PROCESS IMPROVEMENT THROUGH REVERSE ENGINEERING

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Mechanical Engineering

By

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10503018

Department of Mechanical Engineering
National Institute of Technology
Rourkela-769008
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Under the Guidance of

Prof. S.S. MAHAPATRA

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National Institute of Technology
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National Institute of Technology
ROURKELA

CERTIFICATE

This is to certify that the thesis entitled **"Process Improvement through Reverse Engineering"** submitted by RIMIL SING SOREN, Roll No. 10503018 in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Mechanical Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Prof. S.S. MAHAPATRA

Department of Mechanical Engineering

National Institute of Technology

Rourkela-769008

DATE:

PLACE:

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I would also like to thank **Mr. PAL, Mr. UDAY** and **Mr. HEMBROM** for helping me out during different phases of experimentation.

Last but not the least; I would also like to thank all my friends for their help and co-operation.

RIMIL SING SOREN

Roll no: 10503018

Mechanical engineering

N.I.T. Rourkela

ABSTRACT

It has become increasingly important to become able to generate 3d shapes in commercial application using rapid prototyping technologies. In many cases shapes are taken from real world objects that do not have existing computer model. Creating an accurate model for these objects by hand is extremely time consuming and difficult. Therefore 3D scanner is used to capture the objects shape and create a high resolution model of the object. To able to reverse engineer we essentially have to reverse the design decisions. Following the transformation approach we can use the transformation of forward engineering methodology and apply them backwards. ZPrinter 310 plus has been used for producing 3D model directly from CAD model. ZP R 130 powder and ZB binder provided by Zcorporation were used to prepare the physical object. The variation of strength and hardness with respect to built direction is shown. Loctite 406, when added along with above powder and binder shows improvement in properties of the prototype.

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CHAPTER 1

1. INTRODUCTION

While conventional engineering creates a CAD model based on functional specification of a new product, reverse engineering uses the manufactured part to create CAD model. The existence of a CAD model provides enormous gain in improving the quality and efficiency of the analysis, because we can exploit the advantages of the extensive use of CAD/CAM technologies. Reverse engineering basically starts with measuring a physical model to reconstruct a CAD model for application like redesign, reproduction and quality control.

Reverse engineering is, the process of discovering the technology principles of a mechanical application through analysis of its structure, function and operation. That involves sometimes taking something apart and analyzing its working in detail, usually with the intention to construct a new device or program that does the same thing without applying anything from original.

Some common uses for reverse engineering:

1. As a learning tool.
2. As a way to make new compatable products that are cheaper than what's currently on the market.
3. For making software interoperate more effectively or to bridge different operating systems or databases.
4. To uncover the uncoordinated features of commercial products.

This kind of inquiry engages individuals in a constructive learning process about the operation of systems and products. The process of taking something apart and revealing the way in which it works is an effective way to build a technology or make improvements to it.

According to a methodology for reverse engineering, it consists of the following steps:

1. Observe and assess the mechanisms that make the device work.
2. Dissect and study the inner workings of a mechanical device.
3. Compare the actual device to your observation and suggest improvement.

Through reverse engineering, a researcher can gather the technical data necessary for the documentation of the operation of a technology or component of a system. When reverse engineering software, researchers are able to examine the strength of system and identify their weaknesses in terms of performance, security and interoperability. The reverse engineering process allows researchers to understand both how a program works and also what aspects of the program contribute to its not working. Independent manufacturers can participate in a competitive market that rewards the improvements made on dominant products. For example, security audits, which allows user of software to better protect their systems and networks by revealing security flaws, require reverse engineering. The creation of better design and the interoperability of existing products often begin with reverse engineering.

1.1 APPLICATION

Reverse engineering (RE) used to be a nefarious term. It formerly meant making a copy of product or the outright stealing of ideas from competitors. In current usage, however RE has taken on a more positive character and now simply refers to the process of creating a descriptive data set from a physical object. RE methods and technologies can still be used for negative purpose like those mentioned, but today there are numerous important legitimate applications for RE, as well.

This has come about over the last fifteen or more years due to the intense parallel development of many different types of three dimensional digitizing devices and the powerful reverse engineering software that allow the data they produce to be manipulated into a useful form.

Application: There are two parts to any reverse engineering application; scanning and data manipulation. Scanning also called digitizing, is the process of gathering the requisite data from an object. Many different technologies are used to collect 3D data. They range from mechanical and very slow, to radiation based and highly automated. Each technology has its advantages and disadvantages, and their application and specifications overlap. What eventually comes out of each data collection devices; however is a description of the physical object in 3D space called point cloud. Point cloud data typically define numerous points on the surface of the object in terms of x,y and z coordinates. At each x,y,z coordinate in the data where there is a point, there is a surface coordinate of the original object. However, some scanners, such as those based on Xrays, can see inside an object. In that case, the point cloud also defines interior locations of the object, and may also describe its density.

Typical RE Applications

1. Creating data to refurbish or manufacture a part for which there is no CAD data, or for which the data has become obsolete or lost.
2. Inspection and/or quality control- comprising a fabricated part to its CAD description or to a standard item.
3. Creating 3D data from a model or sculpture for animation in games and movies.
4. Creating 3D data from an indivisual model or sculpture for creating, scaling or reproducing artwork.
5. Documentation and /or measurement of cultural objects or artifacts in archaeology, paleontology and scientific fields.
6. Fitting clothing or footwear to individuals and determining the anthropometry of a population.
7. Generating data to create dental or surgical prosthetics, tissue-engineered body parts or for surgical planning.
8. Documentation and reproduction of crime scenes.
9. Architectural and construction documentation and measurement.

2. WHY WE HAVE TAKEN THIS PROJECT

Rapid prototyping is a procedure of producing models. There are various methods of rapid prototyping. The main advantage of rapid prototyping lies in the speed of producing physical prototypes as well as almost unlimited complexity of geometry. RP procedures do not require planning during process, specific equipments for work with materials transport between work places etc. how ever, compared with CNC processing, the main drawback of these processes is that they are currently limited to fewer materials. Therefore CNC process is used for majority of materials including metals. Furthermore physical object made by rapid prototyping is mainly used as models or prototypes for other production procedures. Rapid prototyping machine uses powder and binder which are much expensive. Powder cost around Rs. 30,000/- for 5 kg and binder cost around Rs. 28,000/- for 100 ml. So our aim is to find out the alternatives which can replace original powder. Also our objective of work is to optimize the parameters of rapid prototype product.

CHAPTER 2

3. LITERATUIRE REVIEW

There is usually far too much data in the point cloud collected from the scanner or digitizer, and some of it may be unwanted noise. Without further processing, the data isn't in a form that can be used by downstream applications such as CAD/CAM software or in rapid prototyping.

Reverse engineering software is used to edit the point cloud data, establish the interconnectedness of the points in the cloud, and traslate it into useful formats such as surface models or STL files, It allows several different scans of an object to be melded together so that the data describing the object can be defined completely from all sides and directions.

Usually, the shortest part of any RE task is scanning or data collection. While there are exceptions, scanning might only require a few seconds or a few minutes. On the other hand, manipulating the data can be quite time consuming and labour-intensive. It may even require days to complete this part of the job. The situation is analogous to scanning two- dimensional photographic materials. It doesn't usually take very long to scan a picture or a diagram- but getting that picture into a presentable form can be quite a lot of work, indeed.

3.1 X-ray Powder Diffraction (XRD)

X-ray powder diffraction (XRD) is a rapid analytical technique primarily used for phase identification of a crystalline material and can provide information on unit cell dimensions. The analyzed material is finely ground, homogenized, and average bulk composition is determined.

3.2 Fundamental Principles of X-ray Powder Diffraction (XRD)

Max von Laue, in 1912, discovered that crystalline substances act as three-dimensional diffraction gratings for X-ray wavelengths similar to the spacing of planes in a crystal lattice. X-ray diffraction is now a common technique for the study of crystal structures and atomic spacing.

