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Simulation and Modelling of 3D-Printing Liquefier Heat Sink Model

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Abstract- The main objective of our proposed work is validation of the 3D Printer liquefier heat sink models by comparing numerical and experimental analysis. To predict temperature distribution for different profiles of heat sink i.e. rectangular, elliptical, triangular and circular fins shaped heat sink. Finding out the optimum design of heat sink to maintain the temperature of heat sink under the desirable condition. Finding out the pressure drop inside the liquefier through numerical analysis. Optimization of pressure drop inside the liquefier through analytical analysis.

Keywords: FDM, 3D Printing, Additive Manufacturing, Rapid Prototyping, Liquefier Heat-Sink.

I. INTRODUCTION

Early additive manufacturing equipment and materials were developed in the 1980s. In 1981, Hideo Kodama of Nagoya Municipal Industrial Research Institute invented two additive methods for fabricating three-dimensional plastic models with photo-hardening thermoset polymer, where the UV exposure area is controlled by a mask pattern or a scanning fiber transmitter. On 16 July 1984, Alain Le Méhauté, Olivier de Witte, and Jean Claude André filed their patent for the stereo-lithography process. The application of the French inventors was abandoned by the French General Electric Company (now Alcatel-Alsthom) and CILAS (The Laser Consortium). The claimed reason was "for lack of business perspective". Three weeks later in 1984, Chuck Hull of 3D Systems Corporation filed his own patent for a stereo lithography fabrication system, in which layers are added by curing photopolymers with ultraviolet light lasers. Hull defined the process as a "system for generating three-dimensional objects by creating a cross-sectional pattern of the object to be formed". Hull's contribution was the STL (Stereo-lithography) file format and the digital slicing and infill strategies common to many processes today.

The technology used by most 3D printers to date especially hobbyist and consumer-oriented models is fused deposition modeling, a special application of plastic extrusion, developed in 1988 by S. Scott Crump and commercialized by his company Strategy, which marketed its first FDM machine in 1992. AM processes for metal sintering or melting (such as selective laser sintering, direct metal laser sintering, and selective laser melting) usually went by their own individual names in the 1980s and 1990s.

This paper organized as follows: Section 1 describe the introductory part and history of additive manufacturing and rapid prototype. Section II elaborate the discussion of different research papers and their methodologies, proposed model discusses in the section III, Section IV discusses the simulation results and their discussion, last but not the least conclusion of this paper discusses in the section V.

II. RELATED WORK

In this section discusses the recent development related to 3D printing process technology and their enhancement. This section discusses the different research papers introduce by the researchers and draw some conclusion about their researches. This section also introduce the limitation of their research.

[1] Yifan Jin et al.: Fused deposition modeling has become one of the most diffused rapid prototyping techniques, which is widely used to fabricate prototypes. However, further application of this technology is severely affected by poor surface roughness primarily due to staircase effect. It is necessary to adopt post-treatment operations to improve surface quality. Chemical finishing is typically employed to finish parts in fused deposition modeling. The purpose of this paper is to provide a universal finishing method or solution for FDM parts made up of PLA, and to represent the evolution of surface topography between adjacent layers during the chemical finishing operation by building a geometrical model of the deposited filament.

[2] Shanling Han et al.: Fused deposition modeling (FDM) has been one of the most widely used rapid prototyping (RP) technologies leading to the increase in market attention. Obviously it is desirable to print 3D objects; however, existing FDM printers are restricted to printing only monochrome objects because of the entry-level nozzle structure, and literature on the topic is also sparse. In this paper, the CAD model of the nozzle is established first by UG (Uni-graphics NX) software to show the structure of fused deposition modeling 3D printer nozzle for color mixing. Second, the flow channel model of the nozzle is extracted and simplified. Then, the CAD and finite element model are established by UG and ICEM CFD software, respectively, to prepare for the simulation.

[3] Susana Fafenrot et al.: Fused deposition modeling (FDM) is a three-dimensional (3D) printing technology that is usually performed with polymers that are molten in a printer nozzle and placed line by line on the printing bed or the previous layer, respectively. Nowadays, hybrid materials combining polymers with functional materials are also commercially available. Especially combinations of polymers with metal particles result in printed objects with interesting optical and mechanical properties.

