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Rapid Prototyping of Human Implants with Case Study

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ABSTRACT:In the medical field increasing the product performance and reducing the cycle time are important not for maintaining market place competition but also to comfort the patients and make them heal sooner. The project aims at preparing human implants accurately and more quickly. When it is for human there's no such thing as standard size. Hence RAPID PROTOTYPING technique is used in preparation of human implants. In this paper we have discussed about the manufacturing of the bone, the image of the bone is obtained from a CT-scan. Using PLATO software the image is digitized and 3D model is obtained and it is reconstructed in PRO-E using co-ordinate points. The STL format of the PRO-E file is fed into STRATASYS FDM1650 machine to get the ABS pattern of the required bone. From the pattern the stainless steel implant is made by CO_2 moulding process.

KEYWORDS: FDM,Quick Slice, ABS, STL, BASS, Computer Aided Designing

I. INTRODUCTION

Rapid prototyping is the technology that produces model and prototype parts, from a 3D CAD data, CT and MRI scans and from 3D object digitizing. The prototype is produced in a few days to a few weeks taken by conventional methods. RP is not only for design visualization and evaluation. It's also helps in producing the parts in short time. After design evaluation, the parts can be used as patterns for making moulds. Investment casting wax can be used as RP materials and hence it can be directly used in investment casting process. Any RP process creates the physical object directly from a geometric model of the object. RP process has a common important feature adding materials rather than removing materials of conventional process produces the prototype part. Just as 3D object is degenerated to 2D by cutting it virtually in thin slices in computer. This simplifies the 3D pat producing process to 3D-layer manufacture. By gluing the produced layers, the desired part is then mathematically sectioned into a series of parallel cross section pieces. For each piece, the curing or bindings are generated. These curing or binding are directly used to instruct the machine for producing the part by solidifying or binding a line of material. After this the layer is built on the previous one in the same way. This model is built layer by layer from bottom to top. Of the several RPT techniques available, Fused Deposition Modelling (FDM) is chosen as our process builder.

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II. PRINCIPLE AND DESCRIPTION OF THE PROCESS (FDM)

FDM uses spools of thermoplastic filament as the basic material for part fabrication. The material is heated just beyond the melting point in delivery head. The molten thermoplastic is then extruded trough a nozzle in the form of a thin ribbon and deposited in computer-controlled locations appropriate for the object geometry. The FDM system builds thin layers, as in the case with all current RP & M methods. The FDM technique is based upon the controlled extrusion and rapid subsequent cooling of a thin ribbon created from a number of thermo plastic materials. The spooled filament have diameter of 0.007" feed rate is used to monitor & control the amount of material extruded at any given time. The surface finish depends on the temperature of liquefier & substrate layer thickness ranging from 0.004" to 0.020" and can be varied by changing the speed of delivery head with maximum 15inch per sec speed, ribbon width ranges from 0.001" to 0.24". The delivery head precision is 0.001". The process is explained with Figure 1.

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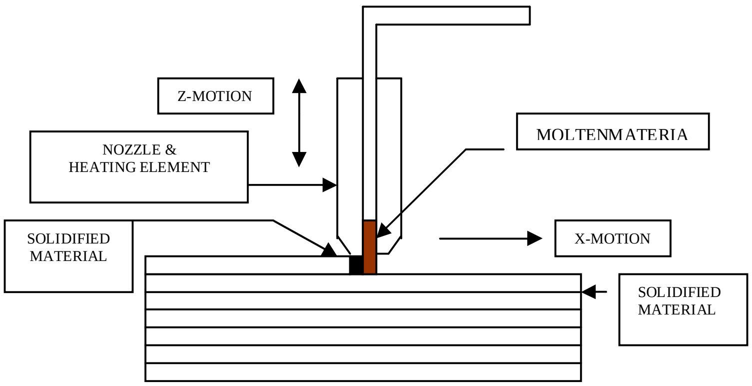

Fig. 1 Fused Deposition Modelling Process

III.FDM SYSTEM STRUCTURE

With the FDM system a project can be taken from the design stage to the conceptual model to final wax pattern or plastic prototype. The main parts of the FDM system are,