X-ray diffraction is based on constructive interference of monochromatic X-rays and a crystalline sample. These X-rays are generated by a cathode ray tube, filtered to produce monochromatic radiation, collimated to concentrate, and directed toward the sample. The interaction of the incident rays with the sample produces constructive interference (and a diffracted ray) when conditions satisfy **Bragg's Law** ($n\lambda=2d \sin \theta$). This law relates the wavelength of electromagnetic radiation to the diffraction angle and the lattice spacing in a crystalline sample. These diffracted X-rays are then detected, processed and counted. By scanning the sample through a range of 2θangles, all possible diffraction directions of the lattice should be attained due to the random orientation of the powdered material. Conversion of the diffraction peaks to d-spacings allows identification of the mineral because each mineral has a set of unique d-spacings. Typically, this is achieved by comparison of d-spacings with standard reference patterns.

All diffraction methods are based on generation of X-rays in an X-ray tube. These X-rays are directed at the sample, and the diffracted rays are collected. A key component of all diffraction is the angle between the incident and diffracted rays. Powder and single crystal diffraction vary in instrumentation beyond this.

3.3 X-ray Powder Diffraction (XRD) Instrumentation - How Does It Work?

X-ray diffractometers consist of three basic elements: an X-ray tube, a sample holder, and an X-ray detector.

X-rays are generated in a cathode ray tube by heating a filament to produce electrons, accelerating the electrons toward a target by applying a voltage, and bombarding the target material with electrons. When electrons have sufficient energy to dislodge inner shell electrons of the target material, characteristic X-ray spectra are produced. These spectra consist of several components, the most common being K_α and K_β. K_α consists, in part, of $K_{\alpha 1}$ and $K_{\alpha 2}$. $K_{\alpha 1}$ has a slightly shorter wavelength and twice the intensity as $K_{\alpha 2}$. The specific wavelengths are characteristic of the target material (Cu, Fe, Mo, Cr). Filtering, by foils or crystal monochrometers, is required to produce monochromatic X-rays needed for diffraction. $K_{\alpha 1}$and $K_{\alpha 2}$ are sufficiently close in wavelength such that a weighted average of the two is used. Copper is the most common target material for single-crystal diffraction, with CuK_α radiation = 0.5418Å. These X-rays are collimated and directed onto the sample. As the sample and detector are rotated, the intensity of the reflected X-rays is recorded. When the geometry of the incident X-rays impinging the sample satisfies the Bragg Equation, constructive interference occurs and a peak in intensity occurs. A detector records and processes this X-ray signal and converts the signal to a count rate which is then output to a device such as a printer or computer monitor.

X-ray powder diffractogram. Peak positions occur where the X-ray beam has been diffracted by the crystal lattice. The unique set of d-spacings derived from this patter can be used to 'fingerprint' the mineral.

The geometry of an X-ray diffractometer is such that the sample rotates in the path of the collimated X-ray beam at an angle θ while the X-ray detector is mounted on an arm to collect the diffracted X-rays and rotates at an angle of 2θ. The instrument used to maintain the angle and rotate the sample is termed a *goniometer*. For typical powder patterns, data is collected at 2θ from ~5° to 70°, angles that are preset in the X-ray scan.

3.4 Shore (Durometer) Hardness Testing:

Shore (Durometer) Hardness is to determine the relative hardness of soft materials, usually plastic or rubber. The test measures the penetration of a special indentor into the material under specified conditions of force and time. The hardness value is often used to identify or specify a particular hardness of elastomers or as a quality control measure on lots of material.

Shore hardness, using either the shore A or shore D scale is the preffered method for rubbers/elastomers and is also commonly used for softer plastics such as polyolefins, fluoropolymers and vinyls. The shore A is used for softer rubber while the shore D scale is used for harder ones. Many other shore hardness scales, such as shore O and shore H hardness exist but are only rarely encountered by most plastics engineers.

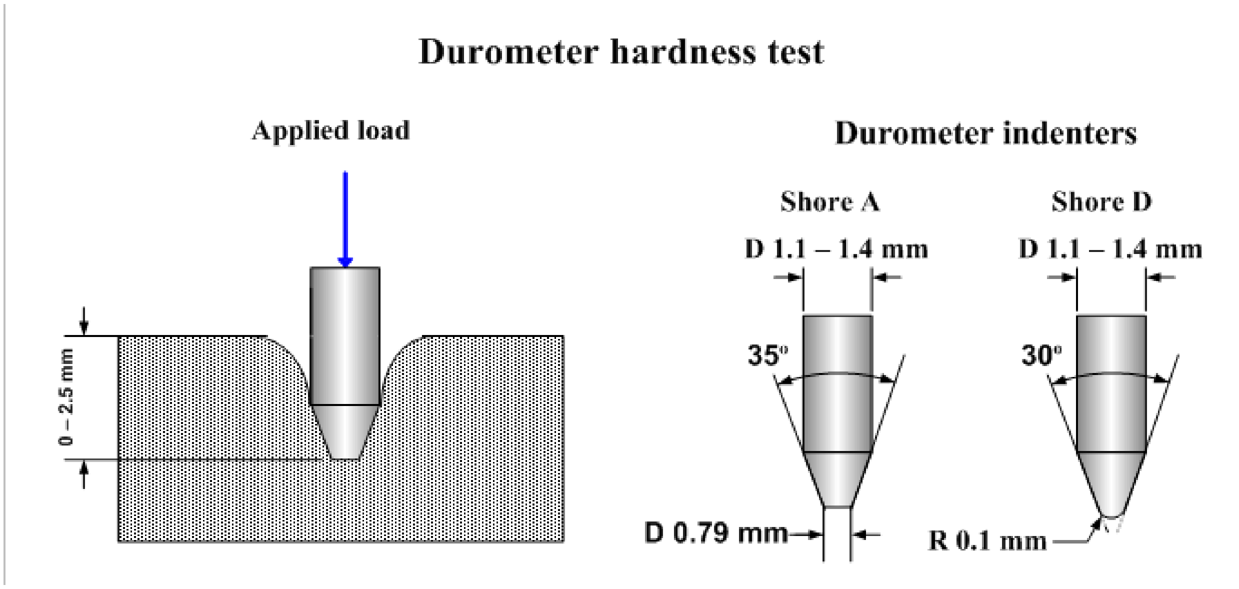
3.5 Test procedure:

Shore hardness is a measure of the resistance of material to indentation by 3 spring loased indenter. The higher the number, the greater the resistance.

The shore hardness is measured with an apparatus known as a Durometer and consequently is also known as ‘durometer hardness’. The hardness value is determined by the penetration of the indentor foot into the sample. Because of the resilience of rubber and plastics, the indentation reading may change over time, so the indentation time is also sometimes reported along with hardness number.

The results obtained from this test are useful measure of relative resistance to indentation of various grades of polymers.

The specimen is first placed on a hard flat surface. The indentor for the instrument is then pressed into the specimen making sure that it is parallel to the surface. The hardness is read within one second (or as specified by the customer) of firm contact with the specimen.



3.6 RAPID PROTOTYPING

A family of unique fabrication processes developed to make engineering prototypes in minimum lead time based on a CAD model of the item.

• The traditional method is machining

− Machining can require significant lead-times –

Several weeks, depending on part complexity and difficulty in ordering materials

• RP allows a part to be made in hours or days rather than weeks, given that a computer model of the part has been generated on a CAD system.

WHY RAPID PROTOTYPING?

• Because product designers would like to have a physical model of a new part or product design rather than just a computer model or line drawing.

− Creating a prototype is an integral step in design

− A *virtual prototype* (a computer model of the part design on a CAD system) may not be sufficient for the designer to visualize the part adequately

− Using RP to make the prototype, the designer can visually examine and physically feel the part and assess its merits and shortcomings.

3.7 Rapid Prototyping Technologies – Two Basic Categories

1. Material removal RP - machining, primarily milling and drilling, using a dedicated CNC machine that is available to the design department on short notice.

