Acetone Vapor Smoothing: A Postprocessing Method for 3D Printed ABS Parts

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***Abstract* - The 3D prototyping methodology is the cutting edge manufacturing technology in the world of fabrication at present. Thermoplastics used in this process produces prototypes building layer by layer on top of each other, where getting a fine and smooth printed part is nearly impossible. Hence there is a huge demand for the post processing of the 3D printed parts that drew the idea of this project. There are methods for the post processing or finishing of the 3D printed prototype but they are abstract and empirical. Under such circumstances, development of a simple and economical post processing unit could be initiated for the enrichment of the 3D printed parts. The niche of this project will be to design and develop a table top vapor smoothening system for ABS 3D printed parts for real time applications like prosthetics and orthotics. The 3D printed part will be incorporated through few steps of processing in order to achieve a smoother finished 3D printed part.**

***Keywords* - prototyping, vapor smoothening, Fused deposition modeling, 3D printed parts**

I. INTRODUCTION

Manufacturing is the process of generation of goods which makes human life easy. Manufacturing can be done of any domestic to industrial component. In ancient days, manufacturing was subtractive which was leading to wastage of material. In modern days, additive manufacturing took place of subtractive. In this era now additive manufacturing processes like 3D printing is widely used. 3D printing (or additive manufacturing, AM) is any of various processes used to make a three dimensional object that comes under the method of Rapid Prototyping. In 3D printing technology, successive layers of material are laid down one after the other under computer control until the entire designed object is made from the raw material used.3D design are created using CAD software's like CATIA, Pro e, Solid works etc. The design should be then converted into Stl file format i.e.; STereoLithography format, based on which the 3D printer(s) works. This format slices the designed object or part into spatial orientations like x, y, z- axis and each orientation confirms the machine on how to proceed with the process of manufacturing. 3D CAD designs can be of any complex dimensions and shapes and wholly could be produced in a 3D printer within less time compared to the conventional methods. Thermoplastics are the raw materials commonly used globally were PLA is the prime material used. Other materials like ABS, nylon, WPC etc.

Properties of ABS material:

- Acrylonitrile Butadiene Styrene
- Boiling Temp :230-250 deg
- Superior hardness , electrical insulation
- Mainly reactive to acetone vapor
- Reduces danger or clogging and jamming in the nozzle

Fig. 1 ABS material

3D printing could be also done using digital files from scanners that scans the object and produce the stl formats. The advantage of using a 3D printer is that there will be no wastage of materials used, since it's controlled via a computer. There is no requirement of any molding or casting for the production of designed prototype which saves money and time!

