A Nozzle Structure of Wire Drawing Prevention for 3D Printing Fused Deposition Manufacturing

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Abstract: The working principle of 3D printing fused deposition Manufacturing is introduced. The reasons for the problems of nozzle material flow and product wire drawing in the process of product printing are pointed out. The structure of traditional nozzle is analyzed, and a new structure of nozzle is proposed. The main feature of the new nozzle structure is that it can generate negative pressure in the closed space when the wire is withdrawn, thus it can effectively prevent the nozzle flow and product drawing. At the same time, by optimizing the heat dissipation system of the new nozzle structure, the stability of the nozzle printing process can be improved. The practical application shows that this new nozzle structure is effective and worth popularizing.

1. Introduction
3D printing is a kind of additional material rapid proto-typing technology, which is based on a kind of digital model file, it has utilized materials of special wax material, photosensitive resin, powder-like metal or plastic, etc to manufacture three-dimensional objects by printing layers of binding materials. Whereas, fused deposition Manufacturing (Shortened form FDM) has heated and melted the filiform hot melting material (Which is generally to be PLA or ABS wire) then it has squeezed and sprayed filiform hot melting onto the working platform to pile up in layer for moulding via a nozzle whose diameter is generally to be 0.4mm, as is shown by figure 1. As during the 3D printing process of the fused deposition manufacturing, the printing nozzle needs constant moving, when the nozzle moves from one printing point to the next printing point, it will appear drawing phenomenon because the fused shape material in the nozzle had not been stopped in time or spilled over, as is shown by figure 2, which therefore has greatly affected the printing quality\cite{1}. Although method for improving draw-bench has properly setting the printer parameters, such as pumpback distance, pumpback speed, fuse temperature, distance of dangling movement, etc., but these are to solve the problem\cite{2} in processing parameter layer; however the design has reached the purpose of completely improving drawing problem of fuse deposition manufacturing product by starting from nozzle structure of the printer.
2. Structural Design of Traditional Nozzle

2.1. Structure of Traditional Nozzle
Nozzle of traditional structure is shown as figure 3 and figure 4, whose main components have included hollow throat, heat dissipation, heating chamber, heating block, nozzle, fixed block and thermal insulation pillar, etc.

2.2. Defect of Traditional Nozzle in Anti-drawing
There are two aspects for defects of the structure of traditional nozzle has existed in anti-drawing[3]: one is that the 3D printing wire material is heated after it enters into the heating chamber, when the printing wire is pumped back, it will flow in the molten state in the heating chamber; so the printing material in the molten state still will be spilled out along the nozzle, which therefore will appear condition of wire re-leaking, with-wire and wire-flowing and will affect product quality; secondly, the printing nozzle structure has mainly dissipated by the thermal baffle and the auxiliary blower, whose dissipation point is rather concentrated and the airflow is too dispersed, which is difficult to reach very
good dissipation effect; therefore it will affect the stability of the heating chamber of the printing wire material, and that finally will affect the quality of the 3D printing product[4].

3. The Improvement of the Nozzle Structure

3.1. Structure of Traditional Nozzle

The nozzle structure after the improvement is shown as figure 5 and figure 6. Schematic figure of ventilation and dissipation is shown as figure 7.

![Figure 5: Three-dimensional figure of the nozzle structure after the improvement](image)

![Figure 6: Section view two-dimensional figure of the nozzle structure after the improvement](image)

![Figure 7: The radiator system after the improvement](image)

The new type anti-drawing 3D printing squeezed-out type nozzle structure[5] has included the radiating tube, hollow throat, the heating apparatus, the cooling fan, the wind scooper, the nozzle and the silicon gel sealing sleeve; the heating fixed block in the heating apparatus has been equipped with the heating tube and the thermocouple, being used as heating control and fixed piece, the lower end of the hollow throat and the nozzle has been connected into the heating fixed block via the screw joint; the upper end of the hollow throat also has been connected onto the radiating tube via the screw joint; the silicon gel sealing sleeve is inset inside the radiating tube and the upper end of the hollow throat tube; the middle hole of the radiating tube, the middle hole of the silicon gel sealing sleeve, the middle hole of the hollow throat and the middle hole of the nozzle have connected into a stripe of printing
wire aisle. And the cooling fin becoming bigger from down to upper has been designed on the external part of the radiating tube; the wind scooper with downward ventilation mouth is installed outside the cooling fin, the cooling fan of 30mmx30mm is fixed on the wind scooper.

3.2. Advantages after the Improvement
Via the practical tracking to the nozzle after improvement, the practice has shown that the nozzle after the improvement has had structural features and advantages of below aspects:

(1) The silicon gel sealing sleeve is inset between the radiating tube and the hollow throat. The silicon gel is a kind of new type macro-molecule elastic material, which has had very good high-temperature resistance (180-200℃); at the same time, it has possessed very good physical stability. Under the tight locking of the radiating tube, it has conducted surrounding sealing to the wire material make the internal part of the hollow throat form the sealing space within the area surrounded by the silicon gel sealing sleeve, printing wire material and the nozzle. Thus in the process of the printing, when the printing nozzle needs the wire-stopping movement to coordinate with the drawing-back of the wire material of the wire-squeezing electric machinery, i.e., the printing wire material will be lifted upward for a section of distance; because of the existence of the sealing chamber, extent negative pressure will be formed at the wire material place of the nozzle head molten state, which will recycle the wire rod of the molten state upward, which therefore has prevented the happening of the drawing phenomenon. Via the experiment, the printing wire material of D1.75 generally needs to set the drawing back distance into 2-3mm as proper; however to printing wire material of D3, then setting it into 1.5-2mm is ok.