− Starting material is often wax, which is easy to machine and can be melted and resolidified.

− The CNC machines are often small.

− Called *desktop milling* or *desktop machining.*

2. Material addition RP - adds layers of material one at a time to build the solid part from bottom to top.

3.8 Starting Materials in Material Addition RP:

1. Liquid monomers that are cured layer by layer into solid polymers
2. Powders that is aggregated and bonded layer by layer
3. Solid sheets that are laminated to create the solid part

3.9 Addition RP Methods:

• In addition to starting material, the various material addition RP technologies use different methods of building and adding layers to create the solid part

− There is a correlation between starting material and part building techniques.

Steps to Prepare Control Instructions:

1. Geometric modeling - modeling the component on a CAD system to define its enclosed volume

2. Tessellation of the geometric model - the CAD model is converted into a computerized format that approximates its surfaces by facets (triangles or polygons)

3. Slicing of the model into layers - the model in computerized format is sliced into closely-spaced parallel horizontal layers.

Alternative Names for Rapid Prototyping:

• *Layer manufacturing*

• *Direct CAD manufacturing*

• *Solid freeform fabrication*

• *Rapid prototyping and manufacturing* (RPM)

− Indicates that RP technologies are being used increasingly to make production parts and production tooling, not just prototypes

3.10 Classification of Rapid Prototyping Technologies:

• There are various ways to classify the RP techniques that have currently been developed

• The RP classification used here is based on the form of the starting material:

1. Liquid-based
2. Solid-based
3. Powder-based

Liquid-Based Rapid Prototyping Systems:

• Starting material is a liquid

• About a dozen RP technologies are in this category

• The following are described here:

− Stereolithography

− Solid ground curing

− Droplet deposition manufacturing

Stereolithography (STL):

RP process for fabricating a solid plastic part out of a photosensitive liquid polymer using a directed laser beam to solidify the polymer

• Part fabrication is accomplished as a series of layers, in which one layer is added onto the previous layer to gradually build the desired 3-D geometry

• The first addition RP technology - introduced 1988 by 3D Systems Inc. based on the work of Charles Hull

• More installations of STL than any other RP method

Some Facts about STL

• Each layer is 0.076 mm to 0.50 mm (0.003 in to 0.020 in.) thick

− Thinner layers provide better resolution and more intricate shapes; but processing time is longer

• The starting materials are liquid monomers

• Polymerization occurs upon exposure to UV light produced by helium-cadmium or argon ion lasers

− Laser scan speeds typically 500 to 2500 mm/s

Solid-Based Rapid Prototyping Systems:

• Starting material is a solid

• Two solid-based RP systems are presented here:

− Laminated object manufacturing

− Fused deposition modeling

Laminated Object Manufacturing (LOM)

A solid physical model is made by stacking layers of sheet stock, each an outline of the cross-sectional shape of a CAD model that is sliced into layers

• Starting material = sheet stock, such as paper, plastic, cellulose, metals, or fiber-reinforced materials
• The sheet material is usually supplied with adhesive backing as rolls that are spooled between two reels
• After cutting, excess material in the layer remains in place to support the part during building

Fused Deposition Modeling (FDM)

RP process in which a long filament of wax or polymer is extruded onto the existing part surface from a workhead to complete each new layer
• The workhead is controlled in the *x-y* plane during each layer and then moves up by a distance equal to one layer in the *z*-direction
• The extrudate is solidified and cold welded to the cooler part surface in about 0.1 s
• Part is fabricated from the base up, using a layer-by layer Procedure

Powder-Based Rapid Prototyping Systems

• Starting material is a powder
• Two RP systems are described here:
− Selective laser sintering
− Three dimensional printing

Selective Laser Sintering (SLS):

A moving laser beam sinters heat-fusible powders in areas corresponding to the CAD geometry model one layer at a time to build the solid part
• After each layer is completed, a new layer of loose powders is spread across the surface
• Layer by layer, the powders are gradually bonded into a solid mass that forms the 3-D part geometry
• In areas not sintered by the laser beam, the powders are loose and can be poured out of completed part

Three Dimensional Printing (3DP):

In 3DP, the part is built in layer-by-layer fashion using an ink-jet printer to eject adhesive bonding material onto successive layers of powders

• The binder is deposited in areas corresponding to the cross-sections of the solid part, as determined by slicing the CAD geometric model into layers

• The binder holds the powders together to form the solid part, while the unbonded powders remain loose to be removed later

• To further strengthen the part, a sintering step can be applied to bond the individual powders

3.11 RP Applications:

• Applications of rapid prototyping can be classified
Into three categories:

1. Design
2. Engineering analysis and planning
3. Tooling and manufacturing

3.12 Problems with Rapid Prototyping

• Part accuracy:

− Staircase appearance for a sloping part surface due to layering

− Shrinkage and distortion of RP parts

• Limited variety of materials in RP

− Mechanical performance of the fabricated parts is limited by the materials that must be used in the RP process.

3.13 Z Corporation - ZPrinter 310 plus :

The ZPrinter 310 Plus creates physical models directly from digital data in hours instead of days. The ZPrinter 310 Plus is fast, versatile and simple, allowing engineers to produce a range of concept models and functional test parts quickly and inexpensively. The system is ideal for an office environment or educational institution, providing product developers easy access to a 3D Printer. The ZPrinter 310 Plus' sleek design and straightforward user interface make it the ideal entry-level rapid prototyping system. In addition, the versatility of the machine allows users to make parts quickly for early concept evaluation and testing, painted parts for a finished look, or patterns for casting applications.

ZPRINTER 310 PLUS

- Build Speed: 2 - 4 layers per minute
- Build Size: 203 x 254 x 203 mm
- Layer Thickness: User selectable at the time of printing; .089 - .203 mm
- Material options: High performance composite, snap-fit, elastomeric, direct casting, investment casting
- Number of Print Heads: One
- System Software: Z Corporation?s proprietary software accepts solid models in STL, VRML and PLY file formats as input. ZPrint software features 3D viewing, text labeling, and scaling functionality. The software runs on Microsoft Windows* NT, 2000 Professional and XP Professional.
- Equipment Dimensions: 74 x 86 x 109 cm
- Equipment Weight: 115 Kg

3.14. Benefits:

- Quickly produce parts directly from 3D CAD or model data
- Address a wide range of applications
- No special training required
- Address design issues early in the development cycle
- Accelerate design cycles and time-to-market
- Reduce product development costs

3.15. Applications:

- Product Design
- Architecture
- Medical Applications
- Engineering
- Computer Games and Film
- Research and Education

CHAPTER 3

4. EXPERIMENTAL PROCEDURE

4.1.INTRODUCTION

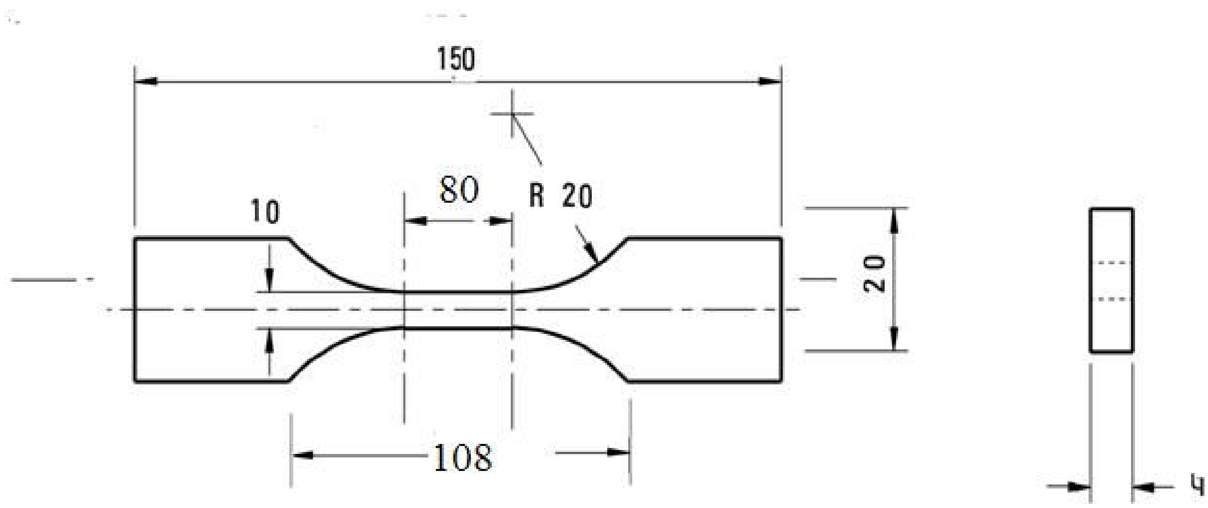
Rapid prototyping is a procedure of producing models. There are various methods of rapid prototyping. The main advantage of rapid prototyping lies in the speed of producing physical prototypes as well as almost unlimited complexity of geometry. RP procedures do not require planning during process, specific equipments for work with materials, transport between work places etc. how ever, compared with CNC processing, the main drawback of these processes is that they are currently limited to fewer materials. Therefore CNC process is used for majority of materials including metals. Furthermore physical object made by rapid prototyping is mainly used as models or prototypes for other production procedures. The objective of work is to optimize the parameters of rapid prototype product.

