1. CAD-CAM Procedures

In the literature, CAD (Computer Aided Design) / CAM (Computer Aided Manufacturing) is an acronym that means using computer design and manufacturing.

This innovative technology that uses digital computers to conduct various design and manufacturing functions tends to fully integrate these activities which, traditionally, have been regarded as two distinct and separate functions. Overall, CAD/CAM develop future enterprise advanced technology, full assisted by computer. The computing system consists of optimized for design hardware and software. Within CAD activity, based on executing drawings, were made 3D models of shields. Based on the overall design, taking into account the existing links between the components, it has been established asynchronous motor assembly. CAM includes indirect applications in which the computer has the support role for manufacturing operations. CNC (Computer Numerical Control) machine tools are designed to change the shape and size of objects in terms of productivity, dimensional accuracy and quality of machined surface. I followed the issues such as energy consumption, process complexity and costs. The emergence and integration of CAD/CAM systems within the production process, enabled engineers to create 3D CAD project, to generate trajectories in the generic language of CAM system and then to perform conversions in multiple languages. The CAD and CAM activities are closely interdependent, because CAD is underlying CAM activities. CAD tools are defined based on three concepts: geometric modeling, computer
graphics and design tools. CAM tools consist of the intersection of three fields used in manufacturing:
CAD tools, network concepts and machine tools.
Computer- Aided Manufacturing – CAM is defined as the use of a computer system in planning,
management and control of the operations of a plant, by any direct or indirect interface between the
computer and production resources.
For implant complex digital prototype realization were taken the following steps:
1. Modeling assembly components;
2. Setting the base assembly (fixed element - "anchored" in assembly)
3. "Assemble" of all components of virtual 3D mode
4. Analysis of functionally prototype obtained

After obtaining the digital prototype, we can start mechanics simulation. Analysis of efforts and
deformations can be achieved by using FEA / CFD (Finite Element Analysis / Computer Fluid
Dynamics). Implant model generation was performed starting from the 3D surface of the femur
obtained from the three-dimensional reconstruction and visualization model of pelvis bones. There
were necessary radiographic image processing (extraction important parameters in arthroplasty) and
processing of CTs and MRIs Magnetic Resonance Imaging (stacks of 2D), in order to reconstruct 3D
surface which is representing the hip bones. Using 3D software application, it was obtained the femur
interior, upon which was built the model prosthesis. Based on the obtained models, implants
prototypes were made, using rapid prototyping device and were performed mechanical tests on
prototypes.

Figure 1 below shows the normal anatomy of the pelvic bone and femur.

![Normal Anatomy of Femurs and Pelvis]

**Figure 1.** The normal anatomy of the pelvic bone and femur.

Inserting the prosthesis in hip arthroplasty involves placing the body and neck of prosthesis in the
place of bone marrow at the level of femoral body and neck and femoral head replacement with
prosthesis head.

Three-dimensional reconstruction and visualization have included the following steps:
- The possibility of charging a stack of CT images in DICOM or BMP format
- Viewing stack of 2D images (one image at a time)
- Reconstruction of three-dimensional surface representing femur and viewing it (with the
  possibility of displacement and rotation of the pattern in the scene);
- Editing stack of 2D images and viewing its effects over three-dimensional rebuilt surface;
- The possibility of radiodensity change of the tissue to be rebuilt;
- Exporting stack of 2D images (DICOM format) in PNG format;
• Exporting the reconstructed surface in a format recognized by 3D software (for the next module of implant generation)

Implant generation comprises the following components:

• Loading polygon surface representing the femur;
• Getting femur interior;
• Prosthesis construction, starting from the femoral bone interior.

The figure 2, below shows the construction of bones from a CT data set of some body parts.