- Quick slice software
- Engineering work station
- FDM hard ware

Quick slice software is powerful slicing program that creates SML code to drive hardware. The software accepts 3D design files from all standard software packages that can produce files in the STL format. Quick slice cuts the STL file model into horizontal slices and is extruded as a single layer of material by the FDM hardware to create a physical model. Quick slice can work in HP, silicon graphics, and sun UNIX systems more over it also works in windows-NT, UNIX operating systems. In the FDM hardware, the head moves in two horizontal axes across a foundation and deposits a layer of material for each slice. The FDM head heats the material so it comes out in a semi liquid state. The successive layers fuse together and solidify to build up an accurate.3D model of design. Overall tolerance is 0.005" in the X, Y, and Z-axes. Actual results depend on the model.

pendent of each other and hence is quite possible to have a flat, fast fading channel or a flat, slow fading channel; and so on.

IV.FDM MATERIALS

The FDM 1650 is capable of using a variety of inert, non-toxic materials. Some of the FDM modeling materials are

- Investment casting wax
- P301 Plastic
- P400 Plastic-ABS Plastic

Here we have used P400 plastic-ABS plastic. P301 is a poly-amide based tough plastic, which produces sturdy prototypes useful for concept models and for examination of an object for fit, form and some function.P400 ABS plastic is an Acrylonitrile-butadiene-styrene based tough plastic, which produces sturdy prototypes. P400 ABS allows much more similar to the desired final product than was possible with previous modeling materials.

V. BREAK AWAY SUPPORT SYSTEM (BASS)

The FDM 1650 uses the unique BASS. BASS uses a second nozzle to extrude the support material. The supports are designated to prop up the overhanging portions of the part during modeling. A significant advantage in using the BASS system becomes obvious when then part is taken out of the FDM 1650 machine. Not only in the finished quality than a part made without BASS system, but also the supports come off easily and clearly.

VI.RAPID TOOLING

Rapid tooling is a process that allows a tool for sand casting, investment casting injection moulding and die casting operations to be manufactured quickly and efficiently so the resultant part will be replaced part will be representative of

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the production materials. This definition means different things to different people. Production quantity for one company may be 1000, for another it may be 500,000. Materials to be moulded are formed differs not only company-to-company, but part-to-part as well. There are basically two types of rapid tooling process based on the production quantities, namely hard tooling & soft tooling.

VII. CASE STUDY

This case study is aiming at preparing human implants accurately & more quickly. When it comes to human anatomy there is no such thing as standard size. Hence Rapid Prototyping Technique is used for the preparation of human implants.The image of the required bone or joint is obtained from CT scan. Using PLATO software (used for radiation planning in cancer treatment) the image is digitized and a 3D model is obtained. This 3D model is reconstructed in PRO-ENGINEER using co-ordinate points. The STL format of the PRO-E file is fed into the STRATASYS FDM 1650 machine to get the ABS pattern of the required bone. From the pattern the stainless steel implant is made by co_2 moulding process. In medical field increasing the products performance and reducing the cycle time are important not just for maintaining market place competition but also to comfort the patients and make them heal sooner. Here the computer aided RP method out stands the traditional, manual method of adding and saving from an “off-the-shelf” wax patterns.

VIII. STEPS IN CASTING OF HIP JOINT

A. Pattern Making

The pattern made out of ABS (acrylo nitrile butadiene styrene) in the FDM 1650 rapid prototyping machine. The pattern made is a split pattern. The split patterns are fitted with match pin by drilling two holes of 2mm diameter in each part of the pattern can be matched without any shift.

B. Mould Making

One part of the pattern (i.e., one without the match pins) is placed upside down on the wooden plate, around which the drag is placed and the sand mixture is filled and rammed tightly. Before sand is filled the suitable gate is placed on the match plate. After ramming 4 or 5 holes are made on the top of the sand and the carbon-dioxide gas is passed for 10 seconds for solidification. After solidification the drag is turned upright and the other part of the pattern is matched and placed over the previous pattern. Over the drag the cope is placed. The runner and raiser are fixed and sand is filled in and again the same process is repeated.Now the boxes the cope and drag are separated and the patterns, gate, runner and riser are removed. Now the boxes are placed one over the other and this is now ready for pouring.