4.2.PREPARATION OF SPECIMEN :

Machine used: ZPrinter 310 plus.

Materials used : ZP ®130 powder. And ZB 58 as binder.

Dimensions of tensile test specimen



Dimensions in mm.---

l_3= total length = 150

Length of the narrow parallel part = 80

r = radius =20

l_2= distance between expanded parallel part=104

b2=width at the end =20

b1=width of the narrow end = 10

h=thickness = 4

L0= measurement length = 50

L= initial distance between machine jaws = 115

With the above dimension we prepared a CAD model. This model is fed to the machine. A 3D model will be printed layer by layer. Finally we get the 3D object.

The test specimen made by ZPrinter 310 plus machine has been made of ZP R 130 powder. and ZB 58 as binder. With different built direction we prepared 5 nos of specimens. Again we prepared 5 nos of specimens with loctite 406 added to the previous materials.

4.3.SHORE HARDNESS TEST

The shore hardness is measured with an apparatus known as a Durometer and consequently is also known as 'durometer hardness'. The hardness value is determined by the penetration of the indentor foot into the sample. The specimen is first placed on a hard flat surface. The indentor for the instrument is then pressed into the specimen making sure that it is parallel to the surface. The hardness is read within one second (or as specified by the customer) of firm contact with the specimen.

zwick hardness tester

4.4. TENSILE TEST

Machine Used: INSTRON 1195

Test specimen prepared .

4.5.**PROCEDURE:**

Though a tensile test is relatively simple and has been around for a very long time, some thought and consideration must be done to ensure that the test will have valid results. Factors involved are the specimen shape and dimensions, the choice of grips and faces, and many more.

INSTRON 1195

4.6. Specimen Shape

The specimen's shape is usually defined by the standard or specification being utilized, e.g., ASTM E8 or D638. Its shape is important because you want to avoid having a break or fracture within the area being gripped. So, standards have been developed to specify the shape of the specimen to ensure the break will occur in the "gage length" (2 inches are frequently used) by reducing the cross sectional area or diameter of the specimen throughout the gage length. This has the effect of increasing the stress in the gage length since stress is inversely proportional to the cross sectional area under load,

$$\sigma = \frac{\text{Load}}{\text{Area}} = \frac{P}{a}.$$

4.7. Grip and Face Selection

Face and grip selection is a very important factor. By not choosing the correct set up, your specimen may slip or even break inside the gripped area ("jaw break"). This would lead to invalid results. The faces should cover the entire tab or area to be gripped. You do not want to use serrated faces when testing materials that are very ductile. Sometimes covering the serrated faces with masking tape will soften the bite preventing damage to the specimen.

4.8 Specimen Alignment

Vertical alignment of the specimen is an important factor to avoid side loading or bending moments created in the specimen. Mounting the specimen in the upper grip assembly first then allowing it to hang freely will help to maintain alignment for the test.

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NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA-769 008

TENSILE TEST OF METALS IN S.I. UNITS

Test type: Tensile

Operator name: shyamu

Instron Corporation
Series IX Automated Materials Testing System 1.26
Test Date: 23 Apr 1994

Sample Identification: RIMIL-2
Interface Type: Data Systems Adapter

Sample Type: ASTM

Machine Parameters of test:

- Sample Rate (pts/sec): 9.103
- Crosshead Speed (mm/min): 2.0000
- Full Scale Load Range (KN): 10.0000

Humidity (%): 50
Temperature (deg. F): 73

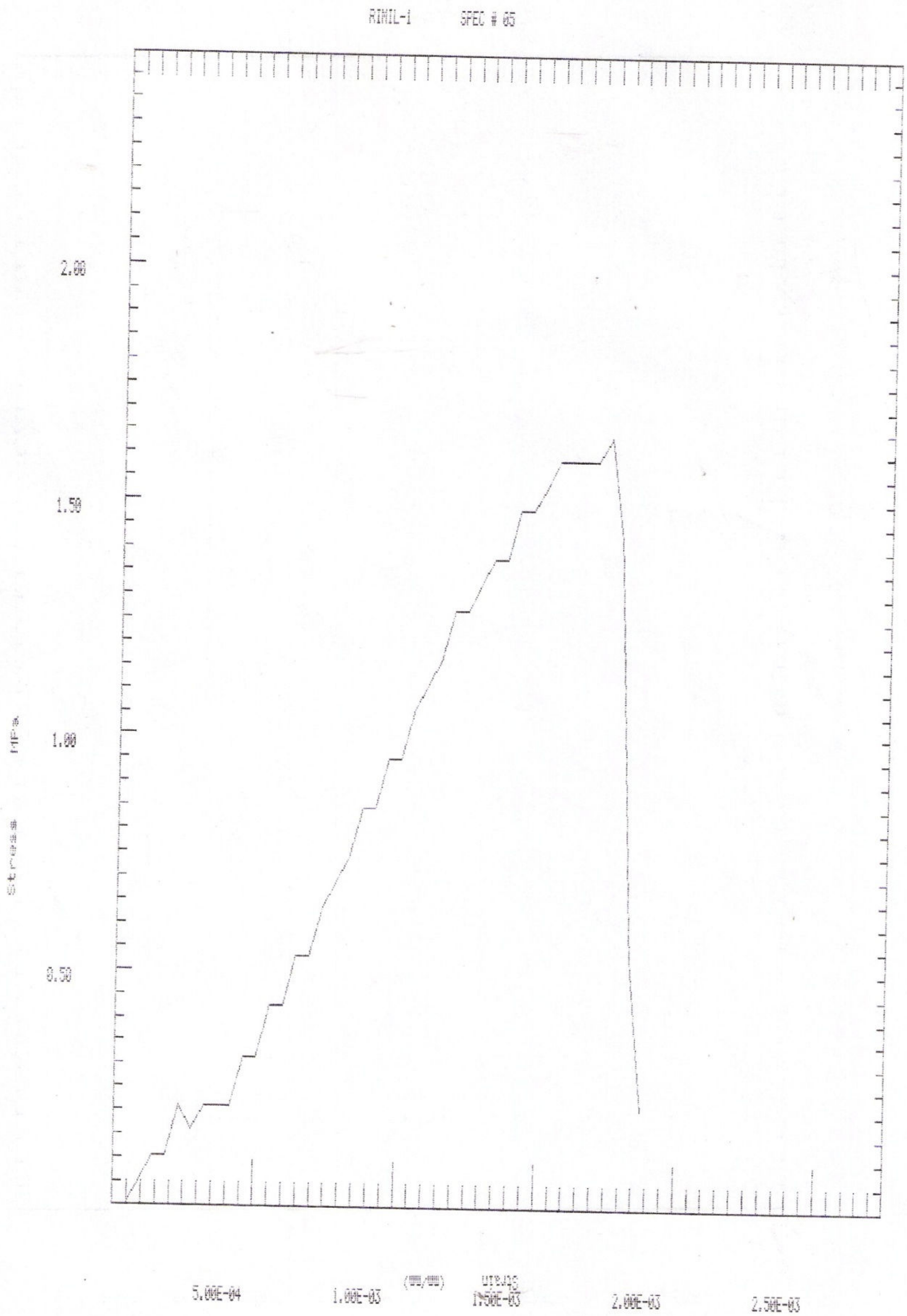
Dimensions:

	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5	Spec. 6
Width (mm)	10.700	10.700	10.700	10.700	10.700	10.700
Thickness (mm)	4.4000	4.4000	4.4000	4.4000	4.4000	4.4000
Spec gauge len (mm)	80.000	80.000	80.000	80.000	80.000	80.000
Grip distance (mm)	65.000	65.000	65.000	65.000	65.000	65.000

Out of 6 specimens, 0 excluded.

