Project no.: 017899

STEMACEL

Development of an innovative iron based cellular material –
new manufacturing routes for porous structures

Instrument CO-OPERATIVE RESEARCH PROJECT

Thematic Priority HORIZONTAL RESEARCH ACTIVITIES INVOLVING SMES

Final Activity Report (full project duration, publishable)

D 5-4

Due date of deliverable: 30 Nov. 2007
Actual submission date: 11 Jan. 2007

Start date of project: 01 Dec. 2005 Duration: 24 months

Organisation name of lead contractor for this deliverable: INASMET

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	XX
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Report D5-4: Publishable summary report

1 Objectives of the project

The major objectives of the Stemacel project are:

- ✓ To further develop the process of making steel and iron foams according to two technologies, the powdermetallurgical route and the meltfoaming route.
- ✓ To adapt these processes according to the products defined by the end-users involved
- ✓ To provide the potential industrial manufactures of these products with the know-how to establish these technologies in their companies
- ✓ To show the feasibility of these technologies through the manufacturing of demonstrators

2 Co-ordinator and contractors

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Contractors

Haute Sambre

Aciérie et Fonderie de Haute Sambre is specialised in the manufacture of foundry components, both individual items and small runs, weighing from 10 kg to 3.5 t. The extensive range of steels and nickel- and cobalt-based alloys means that the foundry can answer the needs of many different industries. With a staff of 130 people, the total monthly production amounts to 130 tonnes. From a simple part to an highly cored component, the technical expertise allied with the extensive experience in the production of nickel- and cobalt-based grades places us among the leaders in this field in Europe. The fields of applications are : Paper industry, Cement industry, Iron and steel industry, Pharmaceutical industry, Chemical industries, Offshore industries, Gas industries, Hydraulic power, Nuclear power. The alloys casted cover a wide scale of steel alloy, and especially carbon and weakly alloyed steels, ferritic and martensitic steels, austenic steels, austeno-ferritic steels, high temperature steels and alloys, nickel based and cobalt based.

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Lagun- Artea
INDUSTRIAS LAGUN ARTEA (ZUMAIA, España) is a SME company of 150 people specialised in mechanical components for the ironworks and steelmaking areas. The company was created in 1962. Its first business concerned the mechanical engineering; then the company moved to applications regarding iron and steel machinery.

Main applications within the iron and steel sector concerns:
- Rolling mill trains for the production of billets, round bars and sections
- Loading and unloading systems for heating furnaces
- Cooling beds
- Pinch-rolls
- Bearing roll mills.

The company is equipped with bundling and tying systems for structural bars up to 300 m, with automatic tying and weighing services. The production is about 140Tm/hour for lengths between 6 and 18 m.

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Urbina
Fundiciones URBINA S.A. (Legutiano, Spain) is a SME company of 99 people specialised in the manufacturing of foundry components. Since its foundation in 1985, Fundiciones URBINA S.A. has specialised in the production of iron casting, principally using spheroidal grapite (nodular) and flake graphite (grey) in all their qualities. The weight of the casting ranges between 1 kg to 1 Ton.

The plant has an automatic green sand moulding line and a self-setting moulding carrousel.
Fundiciones URBINA S.A., owing to the high quality of all its product range, is able to supply any industrial sector. Its main clients come from the valve, industrial vehicle, agricultural machinery and machine-tool sector, as well as from shipbuilding, the railway sector, the iron and steel industry and the automotive industry.

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Cellbond
Cellbond Composites Ltd in Huntingdon, UK has been involved in energy absorption and vehicle safety testing since 1988. Among other things, Cellbond has specialised in the production of crash test barriers and energy absorbers for the automotive and rail industries.

Their services include consultancy, design, prototype and full-scale production. At Cellbond they are committed to providing innovative solutions in partnership with their customers and they also pride themselves on the cultural diversity of their staff and their ability to communicate with their customers throughout the world, often in their own language.

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Eisengiesserei Baumgarte
Eisengiesserei Baumgarte (EGBG) is located in Bielefeld (Germany) with a workforce of 220 people. It was founded in 1951. Since 1953 they are producing in Bielefeld. The gradually accomplished extensions of the manufacturing areas and constant modernisation of the production plants let the Eisengiesserei Baumgarte grow to one modern foundry.

The foundry activity lies in the field of iron casting (mainly flaked graphite iron, spheroidal graphite iron and alloyes iron). The produced components vary from small size up to large parts for machine tools, transmission manufacturing, shipbuilding, pumps, tools for textile industry, and engine building in general.

