ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Experimental Investigations on Prototypes Produced From Selective Laser Sintering

V Sandeepa
Assistant Professor
Geethanjali College of Engineering and Technology.

Kola Praveen
Assistant Professor
Geethanjali College of Engineering and Technology.

ABSTRACT

To increase productivity, industry has attempted to apply more computerized automation in manufacturing. Amongst the various technologies to take the industry by storm is rapid prototyping technology. RP technologies provide that bridge from product conceptualization to product realization in a reasonably fast manner, without the fuss of NC programming, jigs and fixtures. Rapid Prototyping (RP) can be defined as a group of techniques used to quickly fabricate a part or assembly using three-dimensional computer aided design (CAD) data. RP includes various technologies out of which selective laser sintering technology is prominent because SLS allows the production of fully functional prototypes with high mechanical and thermal resistance, strength & rigidity under the extreme conditions of high temperature. Durable metal parts, mold inserts, direct Low density complex investment casting patterns can be prepared directly from CAD data.

In this project, procedure for data preparation is presented and a total of six different models are created varying the orientation and job parameters. The prototypes which are then produced using SLS RP System are examined for various mechanical properties such as Tensile strength, Compressive strength, Young‘s modulus, deflection at maximum elongation using UTM and the microstructures of the prototypes are examined with the aid of Scanning electron Microscope (SEM) do determine the density, porosity and binding mechanism of the powder particles and its effect on strength and surface roughness is exposed. Surface roughness measurement, Vickers hardness and shore D hardness of the laser sintered polyamide are obtained. The effect of laser speed and orientation of part on building time is investigated. The orange peel effect, delamination, effect of foreign particles are also discussed along with optimum part orientation to reduce the errors.

INTRODUCTION

1.1. Rapid Prototyping

Rapid Prototyping (RP) can be defined as a group of techniques used to quickly fabricate a scale model of a part or assembly using three-dimensional computer aided design (CAD) data. What is commonly considered to be the first RP technique, Stereolithography, was developed by 3D Systems of Valencia, CA, USA. The company was founded in 1986, and since then, a number of different RP techniques have become available.

1.3. Methodology of Rapid Prototyping

The basic methodology for all current rapid prototyping techniques can be summarized as follows:

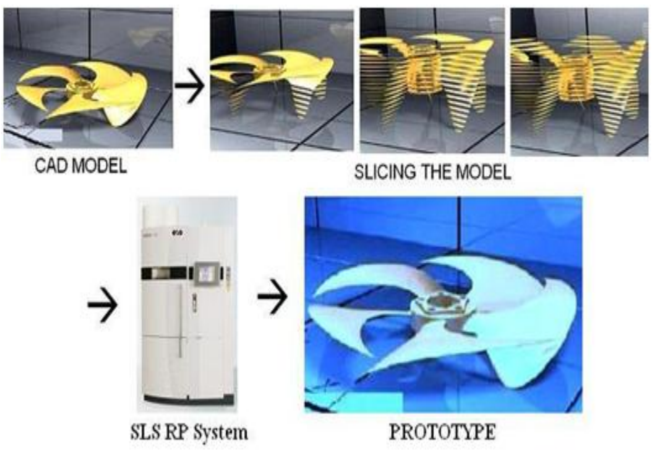

Fig 1.1: Methodology of Rapid Prototyping

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

1.4. Advantages of Selective Laser Sintering:

- Any powder which can be sintered or will bond without melting can be used.
- Materials are non-toxic.
- It does not usually require support structures.
- The accuracy is in the range of +-0.05-0.25mm.
- It has fairly good speed, for example a piece 305x380 mm can be cast at 12-25mm per hour.
- The finished parts are in some cases functional and testable prototypes as well as conceptual models.
- Wax models can be built in a few hours and used to make functional prototypes by investment casting.
- Fully automatic process.

1.5. Disadvantages of Selective Laser Sintering:

- Large flat sheets need tie-down supports to stop curling.
- Part accuracy depends on size and complexity.
- The surface finish is rough compared to SLA, the article is porous and hence of poor mechanical strength.
- The equipment is expensive.
- Cavities are difficult to clean since the powder tends to cling and bead blasting is difficult in confined regions.