C. Carbon Dioxide Moulding

The process is basically a hardening process for moulds & cores. The principle of working of the carbon-dioxide process is based on the fact that if carbon-dioxide gas is passed through a sand mix containing sodium silicate (water glass), the sand becomes extremely strong immediately as the sodium silicate becomes a stiff gel. The gel is responsible for necessary strength to the mould. The chemical reaction can be represented in simplified form as

$$Na_2O\ (x)\ SiO_2 + (x)\ H_2O + Co_2 \rightarrow Na_2CO_3 + SiO_2\ (x)\ H_2O,$$ where x is 3, 4, or 5 usually x=2.

The hardness of the moulds and cores can further increased by exposing them to free atmosphere for a short time after gassing. Sometimes a little heating about 200^0C also helps to increase the hardness.

D. Casting

The mould box is poured with stainless steel (CFS). The piece is allowed for solidification and then removed from the box.

E. Cleaning And Machining

The gate, runner, and raiser are cut off from the piece. The sand sticking to the piece is removed by shot blasting process. Now the piece is ready for checking.

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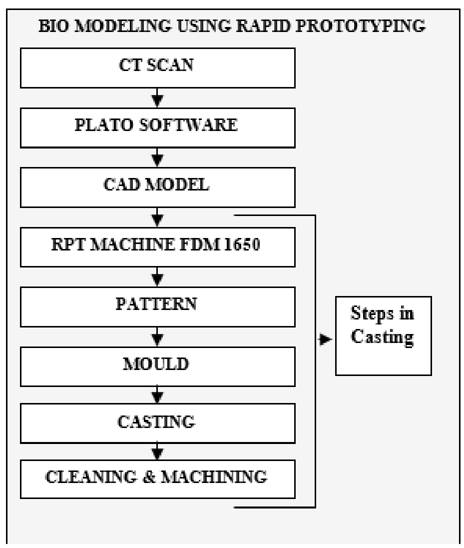
IX.METHODOLOGY

A. *Cad Model*

One of the most important and the most tedious process in this project is making the cad model of the required part of the human (here hip joint). When it comes to human there is no matter of what me say standard size or shape. Here arises the difficulty of making the 3D models of the required bone.We can have the X-ray, CT scan and MRI scan file cannot be directly transferred to the workstation using windows operating system, as their OS is different from windows. This conversion needs a program time and labor and it needs a program to convert it this is a very costly and a time consuming process, which the biomet, medicorp companies of USA are practicing.We had got an idea of taking the essence from the CT scan and reproducing it in CAD software, pro-E.

B. *Plato software for Radiation Planning*

The CT scan of the hip joint of a patient is taken and the scan has about 15 cross sections. The cross sections are scanned through a film scanner and those cross sections are used to reconstruct the hip joint using the PLATO software.



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E. *Co – ordinate point*

After reconstruction of the model the software can provide us with the co-ordinate point as much as we require. We took thirty-six points (X, Y, Z) and these points can be used in constructing the same model in CAD software.

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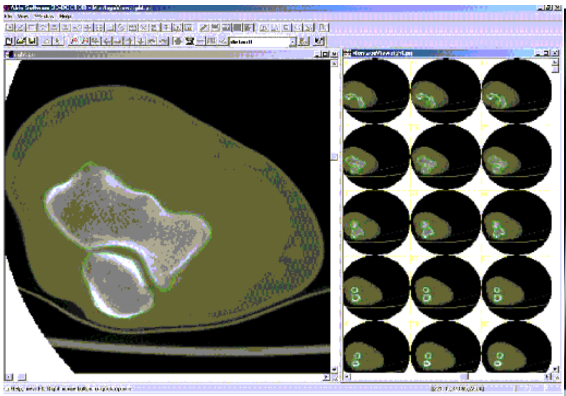

