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# Study and investigation of influence of process parameter for selective laser melting

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***Abstract* - Additive manufacturing process of joining materials to make object 3D model data, usually layer upon layer, as opposed to subtractive manufacturing technologies. There are so many challenges in the AM process like process control, surface finish, tolerance, validation .Selective laser melting process starts by numerically slicing 3D CAD model in to number of finite layers. The process of selective laser melting involves the moving of a laser beam across a powder bed to melt material type layer by layer, from the stand point of modeling. This process is complicated as it is characterized by high temperature gradients caused in non equilibrium, conditions during solidification. This causes various effects on microstructure features properties, dimensional accuracy, and surface finish. The material properties such as yield strength, elongation, ductility are highly affected by the microstructure features. Additives manufacturing process are extensively used in automotive, aero space, bio medical, industries. For selecting laser melting process is most significant joining process in the automobile industries due to high speed and suitable for complex geometries. Strength, hardness and micro structure and surface finish of AM parts are focus of the researchers since last two decades. To get better components that can be used as full functional parts with better process control with full density with various types conventional and new developed materials is the need of modern age. The purpose of this research work to achieve a better understanding of laser based additive manufacturing with the help of taguchi analysis.**

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## I. INTRODUCTION

AM technologies build near-net shape components layer by layer using 3D model data. AM technologies are the direct descendents of the work in 3D printing and could revolutionize many sectors of U.S. manufacturing by reducing component lead time, cost, material waste, energy usage, and carbon footprint. Furthermore, AM has the potential to enable novel product designs that could not be fabricated using conventional subtractive processes and extend the life of in-service parts through innovative repair methodologies.

AM has grown up organically from the early days of rapid prototyping, and as a dynamic field of study has acquired a great deal of related and redundant terminology. The ASTM F 42committee was recently formed to standardize AM terminology. According to their first standard, ASTM F2792-10, AM is defined as

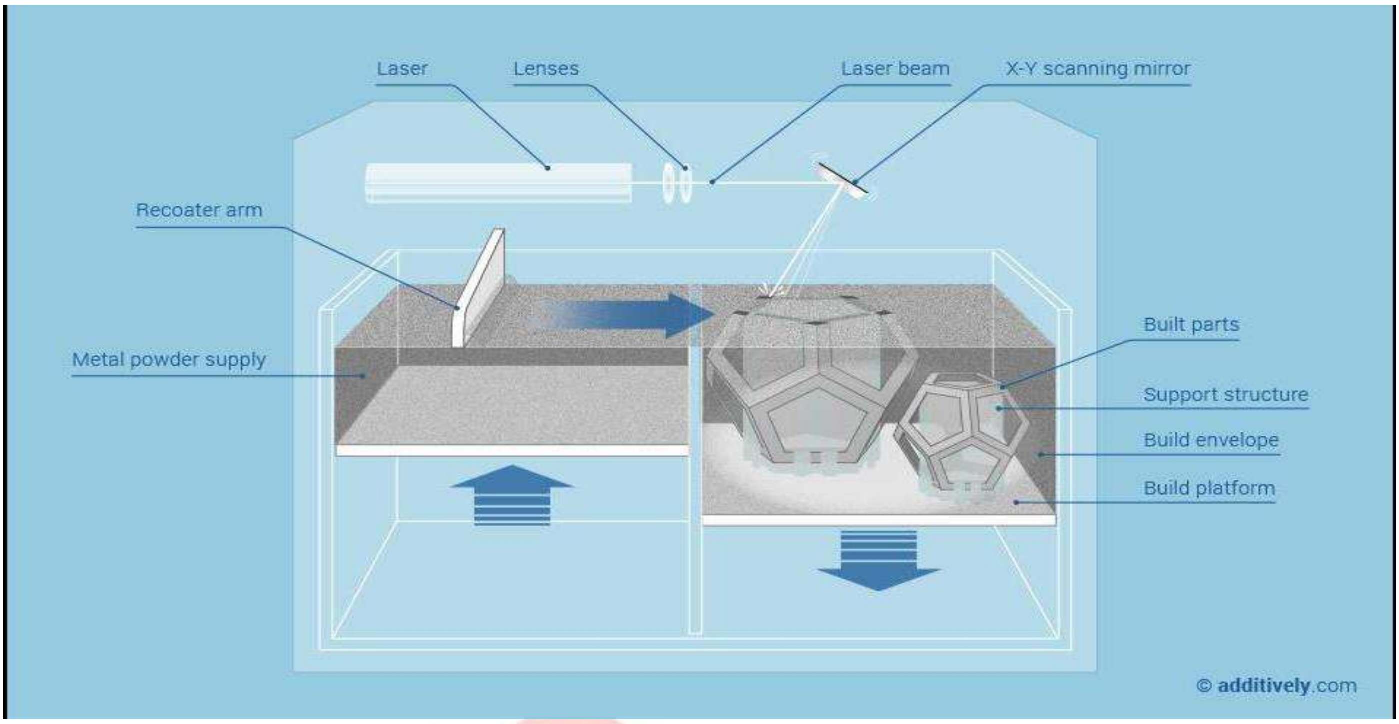
*“The process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing technologies.”*

There are many related terms used to describe AM and common synonyms include: additive fabrication, additive processes, additive techniques, additive layer manufacturing, layer manufacturing, and freeform fabrication.