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Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
The Fraunhofer Institute for Manufacturing and Advanced Materials IFAM, Department for shaping and functional materials, has premises in Bremen and Dresden.
There it works on problems in powder metallurgy and casting of metallic parts and components with a minimum of post-machining.
The Institute carries out feasibility studies and prototype and pilot production of components, in order to give its customers a reliable estimate of the costs of later production. For this purpose, the technical centres and applications centres for casting technologies possess equipment for the complete production chain from metal powder or other materials through to prototype components or pilot production. The institute also cooperates with companies in developing products in the field of powder technology, for example metal foams or fillers for electrically conducting polymers; these can be developed as far as the demonstrator stage.
The department for shaping and functional materials cooperates with the department for bonding technology and polymers in joint projects. The specialist knowledge and technical equipment of the entire institute are available for solving problems covering both fields. There is a laboratory for determining grain sizes and for thermal analysis.

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Inasmet

Fundación INASMET is a non-profit research institute whose activities cover the research and development of materials and process technologies finding environmental applications. The Centre currently comprises around 200 staff and more than 74% of INASMET´s income originates from private contracts where the organisation uses its expertise to solve specific technological problems. Its policy is to work closely with the industry on a research contract and consultancy basis. The main objective in industrial Projects is the incorporation of new technologies and processes as well as the improvement and optimisation of current or new products. INASMET also provides technical assistance, information and training courses.
In addition to this work, INASMET has participated in more than 40 European research programmes and has therefore considerable experience in the field. INASMET´s facilities in this field include a pilot plant with diverse equipment for MMCs and metallic foams as well as laboratories for physical, chemical, mechanical and microstructural characterisation. It has supported European research efforts through the publication of different scientific papers and organisation of lectures/seminars.

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CTIF

CTIF, Centre Technique des Industries de la Fonderie (Sèvres, France) is a well-known Research Institute founded in 1948, involved in all the aspects regarding the foundry industry and the shaping materials (Metallurgy, Engineering, Modelling, Controls and Measurements, Environment).

CTIF serves the French foundry industry through missions of three types:
- collective Research & Development
- dissemination of technology
- standardisation (foundry industry, materials and environment regulations).

CTIF, with its research and development centre can draw on its experience in casting technologies and in other materials forming technologies.

Joint research and development projects are worked out in close cooperation with the foundry industry either through joint bodies or as the result of numerous one-to-one or group meetings with foundries.

CTIF's own resources and skills cover all stages of development of new alloy, new processes. Indeed, CTIF has developed all the skills from the metallurgical aspects, industrial process, physical characterisation, chemical characterisation. For instance, in march 2001, CTIF has lead a work on nitrogen steel alloy and in march 2000 on the use of induction furnaces for the melting of steel alloys.

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3 Achieved results

3.1 Applications and products

The overall goal for the STEMACEL project is the development of two steel resp. iron foam production processes and the integration of steel/iron foam components into products of the SME participants. The developed technology and know how has been transferred to the SME participants to allow for introduction of new products with superior properties into their specific target markets.

At start of the project the RTD partners (CTIF, IFAM, INASMET) introduced the unique property combination of cellular metals to the SME participants (Cellbond, Eisengiesserei Baumgarte, Haute Sambre, Lagun Artea, Urbina). Subsequently the consortium identified products for application of the newly developed steel/iron foam components. The metal foam's characteristic properties of reduced density, highly efficient energy absorption, good vibration damping, etc. shall be employed for improvement of SME participant's products.

Chosen products for application of steel/iron foam components are:

- Side frame of textile machine (steel/iron foam as permanent core in cast side frame for reduced weight and vibration, Eisengiesserei Baumgarte)
- Roller (steel/iron foam as permanent core in cast roller for reduced weight and vibration, Lagun + Urbina)
- Energy absorbing road barrier (steel/iron foam as energy absorber, Haute Sambre)
- Energy absorber for transport industry ((steel/iron foam as energy absorber, Cellbond)

3.2 Iron foam expansion processing and production of shaped parts

Introduction

By definition of the demonstration products the consortium set requirements and boundary conditions for the development of the steel/iron foaming technologies. The research and development activities of the RTD partners where subsequently focussed on two steel/iron foam processing routes:

a. powder metallurgical process route
b. melt foaming process route

Both processing routes are well established for aluminium alloys and aluminium foam part production in industrial scale volumes. The STEMACEL project aimed at technology transfer to iron/steel foam part production.

Powder metallurgical processing route

As the name indicates, the powder metallurgical process starts with a steel/iron powder and a foaming agent powder. Mixing and consolidation delivers a gastight precursor material with homogeneously distributed foaming agent particles in the precursor volume. Heating leads to chemical decomposition of the foaming agent, this then splits off gas. As soon as the metal becomes liquid the gas expands numerous pores and, thus, the volume of the liquid metal. As soon as the maximum (desired) expansion level is achieved, the liquid foam is transferred to the solid phase by freezing below solidus temperature. Processing adaptation (from aluminium foaming) and further development has been the focus of work within the first project year. Precursor material composition, powder consolidation and foam expansion parameters (incl. heating concept, etc.) have been investigated and optimised until an applicable processing steps and a working set of processing parameters have been found.

