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Development of a Copper Based Material for Laser Rapid Sintering Process

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Abstract:

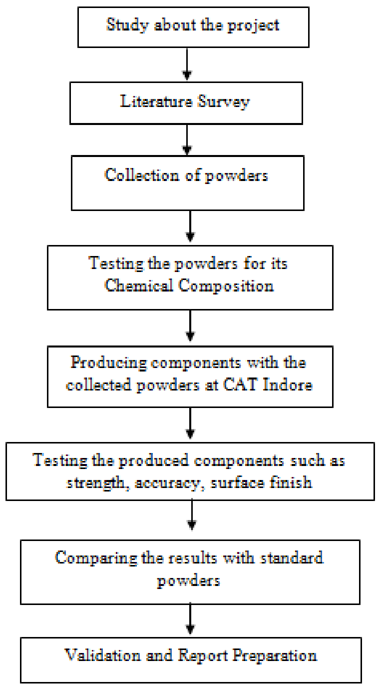
Global Competition, shorter lead times, customer-driven product customization and continued demands for cost savings are forcing companies to look for new technologies to improve their business processes and speed up the product development time. Thus Rapid Prototyping (RP) has emerged as a key enabling technology of Time Compression Engineering with its ability to shorten time to market. In this paper observe various laser sintering techniques and also do a Comparative study of the quality of parts produced using copper based powders with commercially available powders by manufacturing components. In this paper we implement Development of a Copper Based Material for Laser Rapid Sintering Process.

Keywords: Rapid Prototyping, Laser, Copper, Sintering Process.

Introduction:

The developing area in Rapid Prototyping (RP) today is to produce metal parts with higher density and good mechanical properties directly from the metal powder where as to increase the density and strength of the parts produced and also to produce parts with the metal powders what the customer requires. Today there exists different techniques for producing metal parts which includes Selective Laser Sintering and its derived processes like Direct Metal Laser Sintering, Selective Laser Melting, and Laser Assisted near Net Shape Manufacturing, Laser Rapid Sintering, and Selective Laser Cladding and so on. But the production of full dense metal parts using the RP technology is still in an infant stage. But several researches are going on for improving the processes to produce full dense metallic parts with good quality.

Methodology:



Types of Rapid Prototyping
Stereolithography

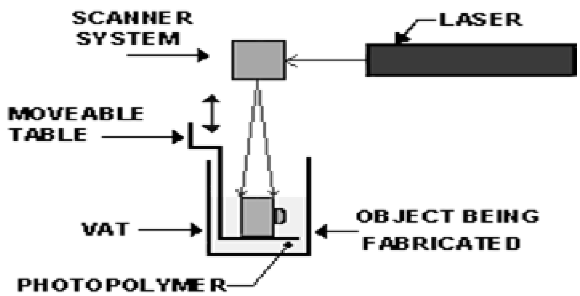


Figure 1 Schematic Diagram of Stereolithography

Stereolithography builds plastic parts or objects a layer at a time by tracing a laser beam on the surface of a vat of liquid photopolymer. This class of materials originally developed for the printing and packaging industries, quickly solidifies wherever the laser beam strikes the surface of the liquid.

Fused Deposition Modeling:

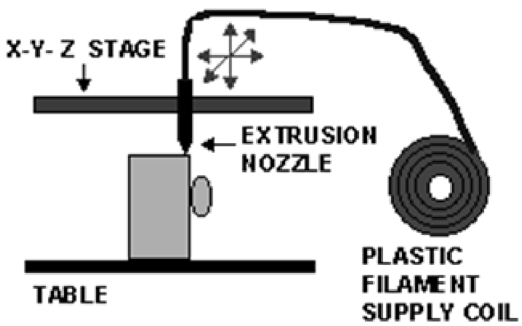


Figure 2 Schematic Diagram of Fused Deposition Modeling.

FDM is the second most widely used rapid prototyping technology, after Stereolithography. A plastic filament is unwound from a coil and supplies material to an extrusion nozzle. The nozzle is heated to melt the plastic and has a mechanism which allows the flow of the melted plastic to be turned on and off. The nozzle is mounted to a mechanical stage which can be moved in both horizontal and vertical directions.