LITERATURE REVIEW

W.A.Y Yusoff, A.J Thomas [1] reports on an experimental study into the effects of using recycled Polyamide 12 (PA12) powder on the manufacture of a Selective Laser Sintered (SLS) part. It was found that through using recycled PA12 material, a poor and unacceptable surface finish was achieved.

Frank Niebling [2], reports Laser sintering of metal parts is a quite new process for the production of metallic parts. The main application field of this process is Rapid Prototyping, Rapid Tooling and Rapid Manufacturing.

Y.F. Shen, D.D. Gu and Y.F. Pan [3] reported Balling process in selective laser sintering of steel powder was investigated. It showed that the balling phenomenon was ascribed to the higher liquid viscosity and surface tension effect during laser sintering.

Kandis. M., Buckley. C.W., and Bergman T. L. [4] reported Laser-induced sintering of powders has become prevalent in a number of Solid Freeform Fabrication technologies such as Selective Laser Sintering (SLS), which is used to produce nearly solid parts from initially-porous powder via laser irradiation.

RAPID PROTOTYPING TECHNOLOGIES

3.1. Stereolithography

The implementation shown is used by 3D Systems and some foreign manufacturers. A moveable table, or elevator (A), initially is placed at a position just below the surface of a vat (B) filled with liquid photopolymer resin (C). This material has the property that when light of the correct color strikes it, it turns from a liquid to a solid. The most common photopolymer materials used require an ultraviolet light, but resins that work with visible light are also utilized. The system is sealed to prevent the escape of fumes from the resin.

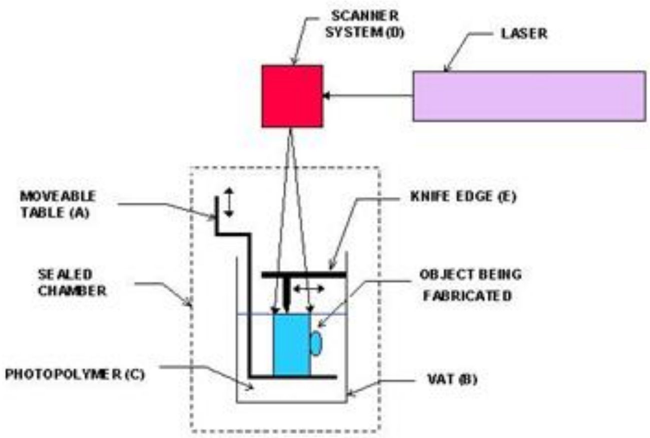

Fig 3.1: Stereolithography

After the layer is completely traced and for the most part hardened by the beam, the table is lowered into the vat a distance equal to the thickness of a layer. The

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

resin is generally quite viscous, however. To speed this process of recoating, early stereolithography systems drew a knife edge (E) over the surface to smooth it. More recently pump-driven recoating systems have been utilized. The tracing and recoating steps are repeated until the object is completely fabricated and sits on the table within the vat.

3.2. Laminated Object Manufacturing

Profiles of object cross sections are cut from paper using a CO2 laser as shown in Fig. 3.2. The paper is unwound from a feed roll (A) onto the stack and bonded to the previous layer using a heated roller (B). The roller melts a plastic coating on the bottom side of the paper to create the bond. The profiles are traced by an optics system that is mounted to an X-Y stage (C). The process generates considerable smoke. Either a chimney or a charcoal filtration system is required (E) and the build chamber must be sealed.

3D CAD MODELING

Computer-aided design (CAD) is the use of computer technology for the design of objects, real or virtual. The design of geometric models for object shapes, in particular, is often called computer-aided geometric design (CAGD). However CAD often involves more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD often must convey also symbolic information such as materials, processes, dimensions, and tolerances, according to application-specific conventions. CAD may be used to design curves and figures in two-dimensional ("2D") space; or curves, surfaces, or solids in three-dimensional ("3D") objects.

