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Title: Increase of the productivity and efficiency of injection processes through the use of metallic foam in the production of moulds**.**

Instrument: Specific Cooperative Research Project for SMEs

PUBLISHABLE FINAL ACTIVITY REPORT

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CONTENTS LIST

1 SECTION 1 – PROJECT EXECUTION 3

1.1 PROJECT OBJECTIVES. 3

1.2 CONTRACTORS INVOLVED: 4

1.3 WORK PERFORMED. 4

1.4 RESULTS ACHIEVED 8

2 SECTION 2 – DISSEMINATION AND USE 10

1 SECTION 1 – PROJECT EXECUTION

1.1 PROJECT OBJECTIVES.

High pressure die casting (HPDC), injection moulding and blow moulding are dominating near-net-shape technologies for the production of light metal and plastic components. Today, more than 2000 EC SMEs are involved only in the mould making industry, with a yearly turnover of more than 6 billion Euros. Due to exhausting competition of “low cost” countries outside the European Community (mainly from Far East), dramatic changes are taking place in these industrial sectors to get more competitive products while reducing costs.

This way, the European SMEs of these sectors find the need to improve the quality and performance of their metallic and plastic products, to optimise their production processes and to accept new challenges of new products developments to increase their market share.

The main objective of the *FOINMOULDS* project was to develop new aluminium HPDC, polymer injection and blow moulding mould concepts in which metallic foams were to be integrated to attain an increased efficiency in heat management control of the three processes. Metallic foams integration could also derive in moulds weight reduction, which, together with improved and better-controlled heat dissipation, would lead to:

- improved mould temperature control
- controlled local solidification
- reduced mould distortions
- avoidance of component distortions
- improved feeding
- reduced mould wear and, therefore, improved surface quality of products,

therefore, better quality products and reduced processing times would be obtained.

1.2 CONTRACTORS INVOLVED:

Consortium Overview					
Role		**Organisation Name**	**Partner Nº**	**Country**	**Business Activity**
End-user	CR	MOLYPLAS	1	Spain	Blow moulding and injection of plastics
End-user/mould maker	CR	MAUSA	2	Spain	Plastic injection/mould maker
Metallic foams supplier	CR	M-PORE	3	Germany	Open pore metal foams producer
Mould maker	CR	MOLDE MATOS	4	Portugal	Mould maker for several technologies
Mould maker	CR	OLABERRIA	5	France	Mould maker for polymer injection
End-user/mould maker	CR	INYECTADOS GABI	6	Spain	Die Casting/mould maker
RTD Performers					
Developer	CO	INASMET	7	Spain	Materials Research Centre
Developer	CR	IFAM	8	Germany	Materials Research Centre

Table 1. List of contractors.

CO = Coordinator

CR = Contractor

1.3 WORK PERFORMED.

With the final aim of selecting suitable demonstrator moulds for each of the technologies under study (blow moulding, high pressure die casting and polymer injection moulding) where foams were to be integrated, the SMEs within the project presented different candidate moulds available at their premises and collected information about them. Finally, the following moulds were selected: A steel mould of a container to store humidified papers (injection moulding demonstrator), an ERG valve steel mould (HPDC demonstrator) and a bottle mould (blow moulding demonstrator) made mainly of aluminium, with some parts made of steel.

For each demonstrator the following information was gathered:

- Mould and part geometries.
- Mould designing rules used during their construction.
- Technical data of used materials for parts and mould.
- Process parameters.
- Part quality control.
- Mould cost.

In parallel, the different metallic foam materials (open and close cell foams) available at the market or inside the project consortium were studied. The main parameters observed were: Type of alloy, type of pore structure, density, size, mechanical and thermal properties (when available), etc. Thanks to the information compiled, a pre-selection of the most suitable foams for the purpose of the project was done. Different types of foams were acquired or manufactured by the partners of the project for further characterization.

Different mechanical and thermal simulations were carried out to investigate the response of the overall system when the selected foams are integrated into the demonstrator moulds, identifying the main parameters controlling the mould behaviour and the processes.

Conceptual mould designs for each of the demonstrators were established: A new blow moulding demonstrator mould was to be built in which close cell aluminium foams were to be integrated as part of the structure of the mould and open cell foams were to be inserted in the modified cooling channels. With respect to the injection and HPDC demonstrators, it was decided to integrate the open cell foams into certain of the cooling channels of the existing moulds. The possibility of enlarging the cooling channels was also studied.

Next, the RTD performers carried out a broad mechanical (compression and flexural tests), thermal (thermal conductivity, heat transfer behaviour) and corrosion characterization of the close cell and open cell foams acquired in previous tasks and of the foams produced by the partners. This work gave a complete set of properties that allowed tackling the subsequent moulds' design and manufacturing phases and selecting the most suitable foams for each of the demonstrator moulds.