***Basic process of SLM process***

The additive manufacturing technology Selective Laser Melting makes it possibility to manufacture metal components layer by layer according to a 3D-CAD volume model. Thereby, SLM enables the production of nearly unlimited complex geometries without the need of part specific tooling or preproduction costs .Figure 1 illustrates the principle of the SLM process and the steps the process can divided into. First, the 3D-CAD volume model is broken down into layers and transferred to the Selective Laser Melting machine. Subsequently, the powder material (grain fraction 10–45µm) is deposited as a defined thin layer on a substrate. The geometric information of the individual layers is transmitted by laser beam to the powder bed wherein the regions to contain solid material are scanned under an inert atmosphere, leaving a solid layer of the piece to be produced. After lowering the substrate by one layer thickness, the process steps are repeated until the part is finished. Since standard metallic powders are used, which melt completely, the part has a density of approximately 100 %, thus assuring mechanical properties that match or even beat those of conventionally manufactured parts (cutting, casting).

Selective Laser Melting enables the production of individual parts with complex geometries matching the mechanical properties of parts conventionally manufactured in series (for example cast). Furthermore, SLM does not need part-specific tooling and preproduction costs when processing series identical materials like steels, aluminium-, titanium- and nickel-based alloys. Since it completely melts the powder material, SLM enables a density of approximately 100 %, Which, in turn, assures series-identical properties?




**Fig(1).basic process of SLM process**

**SELECTED PROCESS PARAMETERS:**

- Thickness of layer(30µm ,50µm, 70µm)
- Verify orientation (0˚,45˚,90˚)
- Power(110w,120w,130w)
- Speed(590m/s,600m/s,610m/s)

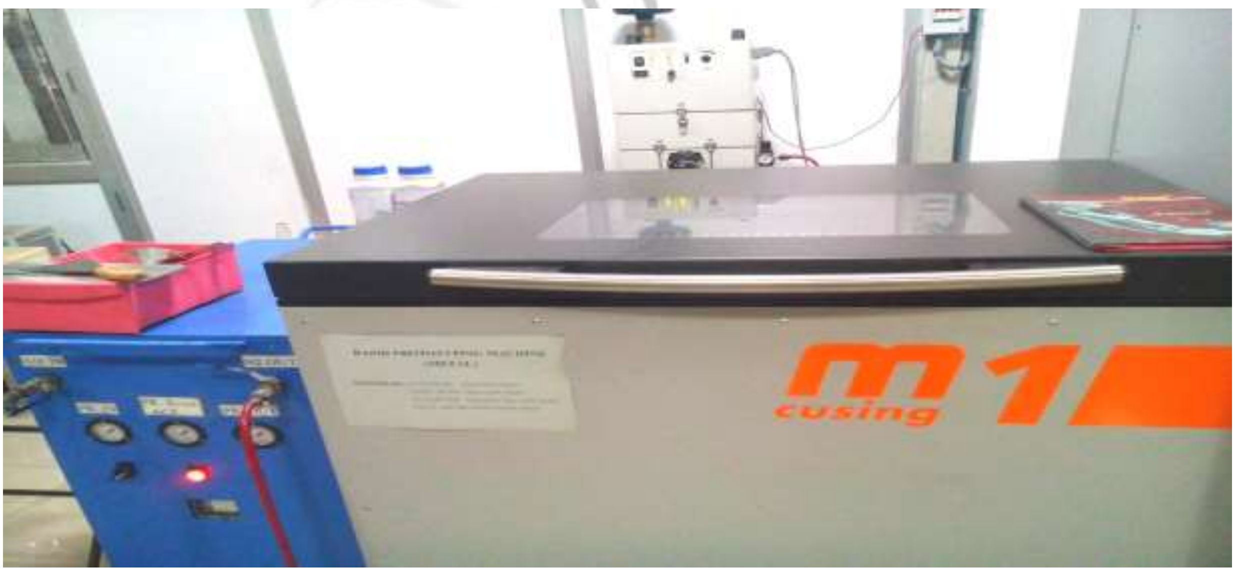
**MATERIAL SELECTION**

CL 50WS is a powder material for the production of components for tool inserts with conformal cooling. These tool inserts can be used for series injection moulding as well as for die-casting. Furthermore the material can also be used for functional components.