4.1. Case study – Universal Coupling

A universal joint, U joint, Cardan joint, Hardy-Spicer joint, or Hooke's joint is a joint in a rigid rod that allows the rod to 'bend' in any direction, and is commonly used in shafts that transmit rotary motion. It consists of a pair of hinges located close together, oriented at 90° to each other, connected by a cross shaft.

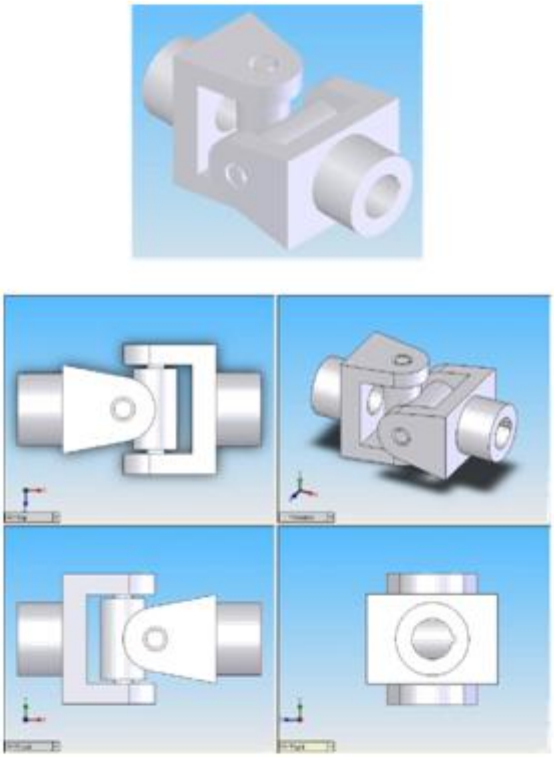

Fig 4.4: CAD Modeling of Universal coupling

PROCEDURE OF DATA PREPARATION

5.1. Introduction to data preparation

Good data preparation is a prerequisite for the correct function of the building process. Poor data or data errors can cause a job to crash or result in poor parts quality. The following schematic diagram shows the basic sequence for data preparation.

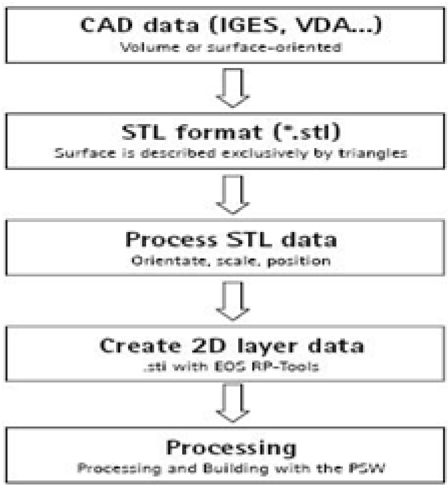

Fig 5.1: Sequence for Data preparation

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

5.2. Overview of Magics RP

Magics RP software can import most standard 3D formats - STL, VDA, IGES, STEP, VRML - and native CAD formats like UG/Parasolid and Catia. Growing numbers of customers also work with scanned data. To meet their needs, Magics offers the import and export of point clouds. The imported files are converted to a dig-ital CAD structure according to user defined accuracy.

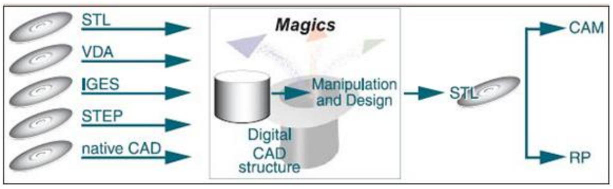

Fig 5.2: Overview of Magics – RP.

5.2.2. Preparing the part

The part designed must first be aligned and positioned in an RP software package, e.g. Magics RP. There are some special aspects that must be taken into account for the laser sintering process.