Fig. 2 CT Scan

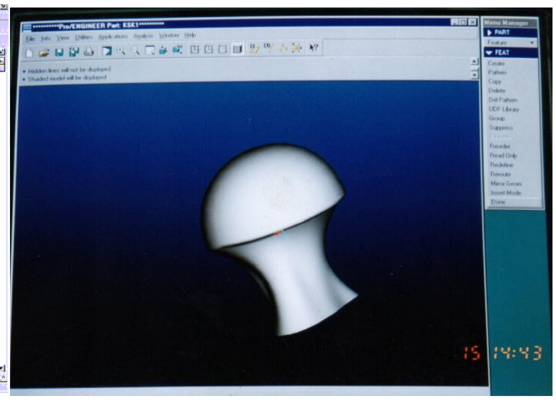

Fig. 3 Pro E Modelling

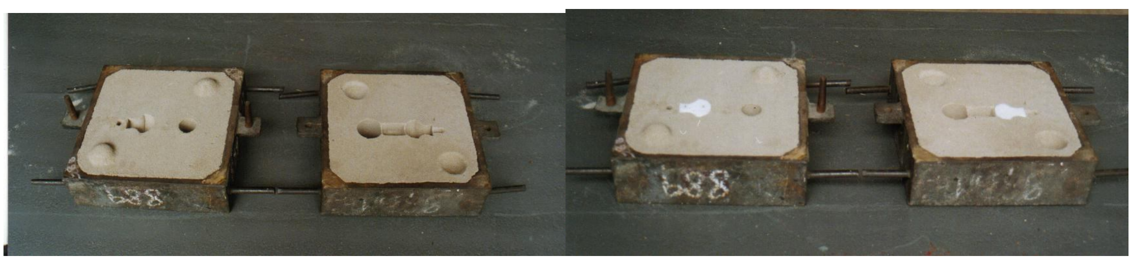

Fig. 3 Pattern Making

X. ADVANTAGES OF THE BIO MODELING

- Designing of the bone model is easier when pro-e is used.
- Manufacturing of bones with non-toxic materials is easily done in RPT.
- This helps to produce human implants.
- Semi-skilled labors can be used.
- Easier than the traditional method.

XI.CURRENT LIMITATIONS IN RPT

- High machine cost.
- High material cost.
- Production speed.
- Surface roughness.
- Accuracy.

XII. RESULTS AND DISCUSSION

An approach to do the implants for human was successful. The stainless steel implant was made in carbon-dioxide casting process with pattern made out of ABS plastic in a rapid prototyping machine.The three dimensional model of the hip joint is made in pro-engineer through the method of creating datum points and three dimensional reconstruction. The co-ordinates X, Y, Z for the hip joint is taken from the reconstructed three dimensional image of the same in a software called PLATO, the one used radiation planning therapy in cancer treatment. The original implants are made by investment casting process are further treated for improving the surface properties. The implants are to be placed inside the human body should have high surface finish and the metal should not react with the fluids such as blood,

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lymph fluids etc. chemically. If there is any such reaction the icons released many developed dangerous diseases.But the implant made by us was just an approach. Due to the highly complex manufacturing standard of the implants, we are unable to perfect it. The implant produced by us does not have the required surface finish. What we had achieved is that the modeling of any human bone can be easily done with the help of pro-engineer and pattern for the same can be obtained in RP machine in very less time with high accuracy.

XIII. CONCLUSION

The ultimate goal of integrating the biomodeling with rapid prototyping was a grand success. This method was developed in U.S.A and widely used in many countries.The achievement of making the 3D model of more complex human implants and obtaining of the same in a prototyping machine outsets the traditional method of adding or shaving off from an “off the shelf” wax pattern in the terms of time, surface finish and accuracy.
Since the human anatomy is very different for each of us. So it is very difficult to obtain accuracy in traditional carving process. But this method can provide very accurate model of the required joint of the patient. This will lead to the increased comfort of the patient can heal quickly. Therefore the project has a wide scope in future.

The project can also be continued to get more perfect implants by refining the process of casting with various new technologies. Also rapid prototyping the technique can apply to produce the “face burn masks” which are used in severe facial burn treatments. These facial masks retain the shape of the face till the tissues grow. The main problem in the facemask is that no single mask can be used to all the persons as the shape and size differs. This can be perfectly done in the same way what is done for implants.

Surgeons, while operating very crucial tumors for example tumor in brain need a planning to do the precisely. For this planning a rapid prototype model can be very useful because the rapid prototyping machine can produce the model of the brain to be operated with tumor differentiated in a different color. The same model can be used for designing of various tools that are used in operations.

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