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Contract nº: COOP – CT -2004 – 508606

Project nº: 508606

Acronym: TECUS

Title: Technology for Titanium High Quality Customized Products.

Instrument: Specific Cooperative Research Project for SMEs

Thematic priority: ---

FINAL ACTIVITY REPORT

Period covered from **26/09/2004** **to** **06/10/2006**

Starting date: 26/09/2004 **Duration:** 24 months

Project coordinator name: Francisco J. Estensoro

Project coordinator organisation name: INASMET - TECNALIA **Revision: 00.**

INDEX

1 SECTION 1 – PROJECT EXECUTION

Project Objectives.

The main technical objective of the project is to develop an easy handling, fully automated, reliable, new titanium casting technology capable to cast up to 150 gr of Ti of excellent metallurgical quality and in a reproducible and reliable process. To attain this objective the following partial objectives need to be addressed:

- Development of a new melting device using cold crucible induction melting system to avoid contaminating Titanium.
- Development of a reliable and reproducible process. Development of an Automatic machine to produce reliable and reproducible cast components. The process will be aided by centrifugal casting, and monitored and controlled electronically, defining as main control parameter the temperature of the Titanium. The aim is to develop a reliable and reproducible process able to cope with the presently demanding quality requirements.
- Development of an easy comprehensive procedure to eliminate human errors. Code of best practice for the production of titanium cast components in the new technology. The aim is to develop an easy comprehensive procedure to eliminate the human errors in the casting of Titanium

Contractors involved:

Part. Role	Part. Nº	Partner Name	Short name	Country	Date enter	Date exit
CR	A1	ARAGONESES S.L.	ARAG	Spain	M1	M24
CR	A2	NRU	NRU	Germany	M1	M24
CR	A3	VALDENTIA C.B.	VALDEN	Spain	M1	M24
CR	A4	BEZNOSKA s.r.o.	BEZNOS	Czech Republic	M1	M24
CR	A5	PHOENIX SCIENTIFIC	PSI	UK	M1	M24

		INDUSTRIES Ltd (PSI)				
CR	A6	BESCOS DENTAL LAB.	BESCOS	Spain	M1	M24
CR	A7	SVATOPLUK KRIZEK ZLATNICTVI (KRIZEK)	KRIZEK	Czech Republic	M1	M24
CO	A8	FUNDACIÓN INASMET	INASMET	Spain	M1	M24
CR	A9	CNRS (GRENOBLE)	CNRS	France	M1	M24

CO = Coordinator

CR = Contractor

Co-ordination Activities.

There has been a change in month 12 related with the person co-ordinating the project. The project is now co-ordinated by:

Name: Francisco J. Estensoro
Company: INASMET – TECNALIA
Address: Paseo Mikeletegi 2.
20009 San Sebastian. Spain.
Telephone: 00 34 943003700
Email: festenso@inasmet.es

Work performed.

During the first 12 month of the project the performed tasks have been focused in the design, manufacturing and integration of the machine components. First of all, and corresponding to WP1, machine specifications and conceptual design were developed and agreed by all the project partners. The end of this workpackage leaded to the detailed design phase, including all the machine modules (heating, vacuum, centrifugal casting, control…) and from mechanical, electrical and software points of view.

These designing stages derived in a collection of drawings, electrical schemes, software and control flow diagrams that were made physical by manufacturing, selection and purchase of commercial components and their integration.

An operative machine was assembled capable of fulfilling all the requirements included in the specifications document. The machine modules were controlled by a PLC interfaced by a tactile screen. All the parameters are displayed in the screen to have a total control of the process. The software leaves the possibility of working in a sequential manual way of control or in a totally automated mode. These two possibilities were considered with the aim of specifying all the needed parameters and to know the machine behaviour and performance characteristics. The totally automated mode has to be adjusted during the first melting and casting tests that are being performed in the actual stage of the project.

At the same time numerous titanium melting test have been performed with CNRS laboratory cold crucible prototype aimed to the definition of the process parameters to be implemented by the developed machine and also to explore the possibilities of the machine.

The second year of the project started with the performing of the first casting tests with the manufactured TECUS prototype first version. Several tests were performed in order to evaluate prototype operability and its compliance with the specifications document set in previous work packages. This tasks leaded to a task of redesigning the different modules up to reach the final design and production route and resulted in the correspondent deliverable D19: Report including the modifications required.

Once the machine design was stated as finished and validated, a code of best practice was elaborated describing machine operating mode and parameters definition. This code of best practice set the procedure for future tests and parts production.