CL 50WS is also called Hot-work steel

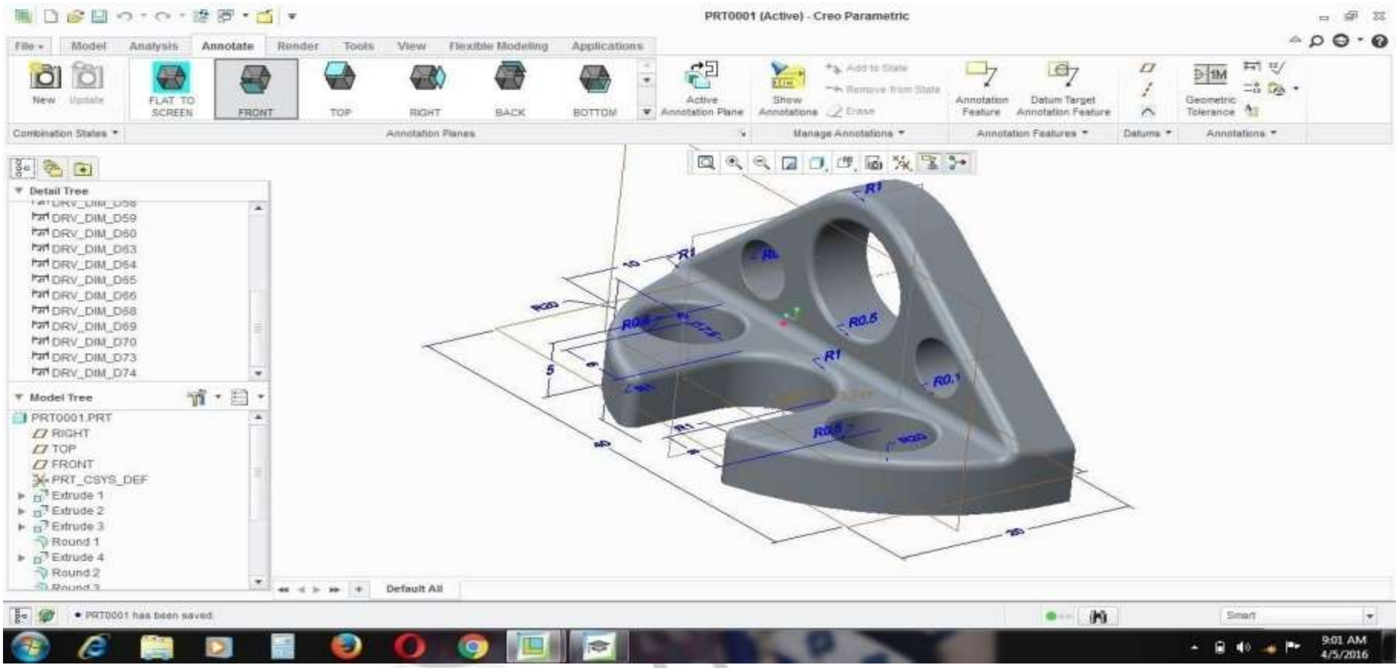
**EXPERIMENTATION**

According to the DOE (TAGUCHI APPROCHES) orthogonal L9 the experimental to be work carried out at INDO GERMAN TOOL ROOM AHEMDABAD on concept laser M1 machine for selected material CL 50 WS . After experimentation the effect of process parameters will be investigated on output parameters like surface roughness, porosity, microstructure, and strength.




**Fig(2)M1 cusing machine**

**Fig(3) selected part made by creo software**



**Fig(4)part made by using creo software**

**TESTING:**

- Microstructure
- Hardness
- Surface roughness

**HARDNESS AND SURFACE ROUGHNESS:**

**(1) What is Hardness?**

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting.

**The basic of Rockwell hardness test:**

Simply put, the Rockwell hardness test is a method of measuring the hardness of materials.

The Rockwell hardness scale is typically administered to characterize the hardness of metals, such as thin steel, cemented carbides, lead,aluminium ,zinc, copper alloys, titanium and iron:

So here we take a hardness testing of our nine experimental samples by Rockwell hardness test. now hardness test value put on table and Rockwell hardness test of nine pieces measured by saroj M.T instrument at available in Rajkot.

.

**(2) what is surface roughness**?

surface roughness often shortened to roughness, is a component of surface texture. It is quantified by the deviations in the direction of the normal of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. Roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface roughness. However, in practice it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for a purpose.

Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces roughness. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. On the other hand, roughness may promote adhesion. Now surface roughness value put in table (11).and **surface roughness test of nine pieces measured by minitoyo sd-400 instrument at available in Rajkot.**

(1) Value of hardness and surface roughness in table:

| no of pieces | thickness of layer(μm) | Orientation(°) | Power(w) | Speed(m/s) | Hardness(HRC) | surface roughness(Ra) |
|---|---|---|---|---|---|---|
| **1** | **30** | **0** | **110** | **590** | 30 | **0.09** |
| **2** | **30** | **45** | **120** | **600** | 31 | **0.08** |
| **3** | **30** | **90** | **130** | **610** | 27 | **0.08** |
| **4** | **50** | **0** | **120** | **610** | 25 | **0.08** |
| **5** | **50** | **45** | **130** | **590** | 30 | **0.08** |
| **6** | **50** | **90** | **110** | **600** | 24 | **0.12** |
| **7** | **70** | **0** | **130** | **600** | 3 | **0.19** |
| **8** | **70** | **45** | **110** | **610** | 13 | **0.08** |
| **9** | **70** | **90** | **120** | **590** | 18 | **0.39** |

## II. MICROSTRUCTURE

When describing the structure of a material, we make a clear distinction between its crystal structure and its microstructure. The term 'crystal structure' is used to describe the average positions of atoms within the unit cell, and is completely specified by the lattice type and the fractional coordinates of the atoms (as determined, for example, by X-ray diffraction). In other words, the crystal structure describes the appearance of the material on an atomic (or Å) length scale. The term 'microstructure' is used to describe the appearance of the material on the nm-cm length scale. A reasonable working definition of microstructure is:

"The arrangement of phases and defects within a material."