In the following steps, the integration, assembly and finishing technologies for the application of the cellular metals in the moulds' cooling channels or structures were investigated. Different cutting techniques for the foams were tested, such as water jet cutting, sawing, milling and spark eroding. Several trials were also performed to test the feasibility of using the following foams' assembly methods: pressing, adhesive bonding and soldering. As a result of the work carried out, the most suitable techniques to cut and assembly each type of foam into each type of mould were obtained.

Once the conceptual designs of the moulds were defined and the properties of the foam characterized, the detailed design and manufacturing of the demonstrator moulds were performed. The blow moulding mould was built by rapid tooling which provides a way to obtain parts with complicated geometries and with the following advantages:

- Reduce mould manufacturing costs by reducing machining and drilling operations.
- Reduce mould manufacturing time.
- Customization of the bottle's surface for trade mark.

Several approaches to improve the cooling were studied and, finally, a concept where the cooling system was adapted to the cavity shape was manufactured and, afterwards, open cell aluminium foams were inserted in the cooling channels.

An HPDC mould, as a demonstrator for the injection processes, was manufactured with aluminium foams integrated in specifically selected cooling channels previously

enlarged by eroding. The selection of the modified cooling channels was done after a dedicated analysis of the overall process.

As a complement to the testing in service conditions of the built demonstrators, and in order to gain a better insight of the thermal behaviour of the system, different aluminium and hot-working steel test blocks with foams inserts of different types were constructed to test the following aspects:

- Influence of the foam inserts upon the heat transfer in channels of the same diameter.
- Influence of diameter extensions upon the heat transfer.
- Comparison of the heat transfer of cooling channels with/without foam inserts and with different diameters, following the results of the simulation analysis.

The results showed that the inclusion of foams into the cooling channels improved the thermal behaviour of the moulds. However, the reaction of the overall system depends upon all components of the system (heating station, pipes, mould, foam,...) so that a very simple generalization of this positive result to other systems is not possible.

In the next phase of the project, the industrial tests were conducted based on the demonstrator moulds built in previous work packages.

During the tests several process parameters were registered:

- Mould surface temperature by thermo graphic camera.
- Temperature, flow and pressure data of the conditioning system.
- Quality of final parts.

Tests were performed with the conventional and the demonstrator moulds in order to make a comparative analysis between the moulds with and without open cell foams

integrated. During the trials, different combinations of the process parameters were also tested to check the influence of the new developed mould over the process.

Based upon the results of the experimental tests and the experiences regarding the application of the cellular materials and the mould manufacturing, a technical and economical evaluation of the application of foams in moulds was carried out. In summary, this evaluation led to the conclusion that the utilization of the metallic foams can provide significant benefits to the considered industrial processes.

1.4 RESULTS ACHIEVED

In general, the activities performed throughout the project have demonstrated that the application of the metallic foams has a positive influence on the response of the moulds which leads to improvements on the three manufacturing processes considered, both in technical and economical aspects.

For example, a mould concept with integrated foams with improved thermal dissipation and mechanical behaviour over conventional moulds was developed. This result stemmed on the integration of metallic foams in conventionally manufactured moulds. The foams provided better heat dissipation rates. The present result is of general application for the three technologies considered in the project, that is, blow moulding, polymer injection and aluminium HP die casting.

Also, a mould concept with integrated foams based on rapid tooling techniques was developed which allowed reducing the parts' manufacturing cycle in 25%. This result relies on the combined solution of a mould manufactured by rapid tooling techniques and integrated metallic foams for improving the thermal regulation and the mechanical response of the system. The investment casting process allows the designer integrating directly the metallic foams in the mould parts which reduces later manufacturing steps for integrating such foams. Additional aspects that must also be considered are the mould manufacturing costs and time and the reduced weight of the

new mould. The mould could be delivered in half time with a 35% estimated reduction of the manufacturing costs.

In addition, the relevant physical, mechanical and thermal properties of the foams were determined for their application in thermal management and structural applications in moulds. A complete database of foams' properties that allowed tackling the subsequent moulds' design and manufacturing phases and selecting the most suitable foams for each of the demonstrator moulds was obtained. This database could be used for the application of the cellular in other moulds and processes.

Regarding the foam technology, the application of new alloys was investigated for the production of foams, new foam's geometries at different scales and pore-sizes were also obtained extending the range of available cellular materials in general.

The feasibility of using conventional cutting and assembly techniques for the integration of the foams into the moulds was proved and the most suitable techniques for the purpose of each foam application was identified among water jet cutting, sawing, milling and spark eroding and adhesive bonding, pressing and soldering.

Another relevant fact that has been confirmed is that the behaviour of the moulds during the considered injection processes is complex and, as ascertained by the tasks performed within the project, it becomes even more complicated when the foams are introduced. The work carried out has provided additional understanding of the influence of metallic foams on the mould behaviour. Thus, the experience gained by the partners offers the possibility for consultant services for injection moulders and foundries which may represent an extension of the portfolio beyond just foam production or application.