Inkjets:

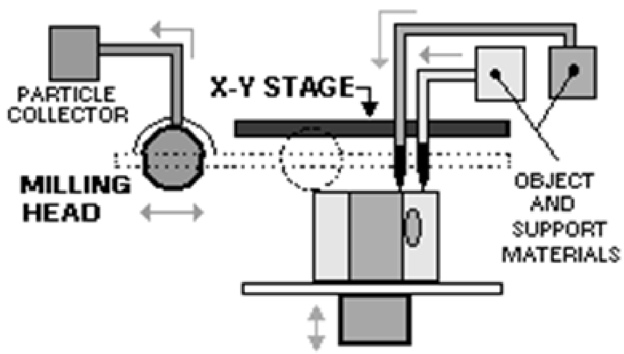


Figure 3 Schematic Diagram of inkjets

This machine uses a single jet each for a plastic build material and a wax-like support material, which are held in a melted liquid state in reservoirs.

The liquids are fed to individual jetting heads which squirt tiny droplets of the materials as they are moved in X-Y fashion in the required pattern to form a layer of the object.

Three Dimensional Printing:

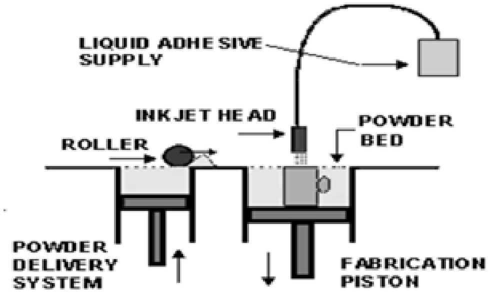


Figure 4 Schematic Diagram of Three Dimensional Printing

Three dimensional printing was developed at MIT. It's often used as a direct manufacturing process as well as for rapid prototyping. The process starts by depositing a layer of powder object material at the top of a fabrication chamber.

Selective Laser Sintering:

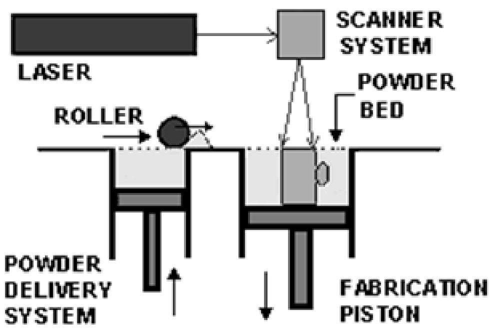


Figure 5 Schematic Diagram of Selective Laser Sintering

Thermoplastic powder is spread by a roller over the surface of a build cylinder. The piston in the cylinder moves down one object layer thickness to accommodate the new layer of powder. The powder delivery system is similar in function to the build cylinder. Here, a piston moves upward incrementally to supply a measured quantity of powder for each layer.

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Laminated Object Manufacturing:

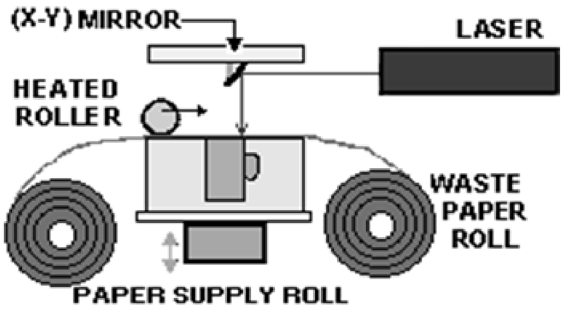

Figure 6 Schematic Diagram of Laminated Object Manufacturing.

Profiles of object cross sections are cut from paper or other web material using a laser. The paper is unwound from a feed roll onto the stack and first bonded to the previous layer using a heated roller which melts a plastic coating on the bottom side of the paper. The profiles are then traced by an optics system that is mounted to an X-Y stage.

Laser Engineered Net Shaping:

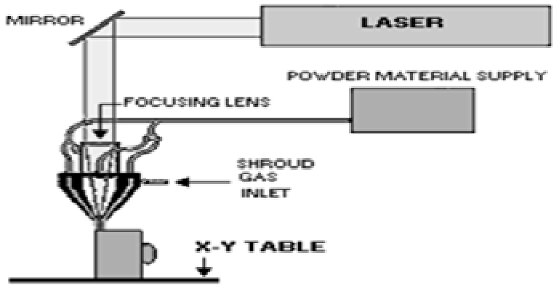

Figure 7 Schematic Diagram of Laser Engineered Net Shaping

Laser Engineered Net Shaping (LENS) is a technology that is gaining in importance and in early stages of commercialization. A high power laser is used to melt metal powder supplied coaxially to the focus of the laser beam through a deposition head. The laser beam typically travels through the center of the head and is focused to a small spot by one or more lenses.