**HERE THE SOME REPORT OF MICROSTRUCTURE**

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**TEST REPORT**

| | | | |
|---|---|---|---|
| Customer Name : | MAYURBHAI | Test Report No. | : QMB-0558.1 |
| Address : | Morbi, Gujrat. | Date of Reporting | : 10-09-16 |
| | | Sample Received Date | : 10-09-16 |

| | |
|---|---|
| Type of Test | : Microstructure examination |
| *Customer's Reference | : NIL |
| *Condition of sample | : Test Piece |
| *Identification of sample | : Sample 1 |
| *Material Specification | : CL50WS |
| Date of Testing | : 10-09-16 |
| Instrument Utilized | : Optical Microscope Model: NIM-1000X |
| Test Method | : ASTM E407-2007, ASM Vol. 9-2004 (Metallography and Microstructures) |

Result :

100X

Microstructure : The Microstructure consist of numerous particles boundaries and Voids.

Magnification : 100X
Etchant : 2% Nital
Remarks: --

Tested By — Authorized Signature — Witnessed By
P. D. Rathod (T.M.) / K. K. Sindhav (Q.M.)

*** End of Report ***

Sample 1

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|---|---|---|---|
| Customer Name : | MAYURBHAI | Test Report No. | : QMB-0559.1 |
| Address : | Morbi, Gujrat. | Date of Reporting | : 10-09-16 |
| | | Sample Received Date | : 10-09-16 |

| | |
|---|---|
| Type of Test | : Microstructure examination |
| *Customer's Reference | : NIL |
| *Condition of sample | : Test Piece |
| *Identification of sample | : Sample 2 |
| *Material Specification | : CL50WS |
| Date of Testing | : 10-09-16 |
| Instrument Utilized | : Optical Microscope Model: NIM-1000X |
| Test Method | : ASTM E407-2007, ASM Vol. 9-2004 (Metallography and Microstructures) |

Result :

100X

Microstructure : The Microstructure consist of numerous particles boundaries and Voids.

Magnification : 100X
Etchant : 2% Nital
Remarks: --

Tested By — Authorized Signature — Witnessed By
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Sample 2

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| | | | |
|---|---|---|---|
| Customer Name : | MAYURBHAI | Test Report No. | : QMB-0561.1 |
| Address | : Morbi, Gujrat. | Date of Reporting | : 10-09-16 |
| | | Sample Received Date | : 10-09-16 |

| | |
|---|---|
| Type of Test | : Microstructure examination |
| *Customer's Reference | : NIL |
| *Condition of sample | : Test Piece |
| *Identification of sample | : Sample 4 |
| *Material Specification | : CL50WS |
| Date of Testing | : 10-09-16 |
| Instrument Utilized | : Optical Microscope Model: NIM-1000X |
| Test Method | : ASTM E407-2007, ASM Vol. 9-2004 (Metallography and Microstructures) |

Result :

100X

Microstructure : The Microstructure consist of numerous particles boundaries and angular pores.

Magnification : 100X

Etchant : 2% Nital

Remarks: --

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Authorized Signature

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Sample 3

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|---|---|---|---|
| Customer Name : | MAYURBHAI | Test Report No. | : QMB-0560.1 |
| Address | : Morbi, Gujrat. | Date of Reporting | : 10-09-16 |
| | | Sample Received Date | : 10-09-16 |

| | |
|---|---|
| Type of Test | : Microstructure examination |
| *Customer's Reference | : NIL |
| *Condition of sample | : Test Piece |
| *Identification of sample | : Sample 3 |
| *Material Specification | : CL50WS |
| Date of Testing | : 10-09-16 |
| Instrument Utilized | : Optical Microscope Model: NIM-1000X |
| Test Method | : ASTM E407-2007, ASM Vol. 9-2004 (Metallography and Microstructures) |

Result :

100X

Microstructure : The Microstructure consist of numerous particles boundaries and Voids.

Magnification : 100X

Etchant : 2% Nital

Remarks: --

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sample 4

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| | |
|---|---|
| Customer Name : MAYURBHAI | Test Report No. : QMB-0563.1 |
| Address : Morbi, Gujrat. | Date of Reporting : 10-09-16 |
| | Sample Received Date : 10-09-16 |

Type of Test : Microstructure examination
*Customer's Reference : NIL
*Condition of sample : Test Piece
*Identification of sample : Sample 6
*Material Specification : CL50WS
Date of Testing : 10-09-16
Instrument Utilized : Optical Microscope Model: NIM-1000X
Test Method : ASTM E407-2007, ASM Vol. 9-2004 (Metallography and Microstructures)

Result :

100X

Microstructure : The Microstructure consist of numerous particles boundaries and angular pores.