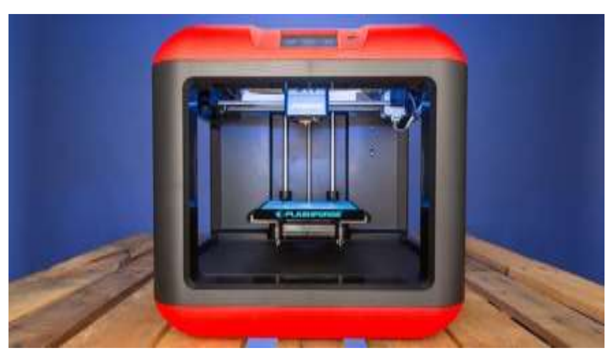


Fig. 2 3D printer

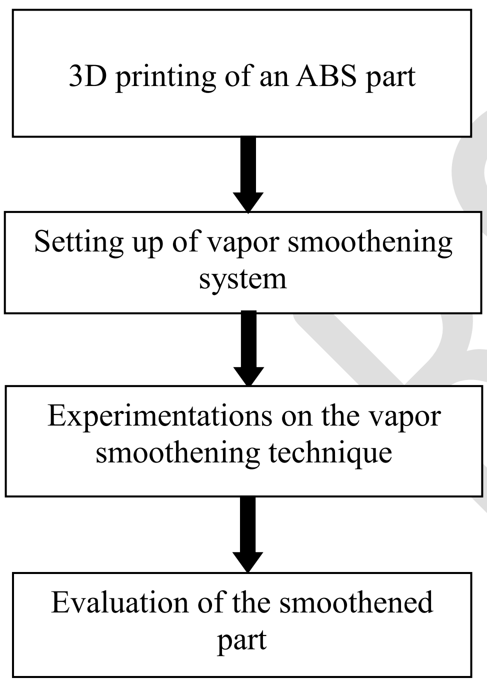
Considering aesthetic and ergonomics of 3D printed parts post processing of this parts become important process. Hence vapor smoothening of 3D printed parts is preferred. Vapor smoothening is a method of polishing plastics to enhance surface roughness or improve clarity. Resolution obtained by this printer is widely suitable for many applications, object is printed with high resolution and then material removal takes place which gives better results. Typically, a component is exposed to a chemical vapor causing the surface to flow thereby improving the surface finish.

II. OBJECTIVES

The objective of this project is to design and develop a table top system for vapor smoothening of 3D printed Acrylonitrile Butadiene Styrene (ABS) parts. The primary focus will be on the development of an indigenous system using acetone as a key reagent for

the process. The 3D printed ABS parts will be instigated into the system for smoothening of its surface and is envisioned for its usage at home.

III. METHODOLOGY



IV. CONCEPT

This method of polishing is frequently used to return clear materials to an optical quality finish after machining. Internal features of the components are better managed by vapor polishing. Feature size changes of the plastic component generally do not occur. Post stress relieving is usually required as vapor smoothening sets up surface stresses that can cause crazing. Plastics that respond to vapor smoothening are polycarbonate, acrylic, polysulfone, PEI and ABS.

The technique is also being used to improve the surface of objects created with 3d printing techniques. As the printer deposits layer upon layer

of material to build the object, the surface is often not entirely smooth. Vapor polishing helps to increase smoothness of the surface. Acetone vapor bath to treat ABS 3D-printed parts is an extremely effective (and only moderately dangerous) way to create parts with a shiny, smooth finish. If the model is dipped inside the acetone vapor bath or acetone is applied on the surface of model with brush then it leads into melting of the surface. Using acetone vapor helps preserve detail while giving a smooth and shiny finish.

There are several ways to smoothen 3D printed parts. Examples are:

- Sanding
- Bead blasting
- Vapor smoothing

Sanding

The process of sanding makes use of sand to smoothen out 3D printed surfaces. Sanding is an inexpensive and proven method to increase a smooth finish of your product. However, it also has some pretty serious downsides. Here accuracy and durability are key, it is important to keep in mind that how much material the sanding process will remove Hence sanding is not better option when one has to decrease layering and increase smoothness.

Bead Blasting

Another commonly used finishing process is bead blasting. In order to remove layer lines small beads are sprayed on model through nozzle. The process is quick, taking roughly 5 to 10 minutes to complete. Although part size is an issue, larger parts cannot be finished with bead blasting. Also parts need to be bead-blasted by hand, which makes mass finishing very labor intensive.

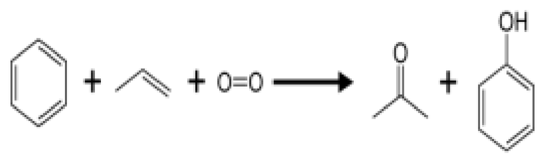
Vapor Smoothing

The printed object is dipped into a vapor tank containing liquid that is brought to boiling point. The vapor melts away a part of the printed object and smooth surface is established. It is the easy and affordable way to get the smooth finishing of the printed parts. There are different reagents whose vapors can be used for smoothening process. They could be;

- Acetone
- Tetrahydrofuran (THF)
- Methyl ethyl ketone (MEK)