Laser sintering for rapid manufacturing:

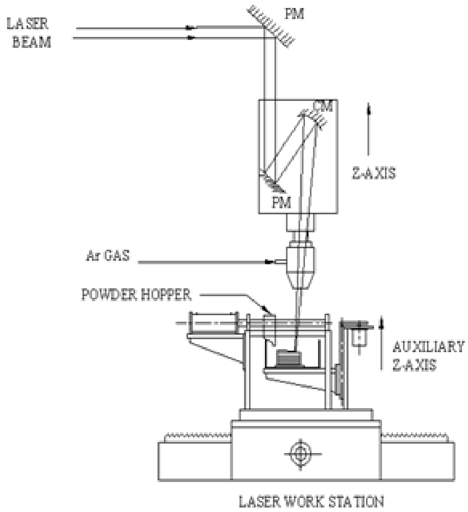

Figure 8 Schematic Diagram of Laser sintering for rapid manufacturing

Similar to Selective Laser Sintering LSRM also starts with a product preparation in cad software, slicing in vertical direction and corresponding machine code generation for every layer .these machine codes are sent to sintering station prior to every layer deposition, the metal powder is laid on the bed and metal powder is sintered as per machine code generation for every layer, thus its extension of pre placed laser cladding at manufacturing.

EXPERIMENTAL SETUP:

The experiment carried out at CAT Indore using indigenously developed Laser Rapid Sintering Manufacturing.

Laser Sintering For Rapid Manufacturing:

Similar to Selective Laser Sintering LSRM also starts with a product preparation in cad software, slicing in vertical direction and corresponding machine code generation for every layer .these machine codes are sent to sintering station prior to every layer deposition ,the metal powder is laid on the bed and metal powder is sintered as per machine code generation for every layer ,thus its extension o pre placed laser cladding at manufacturing end these are the to major differences between LSRM and Selective Laser Sintering

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• First lasers that are used in LSRM are of kilowatt range while Selective Laser Sintering uses only few tens of watt lasers.

• LSRM uses metal powders as raw materials while polymer and poly coated metal powder as are used in Selective Laser Sintering.

Machine Description:

The LSRM machine consists of a high power laser beam delivery system, powder Hooper, powder spreading unit and a three axes laser workstation with an auxiliary z axis.The schematic arrangement is shown in figure.

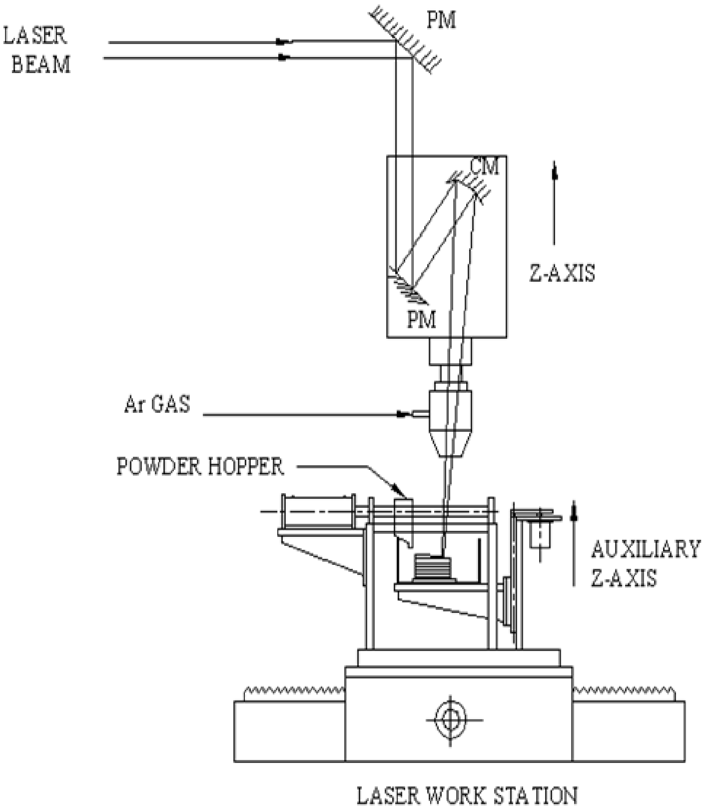

Figure 9 Schematic diagram of LSRM

High power laser system and beam delivery system:

And indigenously developed a high power transversely excited transverse low CO2 laser system has been integrated with the machine .The laser beam is transferred to laser workstation with beam delivery system .The beam delivery system consist of a pair of plain mirrors and a concave mirror with radius of curvature of 600mm at the end of the beam delivery system a nozzle is mounted through which argon gas is passed to working platform this argon gas shields the molten and semi molten powder at one end and it does not allow the powder particles to enter in beam delivery system and protects the optics.

