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Researchers at Cademix Institute of Technology found a new method to avoid filament clogging in 3D Printers by using an optimum shape for Heat sinks.

Researchers at Cademix Institute of Technology have developed a novel method to mitigate filament clogging in FDM/FFF 3D printers by optimizing heat sink geometry. The study focuses on controlling the thermo-mechanical properties of filament, emphasizing the melting and glass transition temperatures. Through finite element analysis, the team systematically altered heat sink fin sizes and analyzed temperature distributions across different zones of the printing head. The research reveals that a heat sink with specifically designed fin dimensions can minimize the length of the critical Zone 2, where filament softening occurs, thereby reducing clogging risks. The ideal fin size was determined to be 20mm, balancing the thermal management requirements for various filament materials, and ensuring efficient operation of the printer head.

FDM/FFF process is the most widely used 3D printing processes, and it has the most significant impact on the desktop 3D printing community, because of the low cost and high accessibility to the users [1]. The process is based on the heating of filament, which consists of different materials. One of the main issues in desktop 3D printer heads is the filament clogging. We can understand it as the issue of controlling the thermo-mechanical properties of the filament. [2] From the thermal perspective, there are two essential material properties of the filament, First, the melting temperature of the filament materials, and second the glass transition temperature of them [2].

3D printer heads have the function to bring up the temperature of the material to the melting point. At the same time, it keep the filament in the solid-state, that is below the glass transition temperature, as long as possible before getting into the melting pool [3]. The length of the printing head can be sectioned by three zones. First zone is where the material is solid (below Tg). Second zone is where the material is soft (between T_g and T_m). Finally, the third zone is where the material is molten (above Tm). The optimum 3D printing head has a minor size of zone 2 and 3. The main issue for clogging in the 3D printers head is due to the size of the zone 2 [4].

In this paper, we present an analysis to find the effect of heat sink geometry on the size of zone 2. We use finite element analysis, to systematically change the fin size, and to study the temperature distribution to determine the size of the zones. The results of this study present guides for designing the optimum heat sink, fin size that offers the minimum length of zone 2 at the same time keeping the heat sink as small as possible.

Standard CAD procedures used to create the simplified model of the 3D printing extruder, compatible with our finite element software, ANSYS workbench. The design was a simple extruder concentrically embedded in a cylindrically symmetric heat sink. The assembly is composed of five parts, corresponding to the different materials, described in Figure 1. It shows the geometry of the extruder under study. The simplified model has superior materials which are essential for thermal analysis. The annotations in Figure 1(Middle) include the following materials and parts. 1. Aluminium, heat sink part, 2. Stainless steel, the screw is connecting the hot end to the heat sink, 3. Brass, hot-end 4. Aluminium, the housing for heater and thermistor, 5. Teflon tube, used for controlling the temperature and enhancing the Zone 2.