Specimen Number	Angle	Displcment at Peak (mm)	% Strain at Peak (%)	Load at Peak (KN)	Stress at Peak (MPa)	Displcment at Break (mm)	% Strain at Break (%)	Load at Break (KN)	Stress at Break (MPa)	Displcment at 0.2% Yield (mm)
1	0	.1428	.1785	.0946	2.0100	.1648	.2060	.0946	2.0100	----------
2	15	.1318	.1648	.0946	2.0100	.1318	.1648	.0946	2.0100	----------
3	30	.1428	.1785	.0996	2.1160	.1428	.1785	.0996	2.1160	----------
4	45	.1391	.1739	.0772	1.6400	.1391	.1739	.0772	1.6400	----------
5	0	.1282	.1602	.0897	1.9040	.1465	.1831	.0349	.7406	----------
:		.1343	.1678	.0834	1.7720	.1568	.1961	.0726	1.5430	----------
Standard Deviation:		.0089	.0111	.0204	.4334	.0310	.0388	.0302	.6422	----------

Specimen Number	% Strain at 0.2% Yield (%)	Load at 0.2% Yield (KN)	Stress at 0.2% Yield (MPa)	Young's Modulus (MPa)	Energy to Yield Point (J)	Energy to Break Point (J)
1	.2701	.0349	.7406	1486.	.0077	.0077
2	----------	----------	----------	1503.	.0067	.0088
3	----------	----------	----------	1156.	.0054	.0054
4	----------	----------	----------	1618.	.0073	.0073
5	----------	----------	----------	1387.	.0073	.0073
6	----------	----------	----------	1486.	.0057	.0071
Mean:	----------	----------	----------	1439.	.0067	.0073
Standard Deviation:	----------	----------	----------	157.	.0009	.0011


RIMIL-1 SPEC # 05
Stress MPa
2.00
1.50
1.00
0.50
5.00E-04
1.00E-03
1.50E-03
2.00E-03
2.50E-03

DEPTT.OF METALLURGICAL & MATERIALS ENGG.
NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA-769 008

TENSILE TEST OF METALS IN S.I. UNITS

Test type: Tensile

Operator name: shyamu

Instron Corporation
Series IX Automated Materials Testing System 1.26
Test Date: 23 Apr 1994

Sample Identification: RIMIL-3
Interface Type: Data Systems Adapter
Machine Parameters of test:
Sample Rate (pts/sec): 9.103
Crosshead Speed (mm/min): 2.0000
Full Scale Load Range (KN): 2.0000

Sample Type: ASTM

Humidity (%): 50
Temperature (deg. F): 73

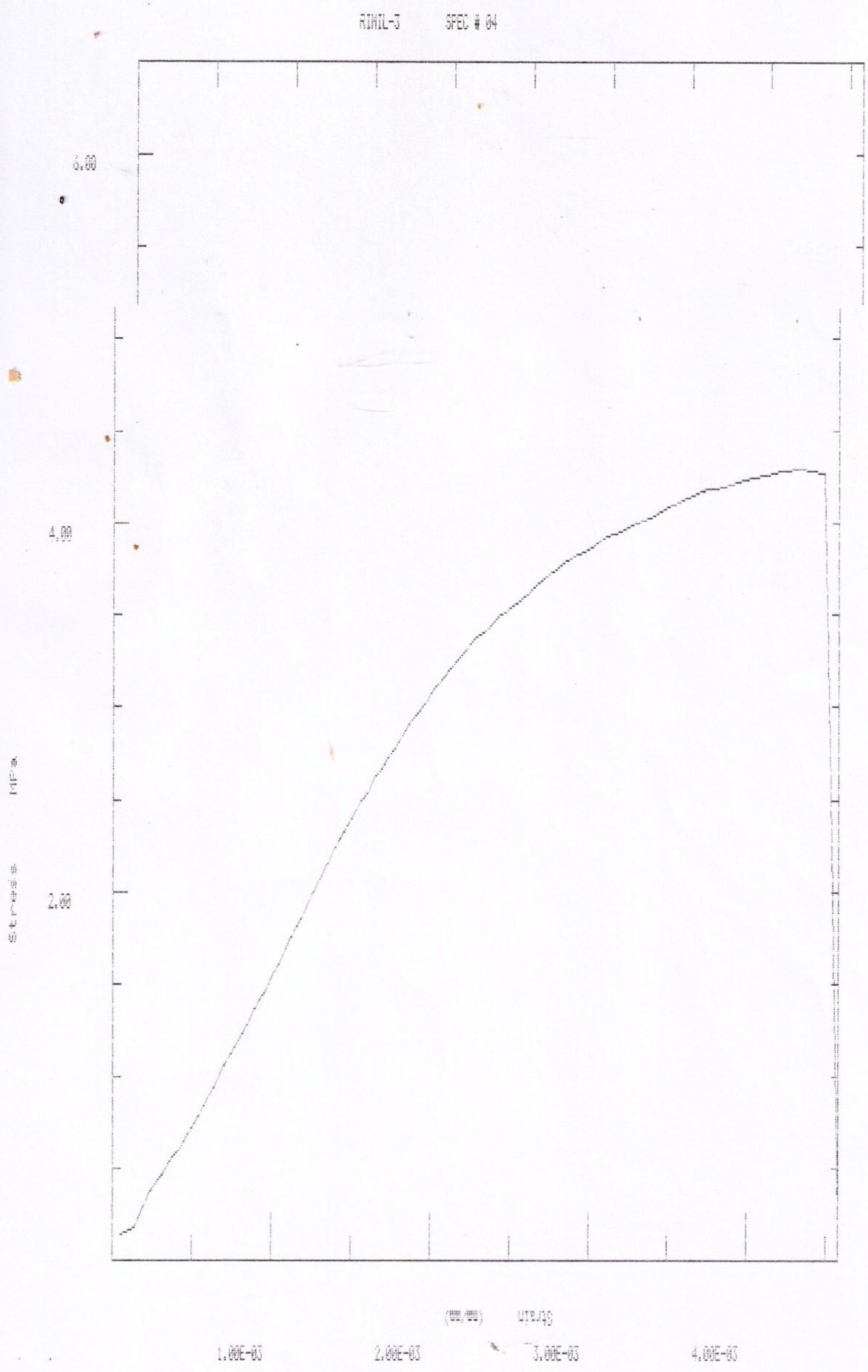
Dimensions:

	Spec. 1	Spec. 2	Spec. 3	Spec. 4
Width (mm)	10.700	10.700	10.700	10.700
Thickness (mm)	4.4000	4.4000	4.4000	4.4000
Spec gauge len (mm)	80.000	80.000	80.000	80.000
Grip distance (mm)	65.000	65.000	65.000	65.000

Out of 4 specimens, 0 excluded.