Magnification : 100X
Etchant : 2% Nital
Remarks: –

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Sample 5

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| | |
|---|---|
| Customer Name : MAYURBHAI | Test Report No. : QMB-0562.1 |
| Address : Morbi, Gujrat. | Date of Reporting : 10-09-16 |
| | Sample Received Date : 10-09-16 |

Type of Test : Microstructure examination
*Customer's Reference : NIL
*Condition of sample : Test Piece
*Identification of sample : Sample 5
*Material Specification : CL50WS
Date of Testing : 10-09-16
Instrument Utilized : Optical Microscope Model: NIM-1000X
Test Method : ASTM E407-2007, ASM Vol. 9-2004 (Metallography and Microstructures)

Result :

100X

Microstructure : The Microstructure consist of numerous particles boundaries and angular pores.

Magnification : 100X
Etchant : 2% Nital
Remarks: –

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sample 6

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| Address : Morbi, Gujrat. | Date of Reporting : 10-09-16 |
| | Sample Received Date : 10-09-16 |

| | |
|---|---|
| Type of Test | : Microstructure examination |
| *Customer's Reference | : NIL |
| *Condition of sample | : Test Piece |
| *Identification of sample | : Sample 8 |
| *Material Specification | : CL50WS |
| Date of Testing | : 10-09-16 |
| Instrument Utilized | : Optical Microscope Model: NIM-1000X |
| Test Method | : ASTM E407-2007, ASM Vol. 9-2004 (Metallography and Microstructures) |

Result :

100X

Microstructure : The Microstructure consist of numerous particles boundaries and angular pores.

Magnification : 100X

Etchant : 2% Nital

Remarks: –

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Sample 7

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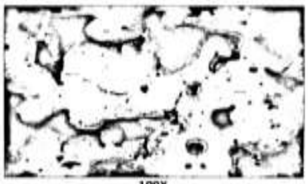
| | |
|---|---|
| Customer Name : MAYURBHAI | Test Report No. : QMB-0564.1 |
| Address : Morbi, Gujrat. | Date of Reporting : 10-09-16 |
| | Sample Received Date : 10-09-16 |

| | |
|---|---|
| Type of Test | : Microstructure examination |
| *Customer's Reference | : NIL |
| *Condition of sample | : Test Piece |
| *Identification of sample | : Sample 7 |
| *Material Specification | : CL50WS |
| Date of Testing | : 10-09-16 |
| Instrument Utilized | : Optical Microscope Model: NIM-1000X |
| Test Method | : ASTM E407-2007, ASM Vol. 9-2004 (Metallography and Microstructures) |

Result :



100X

Microstructure : The Microstructure consist of numerous particles boundaries and angular pores.

Magnification : 100X

Etchant : 2% Nital

Remarks: –

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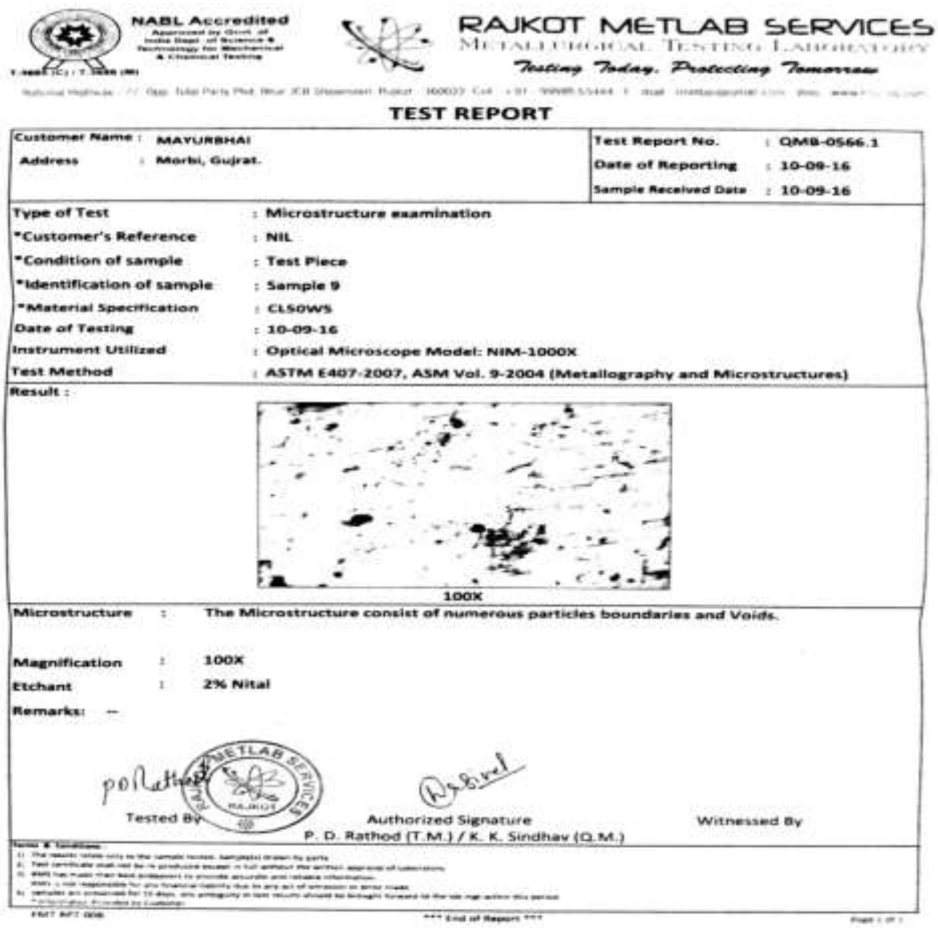
*** End of Report ***