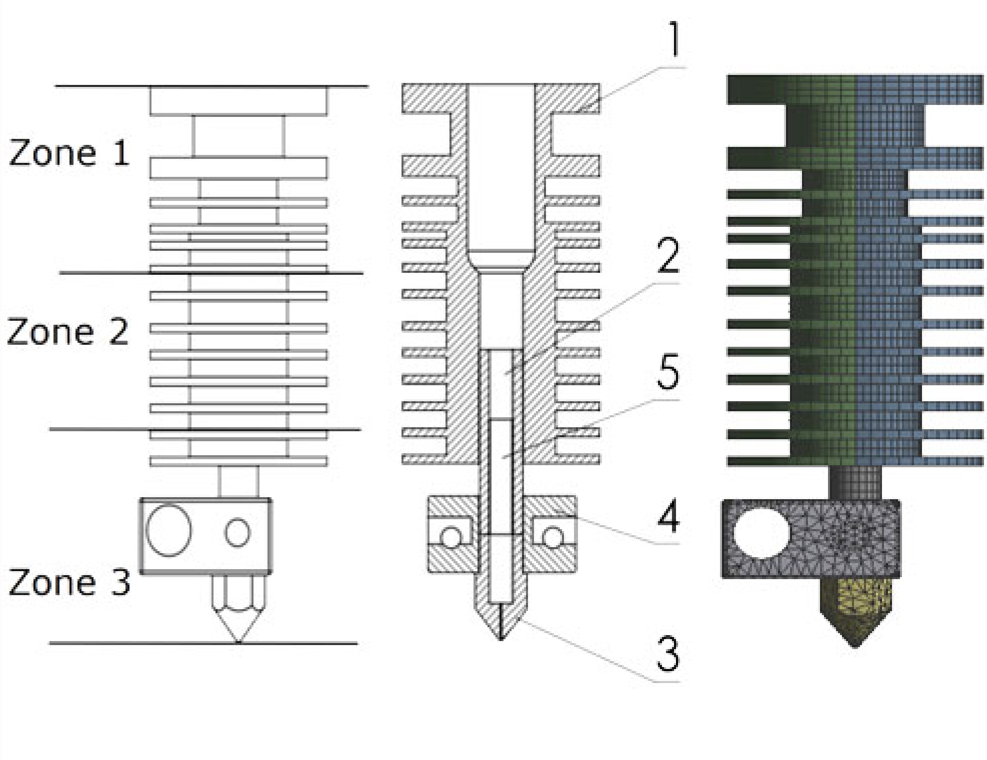
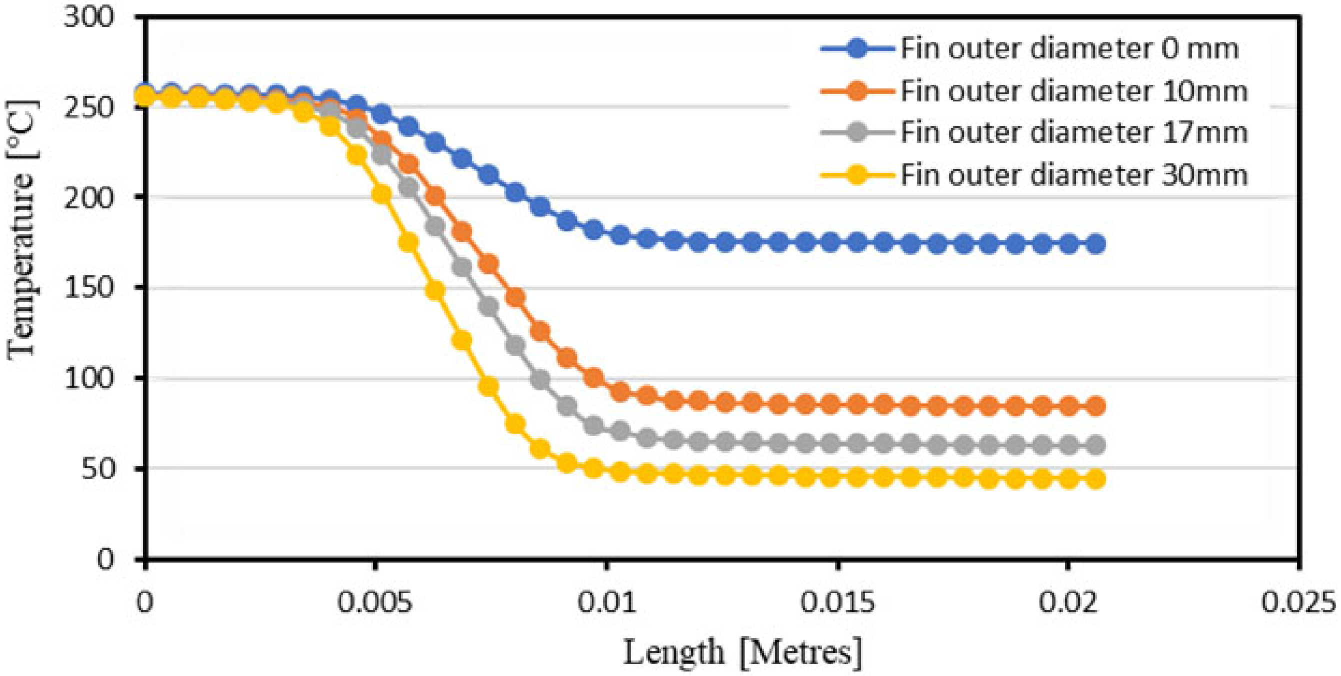


Figure 1 Extruder geometry (Left) the schematic design and indication of the three zones (Middle) cross-section and different material and parts (Right) Meshed model in ANSYS

Here we have quantitively computed the temperature distribution along with the PTFE material which is responsible for maintaining the required temperature in the boundary between zone 3 and zone 2 which is shown in Figure 6 and, more importantly, the temperature drop rate is almost similar to fin diameters 10mm and more.