Acetone

Acetone is a colorless and highly flammable liquid. It has a fruity and mint-like odor with a pungent taste. We can get acetone naturally from plants, trees, volcanic gases, and forest fires, and as a by-product of the breakdown of body fat. Other substances, such as paints, varnishes, lacquers, fats, oils, waxes, resins, printing inks, plastics, and glues dissolves in the acetone due its soluble property. It is used to make plastics, fibers, drugs, rayon, photographic film, smokeless powder, and other chemicals. Precision parts can be cleaned and dried with the help of acetone. Acetone has melting point around 132.8 degree farhenite, but it has ability to melt at room temperature. Many experiments have been performed using acetone vapor at room temperature, but they took up to 40 minutes to smooth a part. Using a boiling acetone vapor process can smooth a part in less than 10 seconds. Print optical Technology, or lot of post-processing helps for complete smoothing of our printed part.



Tetrahydrofuran (THF)

Tetrahydrofuran is a general purpose, highly volatile organic solvent. It is a colorless, water-miscible, mobile liquid. In the various synthesis processes it is used as starting material as it has good solubility. THF can be recovered easily, without decomposition, from off-gas streams and contaminated solvents, making it suitable for closed-loop processes designed to avoid pollution.

Methyl ethyl ketone (MEK)

In processes involving gums, resins, and cellulose acetate and nitrocellulose coatings in vinyl films, common solvent known as Butanone is used. Because of such inherent properties it can be used in the manufacture of plastics, textiles, in the production of paraffin wax, and in household products such as lacquer, varnishes, paint remover, a denaturing agent for denatured alcohol, glues, and as a cleaning agent. Even if its solvent properties are same as that of acetone, it melts at higher temperature than it and has slower rate of evaporation. Acetone is the best liquid to treat ABS parts, either by polishing or vapor smoothing, or using it to stick parts together.

V. EXPERIMENTATION

At beginning stage, as we didn't have any sophisticated system for vapor smoothing we performed the experiment at very basic stage. We had a 3D printed part of ABS material on the surface of which marks of material addition were present which was making the part aesthetically poor. Hence to improve surface finish of part we did vapor smoothening. For vapor smoothing we preferred acetone as our chemical as its properties are favorable for ABS parts.

For vapor smoothing we require acetone, ABS part, container, heater, tin (for covering). Initially we took acetone in container say 20-30 ml and container is placed on heater. Small stand or aluminium foil paper we kept on acetone in order to avoid direct contact between acetone and part. Covering tin is then placed on whole assembely to avoid mixing of acetone vapor with surrounding.

First, acetone is heated up to temperature slightly less than its melting point and then part to be smoothed is kept on stand. Acetone vapor then starts reacting with ABS part which on result vanishes marks on the surface of part and you get polished surface. This process takes less than 20 seconds time.

But, simultaneously there are many disadvantages of this traditional method such as:

Poor surface finish: As this is very basic system for vapor smoothing it does not give better surface finish because improper heating of acetone.

Reduction in part size: As there was direct contact of acetone vapor and part, excess heating of acetone resulted in reduction in part size

Less temperature control: Being very preliminary model there were no connection of sensors, controllers, etc.

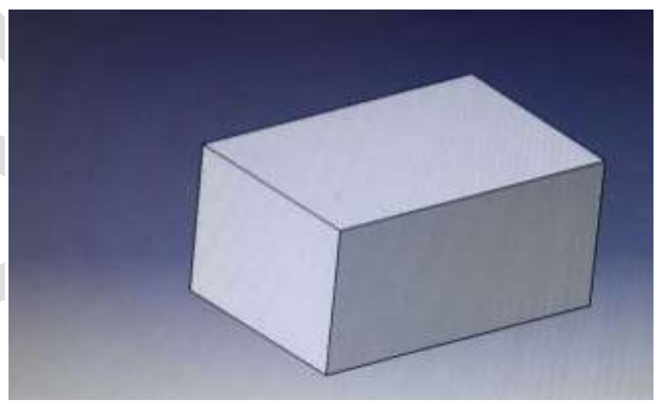


Fig. 3 Rectangular block (Test specimen)

Table 1: Change in dimensions of test specimen

Parameters	Original dimension	Change in dimension
Length	50mm	±0.09mm
Width	30mm	±0.05mm
Thickness	20mm	±0.3mm

Hence, in order to avoid all these demerits of traditional vapor smoothing setup we have designed sophisticated system which will eliminate all problems associated with previous one.