sample 8



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TEST REPORT

| | | | |
|---|---|---|---|
| Customer Name : | MAYURBHAI | Test Report No. | : QMB-0566.1 |
| Address : | Morbi, Gujrat. | Date of Reporting | : 10-09-16 |
| | | Sample Received Date | : 10-09-16 |

| | |
|---|---|
| Type of Test | : Microstructure examination |
| *Customer's Reference | : NIL |
| *Condition of sample | : Test Piece |
| *Identification of sample | : Sample 9 |
| *Material Specification | : CLSOWS |
| Date of Testing | : 10-09-16 |
| Instrument Utilized | : Optical Microscope Model: NIM-1000X |
| Test Method | : ASTM E407-2007, ASM Vol. 9-2004 (Metallography and Microstructures) |

Result :

100X

Microstructure : The Microstructure consist of numerous particles boundaries and Voids.

Magnification : 100X

Etchant : 2% Nital

Remarks: --

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Sample 9

**TAGUCHI ANALYSIS:**

**Taguchi Analysis: surface roughness (Ra) versus thickness, orientation, power, speed**

Response Table for Signal to Noise Ratios

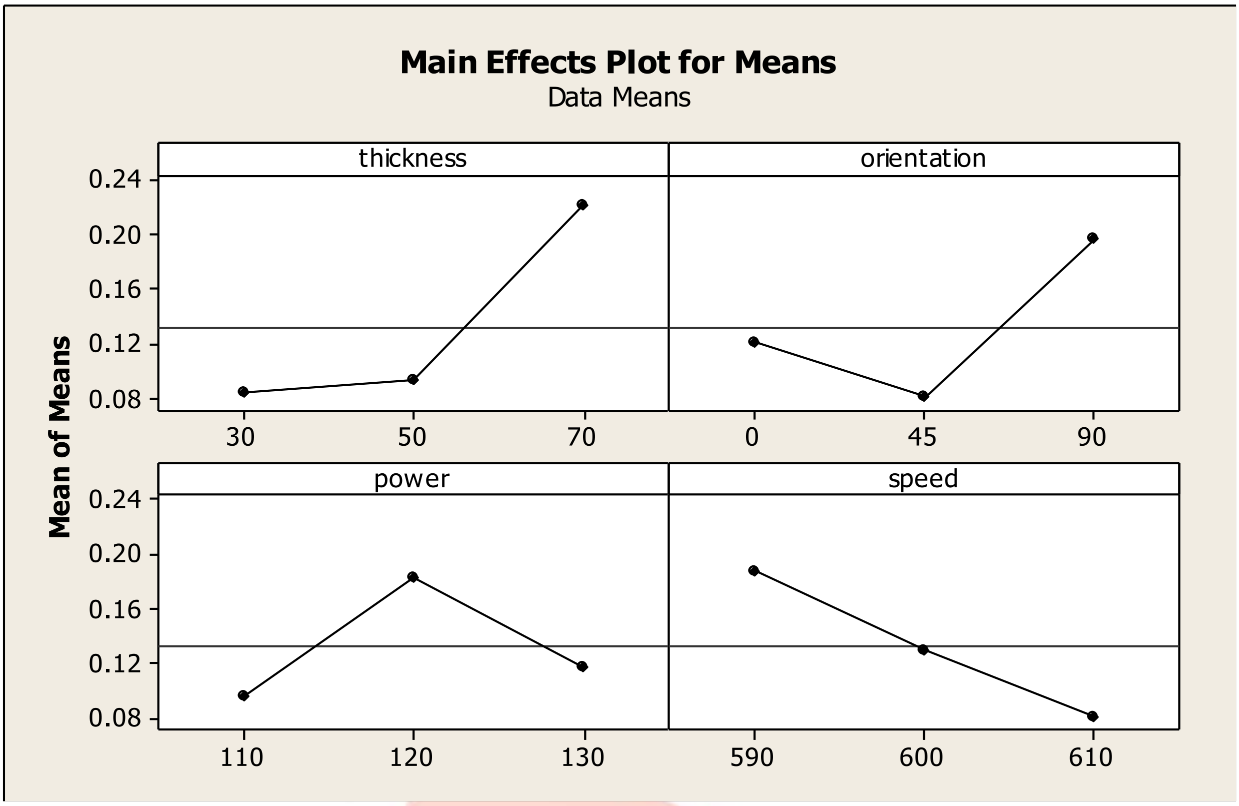
Larger is better

| Level | thickness | orientation | power | speed |
|---|---|---|---|---|
| 1 | -21.60 | -19.09 | -20.42 | -17.01 |
| 2 | -20.76 | -21.94 | -17.35 | -18.26 |
| 3 | -14.85 | -16.18 | -19.43 | -21.94 |
| Delta | 6.75 | 5.76 | 3.07 | 4.93 |
| Rank | 1 | 2 | 4 | 3 |