![Figure 2. Bones reconfiguration from a CT data set.](image1)

2. Implant assembly modeling

Many researchers have found that a geometric adaptation shape of cementless implant rod shape to the inner contour of the proximal femur is essential to optimize the load taking over and for a better mechanical stability. Based on femoral bone obtained from the 3D reconstruction and visualization software (based on tomographic images) we have passed in modeling of customized implant. When is designing the femoral component we can use specialized programs for modeling suite SolidWorks, CATIA, SolidEdge, Pro Engineer, etc (figure 3,4,5).

Within the created assemblies, are defined various components through their degrees of freedom including geometric information and relative positioning of parameters (figure 6,7,8).

![Figure 3. Femoral bone view in SolidWorks](image2)

![Figure 4. CATIA view implant assembly](image3)

![Figure 5. SolidEdge view implant assembly](image4)
Important roles in the optimization of physical – mechanical parameters have design, analysis and test for different loads of newly created implants applications. Starting with the design phase is envisaged performing finite element analysis (FEA Finite Elements Analysis) in the orthopedic area of interest in order to obtain its loads status. Mechanical failures that occur in vivo are due to wear or fatigue request.

Implant assembly components may be made of:
- Metals (pure or alloy);
- Titan Ti6Al4V and stainless steel or 316 stainless steel;
- Chromium is the major element in stainless steel having composition with minimum concentration of 11%.
- Alloys type Co-Cr -Mo;
- Ceramic materials, at ceramic materials manufacturing are used: alumina (Al2O3) or zirconia (ZrO2).

In Figure 9, below was modeled the fastening assembly of femur prosthesis.

- using finite element method, we have determined the request forces appearing in support position and while walking, joint femoral loading, outside different requests influence over all assembly elements.
- determining the safety factor for every constituent assembly to determine possible overloads which could lead to implant failure;
- realization of comparative study for Medin customized femoral rod requests to establish achievement effort opportunity of dedicated implant;
Movement across the bone-prosthesis are shown in Figure 10.

![Figure 10](image1.png)

**Figure 10.** Movement across the bone-prosthesis

-using finite element method, we can obtain animations which are illustrating the evolution of von Mises efforts, during joint request for a better choice of taking the load (Figure 11).

![Figure 11](image2.png)

**Figure 11** Comparisons between von Mises stress states of a hip prosthesis - main section  

- a) operating under 20 degree angle;  
- b) operating under 0 degrees angle;

3. Rapid prototyping techniques

Rapid prototyping technologies are defined as a set of technologies that enable the manufacturing of physical models directly from three-dimensional models or virtual prototyping, through programs such as CAD, CAM, which are transferred to a computer responsible for its materialization.

Rapid Prototyping techniques have as final goal realization in of prototypes in a short time.

The advantages of these processes are the following:

- Low energy consumption;
- Little loss of material;
- High speed manufacturing;
- It can be parts or products with complex geometries.

Rapid prototyping is the technology used in obtaining prototypes based on a 3D CAD model, which is digitally processed in order to recognize the data format by specialized machines through the following processes:

- SLA (Stereo lithography) - polymers solidifying at the impact of a light ray;
- LOM (Laminated Object Manufacturing) - obtained by layering part;
FDM (Fused Deposition Modeling) - process for deposition of material;
SLS (Selective laser sintering) / SLM (Selective laser melting) of metal powders;
DMLS (Direct metal laser sintering) we can get some small unique tools;
Printing three-dimensional (3D Printing).

"Rapid Prototyping Technologies" have grown in importance in the process of arthroplasty due to the fact that within these technologies, the manufacturing times are relatively low from the stage of conception to final completion of the prostheses, the costs of assimilation and manufacture of individualized prostheses have reduced very much.

Rapid prototyping technologies are applied in making parts by casting metal alloys in three directions:
- When designing parts, patterns and molds;
- Making models;
- Making molds.

3.1. The realization of a hip prosthesis

Parts of implant bone are particularly demanding because it is subject to complex applications. Hip prosthesis is made of high alloy steel with Cr-Ni-Mo-Mn. The hip prosthesis should approach the most of the natural shape of the bone forming the joint. In order to achieve three-dimensional model we have used SolidWorks software. The three-dimensional design of bone obtained after requests, may be subject to real bone; The most conclusive mechanical tests is fatigue test. The same program can be used for the processing by milling on a controlled numerically machine with unique prostheses, custom made for each patient.

