RAPID MANUFACTURING BY IMPROVED 3D PRINTING (RAMA-3DP)

Contract no.: COOP-CT-2004-508432

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Summary:

- Project objectives
- Contractors involved
- Work performed
- End results
- Dissemination and use

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This project is funded by the European Community under the 6th Framework Programme

FINAL ACTIVITY REPORT (PUBLISHABLE)

CONTRACT N°:	**COOP-CT-2004-508432**
ACRONYM:	RAMA-3DP
TITLE:	Rapid manufacturing by improved 3d printing

PROJECT COORDINATOR:	PTS Software BV
SME CONTRACTORS:	PTS Software BV Martello Limited Ardeje Sarl NTS Mechatronics B.V. (Nebato B.V.)
ENABLING PARTNER:	Huntsman Advanced Materials UK Ltd.
RTD PERFORMERS:	Netherlands Organisation for Applied Scientific Research (TNO) University of Manchester Materials Science Centre (UMIST)
REPORTING PERIOD:	FROM September 1st, 2004 TO August 31th, 2006
PROJECT START DATE:	September 1st, 2004

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CONTENT

1 PROJECT EXECUTION

1.1 PROJECT OBJECTIVES

The development of new products is an iterative process involving design and visualisation, building prototypes, testing and evaluation. This is usually quite expensive and time consuming, especially if unconventional or complex geometries are required. Worldwide there is a strong need for a Rapid Prototyping (RP) technique, which is able to produce prototypes, which have the technical specifications (integrity, accuracy and shape), appearance (colour, texture) and feel of the desired product. In addition, there is a strong need for Rapid Manufacturing (RM) of (complex) one-offs, e.g. teeth, and implants and small series, e.g. mock-ups for surgical practising, high-end tooling and technical parts. There is increasing need also for manufacturing processes which do not produce onerous waste materials.

The technical/scientific objectives / targets are:

1. To determine the technical feasibility and optimal process parameters of the individual processing steps of the 3 DP prototyping/manufacturing technique. This comprises the determination of:
   - suitable powder-binder combinations. The target is to be able to tune the density between 0.5 and 2.5 gm/cc, and the tensile strength to be greater then 30 Mpa;
   - material specifications (particle size distribution, polarity, shape, etc.) and material processing conditions (temperature, pressure, etc.);
   - suitable colouring agents and composition of the base colours (red-yellow-blue) in relation to the resulting colour intensity and colour resolution;
2. To determine the best way, i.e. process configuration, to prevent contamination of the print head(s). The target is to increase the lifespan of print heads by 500 %, from 40 hours to 200 hours and to increase the maximum operating speed of 5 m/min to 20 m/min;
3. To build a prototype of the to be developed 3 DP prototyping/manufacturing technique with the following preliminary specifications:
   - reproducibility: > 98 %
   - density: at least between 1 and 1.5, preferentially between 0.5 and 2.5 gm/cc;
   - structural integrity/tensile strength: at least 30MPa, preferentially > 50 MPa
   - dimensional accuracy: < 0.2 mm in X,Y,Z direction;
   - surface smoothness: < 50 um, preferentially < 20 um;
   - speed: at least 10 m/min, preferentially > 20 m/min;
   - lifespan of print head: at least 100 hours, preferentially > 200 hours;
   - graphical resolution: at least 200 dpi, preferentially 300 dpi;
   - colour intensity: at least 40 RA; preferentially 100 RA;
   - colour resolution: at least 10 RGB; preferentially 100 RGB;
4. To determine the applicability of the developed 3 DP prototyping/manufacturing technique by development of at least 4 partner-specific (process and) product applications;
5. To increase the creativity of designers by the ability to develop more innovative products more rapidly and more vividly by using colour and texture/prints. It also increases the variety of products, which can be developed;
6. Evaluation of the developed 3 DP prototyping/manufacturing technique by pilot production of demonstrators and 'product' evaluation tests.

1.2 CONTRACTORS INVOLVED

The SMEs

PTS Software BV

In the area of technical system development, PTS provides advice, analysis and design, development, testing, migration, implementation and support.

