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A Research Paper on Types, Advantages, and Components of Hotends

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***Abstract* - This document gives detailed information about the components of hotend used in fused deposition modelling technology of additive manufacturing. This paper also provides different types of hotends used in FDM technology and the advantages of various types of hotends.**

Keywords: Additive manufacturing, fused deposition modelling, 3D printing, hotends, nozzles, heater block, heater cartridge.

I. INTRODUCTION

Hotend is the most essential part of the 3D printer which heats the filament and pushes it for printing to the nozzle. It is the critical component of the 3D printer as faults in this part can create printer failure.[1]

1.1 Components of Hotend

a) Heat sink

The heatsink is located above the nozzle in the hot-end assembly. It is made up of metal. It dissipates the heat from the hotend to avoid overheating. Performance of the hotend increases with the use of a heat sink as heat is dissipated.[8] The heat sink's main role is to clear the filament path when it is outside of the heat block. Without a heat sink, the material can get stuck in the hotend. Also, the other use of a heat sink is to connect the material path through PTFE Tube with the heat break. It is also important for the sturdiness of the hotend. The fan should be connected to a heat sink to get more efficiency.

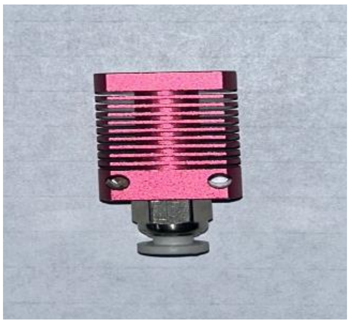

Figure 1: Heat Sink

b) Heat break

The heat break acts as a barrier between the hot and cold zones of the extruder. As the hot zone melts the filament, the cold zone maintains its solidity for it to be fed smoothly into the extruder gears. Additionally, the heat sink, a conductive component with maximum surface area, accompanies the heat break in drawing heat away and dissipating it to the environment.

c) Heater block

The heater block is used to connect the heat break to the nozzle of the hotend. As the name suggests Heater Block melts the filament and provides melted filament to the nozzle for printing. It is typically made up of aluminium.

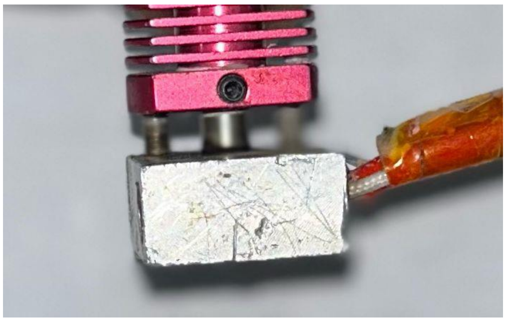

Figure 2: Heater Block

d) Heating cartridge and temperature sensor

A heating cartridge is used to heat the heater block. It consists of the tube-shaped resistive tube element. It converts the electrical energy into heat. It makes sure that the heater

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block heats up to the desired temperature. Without a heating cartridge heating will not take place. The temperature sensor is used to measure the temperature of the heater block. It is important as a constant temperature is required while printing. If the temperature varies it directly affects the melting of the material.

e) Nozzle

It is the mechanical part which extrudes the filament on the print bed. It conducts the heat provided by the heating cartridge and heat block for the smooth flow of the filament. 3 important factors related to the nozzle are:

Inner diameter: It regulates the flow of the filament per second. It also relates to the accuracy of the final print. Smaller the diameter thinner the layer printed.

Material of nozzle: Different materials have different thermal conductivity so it is an important factor while choosing the nozzle.

Size of the nozzle: The bigger the nozzle, the more mass and surface area available for transferring heat to the filament, making this process more effective and capable of higher extrusion speeds.

Figure 3: Nozzle

1.2 Types of Hotend

a) Direct drive

With a direct-drive extruder, the motor pushing the filament is installed by the hotend and pushes the filament directly into the nozzle. Direct-drive designs have several advantages, typically give better extrusion, and faster retraction, are able to print more types of filaments, and can use a smaller and lighter motor due to the short distance to the nozzle. One typical disadvantage of direct-drive extruders is the added mass to the hotend, compared to a typical Bowden extruder, which may cause more vibrations so that the direct-drive printhead has to move slower, which can affect print speed. Another typical disadvantage is more complex maintenance due to the tight packaging of many components in the hotend.[3]

b) Bowden drive

The Bowden extruder has the motor on the frame, far away from the print head. This is where the Bowden tube comes in. The motor feeds the filament through a Bowden tube (usually made of PTFE plastic) to the print head. The tube guides the filament from the fixed motor to the moving hot end, protecting the plastic from snapping or being stretched by constant movement.

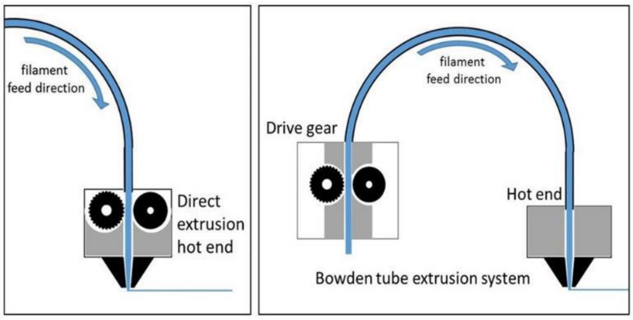

Figure 4: Types of hotend

II. HEAT SINK

Depending on the temperature range of the hotend as well as the type of feed system used the shape and size of the hotend the shape and size of the heat sink also change the changes are not very significant for low-temperature hotness but may have drastic changes when the hotend operates at high temperatures, the most popular type of a heat sink is the J type as shown. [4]

As the heat sink helps in controlling the heating zone in the hotend it is essential that they are made of good heat-conducting materials such as aluminium, copper, etc.