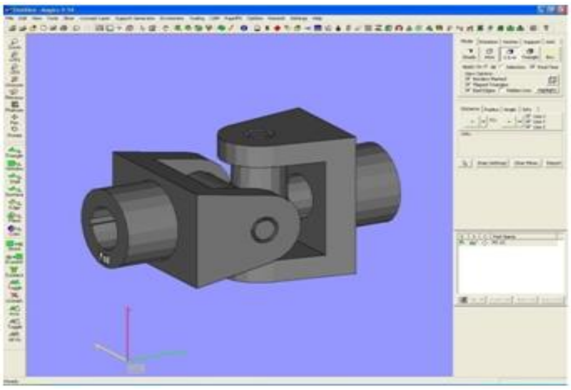

Fig 5.7: STL file loaded at an orientation of 00 in Magics RP

S.No	Job Parameter	Nomenclature	Orientation
1	Mechanic	M1	0^0
2	Mechanic	M2	45^0
3	Mechanic	M3	90^0
4	Sorted	S1	0^0
5	Sorted	S2	45^0
6	Sorted	S3	90^0

Table 1: Nomenclature for job parameters and orientations

5.2.3. Positioning

The parts should be position in the middle of the building area as far as possible. It is possible to utilize the complete building area of 200 x 250 mm and a building height of 330 mm. However, here it must be noted that the temperature distribution over the building area is not exactly the same. As rule the temperature profile starting from the middle has a circular shape with the highest temperature in the middle and the lowest temperature in the corners. The closer the parts are positioned to the edge of the building area, the greater the risk that parts could be torn out or that parts could be deformed. The distance between the parts should be at least 5 mm. The parts must be positioned at a Z position of at least 6 mm. At least 6 mm must be applied to the parts in layers before they start, otherwise the parts can start to curl or deform. After aligning, positioning and scaling the parts, they should be saved with a new name.

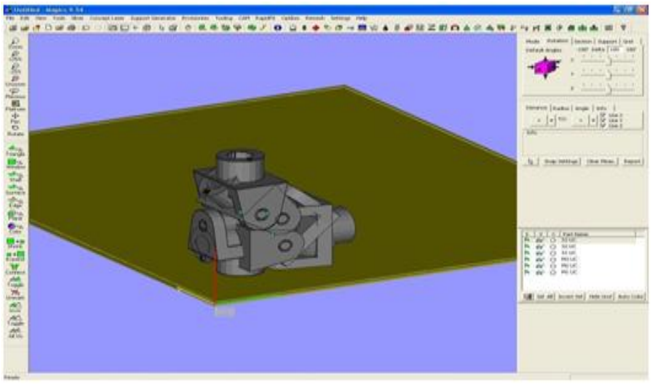

Fig 5.11: STL files imported into Magics-RP

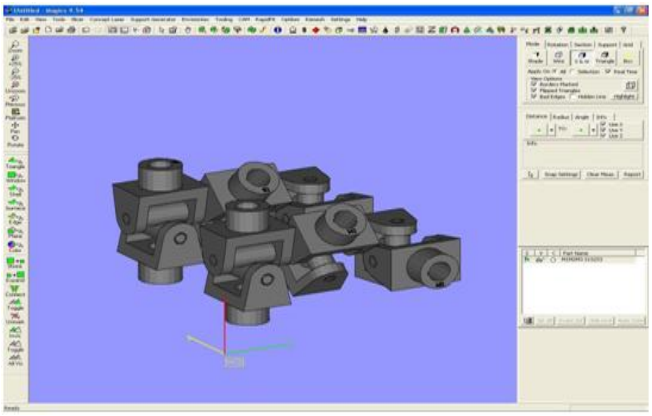

Fig 5.16: Position of parts on work bed after Rotation

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

SLS – RP SYSTEM

6.1. Introduction

FORMIGA P 100 - small, fast, efficient, e-Manufacturing in the Compact Class Plastic laser-sintering system for the direct manufacture of series, spare parts and functional prototypes The FORMIGA P 100 represents laser-sintering in the compact class. With a build envelope of 200 mm x 250 mm x 330 mm, the FORMIGA P 100 produces plastic products from polyamide or polystyrene within a few hours and directly from CAD data. The machine is ideally suited for the economic production of small series and individualized products with complex geometry – requirements which apply among others to the medical device industry as well as for high-value consumer goods. At the same time, it provides capacity for the quick and flexible production of fully functional prototypes and patterns for plaster, investment and vacuum casting. With turnover times of less than 24 hours the FORMIGA P 100 integrates itself perfectly in a production environment that requires the highest level of flexibility. The system distinguishes itself also by comparatively low investment costs.