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Martello Ltd.

Martello is an SME specialised in prototypes and pre-series of complex electronic hard-

ware and customer made household electronic parts. Its main activities are in making small series of product by vacuum casting in the process of product development. Its speciality lies in the innovative character of its product to compete with and distinguish itself from the main competitors.

Contact person: Martin Peters, Managing Director

Ardeje Sarl
Ardeje is an engineering company based in Valence, which supports the print industries with analysis instrumentation and techniques for studies throughout the ink jet development cycle. The manufacturing activities include supply of subsystem developments of ink circuit driving system, studies related to ink/substrate and ink / printhead behaviour, machine architecture study as well as market surveys, feasibility studies and technological assessments.

Contact person: Ms. Sandrine Allaman, Research Engineer

NTS Mechatronics
The group consists of 5 business units each having another specialism in the sheet metal industry. At *NTS Sheet Metal* the manufacturing of sheet metal products takes place. In addition, NTS Sheet Metal has become a specialist in frame and covering production. *NTS Finishing* is specialized in wet painting, powder coating and all related processes. *NTS Combimetal* is the part of the group that has a very flexible organization and is especially equipped for one-off projects and prototype building. *NTS Prometal* is located in Czech Republic and a specialist in the production of mechanical parts. With modern CNC processing centers (five axial) milling, turning and electrical discharge machining production in small series is realized. Next to the machining activities a constantly increasing number of products is assembled at Pro Metal. *NTS Modules & Machines* is the system supplier who develops, manufactures and tests complicated systems, in close collaboration with the customer.

Contact person: Dr. Gert Bossink, Operations Director/COO

The Enabler

Huntsman Advanced Materials UK Ltd.
Huntsman Advanced Materials operates as a global leader in providing solutions in the field of innovative coatings, structural composites, adhesives, tooling materials, and electrical and electronic insulation, utilising thermosetting and photo setting polymers for the automotive, electronic, electrical, aerospace and consumer-durable industry.

Contact person: Dr. Ranjana C Patel, Global Research and Patent Support.

The RTD performers

TNO (RTD)
TNO is the Netherlands Organisation for Applied Scientific Research. This independent body comprises 14 specialised institutes. Its primary tasks are to support and assist trade and industry, governments and others in technological innovation and in solving problems.

Key researchers: Frits Feenstra, Rene Houben

University of Manchester Materials Science Centre UMIST (RTD)
The Manchester Materials Science Centre is part of the University of Manchester Institute of Science and Technology (UMIST). The Materials Science Centre concentrates on the processing-structure-property relation in a range of materials (like ceramic and ceramic-metal systems).

Key researcher: Prof. Brian Derby and Dr. Tianming Wang

1.3 WORK PERFORMED

The realisation of the concept of the 3D printing process of functional plastic parts was split up into a materials and process study, a machine concept and a controlling software system. In parallel the first market study was performed to map potential markets and customers.
Based on the material processing work which was performed by partners, (powder and binder) and the use of a testing machine mounted with a specific print head, some straightforward geometries were realised.

In the second year of the project, a useful gain in speed has been developed. Fluid is shown to be compatible with stable jetting properties in the selected printing system.
Study proved that contamination of the printing heads appears to be a minor problem: there is no tendency of the selected powder to clog the head.

A variety of simple and complex geometries has been modelled on a 3D CAD system to create test files for the prototype RAMA3DP machine. Some tensile testpieces have been produced successfully on a testbed at TNO. Results to date are very encouraging.

After completion of the specs, the building of the main RAMA 3DP prototype machine has been started. Additional motion control software was identified and implemented by PTS. The original plan did not take extra software development for general machine management into account.

Due to delivery problems of the printheads, the assembly of the main prototype was delayed until after the project end date.

Therefore the testing of the additional software was postponed till after the complete machine has been assembled. This will take place in the months after completion of the CRAFT project. After this integration testing the machine still has to be completely tested on the performance handling complete 3d objects. In the current phase only rectangles and dogbones have been thoroughly tested.