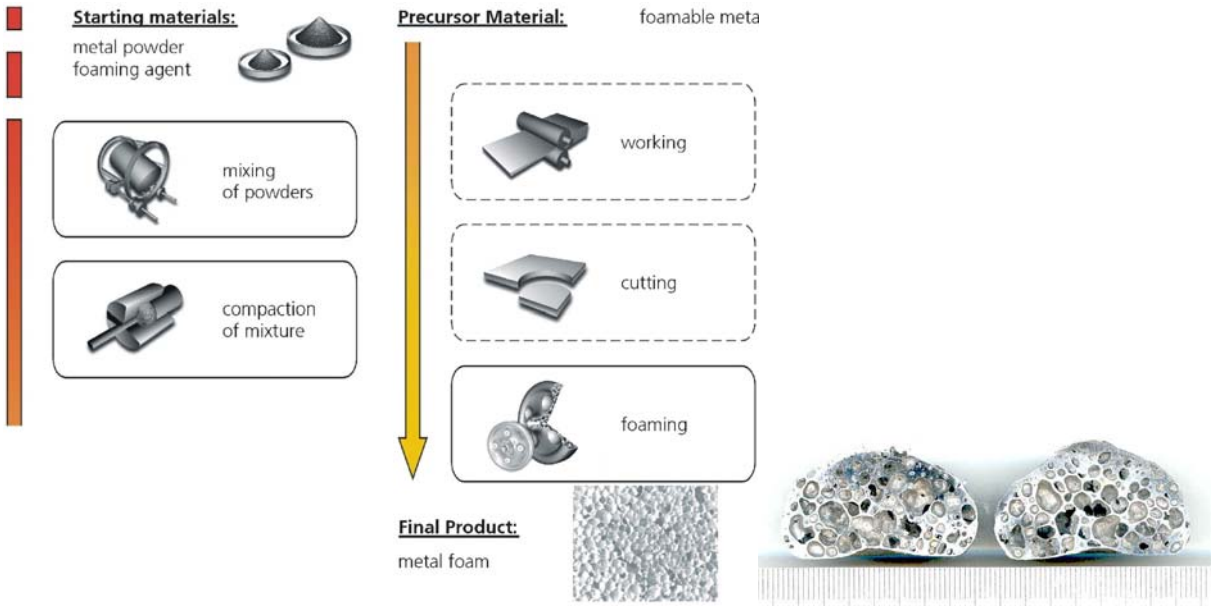

Fig. 1: Schematic of powder metallurgical process and cross section of achieved iron foam sample

Performing the expansion process in a high temperature resistant mould allows for production of shaped metal foam parts. The expanding foam reproduces the inner contour of the mould. As soon as the mould cavity is completely filled by the liquid foam cooling freezes the foam into the solid state. The shape remains as in the liquid phase (Fig. 2). Iron foam part production in high temperature resistant moulds was one work field in the second project year. Foaming mould design and production of shaped foam parts has been developed to an industrially applicable level.

Fig. 2: Cuboid iron foam parts produced in high temperature resistant moulds (left) and cross sections of iron foam part

Analysing and mechanical testing showed the following characteristic properties of iron foam parts produced via the powder metallurgical processing route:

- Minimum density: 3,0 g/cm^3
- Maximum porosity: approx. 60%
- Type of porosity: closed cell
- Smooth and closed surface skin of iron foam parts
- Good energy absorption performance
- Competitive weight specific mechanical properties

The application of iron foam parts as lightweight permanent cores in cast machine side frames not only required the development of the iron foam part production procedure. Since the part was planned to be used as permanent core the integration procedure also need evaluation and development. Machine side frames are produced in an automatic production line by casting in sand moulds. For iron foam part integration the sand mould needed to be adapted and a positioning system for placing the iron foam part into the mould was developed. The general cast part production process chain remained unchanged. Production tests showed the successful integration of the iron foam part into the cast part (Fig. 3).

Fig. 3:Iron foam part cast in as permanent core

Melt foaming route

The aim of the Stemacel project was to demonstrate the feasibility of the casting route to obtain iron and steel foams.

During two years of research and work, iron based metallic foams have been successfully produced by the meltfoaming route.