Response Table for Means

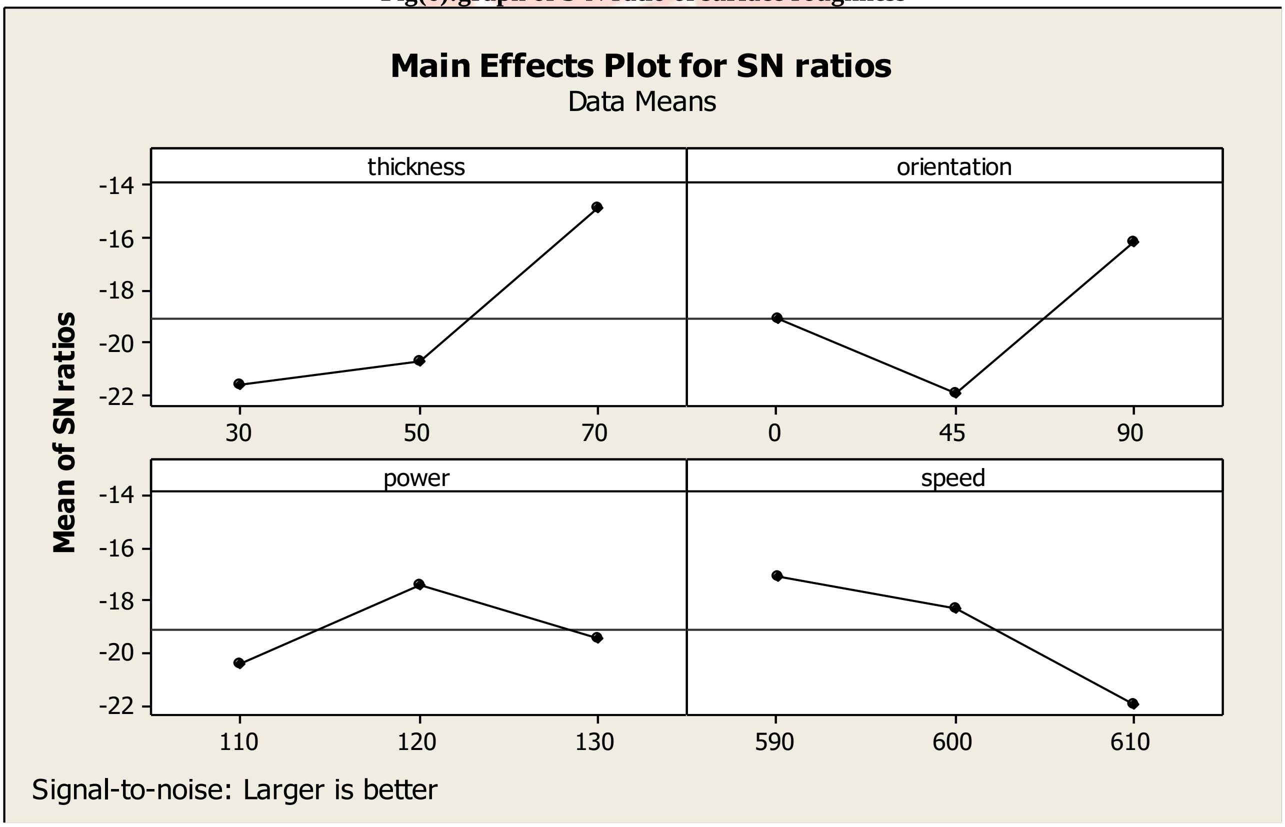
| Level | thickness | orientation | power | speed |
|---|---|---|---|---|
| 1 | 0.08333 | 0.12000 | 0.09667 | 0.18667 |
| 2 | 0.09333 | 0.08000 | 0.18333 | 0.13000 |
| 3 | 0.22000 | 0.19667 | 0.11667 | 0.08000 |
| Delta | 0.13667 | 0.11667 | 0.08667 | 0.10667 |
| Rank | 1 | 2 | 4 | 3 |

Conclusion: Here input parameter thickness is more affected than other parameter like orientation, power, speed




**Fig(5):graph of means value of suface roughness versus thickness,orientation,power,speed**

**Fig(6):graph of S-N ratio of surface roughness**




**Taguchi Analysis: hardness(HRC) versus thickness, orientation, power, speed**

Response Table for Signal to Noise Ratios
Larger is better
Level thickness orientation power speed