Figure 5: Direct and Bowden Type of Heat Sink

A) Bowden tubing

A standard 3D printer generally features a heat break composed of stainless steel, integrated with an internal PTFE tubing.

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Figure 6: Bowden Type Heat Sink

B) Bi-metallic

Bimetallic heat breaks are very popular as they fulfil the need for good heat retention near the heater block and nozzle and also provide good heat dissipation at the upper portion of the hotend. In general, they are made with a combination of metals such as aluminium, copper, titanium, etc with the material of lesser conductivity near the nozzle/ inside the heater block.

Figure 7: Bimetallic Heat Sink

C) Threaded and smooth heat sink

These hotends serve the same purpose and are easily available in a large variety depending on the brand and the purpose of the hotend.

Figure 8: Smooth and Threaded Heat Sink

2.1 Advantages and Disadvantages

The biggest advantage of bimetallic heat breaks is that they help in keeping the filament cool/rigid in the heatsink and help prevent clogging because of premature melting of the filament in the heat sink they also help in high-speed printing as for highspeed printing material is required to melt at higher rates as a result the heating rate of the hotend also increases which may melt the material in the heat sink itself. [5]

III. HEATER BLOCK

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3.1 Types of Heater Blocks

a) Standard

The standard heater block is made up of aluminium material because of its easy availability and ease of manufacturing along with good heating properties the standard heater block has the following dimensions 11.5x20x16 mm^3.

Figure 9: Standard Heater Block

b) Volcano

The volcano heater block is used for materials where a higher rate of heat transfer and longer melt zones are required as well as fast printing, the volcano is one of the most affordable upgrades for any 3d printer but reduces the default offset between the nozzle and the bed of the printer thus requiring recalibration of z-offset in the printer, but sometimes this may also cause clogging in the hotend due to excessive heating and poor heat dissipation of the heatsink and thus requiring a heatsink of higher conductivity as well.

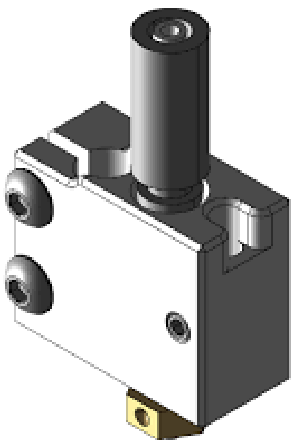

Figure 10: Volcano type Heater Block

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C) Ceramic

These heater cores are very popular with recently developed hotends because of their high durability and heat retention as ceramic material has sufficient electrical conductivity and thermal resistance to provide uniform heating for the material and perform very well.

IV. NOZZLE

4.1 Materials used for the nozzles

Nozzles are popularly made of brass, the material is easy to machine and produce and has an excellent thermal conductivity which brings to light that it is the most popular martial of choice for a nozzle, but that's not all as the field of 3d printing itself grows more materials are being used for the nozzle and have proven to be useful, these materials include steel, hardened steel and even gemstones like a ruby. [6]

4.2 Types of Nozzles

a) Brass

As stated above these nozzles are the most popular and is the default option when we buy a standard hotend kit. The brass nozzles are available in a variety of sizes and are cheap to buy as well as manufacture, their nozzles have standard m6 threading on them

b) Stainless steel

The stainless-steel nozzles are used for abrasive materials where the filament may corrode the nozzle and the little lead present in the nozzles is not sufficient to extrude abrasive materials even after heating.

c) Steel hardened

These are special-purpose nozzles used for high abrasive material and are used for printing materials such as NylonX, NylonG, etc. These are expensive compared to other nozzles as hardened steel is difficult to machine but has high durability and strength.

d) Ruby tip nozzle

The ruby tip nozzles are brass based with a ruby tip attached to the bottom. The ruby tip nozzle is extremely abrasion resistant and durable which allows us to print any material as long as the nozzle can heat up to a specified temperature.

e) Volcano nozzle

Volcano nozzles are super-fast printing nozzles for use with the Volcano block and packs to print large layer heights and at extremely high flow rates. Volcano nozzles have extra-long heated melt zones for ultimate filament melt speeds.

f) Diamond nozzle (multi-material)

The diamond nozzle can print any material and no nozzle change is required for a change in material. The diamond nozzles have a solid diamond tip like a ruby. The diamond nozzles are used to improve layer adhesion and print quality.

g) Teflon-coated nozzle

The Teflon-coated 3D printing nozzles are used to avoid the sticking of filament on the nozzle. To circumvent forming a blob on a nozzle these types of filaments are used.

Figure 11: Different types of Nozzles

V. HEATING CARTRIDGE AND TEMPERATURE SENSOR

A cartridge heater consists of a resistance coil wound around a ceramic core that is surrounded by dielectric and encased in a metal sheath. Powered heat transferred through the coil to the sheath causes the sheath to heat up. This heat is then transferred to the inside metal part requiring heat.

Cartridge heaters can operate at low, medium, and high watt densities. They are designed to withstand a working temperature of up to 1400°F. General heater cartridges come in 4 categories based upon their wattages and heating needs of the user. Typical wattages you will find for hot-end heater cartridges are 25W, 30W, 40W, and 50W. But you can find them as low as 20W and as high as 60W and even 80W for a Super Volcano hot end. Their labelled voltages are nearly always 12V and 24V because those are the voltages that typical 3D printers run on.

VI. CONCLUSION

In this paper, the different components of an FDM printer's hotend were studied and discussed in detail starting from the heatsink to the nozzle of the hotend as well as different types of materials used to manufacture the components were also discussed along with their advantages

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and disadvantages as well as the availability and general features which include heating characteristics material suitability and cost of the components.

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