Fig 6.3: Prototypes of Universal Coupling produced using FORMIGA P100

EXPERIMENTAL INVESTIGATIONS

7.1 Effect of Part orientation:

An experimental investigation is carried out to find the variation in building time with the part orientation. The STL part is tried with different orientations in Magics RP and the building time was calculated using Desktop PSW from which the optimum part orientation is derived.

7.2 Effect of laser speed on building time:

An experimental investigation is carried out to find the variation in building time with the laser speed. The SLI file is tried with different laser speed and the building time was calculated using Desktop PSW from which the optimum laser speed is derived considering other process parameters.

7.3 Surface roughness measurement:

Roughness is a measure of the texture of a surface. It is quantified by the vertical deviations 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.

Experimental investigations for surface roughness were done on laser sintered polyamide products manufactured at different part orientations and job, process parameters. The average roughness value is been calculated.

RESULTS AND DISCUSSIONS

8.1 Effect of Part orientation

8.1.1. Building Time

In Selective laser sintering, the orientation of the part during fabrication is critical as it can affect part accuracy, reduce the production time, and minimize the cost of building the model. This presents a multi-objective approach for determining the optimal part-building orientation. Considering different objectives such as part accuracy and building time.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Test Sample: Cube 50X50X50 mm^3

S.No.	Orientation	Building Time
1	0^0	3.18
2	15^0	3.56
3	30^0	4.21
4	45^0	4.31
5	60^0	4.21
6	75^0	3.56
7	90^0	3.18

Table 7: Effect of Orientation on building time

A test model of basic solid primitive i.e., a cube of 50X50X50 mm^3 is considered for which different part orientations are tried using Magics RP and the corresponding building time is calculated with Desktop PSW. The fig. shows that the maximum building time is for reported for 45^0 for the model.

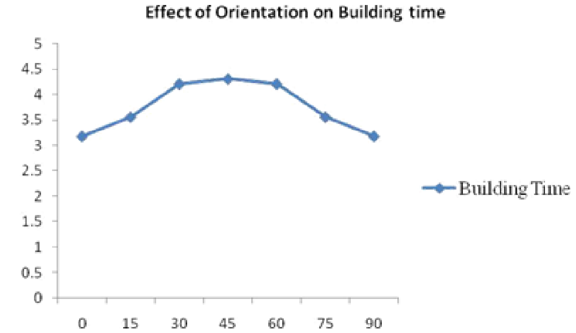

Fig 8.1: Effect of Orientation on building time

8.1.2. Delamination Effect

The effect of delamination on the flutter boundary of two-dimensional layer is because of bad part orientation. However it also depends on the laser scan area. From this it can be suggested that the part should be oriented in such a way that there is no sudden deviations in the slice area. A gradual deviation is generally recommended.

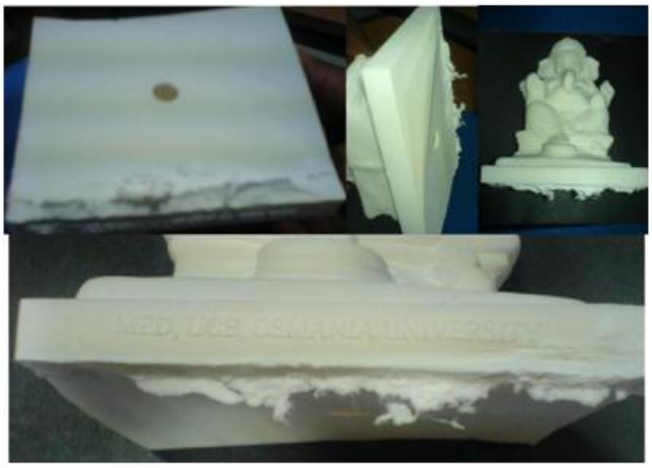

Fig 8.2: Delamination Effect

8.1.3. Effect of Foreign particles:

fig 8.3: Effect (a) With and (b) Without Foreign particles

The outcomes of incomplete job completion and emergency stop are the possible effects of dust and foreign particles present in the powder. The improper sieving and mixing are the possible causes. Care has to be taken while cleaning the job so that the powder which is near to the component has to be trashed because there is possibility for exposure of laser to it. The powder which is exposed to laser will lose it mechanical properties to some extent, so it is suggested that powder near to the part has to be removed thoroughly and not to be mixed up with the new powder.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