Specimen Number	Angle	Displcment at Peak (mm)	% Strain at Peak (%)	Load at Peak (KN)	Stress at Peak (MPa)	Displcment at Break (mm)	% Strain at Break (%)	Load at Break (KN)	Stress at Break (MPa)	Displcment at 0.2% Yield (mm)
1	0	.1794	.2243	.1449	3.077	.2160	.2701	.0490	1.040	.2160
2	15	.1867	.2334	.2183	4.636	.1867	.2334	.2183	4.636	.2014
3	30	.3076	.3845	.2388	5.071	.3405	.4257	.1449	3.077	.3405
4	45	.3479	.4348	.2023	4.297	.3625	.4531	.1199	2.546	.3625
Mean:		.2554	.3193	.2010	4.270	.2765	.3456	.1330	2.825	.2801
Standard Deviation:		.0852	.1065	.0403	.856	.0880	.1099	.0699	1.484	.0832

Specimen Number	% Strain at 0.2% Yield (%)	Load at 0.2% Yield (KN)	Stress at 0.2% Yield (MPa)	Young's Modulus (MPa)	Energy to Yield Point (J)	Energy to Break Point (J)
1	.4257	.1449	3.0770	2368.	.0518	.0518
2	.2517	.0100	.2122	2252.	.0252	.0252
3	.2701	.0490	1.0400	1714.	.0193	.0193
4	.4531	.1199	2.5460	1758.	.0487	.0487
Mean:	.3502	.0809	1.7190	2023.	.0363	.0363
Standard Deviation:	.1039	.0623	1.3240	335.	.0164	.0164


RIMIL-3 SPEC # 04
6.00
4.00
2.00
Stress MPa
(mm/mm)
1.00E-03
2.00E-03
3.00E-03
4.00E-03

R

5. X- Ray Diffraction:

MATERIALS USED:

ZP R 130 --POWDER

MACHINE USED:

X-Ray Diffractometer

X-ray diffraction finds the geometry or shape of a molecule using X-rays. X-ray diffraction techniques are based on the elastic scattering of X-rays from structures that have long range order. The most comprehensive description of scattering from crystals is given by the dynamical theory of diffraction.

5.1 **Powder diffraction** :

Powder diffraction (XRD) is a scientific technique using X-ray on powder or microcrystalline samples for structural characterization of materials

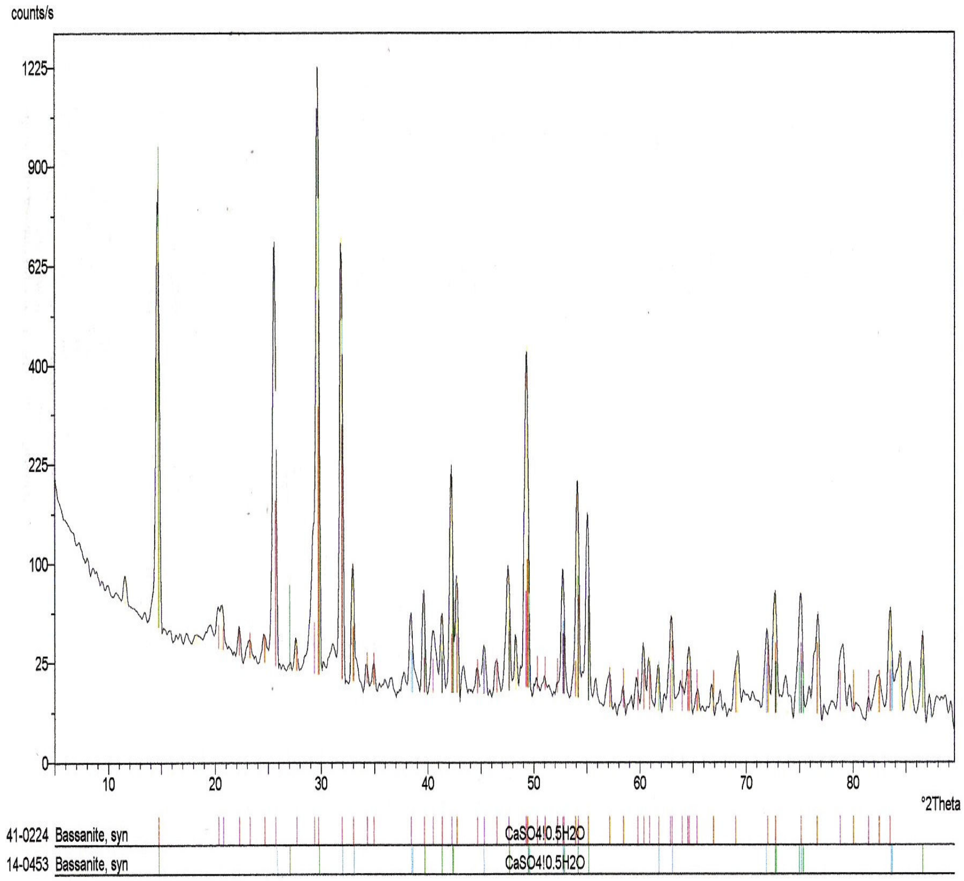
- It is used to characterize the crystallographic structure, crystallite size (grain size), and preferred orientation in polycrystalline or powdered solid samples. Powder diffraction is commonly used to identify unknown substances, by comparing diffraction data against a database maintained by the International Centre for Diffraction Data. It may also be used to characterize heterogeneous solid mixtures to determine relative abundance of crystalline compounds and, when coupled with lattice refinement techniques, such as Rietveld refinement, can provide structural information on unknown materials. Powder diffraction is also a common method for determining strains in crystalline materials. An effect of the finite crystallite sizes is seen as a broadening of the peaks in an X-ray diffraction as is explained by the Scherrer Equation.

Result of XRD:

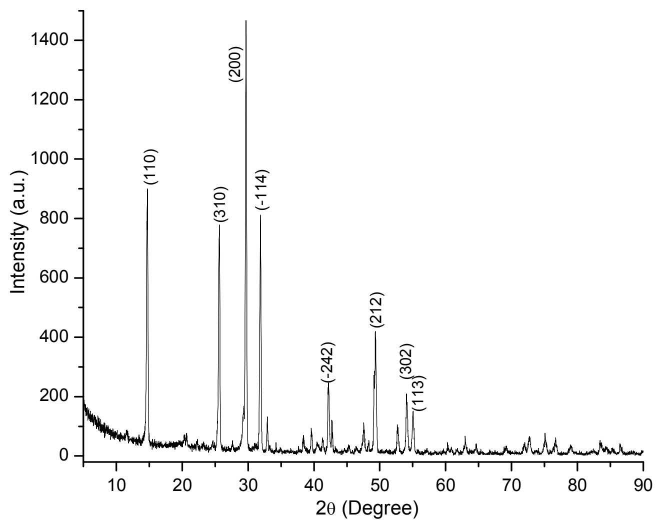
After anlayzing the crystal structure of powder through XRD, $CaSO_4$ is found to be the main composition of ZP R130 powder.

X'Pert Graphics & Identify
Graph: STRACH BASED POWDER

UDAY
Date of Edition: 5/8/09 11:49



Philips Analytical X-Ray B.V.