Powder hopper and powder spreading system:

The powder hopper and powder spreading unit is mounted on a frame made of square section tube the frame is designed in such a way that it provides stability and rigidity to achieve the accuracy during LSRM process. The powder hopper has a capacity of 3 kilogram of powders capacity a rectangular slit of 1.5mm is provided at the bottom of the hopper to spread powder .one wiper is also provided adjacent to powder hopper it levels the powder and forms a uniform powder layer the hopper and wiper are mounted on two rod through linear bushes .The transverse motion in the horizontal plane to the hopper and wiper is given by double acting pneumatic cylinder are to be in the same plane to provide jerk free uniform motion these are aligned within .05m along the travel length.

Water cooled tray:

A tray made up of aluminium is mounted on the working platform .It is water cooled to extract heat produced during LSRM .The main function of tray is to support the metal powder, being spread by spreading unit .One side face of the tray is suitably cut to accommodate the piston rod of the double acting pneumatic cylinder during LSRM the dimension of the tray governs the size of the component that can be fabricated it is 75mm x 75mm x 50mm for the present LSRM system at CAT Indore.

Experimental Procedure:

1.A base plate of size 220 x 110 x 8 mm MS plate is chosen. The base plate is sand blasted to remove the burrs and other oxidized layers.

2.The base plate is placed inside the sintering chamber.

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3.The wiper is moved over the base plate such that it just touches the base plate and zero setting is made for the Z-axis.

4.The initial layer thickness is set in the auxiliary Z-axis and the powder is placed before the wiper.

5.The wiper is moved over the base plate to obtain a constant layer thickness.

6.Here the laser is constant and the machine table moves. The machine is switched on and the laser sinters the deposited layer as per the geometry defined in the CAD model.

7.The auxiliary axis is increased for another layer and the powder is spread using the wiper and the process continues until the complete part is produced.

8.After the part is completed, the base plate is removed from the chamber and it is cleaned.
9.The final part is removed from the base plate by machining.

Detailed process of the experiment:

1. A base plate of size 220 x 110 x 8 mm MS plate is chosen. because due the laser power concentrating on to the point of the plate the plate bends resulting in geometrical error of the part and so a thickness of 8mm was taken for this purpose which gives good results when compared to 6mm plate. Then the base plate is sand blasted to remove the burrs and other oxidized layers so in order to get good adhesion of the part to the base plate and this sand blasting is done on a machine which consists of iron pellets of same diameter instead of sand particles and the experiment is carried out all the base plates have been sand lasted.

2. The base plate is placed inside the sintering chamber of the tray which is of the same dimension as the tray 220 x 110 (L x W) where the laser moves to make a sintered part and this plate is placed on the water cooled tray in order to minimize the plate distortion by absorbing the heat transferred from the laser to the bottom plate in order to achieve a good part.

3. The wiper is moved over the base plate such that it just touches the base plate and zero setting is made for the Z-axis in order to assure a uniform layer spreading of the powder on to the plate of the required dimensions.

4. The initial layer thickness is set in the auxiliary Z-axis and the powder is placed before the wiper and the double pneumatic operated piston moves the wiper until end of the plate and hence getting a uniform layer thickness.

5. Here the laser is constant and the machine table moves. The machine is switched on and the laser sinters the deposited layer as per the geometry defined in the CAD model in the PMAC editor and the table speed is maintained by the controller and the table moves I such a way achieving the geometry of the part required.

6. The auxiliary axis is increased for another layer of the required thickness and the powder is spread using the wiper and the process continues until the complete part is produced on the machine.

7. After the part is completed, the base plate is removed from the chamber and the extra powder unused for the operation is been collected and reused and later the powder particles surrounding the part are cleaned using the wire brush and the part is removed by machining.

8. This is the process of achieving good accurate parts by LSRM.

RESULTS &OBSERVATIONS:

Considerable effort has been made devoted to the development of suitable powders ,the first problem is extremely short interaction time between the laser beam and the powder particles being scanned .

The test powders used are a mixture of

- 80 wt % Cu and 20 wt% Sn
- 70wt % Fe and 30 % Cu.

The powders are thoroughly hand mixed in order to get the exact mixing proportions The powder samples have been tested for its chemical composition and different compositions of the materials present are given below in the tabular form.