8.1.4. Orange Peel Effect

Orange peel is a certain kind of finish that may develop on painted and cast surfaces. The texture resembles the bumpy surface of the skin of an orange (fruit) hence the name.

Fig 8.4: Orange peel effect

8.2. Effect of Laser Speed on Building time

In Selective laser sintering, the speed of the laser during sintering is critical as it can affect the density and strength of the prototype. The optimization of the sintering process parameters showed that the speed and the sintering strategy have the biggest impact onto the quality of the sintered prototypes, besides the laser power and the hatch distance. Slower scan speed leads to a higher particle density by a lower roughness.

S.No.	Laser Speed (mm/sec)	Building Time
1	50	3.46
2	100	3.30
3	150	3.26
4	200	3.22
5	250	3.21
6	300	3.19
7	350	3.19
8	400	3.19
9	450	3.19
10	500	3.19
11	1000	3.19
12	1500	3.19

Table 8: Effect of Laser speed on building time

8.3. Surface Roughness

Six case studies are presented and the obtained results are discussed in detail in order to demonstrate the capabilities of the developed system of optimum part deposition orientation. A three dimensional part is considered for determination of optimum part deposition orientation if it is to be produced using Selective laser sintering, varying its job parameters. A solid model of the part is created in Solid works in the same orientation and STL file is imported. This STL file is used as an input to the developed system of optimum part deposition orientation determination.

Result:

Experiment used: Form Talysurf

Parameters used: Filter: Gaussian, L_c = 0.8mm, L_s = 0.008mm, Cutoff=6, Data Length=4.8mm

If the part is deposited in an orientation of 0^0, 45^0, 90^0 with the job parameters are mechanic the average part surface roughness is obtained as **14.0075µm**, **13.6975µm**, **13.365µm** respectively. If the job parameters are sorted then the average part surface roughness is obtained as **11.0425µm**, **10.77µm**, **10.5175µm** respectively.

S.No.	Nomenclature	Orientation	Surface finish(Ra µm)				Average Ra (µm)
1	M1	0^0	14.02	14.49	13.82	13.70	14.0075
2	M2	45^0	13.82	14.08	13.59	13.30	13.6975
3	M3	90^0	13.24	13.78	13.32	13.12	13.3650
4	S1	0^0	11.48	10.82	10.66	11.21	11.0425
5	S2	45^0	11.32	10.40	10.34	11.02	10.7700
6	S3	90^0	11.00	10.22	10.18	10.67	10.5175

Table 9: Surface Roughness for prototypes

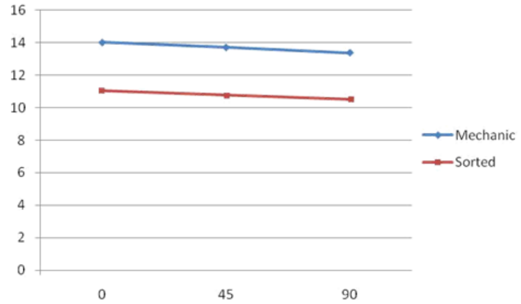

Fig 8.7: Effect of on orientation surface roughness.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Hence it can be noticed from the both the job parameters that the part orientation of 90^0 i.e., parallel to the work bed is optimum for a good surface finish.

It can be seen from the graph that the surface roughness for sorted job parameters are better when compared to that of the part with mechanic job parameters.

8.4. Hardness Test

Hardness test is gives a measure of resistance for plastic deformation usually by penetration. In this project two different types of hardness test were carried out for evaluating Vickers hardness and Shore D hardness of a laser sintered polyamide with variant job parameters and part orientations.