1400
1200
1000
800
600
400
200
0
Intensity (a.u.)
10
20
30
40
50
60
70
80
90
2θ (Degree)
(110)
(310)
(200)
(-114)
(-242)
(212)
(302)
(113)

Description:

PROF. S.S. MOHAPATRA

Peak search parameter set: As Measured Intensities
Set created: 4/8/09 15:02
Peak positions defined by: Minimum of 2nd derivative
Minimum peak tip width (°2Theta): 0.00
Maximum peak tip width (°2Theta): 1.00
Peak base width (°2Theta): 2.00
Minimum significance: 0.20

d-spacing (Å)	Relative Intensity (%)	Angle (°2Theta)	Peak Height (cps)	Background (cps)	Tip Width (°2Theta)	Significance
7.66367	2.01	11.5371	24	65	0.2400	0.24
6.03687	67.04	14.6614	809	47	0.2400	2.99
4.86623	0.35	18.2154	4	37	0.5600	0.24
4.30913	2.54	20.5945	31	33	0.2400	0.21
3.99543	1.46	22.2313	18	30	0.2400	0.25
3.83139	0.81	23.1961	10	28	0.5600	0.73
3.61391	1.32	24.6132	16	26	0.3200	0.31
3.48010	57.81	25.5753	698	24	0.3200	6.67
3.22887	1.49	27.6032	18	22	0.2400	0.26
3.01062	100.00	29.6484	1207	20	0.3200	9.40
2.80831	56.86	31.8389	687	18	0.2400	3.29
2.71957	7.00	32.9069	85	17	0.2400	0.94
2.61893	0.70	34.2095	8	16	0.2400	0.23
2.57071	0.85	34.8716	10	16	0.2400	0.22
2.34230	3.75	38.3988	45	13	0.2400	0.53
2.27419	5.43	39.5960	66	13	0.2400	0.86
2.22574	2.61	40.4952	31	13	0.4000	0.99
2.18345	3.68	41.3151	44	13	0.2400	0.51
2.14036	17.80	42.1860	215	12	0.2400	1.64
2.11583	6.32	42.6990	76	12	0.2400	1.04
2.08724	0.94	43.3131	11	12	0.2400	0.22
2.00207	1.88	45.2554	23	12	0.3200	0.67
1.95511	1.11	46.4052	13	13	0.4000	0.78
1.91181	7.13	47.5199	86	13	0.3200	1.49
1.88466	2.34	48.2477	28	14	0.2400	0.44
1.84795	35.57	49.2692	429	14	0.3200	4.05
1.73585	7.11	52.6866	86	12	0.3200	2.04
1.69498	16.46	54.0588	199	11	0.3200	3.35
1.66808	12.66	55.0036	153	10	0.3200	2.89
1.61277	1.00	57.0592	12	8	0.4800	1.03
1.54882	0.96	59.6476	12	7	0.2400	0.22
1.53362	2.40	60.2995	29	7	0.1600	0.97
1.52157	1.68	60.8275	20	7	0.1600	0.47
1.50257	1.41	61.6801	17	7	0.2400	0.34
1.47585	4.04	62.9225	49	7	0.3200	1.18
1.44221	2.27	64.5653	27	7	0.2400	0.39
1.42671	0.53	65.3537	6	7	0.3200	0.33
1.40142	0.77	66.6852	9	7	0.1600	0.26
1.35761	2.04	69.1355	25	6	0.4800	1.00
1.31185	3.28	71.9127	40	6	0.3200	0.93
1.30025	5.73	72.6562	69	6	0.3200	1.43
1.28445	1.00	73.6960	12	6	0.4800	0.28
1.26430	5.66	75.0710	68	6	0.3200	1.52
1.24196	4.22	76.6637	51	6	0.3200	1.34
1.21150	2.32	78.9594	28	7	0.5600	2.22
1.16999	1.03	82.3506	12	6	0.5600	0.97
1.15709	4.47	83.4730	54	7	0.3200	1.30
1.14700	2.02	84.3756	24	7	0.2400	0.35
1.13654	1.56	85.3352	19	7	0.2400	0.28
1.12411	3.00	86.5086	36	7	0.2400	0.59

CHAPTER 4

6. RESULT:

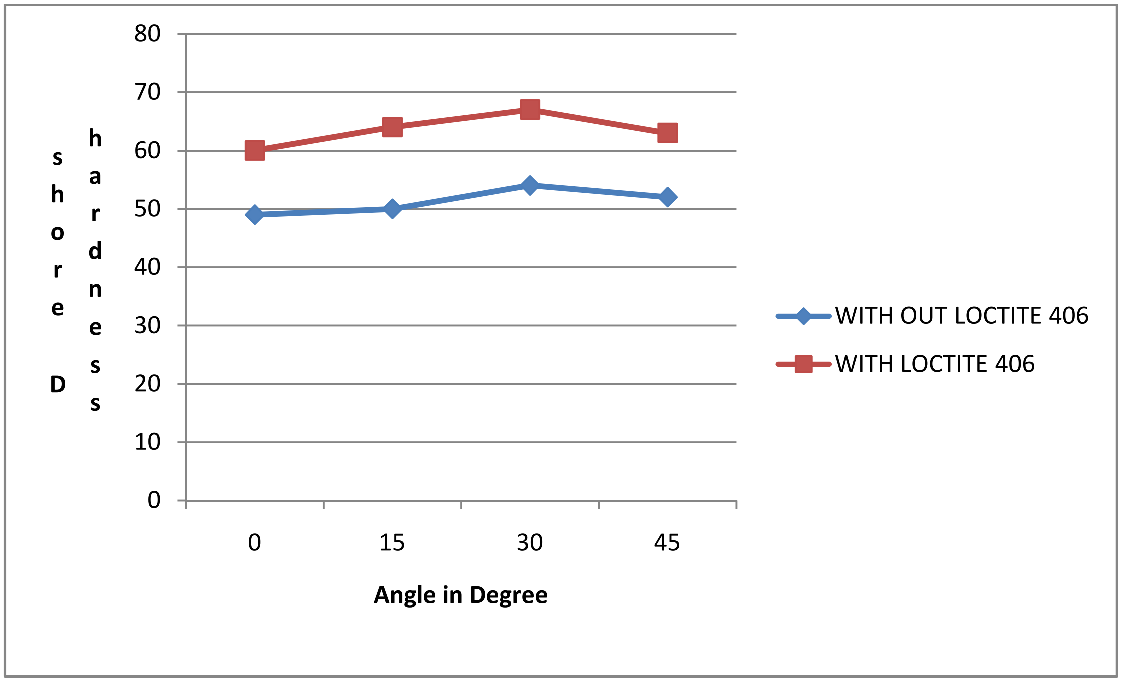
The variation of hardness and strength with built direction is shown in the following table. From the graph given below, it is clear that both the parameters increases as we increase the angle up to certain degree (in this case 30 degree), then again decreases. When Loctite 406 is used along with powder and binder provided by Zcorporation, there is improvement in the properties of the prototype.

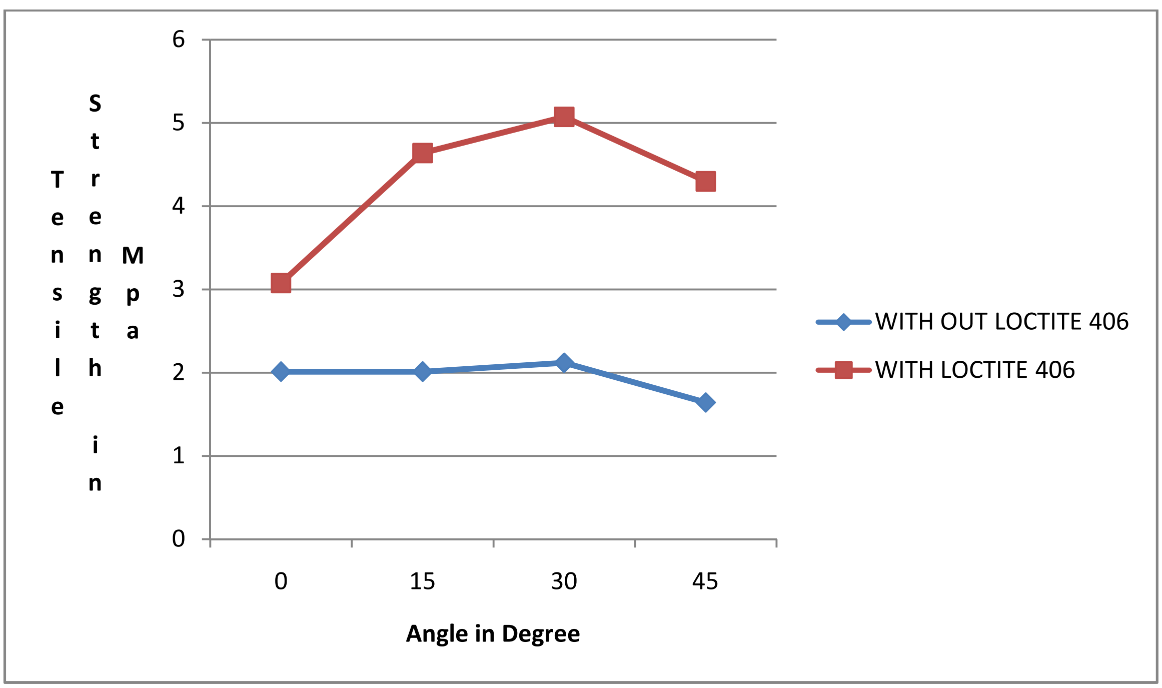
WITH OUT LOCTITE 406:

SL NO	ANGLE in degree	SHORE D hardness no	VICKER HARD NESS	Stress at peak (Mpa)
1	0	49	354	2.0100
2	15	50	363	2.0100
3	30	54	392	2.1160
4	45	52	382	1.6400

WITH LOCTITE 406:

SL NO	ANGLE in degree	SHORE D Hardness no	VICKER HARD NESSS	Stress at peak (Mpa)
1	0	60	446	3.077
2	15	64	484	4.636
3	30	67	513	5.071
4	45	63	471	4.297


80
70
60
50
40
30
20
10
0
shore D hardness
0
15
30
45
Angle in Degree
WITH OUT LOCTITE 406
WITH LOCTITE 406

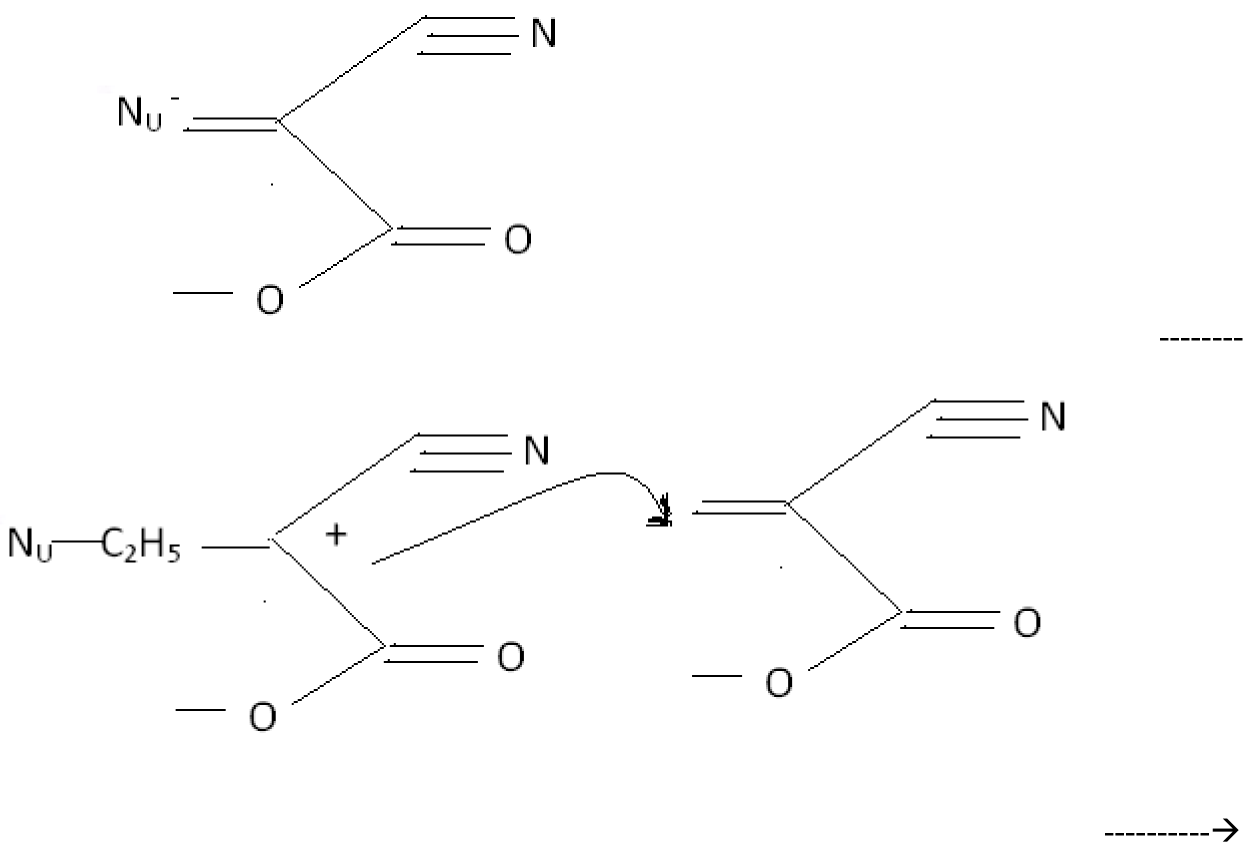

6
5
4
3
2
1
0
Tensile Strength in Mpa
0
15
30
45
Angle in Degree
WITH OUT LOCTITE 406
WITH LOCTITE 406

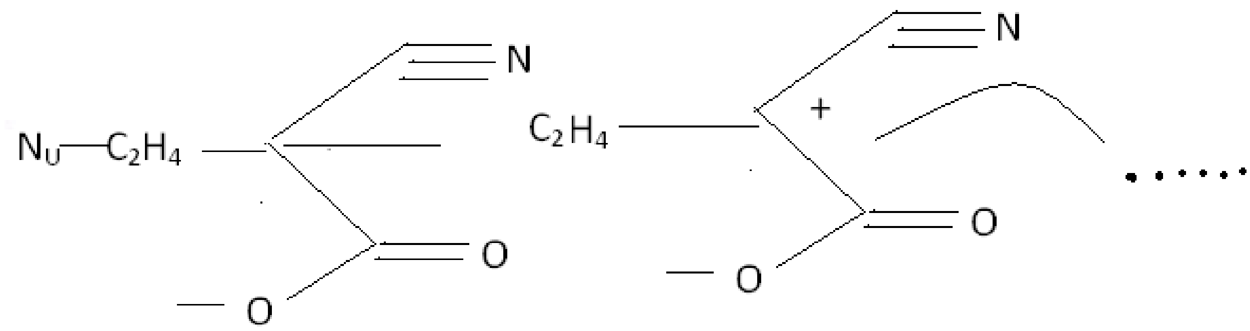
Explanation:

It is found that properties of a specimen is increased when we used loctite 406. Reason can be explained as follows-

mechanism of the reaction :

Mechanism of the reaction that is taking place between loctite 406 and ZP R 130 is –





nucleophile coming from ZP powder induces ethyl 2cyano acrylate and forms reasonating structure as shown above . In this way they form a long chain like structure which is much strong and stable.

Because of this reason specimen with loctite 406 are having more hardness and strength than that prepared only with ZP powder.

7. CONCLUSION

Products built by process of 3D printing can be later used in different processes for creation of new parts. As example, by 3D printing we can produce models out of powder material and binder that given by Zcorporation. This technique can be used for creation of any type of complex shape directly from the CAD model. When specimen is prepared with the built direction (30 degree angle), it will give better result. Again, specimen prepared with addition of Loctite 406 are having better hardness and strength. Thereby we can extend the area of application of rapid prototype.

8. REFERENCES

1.Castle Island Co. *Three Dimensional printing* [online]. 10.march.2007. [cited 12.february.2008]. availablefrom world wide web: http://home.att.net/~castleisland/3dp
_int.htm

2 ZCORP, *ZPrinter 310 Plus* [online]. [cited 12.february. 2008], available from world wide web: <http: //www.zcorp.com>

3 ZCORP, *Zprinter 310 hardware manual* [hard copy], [cited 12.february.2008], rev.C, September 2003, pages 5-21.

4 http://www.zcorp.com. Accessed 29.04.2006

5 Inzenjerski prirucnik IPI, Skolska knjiga, Zagreb, 1996