Innovative technology through selective laser sintering in mechatronics, biomedical engineering and industry

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Abstract: *A new technology, using new materials specially designed for complex geometries, extensively used in research-development and innovation area will be presented in this paper. Even highly complex geometries are created directly from 3D CAD data, fully automatically, in just a few hours and without any tooling. It is a net-shape process, producing parts with high accuracy and detail resolution, good surface quality and excellent mechanical properties.*

Key Words: rapid prototyping and manufacturing, 3D CAD, laser sintering

1. INTRODUCTION

A new technology, using new materials specially designed for complex geometries, extensively used in research-development and innovation area will be presented in this paper. Firstly we'll provide an overview of basic principles for a rapid prototyping technology, materials and capabilities.

This technology uses the EOSINT M270 machine, which is a laser-sintering system for the production of tooling inserts, prototype parts and end products directly in metal. Laser-sintering is the key technology for e-Manufacturing.

The implementation of this technology took place at the Biomechatronics Department of the National Institute of Research and Development for Mechatronics and Measurement Technique of Bucharest, Romania.

We were the first Romanian entity to install a DMLS equipment, and yearly/annual demand for laser-sintering services is increasing.

We expect interest in titanium parts to follow the same strong demand curve. Since 2007, INCDMTM works to identify product applications and introduce our systems within the manufacturing industry.

With the purchase of this new titanium-based system, INCDMTM stays among the leading suppliers who are willing to explore DMLS (Direct Metal Laser Sintering) and the breakthroughs it holds for innovative companies. The EOSINT M 270 system uses laser-sintering to additively manufacture parts layer-by-layer.

A range of metal materials is available, including steels, cobalt- and nickel-based super alloys and titanium alloys. EOS Titanium Ti64 is a pre-alloyed Ti6AL4V alloy with excellent mechanical properties and corrosion resistance, low specific weight, and biocompatibility.

2. INNOVATIVE TECHNOLOGY: METAL PARTS DIRECTLY FROM CAD DATA

A number of different materials are available to be utilized with EOSINT M systems, offering a broad range of e-Manufacturing applications. EOS CobaltChrome MP1 is a multi-purpose cobaltchrome-molybdenum-based superalloy powder which has been optimized especially for processing on EOSINT M 270 systems.

Other materials are also available for EOSINT M systems, including a special-purpose cobalt-chrome-molybdenum-based superalloy for dental veneering application, and further materials are continuously being developed - please refer to the relevant material data sheets for details. The ability to produce such parts very quickly enables flexible and economic manufacture of individual parts or batches, which in turn enables design or manufacturing problems to be identified at an early stage of product development and time to market to be shortened.

This new technology is used in top domains of engineering and medicine, both for civil and military purposes. The most advanced engineering entity, National Aeronautics and Space Administration (NASA), use the EOSINT M270 machine, Titanium Version.

3. THE MECHANICAL AND OPTICAL UNIT PRINCIPLES OF THE SLS MACHINE

The mechanical unit contains the following components:

1. Recoater
2. Dial gauge with bracket
3. Building platform
4. Feeler gauges (graduation 0.05 mm)
5. Measuring strip

A. Adjusting motor for adjusting the Y-axis
B. Adjusting motor for adjusting the X-axis

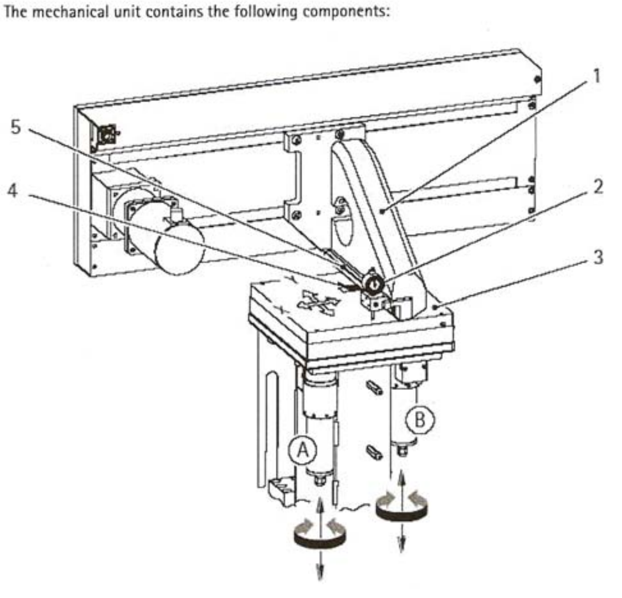

Fig. 1 – EOSINT M – mechanical unit

The optical unit contains the following components:

1. Scanner with protective covers
2. Adjusting knob BEAM EXPANDER ADJUSTEMENT
3. Beam expander optics
4. Collimator with holder and protective cover
5. Laser fibre optic

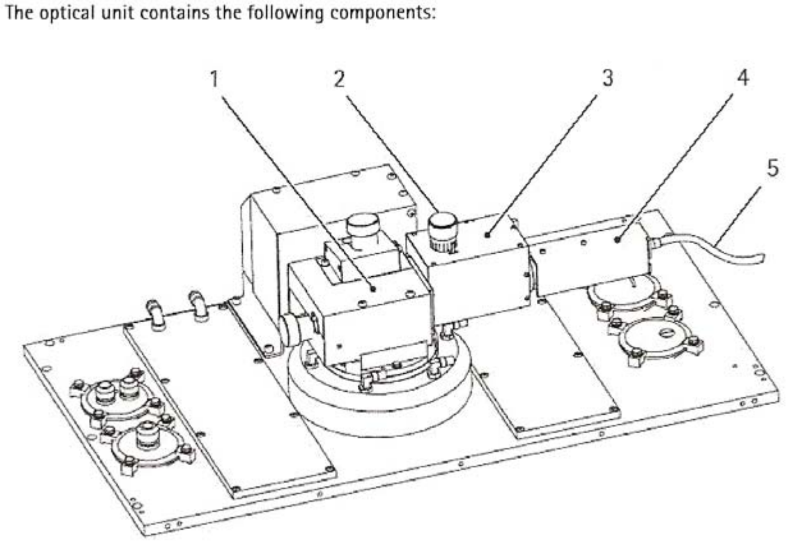

Fig. 2 – EOSINT M – optical unit

4. MECHANICAL AND BIOCOMPATIBILITY PROPERTIES

This is only a short list, because new powders with increased mechanical, physical and thermal properties are constantly developing.

Table 1 – Categories of metal powders that can be used

Material name	**Material type**
DirectMetal 20	Bronze-based mixture
DirectSteel H20	Steel-based mixture
EOS MaragingSteel MS1	18 Mar 300 / 1.2709
EOS StainlessSteel 17-4	Stainless steel 17-4 / 1.4542
EOS CobaltChrome MP1	CoCrMo superalloy
EOS Titanium Ti64*	Ti6Al4V light alloy
EOS Titanium TiCP*	Pure titanium

Titanium alloys offer a unique combination of properties [1] for many biomedical applications.

Summary of important biomedical properties:

- Excellent corrosion resistance, biocompatibility and bioadhesion;
- Titanium and its alloys are used for many biomedical and dental applications (implants, screws, crowns...).

Table 2 – Summary of important biomedical properties

Property	Stainless steel	Titanium alloys	CrCo alloys	Nb/Ta
Corrosion resistance	o	++	+	++
Biocompatibility	o	++	+	++
Bioadhesion	o	++		
Price	++	+	+	-

Titanium alloys [2] offer a unique combination of properties for many engineering applications. Summary of important engineering properties:

— Light weight material with high specific strength (strength per weight)

— Ti6Al4V with high strength also at elevated temperatures

The combination of mechanical properties and the corrosion resistance is the basis for applications in Formula 1 and aerospace. Various grades of Titanium (alloys) are commonly used in industrial applications.

Table 3 – Summary of the most important Ti materials

Material name	Composition	Typical applications
CP Ti grade 1	Ti; O <0.18%; N <0.03%	Medical and dental
CP Ti grade 2	Ti; O <0.25%, N <0.03%	Medical and dental, chemical industry
CP Ti grade 3	Ti; O <0.35%, N < 0.05%	Medical and dental
CP Ti grade 4	Ti; O < 0.40%, N < 0.05%	Medical and dental
Ti6Al4V (grade 5)	Ti; Al 6%; V 4%; O <0.20%, N < 0.05%	Aerospace, motor sport, sports goods, medical and dental
Ti6Al4V ELI	Ti; Al 6%; V 4%; O <0.15%, N < 0.05%	Medical and dental

5. USES OF CAD AND RAPID PROTOTYPING IN MEDICINE

Combined with traditional CT scanning techniques, the rapid technologies (prototyping and tooling) can be used as instruments for better (three-dimensional) visualization, simulation of procedures and treatment of patients.