Six case studies are presented and the obtained results are discussed in detail in order to demonstrate the resistance for plastic deformation of the developed prototypes of different orientations and job parameters.

CONCLUSIONS

9.1. Conclusions

The study of Mechanical properties and microstructure are crucial for any layered manufacturing process so the experimental investigations on laser sintered polyamide products produced with varying orientation and job parameters are carried out. The following occlusions are drawn from the experimental investigations.

- The components with sorted parameters have 27% more surface finish compared to that of the mechanic parameters. The components which are oriented at 90^0 found to have 5% more surface finish from surface roughness measurement.
- The components with Sorted job parameters 7% more Vickers hardness value compared to that of the Mechanic job parameters. The components which are oriented at 90^0 found to have 6.5% more Vickers hardness value.
- Shore D hardness test is carried out and the results are compared with the standard data and found to have 3% less comparatively.
- The recycled powder will have a 19% less mechanical strength from Tensile and compression test.
- The• components with mechanic job parameters are dense compared to that of the sorted job parameters which resulted in better surface finish. However the mechanic job parameters will give suitably more strength.
- That components oriented at 90^0 are porous compared to that of components oriented at 0^0. Suggesting a better surface finish and less mechanical strength in the other hand, components oriented at 0^0 will have a more strength and higher surface roughness values

9.2. Future work scope

The experimental investigations are performed on PA2200 powder; in future researchers who are willing to work in this area can compare the given results with PA3200GF which is a glass filled powder. Also the mixture of PA2200 and PA3200GF can also be examined for different mechanical properties. Effect of additives and filler materials can also be included.

Determination of optimum process parameters using Taguchi‘s approach to improve the quality of SLS can be carried out. Study of mechanical anisotropy and microstructures at different temperatures can be done. Topography characterization of surface produced by SLS can be measured. Measurement of micro hardness was found difficult during the course of the project, so methods can be adopted to avoid the difficulty can be examined. Experiment investigations on recycled powder can also be done and can be compared with the results obtained during this project.

REFERENCES

1. W.A.Y YUSOFF, A.J THOMAS; "The effect of employing an effective laser sintering scanning strategy and energy density value on

eliminating "Orange Peel" on selective laser sintered part" International Association for Management of Technology, IAMOT 2008 Proceedings.

2. Frank Niebling; "Qualification of a Process Chain for Laser Sintering of Metal Parts" PhD - Thesis, Department of Manufacturing Technology, University Erlangen-Nurnberg, 2005.

3. Y.F. Shen, D.D. Gu and Y.F. Pan; ―Balling process in selective laser sintering 316 stainless steel powder‖, Journal of Key Engineering Materials, Vols. 315-316 (2006), pg 357-360.

4. Kandis. M., Buckley. C.W, Bergman T. L; ―An Engineering Model for laser- Induced sintering of polymer powders‖, Journal of Manufacturing Science and Engineering, 1999, Vol. 121, No. 3, Pg 360-365.

5. Lin Liu-lan, Shi Yu-sheng, Zeng Fan-di and Huang Shu-huai; "Microstructure of selective laser sintered polyamide", journal of wuhan university of technology - Materials science edition, 1999 vol 18, No. 3, Pg 60 - 63.

6. Prashant K. Jain, Pulak M. Pandey, P. V. M. Rao; "Experimental investigations for improving part strength in selective laser sintering", journal of Virtual and Physical Prototyping, Volume 3, Issue 3 September 2008 , pg 177 – 188

7. Prashant K. Jain; Pulak M. Pandey; P V M Rao; "Effect of delay time on part strength in selective laser sintering", journal of Advanced Manufacturing Technology, Vol 43, No. 1,2, july, 2009.

8. H. Zarringhalam, N. Hopkinson, N.F. Kamperman and J.J. de Vlieger; "Effects of processing on microstructure and properties of SLS Nylon 12" journal of Materials Science and Engineering: A, Volumes 435-436, November 2006, Pg 172-180.

9. Y Shi, Z Li, H Sun, S Huang, F Zeng; "Effect of the properties of the polymer materials on the quality of selective laser sintering parts", Journal of Rapid Prototyping, 2005, vol 24, pg 58-66