide facilities for using optimization method based on Gradient methods (Levenberg-Marquardt, SQP and FSQP, Genetic algorithm, Surface responses or evolutionary algorithms, …)

Strategy:

- Sensitivity analyses and restriction of the parametric space
- Construction of a local approximation step by step
- Optimization of a process stage
- Complete optimisation of the process - Control

References:

[1] K.T. Kim, Y.C. Jeon, J. Materials Science and Engineering, (1998), 242-250.
[2] R.M. German, A. Bose, Injection of metals and ceramics, Princeton, USA, (1997).
[3] T. Barriere, Phd Thesis, University of Franche-Comté, Besançon, (2000).
[4] M. Dutilly, Phd Thesis, University of Franche-Comté, Besançon, (1998).
[5] J.C. Gelin, T. Barriere and M. Dutilly, Annals of the CIRP, 48 (1) (1999) 179-182.
[6] T. Barriere, D. Renault, J.C. Gelin and M. Dutilly, Mécanique et Industries, 1 (2000) 201-211.
[7] T. Barriere, J.C. Gelin and B. Liu, Powder Metallurgy, (2001), Vol. 44, 3, pp. 228-234.

7. List of publications

a) Published

1) J.C. Gelin, T. Barriere, M. Dutilly, Experiments and computational modeling of metal injection molding for forming small parts, Annals of the CIRP, Vol. 48/1, 1999, pp. 179-182.
2) T. Barriere, J.C. Gelin, B. Liu, Experimental and numerical investigations on the properties and quality of parts produced by MIM, Powder Metallurgy, Vol. 44, 3, 2001, pp. 228-234.
3) T. Barriere, D. Renault, J.C. Gelin, Experimental and numerical analyses of the effects of process parameters on the properties of components in metal injection molding, Journal de Physique IV, Vol. 11, 2001, pp. 249-256.
4) J.C. Gelin, B. Liu, T. Barriere, Modeling and simulation of the injection of loaded thermoplastics mixtures, Application in metal injection molding, 3rd ESAFORM Conference on Material Forming, Ed. by H.G. Fritz, Institut fur Kunststofftechnologie, Uniservitat Stuttgart, Germany, April 2000, pp. 43-47 (keynote paper).

b) Submitted for publications

c) In preparation