Forging in mold is recommended to obtain prostheses in series; this process ensures maximum durability of the part in terms of fatigue. The shape of the mold cavity can be processed by milling using the same coordinates of contours obtained by sectioning and applying the necessary correction range.

Following the heat treatment, the mold cavity will be finished by Electrical Discharge Machining (EDM), with an electrode obtained by electroplating after the model made by SLS.

The easiest way to rebuild bone structure of a patient is to use Computed Tomography (CT) images which are already exist from previous treatments of the patient. A set of CT images can be converted to a digital model using one of several available SolidWorks software packages available for conversion.

Input Data to this software is usually in the form of DICOM files and output data is predominantly STL (Standard Tessellation Language), which can be directly used in most of Rapid Prototyping technologies to produce real models. The reconstruction of the patient bone structure can be individualized with minimal effort and in complete safety thanks to handling CT files type DICOM and transforming them into STL files and / or CAD that can be 3D processed. Rapid prototyping technology is the technology used to obtaining prototyping based on a 3D CAD model, which is digitally processed in order to recognize the data format by specialized machines.

The STL files are required for Rapid Prototyping machines. Digital prototype is used to define the assembly of 3D entities.

The advantages of digital prototype are:
- Removing the need for physical prototype;
- Reducing the execution costs;
- Increasing the product quality;
- Reducing the time required to launch the product on the market;
- Information being accessible to design teams takes place much faster.

4. CAM Technologies for individualized prostheses

In the stage of physical achievement of prostheses (CAM) there are used the following technologies:
1. CAM technologies processing through the removal of material, starting from a semi-finished
product (a large amount of raw material) and the excess material is removed using conventional methods (turning, milling, grinding, etc.), or by using unconventional methods (EDM - Electrical Discharge Machining, laser machining, ultrasound, etc.).

2. CAM processing technologies by redistribution of material. According to these technologies, a fair amount of raw material is redistributing in the required prosthesis form, using solid forming (forging, stamping, drawing, extrusion, etc.) or redistribution in liquid or semi (molding, injection molding, etc.).

3. Rapid Manufacturing Technologies or Rapid Prototyping (RP), performing the part by adding material as needed and where needed.

4. Modern technologies, which are based on the implementation of modular elements with simple geometries, easily assembled into a solid body with complex geometry.

5. Stereo Lithography (SLA) procedures

Modern lithographic procedures were used initially in electronic components technology, which exploits the property of photosensitive substances, which were initially liquid monomers, polymerizing under a radiation of a certain wavelength (typically ultraviolet radiation). If the monomer layer is selectively covered by means of a cliche or the used radiation is concentrated as a spot, the light-sensitive substance will polymerize selectively; such a configuration results "in plan". The configuration thickness depends on the depth of penetration of used radiation. Unexposed monomer is removed by washing. Stereo lithography is defined as polymers solidifying at the impact of a light ray. Stereo lithography (SLA) was patented in 1982 by Chuck HULL and uses the principle of superposition of successive shaped in plan layers and polymerized under the action of ultraviolet radiation emitted by a laser. It was the first method of prototyping technique. The polymerization is a reaction where smaller molecules (monomers) are combining chemically (by main valences) to form a macromolecule, branched approximately in the same composition. SLA cannot be imposed except by using the computer. The desired model is designed in three dimensions using 3D software modeling. The work principle of stereo lithography is resulting in the figure 12. The stereo lithography installation is shown in figure 13.

A photosensitive resin in the form of liquid monomer is put in machine tank car. At the liquid surface is focused a beam originating from a laser generator using ultraviolet radiation. The beam can be scanned with a computer controlled mirrors system on the liquid surface contour plan in desired coordinates X - Y; The plan represents a cross-sectional through the work part. The result will be polymerization of monomers after the programmed contour. To obtain three-dimensional form, the model support will receive a Z-axis movement, whose value is a direct function of the thickness of the laser beam polymerized layer to obtain a compact and rigid form. Thus, the model dips in tank as it is formed.