The process developed is standard foundry process with no significantly additional operations costs except additional materials (foaming agents) and is easily adaptable to the common foundry process. Moreover the process is valid to produce any type of iron based material such steel or iron. In fact, samples, shaped samples and finally industrial demonstrators have been casted in several iron based materials like carbon steel, grey iron and ductile iron.

Foaming iron or steel by the meltfoaming route process start with introducing foaming agent (0.3 – 0.6 wt.-%) into the mould. The foaming effect occurs when the liquid metal is directly poured into the mould, foaming agent releases gas by the effect of the liquid metal high temperature.

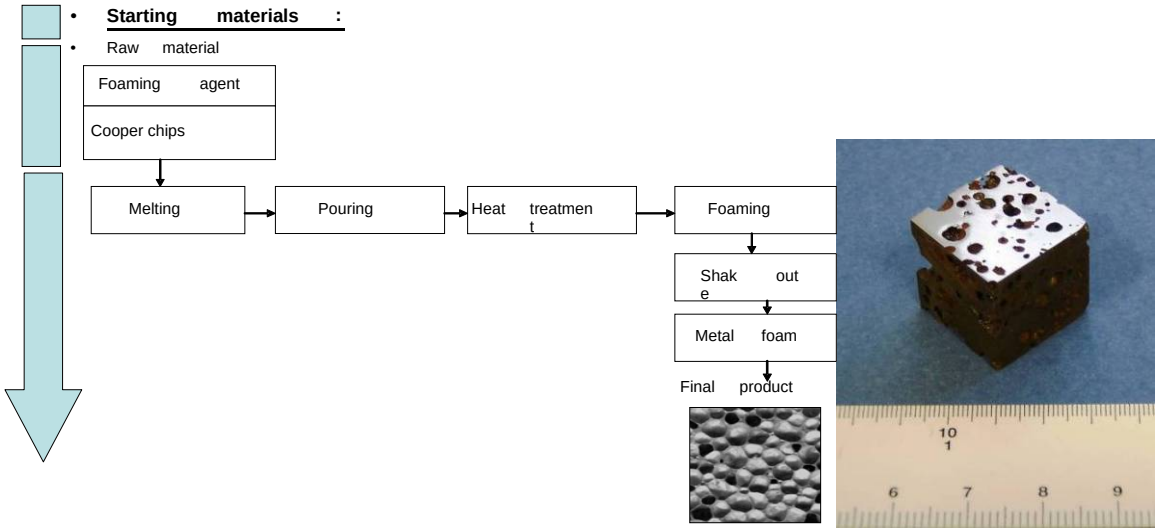

Fig. 4: Schematic of meltfoaming route process& a specimen achieved of iron foam

The minimum density achieved is 5.1 g/cm3: 30% of weight reduction compared to "full material".

Fig. 5: Iron foam demonstrators made by meltfoaming route

Partners worked also on a Fe-S-P alloy, and such metallic foams have been successfully produced by the meltfoaming route. The common foundry process has been used, with the addition of foaming agents, and so the cost, for the casting of cellular iron based material will be roughly similar to the full material, obtained in the identical conditions.

During the whole project, samples, shaped samples and at last industrial demonstrators have been casted. One demonstrator is a 100mm x 100mm x 40mm cast product, whose density varies from 5,3 g/cm3 to 6,4 g/cm3 (27 % of weight reduction compared to "full material"). The structural characterization has been performed using micrographic examination and X-ray tomography. 2D and 3D quantitative image analyses have been carried out to obtain information on the pores (size, distribution and morphology): the repartition of pores inside the cast foam is homogenous. Compression tests have been achieved on the demonstrators, and the results are good and promising.

Summary

The two years project work and close cooperative of SME and RTD participants delivered:

a. developed and industrially applicable process for production of shaped steel/iron foam parts by the powder metallurgical process route
b. developed and industrially applicable process for production of shaped steel/iron foam parts by the melt foaming process route
c. demonstration items showing the application of steel/iron foam in existing products of SME companies in Europe
d. know how on integrating iron foam parts into real-life products for performance improvement
e. know how transfer from RTD to SME partners

4 Use and dissemination

Use and dissemination of the achievements in the STEMACEL project is structured into two main activity areas.

First, the complete produced know how has been transferred to the SME partners. The SME partners use and disseminate this know how in improvement of their products. New market fields will be entered and the total market position of these European SMEs will be strengthened resp. extended. The SME partners decided to keep all product relevant achievements confidential.

Second goal of the project is spreading the publishable part of the project's achievements to the European Community to promote application of innovative steel/iron foam components in various products. Selected project results will be published in journal articles and by participation in scientific conferences etc. By promotion of steel/iron foam application the STEMACEL project will contribute to the European Commission's target of strengthening Europe's technology leadership in innovative material development and application.