[4] Kensuke Takagishi et al.: The authors focus on the Fused Deposition Modeling (FDM) 3D printer because the FDM 3D printer can print the utility resin material. It can print with low cost and therefore it is the most suitable for home 3D printer. The FDM 3D printer has the problem that it produces layer grooves on the surface of the 3D printed structure. Therefore the authors developed the 3D-Chemical Melting Finishing (3D-CMF) for removing layer grooves.

[5] A. Tsouknidas et al: Despite additive manufacturing emerging as an effective alternative to conventional manufacturing methods, ought partially to the support of open source communities, little is known about the shock absorbing properties of the parts produced. An open source fused deposition modelling device was employed to fabricate 3D polymeric structures and their shock mitigating properties were evaluated. The effect of commercially available layer heights, infill patterns and density on the energy dissipation properties of the printed PLA (poly-lactic acid) cylinders was examined.

[6] Caterina Casavola et al: The Fused Deposition Modelling (FDM) has become one of the most used techniques to 3D object rapid prototyping. In this process, the model is built as a layer-by-layer deposition of a feedstock wire. In recent years, the FDM evolved from rapid prototyping technique towards a rapid manufacturing method, changing the main purpose in producing finished components ready for use.

[7] Sithiprumnea Dul et al: For the first time, graphene Nano-platelets (xGnP) were incorporated at 4 wt% in acrylonitrile–butadiene– styrene (ABS) filaments obtained by a solvent-free process consisting of melt compounding and extrusion. Nanocomposite filaments were then used to feed a fused deposition modelling (FDM) machine to obtain specimens with various build orientations.

[8] Fuda Ning et al: Carbon fiber-reinforced plastic composites have been intensively used for many applications due to their attractive properties. The increasing demand of carbon fiber-reinforced plastic composites is driving novel manufacturing processes to be in short manufacturing cycle time and low production cost, which is difficult to realize during carbon fiber reinforced plastic composites fabrication in common molding processes.

[9] Zixiang Weng et al: Acrylonitrile butadiene styrene (ABS) nanocomposites with organic modified montmorillonite (OMMT) were prepared by melt intercalation. ABS nanocomposite filaments for fused deposition modeling (FDM) 3D printing were produced by a single screw extruder and printed by a commercial FDM 3D printer.

[10] Fuda Ning et al: Additive manufacturing (AM) technologies have been successfully applied in various applications. Fused deposition modeling (FDM), one of the most popular AM techniques, is the most widely used method for fabricating thermoplastic parts those are mainly used as rapid prototypes for functional testing with advantages of low cost, minimal wastage, and ease of material change.

III. PROPOSED SYSTEM MODEL

The main objective of our proposed work is validation of the 3D Printer liquefier heat sink models by comparing numerical and experimental analysis.

- To predict temperature distribution for different profiles of heat sink i.e. rectangular, elliptical, triangular and circular fins shaped heat sink.
- Finding out the optimum design of heat sink to maintain the temperature of heat sink under the desirable condition.
- Finding out the pressure drop inside the liquefier through numerical analysis.
- Optimization of pressure drop inside the liquefier through analytical analysis.

The procedure that is followed during the solution method are shown in figure. Here pressure based solver is used. The pressure-based solvers take momentum and pressure (or pressure correction) as the primary variables. Pressure-velocity coupling algorithms are derived by reformatting the continuity equation. The pressure-based solver is applicable for a wide range of flow regimes from low speed incompressible flow to high-speed compressible flow. The pressure-based coupled solver (PBCS) is applicable for most single phase flows, and yields superior performance as compared to the pressure-based (segregated) solver.

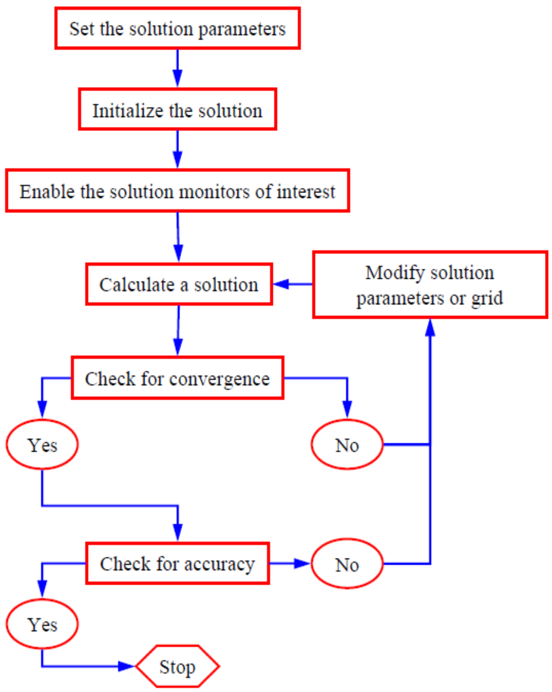

Figure 1: Flow chart for solution setup

To achieve the objective of proposed dissertation work following steps is going to be followed:

- Study of additive manufacturing processes.
- Literature survey and problem identification.
- Study of 3D printing operation and related liquefier components.
- Selection of working material and 3D printer.
- Study of temperature distribution of heat sink of a liquefier.
- CFD analysis of Extruder liquefier in order to analyze the thermal behavior heat sink
- Finding the temperature distribution of heat sink having different fins and Finding the optimum transfer at heat sink of liquefier through CFD analysis.
- Finding the pressure drop inside the liquefier through analytical analysis performed develop by Bellini.
- In order to finding out the optimum value of pressure here it considered the four different nozzle angles and four different nozzle diameters.
- With the help of different nozzle angle and nozzle diameter here it considered sixteen different cases and find out the value of pressure drop inside the liquefier.
- Finding the optimum value of RPM of stepper motor of feeder mechanism.

IV. RESULTS & DISCUSSION

As the aim of presented simulation is to successfully model heat transfer from heat sink of 3D printer extruder having rectangular fin, triangular fins, elliptical fins and circular fins for different velocity of exhaust fan which is used in order to provide force convection at heat sink and also optimizing the extruder heat sink geometry for better heat dissipation that is which one is better either rectangular fins, triangular, elliptical heat sink or circular fin heat sink.

Here it also analyzed the heat dissipation of extruder heat sink for different working material that is poly-lactic-acid, acrylonitrile butadiene styrene.

The temperature measured at the top of the heat sink which is having different profiles of fins that is rectangular annular fins, circular annular fins. After measuring the temperature at the top of the heat sink, it is find that the heat sink having circular annular fins design is better than the heat sink having rectangular annular fins, because for the same velocity temperature at the top of the heat sink having circular annular fins is less as compare to heat sink having rectangular annular fins.

From this it shows that the circular annular fins are better as compare to the rectangular annular fins. This analysis helps in finding the more efficient design of heat sink in order to increase the heat transfer from the heat sink in order to maintain the temperature of the heat sink below the recrystallization temperature of the PLA polymer.

From the figure 2 it is shown that the temperature at the top of the heat sink having elliptical fins is less as compared to the other heat sink having different geometry fins for different velocity that is consider in this analysis. So sink having elliptical fins is better than the other fins. Whereas it is also analyzed that the temperature at the top of heat sink is maximum in case of triangular fins because the surface area responsible for heat transfer through forced convection is less.

Table 1: showing the comparison of temperature measured at the top of the heat sink having different types of fins

S. No.	Velocity (m/s)	Temperature (K) for Rectangular annular fins	Temperature (K) for circular annular fins	Temperature (K) for triangular fins	Temperature (K) for elliptical fins	Temperature (K) for rectangular with elliptical perforation fins
1	0.25	367	365	392	357	363
2	0.3	365	363.2	391.4	355.8	362.5
3	0.4	362.5	361	389.6	354	361.5
4	0.7	358.9	357.6	384	351.4	358.5
5	1	355.5	353	380.8	349.6	356