In the new sophisticated system basic idea of experimentation remains same. Some components get add in the new system in order to achieve better results.

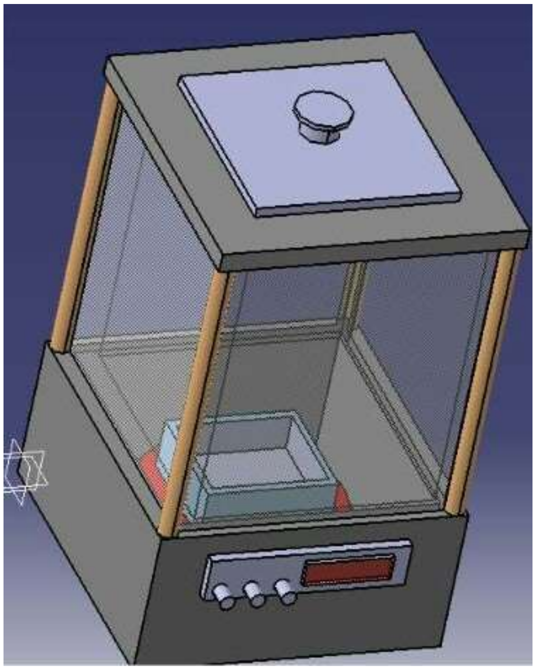


Fig. 4 CAD model of sophisticated vapor smoothing setup

Fig 4 shows exact model of the table top vapor smoothing setup. This new system has “display board” at front in order to display the temperature of vapor. For the detection of temperature, “temperature sensors” are used. In market various types of temperature sensors are available. Along with that various knobs are provided to control the temperature and for some other functions. This addition in the new system is the remedy for the temperature control in the previous system. Inside the glass chamber at the bottom of system “heater” is placed which is used to heat the acetone to get converted into vapor. Above that small stand is placed on which 3D printed part that to be polished is placed. Chamber is surrounded by glass to avoid vapor loss to surroundings. Also pungent smell of acetone vapor causes irritation and headache so; to avoid this system is isolated from surroundings.

Detailed Working Procedure

1. CAD model of the part that to be printed is prepared using any CAD software.
2. CAD file is then converted into STL format by stereo lithography technique.
3. G-code is then generated using appropriate software.
4. This G-code is fed to 3D printer and then part is printed. In this way 3D part is obtained.
5. As this printed part as markings of layer by layer material addition it minimizes aesthetic look of the object hence vapor polishing the best post processing method is performed.
6. In this technique, system as showed in Fig 4 is used.
7. Heater placed at the bottom of the system heats acetone to convert into vapor.
8. This vapor polishes 3D printed part by reacting with ABS material
9. Acetone vapor melts the material on the surface of the part such that its roughness gets reduced. It does not reduce total mass or geometrical parameters of the part.

Fig. 5 Temperature controller by DIGICON

Fig. 6 LC1-D173 Contractor control relay by TC

Fig. 7 PT-100 Temperature sensor

VI. RESULT

Many test specimens we printed through 3D printer and then polished by acetone vapor with sophisticated system. By observation we observed dramatic change in the surface roughness of all specimens after polishing compare to that of before polishing.

From the available data we plotted graph of the surface roughness showing change in the surface roughness of four same test specimens before and after vapor smoothing for the same interval of time.

On the Y axis of the graph values of surface roughness in micrometer are provided while on X axis numbers of specimens are provided.