2 SECTION 2 – DISSEMINATION AND USE

The consortium is not ready to publicise all the results of the project since some IPR actions are in progress. The decision will be taken by the end of September so the public disseminating actions are delayed until October 2007.

Once this decision is taken, several dissemination actions are foreseen, which in summary comprise the following:

1. Information about the obtained results and the benefits of the project will be published at the RTD performers' websites.
2. Information about the obtained results will be published in the RTD performers' magazines as "Innovación y Tecnología" from INASMET and "Fraunhofer magazine" from IFAM.
3. Few pages coloured information brochures will be distributed by SMEs, mould makers above all, through large dissemination mailing to their customers.
4. In the same way, catalogues will be made emphasizing the benefits of the products obtained under the project.
5. Participation in conferences (oral communications and/or posters) will be scheduled to generate interest in potential customers as well as to identify additional applications for new research.
6. Workshops and seminars will be organized for many industrial sectors where potential end-users will be targeted.
7. Publication in scientific and technical journals will be made, technical papers in specialise journals mainly.

Table 2, Table 3 and **¡Error! No se encuentra el origen de la referencia.** present an overview of the main actions that are planned by the mould makers, the component manufacturers and the cellular material producer respectively.

Action	***Type***		***Type of audience***	***Countries addressed***	***Size of the audience***
- Publications in technical magazines	***Items***	***Targeted Journal****	General	Europe	1000-10000
	Articles (#: 2-3)	*- Moldes* *- Injection Molding* *- Fraunhofer magazine* *- Innovación y Tecnología (INASMET)*			
- Presentations to clients	Brochures, Power point presentations, technical meetings		Main Clients	Europe America	5-40
- Presentations of the technology in mouldmaking and tooling forums and workshops	***Item***	***Workshops / Exhibitions****	Mouldmaking and tooling sector.	Europe	1000-5000
	-Oral presentations -Posters	*- Euromold* *- Bi-Mu (Italy)* *- Bienal Máquina herramienta (Bilbao-Spain)* *- Expomoldes (Zaragoza-Sapin)* *- Intermolde (Alicante-Spain)*			

** The journals and workshops/exhibitions selected have been considered as the most suitable ones for publishing the results of the mould makers. The results will be presented once the Project is finished.*

Table 2. Dissemination actions of mould makers MAUSA, MATOS and OLABERRIA. Overview table.

Action	***Type***		***Type of audience***	***Countries addressed***	***Size of the audience***
- Publications in technical magazines	***Items***	***Targeted Journal****	General	Europe	1000-10000
	Articles (#: 2-3)	*- Kunstoffe Plast Europe* *- Aluminium Internacional Today* *- Fraunhofer magazine* *- Innovación y Tecnología (INASMET)*			
- Presentations to clients	Power point presentations, technical meetings		Main Clients	Europe	5-50
- Presentations of the technology in plastics and aluminium forums and workshops	***Item***	***Workshops / Exhibitions****	Plastics and aluminium sectors.	Europe	1000-5000
	-Oral presentations -Posters	*- K2007* *- TransAl* *- Euroguss (Nürnberg)* *- Equiplast (Barcelona)*			

** The journals and workshops/exhibitions selected have been considered as the most suitable ones for publishing the results of the component producer. The results will be presented once the Project is finished.*

Table 3. Dissemination actions of component manufacturers INYECTADOS GABI and MOLYPLAS. Overview table.

Action	***Type***		***Type of audience***	***Countries addressed***	***Size of the audience***
- Publications in technical magazines	***Items***	***Targeted Journal****	General	Europe	1000-10000
	Articles (#: 2-3)	*- Advanced Materials & Processes* *- Materials Today* *- Fraunhofer magazine* *- Innovación y Tecnología (INASMET)*			
- Presentations to clients	Power point presentations, technical meetings Add to potential applications of Metal Foams		Main Clients	Europe	5-30
- Presentations of the technology in porous metals and metallic foams forums and workshops	***Item***	***Workshops / Exhibitions****	Porous Metals and Metallic Foams sector.	Europe	1000-5000
	-Oral presentations -Posters	*- MetFoam* *- EuroMat* *- Euromold*			

** The journals and workshops/exhibitions selected have been considered as the most suitable ones for publishing the results of the cellular metal producer. The results will be presented once the Project is finished.*

Table 4. Dissemination actions of cellular material producer M-PORE. Overview table.

At the same time, since the use of the results is still under discussion, only a short description of the publishable results is included hereafter.

- **Application of foams in injection moulds**

– Result description:

Consultancy services for the application of cellular materials in moulds to improve the injection processing technologies through optimized thermal regulation and mechanical behaviour.

- Market application:

  Mould making industry, foundries.

- Stage of development:

  Available for consultancy

- Collaboration sought or offered:

  Available for consultancy

  Information exchange

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