**Figure 12** The work principle of stereo lithography

**Figure 13** The stereo lithography installation
SLA is the fastest current process for obtaining the photopolimerizable resin complicated models, with the possibility of change or adapt quickly the shape, which is impossible without a CAD system.

5.1. The use of photosensitive substances
The photo polymerizable resin is used consisting mainly of a photo initiator and a mixture of various monomers. Photo initiators selectively absorb light radiation, in the range of ultraviolet and visible range, i.e. between 250-450 nm; They convert light energy into chemical energy that primes the polymerization reaction. The monomer mixture is containing various molecules belonging to the family of acrylic and methacrylic esters. The design model is oriented so as to obtain a secure basis on which to "build" model, with maximum stability and avoiding detachment of parts of the model that could float freely in the liquid.

6. Selective Laser Sintering (SLS)
A similar process with the same advantages but using powdered metallic materials (SLS - Selective Laser Sintering) allows not only getting wax models, polycarbonate or nylon but even finished parts of the metal or polymer. Selective laser sintering principle (SLS) of using as raw material polymer powders, is shown in the figure 14. A selective laser sintering system is shown in the figure 15.

6.1. The metallic powders used in Selective Laser Sintering (SLS)
The metallic powders that can be used in Selective Laser Sintering include a variety of materials including implantable stainless steel, cobalt or nickel superalloys, titanium alloys and pure titanium. All these materials have excellent mechanical and physical qualities, better than cast or forged materials, so are recommended for biomedical implants. The biocompatibility properties, corrosion resistance and low specific gravity, combined with the infinite possibilities of 3D geometric modeling recommend this technological process as a tool of the future micro-mechanical engineering, mechatronics and robotics. The parts obtained by this process can be further processed as desired, if deemed necessary, by any known mechanical process: milling, turning, drilling, countersinking, reaming, tapping, slotting, grinding, broaching, lapping, honing and over finishing. Also, the parts can be further processed by sandblasting, polishing and welding, Electrical Discharge Machining and coating.

The process of rapid prototyping by laser direct sintering unfolds in five stages:

- Creating virtual 3D-CAD model and exporting of CAD file in STL format;
- Part orientation and positioning, supports generation and STL file checking;
- STL 3D file conversion into 2D files and preparation for prototyping machine;
- Making physical model by melting successive layers;
- Post processing of physical model.

Sintering achievement of two models of customized hip implants is shown in figure 16.
Whatever rapid prototyping method of hip prosthetic works, the test pieces obtained from new material will be tested before (to determine its characteristics) and after manufacturing, performing mechanical (tensile, compression, shear, etc.) and physical tests (corrosion) on real models according ISO 7206-4 (2002), ISO 7206-8 (2002). Different types of prosthetic hip implant are presented in figure 17.

7. Conclusions
The doctor and engineer always have the real picture of the patient's anatomy and its data can be manipulated without it bothering the patient at all. The final physical version of hip prosthesis can be tested on static and dynamic machines mechanical test to confirm the safety of designed solution. Through advanced methods of CAD /CAM computer we can create the necessary elements for customized prosthetics which is tailored to each individual. The use of CAD CAM procedures increases the efficiency of therapeutic methods, leading to more efficient health services, by decreasing the number of required intervention, and increasing creativity in healthcare, because prosthetic implants are adapting to the characteristics of each individual. In the article it was presented briefly the possibility of obtaining customized prosthesis by sintering and stereolithography, using computer generated 3D models.

The flow chart below (figure 18) was made by the authors as a synthesis of all CAD / CAM procedures needed to achieve physical hip implant.
Figure 18. The synthesis of all procedures CAD / CAM needed to achieve physical hip implant
Different types of prosthetic hip implant
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