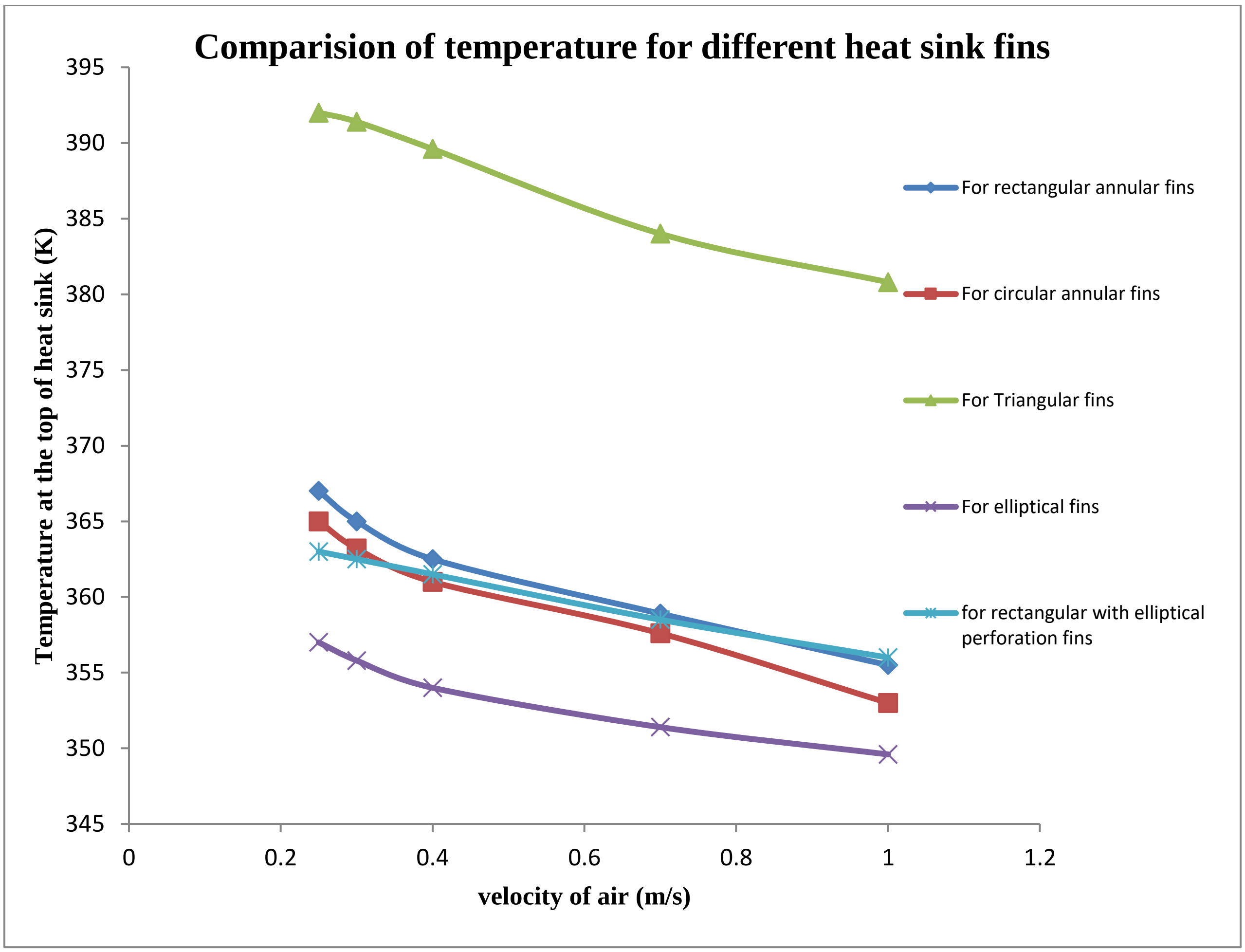

Figure 2: shows the comparison of temperature at the top of the heat sink using PLA as a working material for heat sink having different fins profile

V. CONCLUSION

The main objective of our proposed work is validation of the 3D Printer liquefier heat sink models by comparing numerical and experimental analysis. In this dissertation validate the rapid prototype 3D printing liquefier heat sink model and analysis at different condition i.e. pressure, velocity and many other. From these analysis of simulation results draw some conclusion as follows:

[1] The CFD model was developed on uni-graphics and analysis was done by Fluent 16.0.

[2] The prediction of CFD model show good relation with experimental result present in literature.

[3] Through CFD analysis it can find the temperature distribution through the extruder which helps in design of extruder geometry.

[4] Simulating the 3D printer liquefier heat sink having different shaped fins for different velocity of (0.25-1.00m/s).

[5] From the above result we have least temperature distribution for elliptical shaped profiled heat sink for different velocity of air coming from the exhaust fan.

[6] From the above result we have best temperature distribution on elliptical shaped heat sink of 3D printer liquefier with different air velocities and in filaments of PLA

[7] So, from the above we can conclude that the elliptical shaped heat sink profile at different velocity having better heat transfer rate, due to increase in surface area of sink thus heat concentration decreases as increase in surface area of heat sink of 3D printer liquefier.

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