Temperature drop rate for zero fin diameter is around 80 degrees per 10mm which tend to maintain more than 180-degree Celcius in zone 2 which is quite more substantial than the glass transition temperature of our material(65°C) and significantly affecting the zone 1 temperature which is the reason for clogging problems. In the graph, it is clear that when the fin diameter increases the temperature drop rate increases, so the fin diameter with 30mm has the highest temperature drop rate and this fin diameter can maintain the glass transition temperature in zone 2 and significantly maintains the transportation temperature in zone 1.

Result of our study showed that having the fins in extruder are required to secure the position of the zone 2, and also the fin size should not go beyond specific size which is 20 mm to secure the length of zone 2 which is also a right solution for clogging problem and any fin size larger than 20 mm will be over Engineering of the heat sink which means size of the zone 2 will not be affected beyond 20 mm of fin size, so for this design 20 mm fin size is the efficient one among the other designs. Other materials where the melting point is different, we need to re-run simulations for different diameters of the fin to find the efficient one considering the clogging effect.



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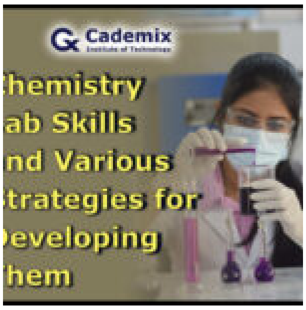

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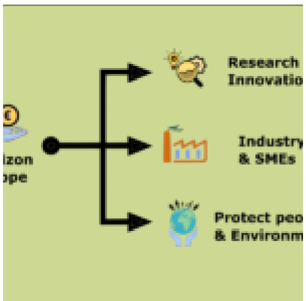

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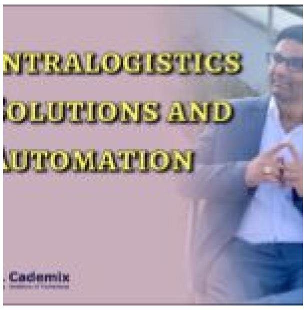

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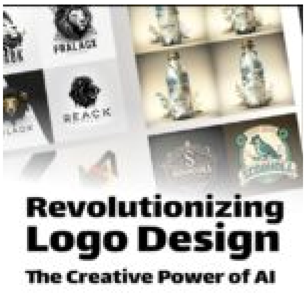

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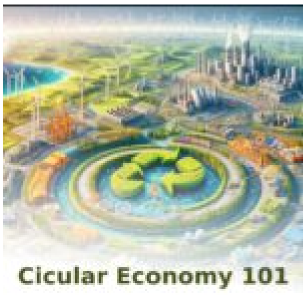

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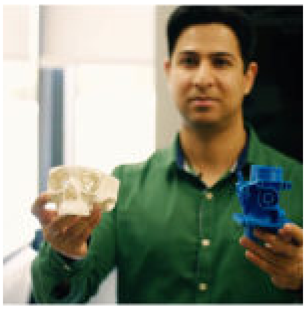

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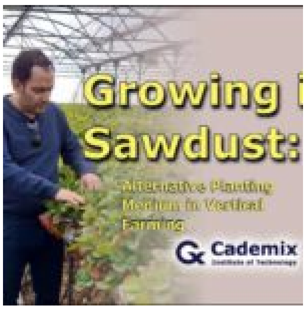

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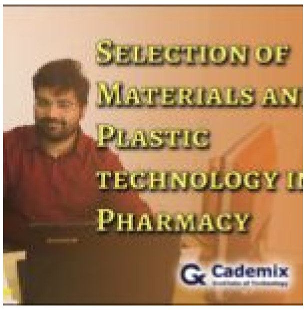

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