Next stage was focused on parts production. The end users of the consortium (A1,A2,A3,A4,A6,A7) proposed specimens that they were casting or producing at their respective facilities and with existing technologies to be produced by the new

developed TECUS machine. 4 parts were selected as typical components of the SMEs in the main features acceptable by the TECUS machine (minimum wall thickness, different sizes, massive and thin areas etc.)

These selected 4 parts were produced by the SMEs and also by the TECUS machine. Wax models were produced for each part, from those wax models refractory moulds were manufactured and finally the parts were successfully cast in the TECUS machine. Lots of tests were produced due to foundry inherent development difficulties. Machine prototype worked properly and provided the performance expected from the design and manufacturing stages. The number of tests performed was very high due to the foundry difficulties encountered. Casting acceptable parts requests a development process that could not be avoided. Filling of the moulds, feeding systems in the mould, gas entrapments, centrifugal forces, refractory material selection, surface finishing improvement related to the wax model and refractory surface finishing,… brought into scene a lot of foundry development work that finally resulted in the production of several acceptable parts from each previously selected part model. Once the process was adjusted for every part the machine was able to produce reproducible parts in an automatic operating mode.

With the TECUS produced parts, a comparison between existing technologies and TECUS technology was carried out. The comparison was based on the different specifications for each part. A deep metallurgical analysis was be carried out in order to detect the soundness of the demonstrators. The corresponding chemical analysis were also carried out to ascertain the degree of contamination in the samples, chemical composition, nature and extension of the a case, microstructure etc. Mechanical analysis were also performed onto the produced parts and onto specifically cylindrical samples produced for the characterization.

A technical evaluation was carried out with the results obtained from the characterization performed. This evaluation confronted obtained results from TECUS produced parts with the results obtained from the characterization of the parts produced by conventional technologies and with the objectives of the project set in the early stages of the project.

An Exploitation Plan has also been drawn in the correspondent work package. A dissemination Plan has been also discussed and proposed.

Results achieved.

A cold crucible Titanium melting and centrifugal casting machine has been developed and manufactured. Successful tests have been carried out with different titanium masses (10-150 g.) in the same cold crucible. Vacuum levels of 1 mbar have been achieved as maximum with around 100 mbar of pressure values when centrifugation.

A compact and integrated machine has been manufactured with an easy and visual display and a tactile control screen as human interface.

The machine integrates several sensors which permit a safe and totally controllable process. The software includes several warning subroutines that inform in every moment about the status of the different process parameter values. The fixtures and dismountable components of the machine have been designed user friendly and safe.

A data base with melting parameters has been elaborated with the aim of knowing the machine parameters working with different titanium masses. This data base has been developed by means of a battery of tests performed on another laboratory cold crucible melting prototype.

As described in the former paragraph the TECUS machine prototype first version was modified to comply with the specifications and to perform successful casts.

A code of best practice was elaborated as a machine operating procedure.

Previously selected parts were successfully cast as demonstrators. The parts were always produced in an automatic operating mode and with a good reproducibility.

Produced parts characterisation results were compared with the results obtained on conventionally produced parts. Results in terms of chemical composition, microstructure, porosity and oxygen content can be declared as very good. Mechanical properties and surface finishing results can be assessed as very promising. Conventional parts showed better results in terms of toughness and utilised wax model finishing in some of the parts was not the best. In any case, these results (toughness and finishing) are related to the refractory material used and the production route of the mould. These aspects have not been fully developed during the project due to a lack of time and resources. The main objective of these tasks was concerned to the validation of the developed machine and from this point of view the machine produced parts satisfactorily and with a good reproducibility.

Aspects for competitive improvement	***Present situation***	***By using the new technology***
Direct scrap	>10%	0-5%
Maximum casting quantity	<35g, with strong limitations	150g
Rejections in large components	>35%. Maximum size is very limited	<15% in complicated shapes. Large sizes will be possible
Cost in consumables different from Titanium (in the melting step)	10 Euros/casting	0
Minimum Thickness of components	0.5-0.8 mm due to brittleness	0.3-0.5 mm.