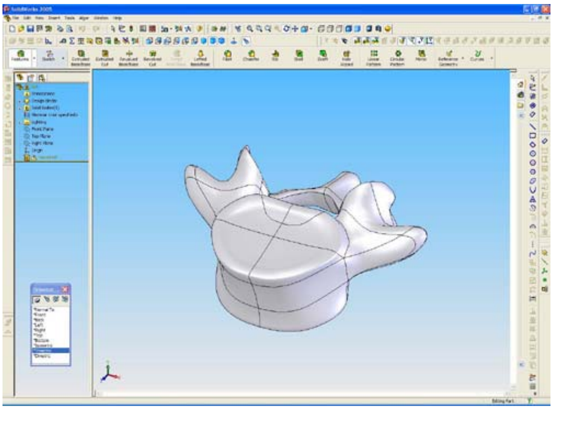

Fig. 3 – Parametric model in 3D CAD - SolidWorks

The CAD models, virtual model of a human body or a part of it can be used to study the problematic area before the actual operation starts.

This is especially important in cases where functionality of the body part has to be re-established (orthopaedic surgery).

Besides the continuous flow and other FEA methods that are used to calculate required mechanical and physical properties of the implant, the virtual models can also be used to study the surgical procedures, like directions of implantation, required preoperational treatments and preparations, etc.

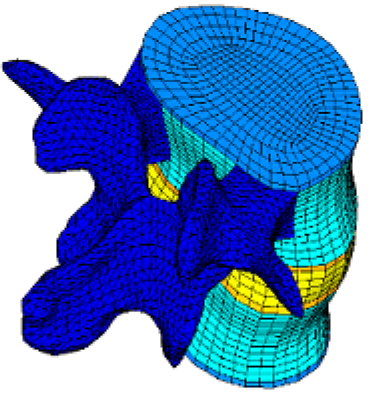

Fig. 4 – CAD model on human vertebrae used for FEM analysis

The easiest way to reconstruct the structure of a patient's bones is to use those CT images that already exist from previous treatments of the patient.

A set of CT images can be converted into a three-dimensional, digital model using one of the available conversion software, such as: Mimics (Materialize), RapidForm (Inus Technology), 3D doctor (Able Software), Amira (Marcury Computer), or others.

The input to this software is usually in the form of DICOM files and the output is predominantly STL (Standard Tessellation Language), which can be directly used in most RP technologies to produce real models.

6. USES OF CAD AND RAPID PROTOTYPING IN MECHATRONICS AND AEROSPACE

Main advantages of the rapid prototyping technology:
Finally, to name just a few of the key advantages of this technology:

- no tooling or part-specific tools required
- no tool path generation or design of EDM electrodes necessary
- metal parts created directly in one step
- simple, fully automatic operation
- complex geometries such as freeforms, deep slots and conformal cooling channels can be produced without additional effort
- unsintered powder can be reused, giving minimal waste.

Fig. 5 – Straightener for a helicopter gas-turbine engine. PEP / Turbomeca / Best in Class

The implementation of this revolutionary technology was possible through the research contract between INCDMTM - NATIONAL INSTITUTE OF RESEARCH AND DEVELOPMENT FOR MECATRONICS AND MEASUREMENT TECHNIQUE and NASR - National Authority for Scientific Research, through the NPRDI-II The National Plan for Research, Development and Innovation for the period 2007-2013, under the high authority of the Romanian Government.

Fig. 6 – Examples of parts built in EOS superalloy CoCr MP1 on INCDMTM for industry

7. CONCLUSIONS

The functional and design capabilities of a metallic implant material are important with respect to the ability of the metal to be formed, machined, and polished. An implant metal must be capable of being utilized with state-of-the-art metallurgical techniques. In addition, the implant device must remain functional during its expected performance life; it must not be degraded with time in the body through fatigue, fretting, corrosion, or impact loading. Titanium and its alloys meet all of these requirements [3].

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