(2) By matching the feature that the temperature has been gradually reduced from down to up of the heating tube and the process that the printing wire needs a temperature accumulation to be enhanced to the molten state, which therefore has designed the cooling fin of the radiating tube into a structure being gradually bigger from down to up. The wind scooper has been installed on the outer ring of the radiating tube, which has intensively conducted the radiating airflow away from the cooling fin and it has increased the radiating effect; however the ventilation mouth that guiding the wind to the lower end of the nozzle has been added at the downside of the wind scooper, which has partially conducted the airflow at the bottom to the printing wire of the nozzle; it has not only strengthened the dissipation of the printing wire, but also has reduced some lower airflow and has strengthened the effect that the temperature is gradually reduced upward. Via the test, the upper temperature of the radiating canister has been kept at 60~70℃, which therefore has guaranteed that the wire material will not occur thermoplastic variation at the place of silicon gel sealing sleeve; it let the wire material will not be too hot to occur deformation then lose sealing effect at this place,s drawing-back and it has also guaranteed the negative pressure enhancing effect of the sealing chamber at the nozzle mouth; and the temperature of the down part is among 130~150℃, which has promoted the formation of the molten effect for the printing wire. Additionally, it has conducted parts of the wind to the two sides of the nozzle mouth, which has accelerated the heat evolution at the nozzle mouth and at the sprayed out melting wire; it has also played the role of guaranteeing the product printing quality and the stability of the printing.

3.3 The Experimental Data after the Improvement
It has conducted experimental verification to the nozzle after the improvement, which has adopted the assembly machine whose type is Repar p i3 and it has used PLA printing wire material of 3mm diameter, whose wire feeder is near-end material feeding; related data for moulding printing into the 3D model of the same vase is shown as the table in the article (Except the data on the table, other parameters have kept same), whose testing result is shown as the experimental data table of the research. From the table, it can be seen that when it is 205℃, 50mm/s and the drawing-back distance is 1.5mm, the degree of finish for all joints of its finished printing pieces are very good and there is no obvious defect, which has effectively improved the generation of drawing phenomenon in 3D printing fused deposition manufacturing.
4. Conclusion
The design has conducted the design improvement of the printing nozzle structure mainly aiming at the common defect—wire drawing of 3D printing fused deposition manufacturing, whose main measure is to add silicon gel sleeve between the radiating tube and the hollow throat in order to form the sealing space inside the hollow throat therefore to make it form extent negative pressure at the nozzle mouth place when the wire material draws back and to make the wire material of the molten state at the head of the nozzle mouth halt and recycle, which therefore has prevented the occurrence of the wire drawing phenomenon. At the same time, it has optimized the structural design of the cooling system and it has prevented the wire material’s deformation at the place of silicon gel sealing sleeve, which therefore has guaranteed the reliability of the sealing space formed interior the hollow throat. Additionally, the design has also improved the ventilation system by letting wind from one part blow to the two sides of the nozzle mouth to make the nozzle mouth and the wire material heat just squeezed from the nozzle mouth drop off very quickly in order to improve the effect of 3D printing.

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Table 1 Experimental Data Table for this Research

| No. | Diameter of the nozzle mouth | Temperature of the nozzle mouth | Printing speed | Drawing-back distance | Printing effect | Appearance quality |
|-----|-----------------------------|---------------------------------|----------------|----------------------|----------------|------------------|
| 1   | 0.4mm                       | 195℃                            | 50mm/s         | 1.5mm                | The printing route is rather obvious | It sometimes has wire lacking and wire drawing |
| 2   | 0.4mm                       | 195℃                            | 50mm/s         | 2mm                  | The printing route is rather obvious | It sometimes has wire lacking but has not wire drawing |
| 3   | 0.4mm                       | 195℃                            | 70mm/s         | 1.5mm                | The adhesive force of the printing layer has some defects | It sometimes has wire lacking and wire drawing |
| 4   | 0.4mm                       | 195℃                            | 70mm/s         | 2mm                  | The adhesive force of the printing layer has some defects | The wire lacking is rather obvious |
| 5   | 0.4mm                       | 205℃                            | 50mm/s         | 1.5mm                | The surface is very exquisite and has no obvious defects | No obvious wire drawing and wire lacking |
| 6   | 0.4mm                       | 205℃                            | 50mm/s         | 2mm                  | The surface is very exquisite and has no obvious defects | No wire drawing and wire lacking |
| 7   | 0.4mm                       | 205℃                            | 70mm/s         | 1.5mm                | The surface is very exquisite and it is a little warping | No obvious wire drawing and wire lacking |
| 8   | 0.4mm                       | 205℃                            | 70mm/s         | 2mm                  | The surface is very exquisite and it is a little warping | No obvious wire drawing and wire lacking |
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