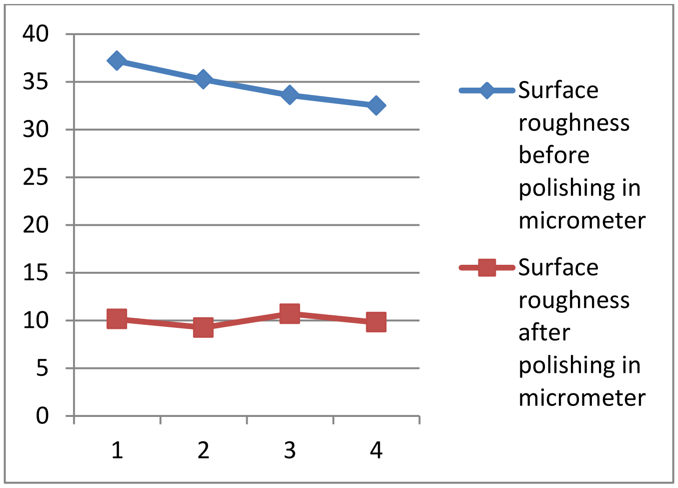


Fig. 8 Graph showing change in the surface roughness

Also, we can state that surface roughness is inversely proportional to time in case of vapor smoothing. More the time for which part and vapor are in contact less will be the surface roughness value.

We polished four same specimens for different time intervals. First specimen kept in chamber for 5 seconds, second, third and fourth for 10, 15, 20 seconds respectively. Then we observed that we get better surface finish if it is kept in contact with acetone vapor for more time

Fig 9 shows surface roughness values for all four specimens for their respective time interval. Specimen 1 is kept in contact with acetone vapor for 5 seconds and its surface roughness value is 9.9 micrometer. Similarly, for all other specimens.

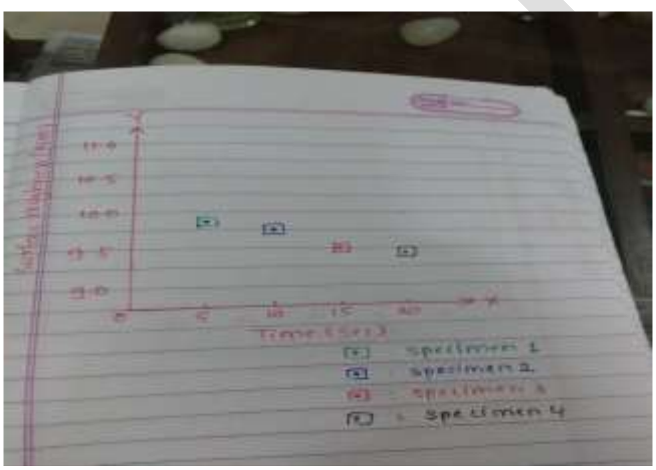


Fig. 9 Surface roughness versus time graph for four specimens

Change in the surface roughness observed during experimentation is as follow:

Fig. 10 Part before vapor smoothing treatment

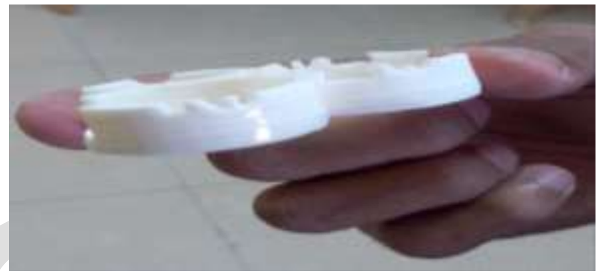


Fig. 11 Smoothen part after vapor smoothing treatment

VII. CONCLUSION

Vapor smoothening of the 3D printed ABS part using a table top system incorporating acetone as a medium was carried out successfully to an extent. This method of post processing of the ABS 3D printed part for smoothening its surface was iterated on visual inspection on time constraints which was an abstract method turned out to be worthy enough. This method was one of the fastest and less costly approaches of smoothening of the 3D printed part made from ABS thermoplastics. Proper care was taken during the process in order to avoid the accidental melting of the 3D printed part.

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