2 SECTION 2 – DISSEMINATION AND USE

2.1. EXPLOITABLE RESULT: COLD CRUCIBLE

- Functionality, purpose, innovation: The cold crucible is a device that allows melting of titanium without contact with the crucible, in a levitation state. It already exists, but its development in the small size required for the present function, and its employment for the melting of small titanium quantities is a large innovation. The purpose of this device is to allow the production of dental castings and titanium jewels, which cannot be presently produced with the sufficient metallurgical quality.
- Partner(s) involved in the exploitation, role and activities: The cold crucible has been developed by EPM, but the exploitation will take place between all the industrial partners in the consortium
- How the result might be exploited: The cold crucible could be exploited in the development of new technologies or devices for other applications. Also, it can be exploited for the production of different types of machines by the members of the consortium, either by themselves or by preparing spin-off companies.
- Further additional research and development work: It can be foreseen that the technology developed could lead to further research to 1) reduce the cost of the induction melting system, and to 2) develop new devices for other applications. Collaboration between EPM, Inasmet, PSI, and other members of the consortium can be expected.
- Intellectual Property Rights: The device won't be patented in order to avoid benchmarking and due to the uncertainty of the possibility of patenting .
- Any commercial contacts already taken (demonstrations given to potential licensees and/or investors and any comments received, market requirements, potential etc.): A web site will be launched to publicise and disseminate the result.

1st result: Cold Crucible.

Result description: Physical device. Design and fabrication.

Market application: Dental, Jewellery, Implants, Scientific, Research.

Stage of development: Advanced

Intellectual property rights granted or published: None.

Contact details:

Francisco J. Estensoro.

INASMET-TECNALIA.

Paseo Mikeletegi 2. 20009 San Sebastian. Spain.

0034943003700.

festenso@inasmet.es

2.2. EXPLOITABLE RESULT: MELTING-CASTING INTEGRATION

- Functionality, purpose, innovation: The melting-casting integration is the most critical part of the machine developed. The innovation of the machine is the integration of both modules while allowing the use of moulds of different sizes and types, while maintaining the metallurgical quality of the cast titanium.
- Partner(s) involved in the exploitation, role and activities: The integration has been developed by EPM and INASMET, but the exploitation will take place between all the industrial partners in the consortium
- How the result might be exploited: The melting-casting integrated modules could be exploited in the development of other machines for dental casting (not based in cold-crucible technology), or for other types of casting processes. It can also be exploited by the partners in the consortium to upgrade their presently existing machines. It can be exploited by PSI for incorporating the solutions developed in other type of machines.
- Further additional research and development work: It can be foreseen that the technology developed could lead to further research to 1) reduce the cost of the machine, 2) to develop new machines and technologies (i.e. casting not based in cold crucible) . Collaboration between EPM and Inasmet, and potentially other members of the consortium, can be expected.
- The device won't be patented in order to avoid benchmarking and due to the uncertainty of the possibility of patenting .

- Any commercial contacts already taken (demonstrations given to potential licensees and/or investors and any comments received, market requirements, potential etc.): A web site will be launched to publicise and disseminate the result.

2nd result: Melting – casting integration.

Result description: Mechanical design.

Market application: Casting and foundry. Dental, Jewellery, Implants. Scientific Research.

Stage of development: Advanced. Testing stage.

Intellectual property rights granted or published: None.

Contact details:

Francisco J. Estensoro.

INASMET-TECNALIA.

2.3. EXPLOITABLE RESULT: MACHINE

- Functionality, purpose, innovation: The machine is able to produce dental, jewel and biomedical Titanium casting with an excellent metallurgical quality and in a highly standardized automatic mode.
- Partner(s) involved in the exploitation, role and activities: The machine is owned by the whole consortium.
- How the result might be exploited: Design and development of a web site devoted to the TECUS machine and Project.
  - The potential market for such a technology includes Dental companies scientific institutions, R+D departments, implants industry.
- Further additional research and development work: It can be foreseen that the technology developed could lead to further research to 1) reduce the cost of the machine, and to 2) develop new machines for other applications. Collaboration between EPM, Inasmet, and other members of the consortium can be expected.
- Intellectual Property Rights: The device won't be patented in order to avoid benchmarking and due to the uncertainty of the possibility of patenting .

- Any commercial contacts already taken (demonstrations given to potential licensees and/or investors and any comments received, market requirements, potential etc.): A web site will be launched to publicise and disseminate the result.

3rd result: Machine.

Result description: Physical device. Hardware and software.

Market application: Dental, Jewellery, Implants. Scientific Research.

Stage of development: Advanced. Testing stage.

Intellectual property rights granted or published: None.

Contact details:

Francisco J. Estensoro.
INASMET-TECNALIA.
Paseo Mikeletegi 2. 20009 San Sebastian. Spain.
0034943003700.
festenso@inasmet.es