Tested report for copper powder

S.No:	Description	Analysis values	%
1.	Copper powder	Cu	99.89
2.	Copper powder	Sn	0.02
3.	Copper powder	Pb	0.01
4.	Copper powder	Zn	0.02
5.	Copper powder	Fe	0.02

Table 1 report for copper powder

Tested report for Tin powder:

S.No:	Description	Analysis values	%
1.	Tin powder	Sn	99.90
2.	Tin powder	Pb	0.02
3.	Tin powder	Cu	0.03
4.	Tin powder	Zn	0.01
5.	Tin powder	Sb	0.01

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Table 2 report for Tin powder

TESTED REPORT FOR IRON POWDER

S.No:	Description	Analysis values	%
1.	Iron powder	Fe	99.70
2.	Iron powder	Mn	0.21
3.	Iron powder	C	0.02
4.	Iron powder	Si	0.01
5.	Iron powder	S	0.012
6.	Iron powder	P	0.015

Table 3 report for Iron powder

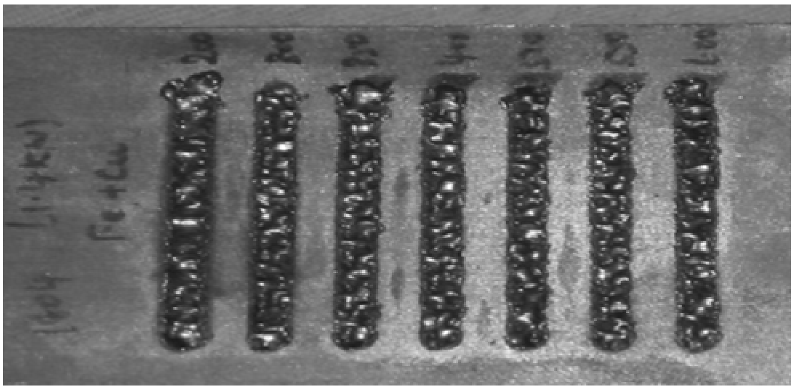

Figure 10 Fe-Cu powder at 1.4kw power

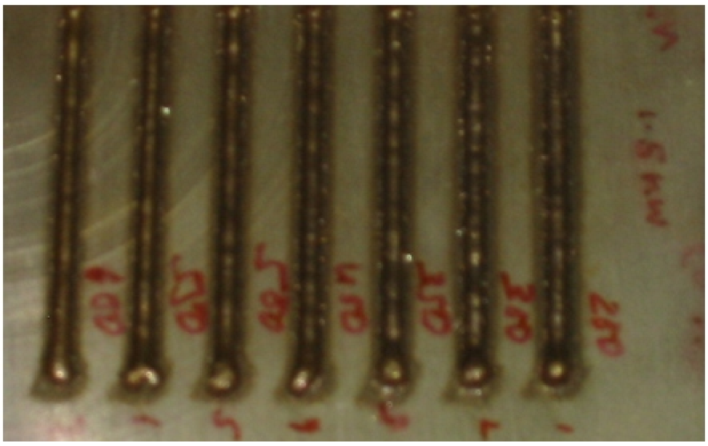

Figure 11 Cu-Sn powder at 1.5 Kw power

CONCLUSION:

The metal powders are able to be sintered and experimental results have shown that although the same energy densities can be obtained by varying different combinations of laser power, scan speed , and laser beam diameter depth increases with increase in laser energy density due to increase in laser power or scan speed .At the same laser energy density OF 12OO W and 1500 W the laser power has much stronger effect on the depth of melting .The size of the laser beam has almost no effect on the depth of melting; in fact the depth of the melting even decreases slightly as laser beam decreases.

The density of the processed parts always increases as the laser energy density increases at the same laser energy density, the scan speeds shows the strongest influence on the density, while the laser beam power shows the least effect, this is because the laser melt lines are less broken with reduced scan speed and more closely connected with decreasing beam size Compared with laser power, the effect of scan speed on balling is more dominant .A low scan speed tends to keep the instantaneous liquid track and hence a smooth surface can be obtained therefore a low scan speed is preferred furthermore the tendency for the formation of balls is also closely associated with oxygen content in the powder the formation of oxides may increase the surface temperature coefficient across the surface it is observed that the parts produced in inert gas atmosphere where they are no oxide formation and a good surface finish is achieved and in open atmosphere it reacts with the oxygen in the open atmosphere and oxides have been formed .

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