The market potential is assessed (and quantified) based on recent data from Wohler's Report, indicating good potential for the CRAFT apparatus. A patent application has been filed.

The technical and economical assessment of the production of 3DP rapid manufacturing machines will not be performed. It is too premature. Moreover, this activity falls outside the scope of this research project.

1.4 END RESULTS

The **final achievements** of the project are:

- A prototype 3D-printing machine except for the printheads and drivers that in principle is able to 'produce' various components and parts;
- The ability to design and develop client-specific 3DP rapid manufacturing systems which produces reproducible consistent plastic like end products (size 20x20x20cm) that come close to 70% of the mechanical strength and 98% of the accuracy of injection moulded (IM) parts;
- The know-how of the process and the products that can be made with the new 3DP technique;
- A process for the reliable manufacturing of coloured parts having targeted colour properties with incorporation of texture/bitmaps on models directly being printed with a high resolution;
- User-friendly software, which allows the handling of coloured 3D models and/or to add colour and texture information to colourless models.

2 DISSEMINATION AND USE

The knowledge gained shall be useful in achieving longer term commercial outcomes: for realistic positive commercial outcomes, considerable further investment shall be required at the end of the CRAFT programme in terms of further development to commercialisation, consideration of surrounding art, and business models. To ensure that these plans are protected, the results of the CRAFT programme have therefore been covered by patent applications and subsequently by careful publication with the RTD performers into scientific and similar literature.

The SMEs are hopeful of making plans with the Enabling partner and the RTD performers, for future strategic commercialisation.

2.1 EXPLOITABLE KNOWLEDGE AND ITS USE

Exploitable Knowledge, products or measures (description)	**Sector(s) of application**	**Timetable for commercial use**	**Patents or other IPR**
1. An improved 3D-printing process	Various	2 years	Patent application
2. A prototype 3D-printing machine/system	Various	2 years	Patent application
3. The know-how of the process and the products that can be made with the new 3DP technique	Industrial design	2 years	Proprietary knowhow
4. A 3D-printing process for producing coloured parts	Industrial design	2 years	Proprietary knowhow
5. User-friendly software allowing the handling of coloured 3D models and/or to add colour and texture information to colourless models	Various	2 years	Proprietary knowhow

1. A 3DP process improvement (or change of the process configuration) that strongly reduces (preferentially prevents) contamination of print heads. At the start of the project, a new print head was recommended for every print job. The effect of resolving the cartridge problem will be mainly in the reliability and costing area.

2. An innovative 3DP system, which produces reproducible consistent plastic-like end-products.

3. The know-how of the applicability of the developed 3DP prototyping/manufacturing technique.

4. The know-how of the possibility to manufacture coloured parts having targeted colour properties and the know-how to efficiently translate a picture design onto a physical product.

5. User-friendly software allowing the handling of complex 3D models.

2.2 DISSEMINATION OF KNOWLEDGE

Planned/ actual Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible/involved
In preparation	Paper (2x)	Scientists	Worldwide	(paper)	UMIST/ Huntsman

2.3 PUBLISHABLE RESULTS

The main exploitable result of the project is a 3D printing system (prototype, know-how and patent application), that is able to produce reproducible plastic-like end-products (max. size 20x20x20cm) that come close to 70% of the mechanical strength and 98% of the accuracy of injection moulded parts.
Possible market sectors/applications are: industrial design (e.g. for making true colour, functional (demo) parts and models), architecture (e.g. for making scale-models), machine development (e.g. for making (and trying) functional parts), research purposes, etc.

The stage of development is as follows. The definite machine and process specifications together with the design of the 'mature' prototype has been completed and the development of a prototype machine is completed except for the printheads and corresponding drivers and the debugging/tuning of the machine control/devices.

The collaboration sought is a company that has the resources to commercialize the 3DP RAMA system as well as the entrance to the market for rapid prototyping systems. A significant investment is necessary to turn the current β-prototype into a sellable (marketable) product.

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