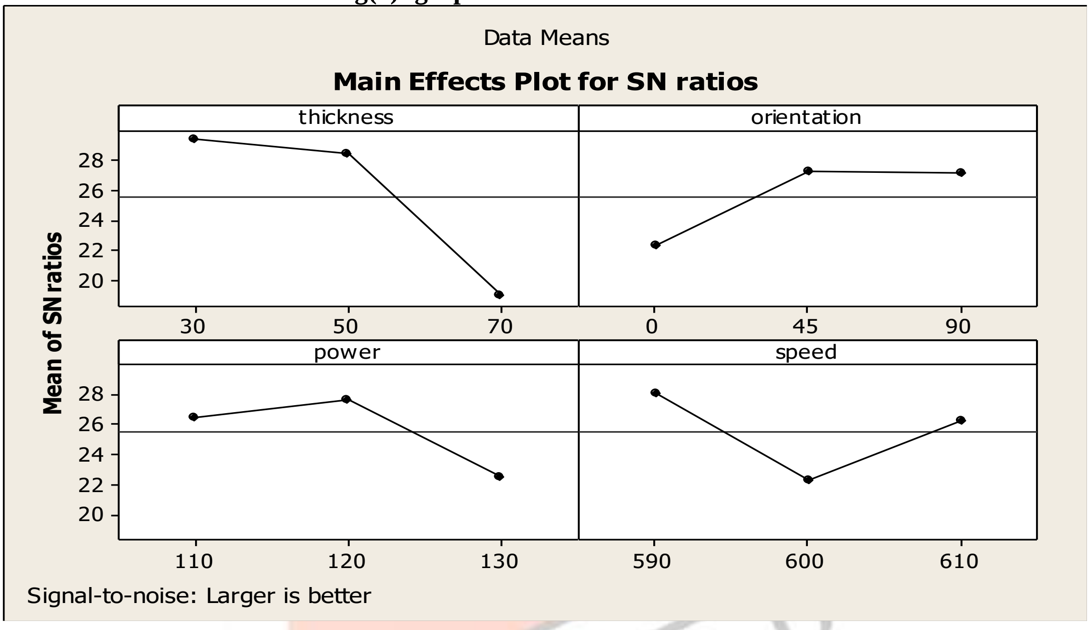
| | | | | |
|---|---|---|---|---|
| 1 | 29.33 | 22.35 | 26.48 | 28.06 |
| 2 | 28.37 | 27.22 | 27.63 | 22.32 |
| 3 | 18.98 | 27.11 | 22.57 | 26.29 |
| Delta | 10.36 | 4.87 | 5.06 | 5.74 |
| Rank | 1 | 4 | 3 | 2 |

Response Table for Means

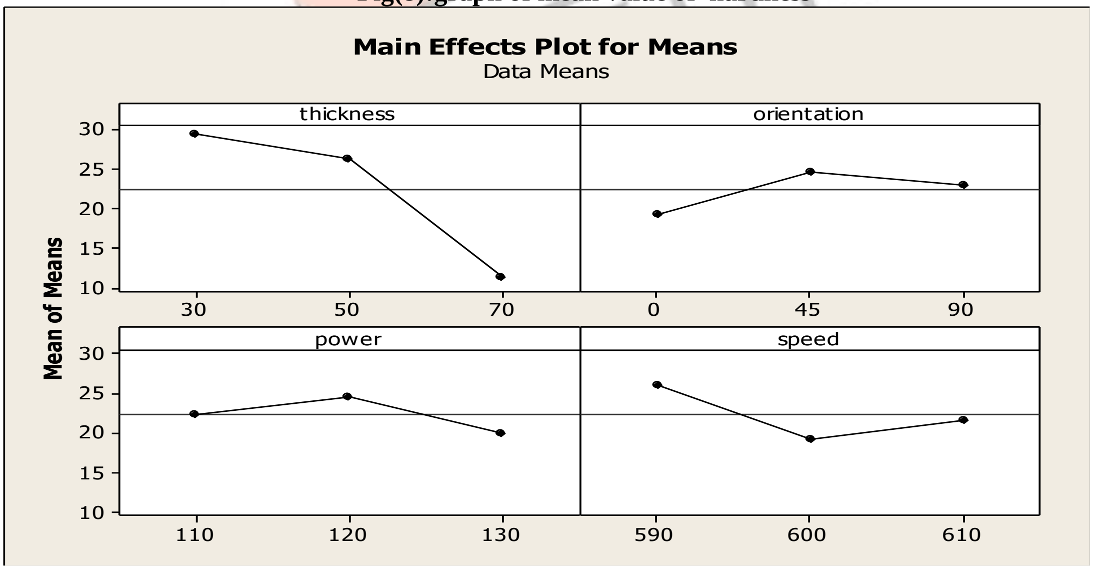
| Level | thickness | orientation | power | speed |
|---|---|---|---|---|
| 1 | 29.33 | 19.33 | 22.33 | 26.00 |
| 2 | 26.33 | 24.67 | 24.67 | 19.33 |
| 3 | 11.33 | 23.00 | 20.00 | 21.67 |
| Delta | 18.00 | 5.33 | 4.67 | 6.67 |
| Rank | 1 | 3 | 4 | 2 |

Conclusion: Here also input parameter thickness is more affected than other parameter like orientation, power, speed

**Fig(7): graph of S-N ratio of hardness**




**Fig(8):graph of mean value of hardness**




## III. Conclusion And Result

From experimental result it is clear that various experimental sample have various output parameters like hardness, microstrucutre and surface roughness

From taguchi approaches and analysis based on s-n ratio and mean value it is suggested that output process parameter like thickness of layer is more effective parameters than other process parameters like orientation,power,and speed

Here taguchi analysis and S-N ratio graph suggest that it gives a better result
The value of thickness is 30µm , orientation result is 45˚, power is 120w and last parameter speed is 590m/s.
To get better components that can be used as full functional parts with better process control with full density with various types conventional and new developed materials is the need of modern age.
The proposed research can be useful for obtaining components with better properties that can be used as full functional parts and that can challenge the conventional manufacturing processes.

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