Waste recycling 3D printing and silk-making system

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Abstract. With the continuous development of 3D printing technology, 3D printing has been widely used in various industries. 3D printing has more and more consumables, more and more wastes are generated, and more and more pollution is generated to our environment. This system is based on the single-chip microcomputer, and uses the fuzzy PID algorithm to melt, shape and wire various types of 3D printing consumables at different temperatures. It can recycle 3D printing waste and directly use consumables for printing to reduce environmental pollution and printing cost.

1. Introduction
With the continuous development of 3D printing technology, 3D printing is widely used in various industries. It is predicted that by 2020, the global sales volume of 3D printers will exceed 6.7 million, and the consumption of FDM type 3D printing consumables used in the world is expected to be 3350 tons per month. In the process of printing, the generated base plate and support will become waste; and after printing, the unsatisfied or used model will also become waste; therefore, the waste volume of 3D printing is growing exponentially, and the environmental problems caused by it are increasingly serious. Among them, PLA, ABS, TPU and other materials have accounted for 76% of the use market of FDM type 3D printing materials, and such materials are not easily degradable materials. If they flow into the natural environment, they will pollute the soil and water source. In order to reduce the impact of 3D printing waste on the environment, effectively relieve the environmental pressure, and at the same time make the secondary use of resources, a desktop level 3D printing and silk making system is designed to make use of 3D printing waste materials and industrial particles in a more economic way to make and print consumables and reduce environmental pollution and printing costs. First of all, the waste or granular raw materials are put into the waste regeneration 3D printing and silk making system, which is controlled by single chip microcomputer, and the appropriate temperature is selected to melt the waste or granular raw materials and extrude them from the nozzle to produce the wires needed for 3D printing. These wires can be directly used for 3D printing, and can also be converted into wire storage, so as to reduce the environmental pressure and energy caused by waste disposal Source consumption, while reducing the 3D printing wire purchase printing costs.

2. Composition of printing and silk-making system
As shown in figure 1, the waste recycling 3D printing and silk making system consists of three parts: the silk making system, the wire storage system and the linked 3D printer printing system.
Figure 1. structure diagram of waste recycling 3D printing and silk-making system

2.1. Silk system
The system consists of extrusion system, heating system and traction system. The silk-making system can produce wire with different diameters for various types of wastes and particles. The main control part of the silk making system is the single-chip microcomputer. Before starting the work, the type of waste and the diameter of the wire should be set first. The single-chip microcomputer will control the heating chamber to heat to the corresponding melting temperature. The extrusion system includes feeding port (as shown in figure 2-a), screw (as shown in figure 2-b) and extrusion nozzle (as shown in figure 2-d). After the waste or industrial particles are put into the feed port, the material will enter the extrusion system. In order to ensure that the melting process of particles in the heating chamber is relatively ideal, it is necessary to establish the DEM model of the extrusion chamber through fluid dynamics simulation, and analyze the velocity distribution characteristics of particles in the extrusion chamber, as well as the influence of the heating chamber and screw structure on the molten extrusion of particles. In order to ensure that the extrusion system continuously pushes materials forward, the system will combine the reasonable data given by the simulation, and then model and assemble the whole model and each part through SolidWorks.

The heating chamber (as shown in figure 2-c) is a place for melting materials; Because the heating cavity is a time-varying system with large time delay, strong coupling and nonlinear, and the heating thermal inertia is large, the traditional PID control can not meet the requirements for the temperature control precision of the heating cavity. This system adopts fuzzy PID control algorithm, which has strong robustness and interference suppression ability. The fuzzy PID control can get the fuzzy rule table through the theoretical design and experimental summary. The PID control parameters can be obtained by looking up the table. The control precision can be improved to ±1°C.

After that, the molten material will pass through the diameter detection module (as shown in figure 2-f), where the diameter of the obtained wire will be detected, the current wire diameter will be compared with the set target diameter, and the rotation speed of the screw and the traction roller will be adjusted. If the current wire diameter is too large, the system will automatically adjust the traction speed to be greater than the extrusion speed, and stretch the wire to reduce its diameter. If the current diameter is too small, the system will automatically adjust the traction speed less than the extrusion speed to increase the wire diameter. Finally, it is connected to the traction roller (as shown in figure 2-g). By rotating the traction roller, the wire is stretched to ensure that the wire is even and straight.

After the material is completely cooled, 3D printing consumables with uniform diameter can be formed.
2.2. Wire storage system
In order to avoid loose wire disk and bad winding of wire disk, the generated wire can pass through the horizontal wire hole (as shown in figure 3-c) and be connected to the winding axis (as shown in figure 3-b) after passing through the silk making system, and the drum will keep the appropriate and constant winding tension while matching the wire speed. The constant tension generated by the uniform speed of the motor not only avoids the loss of elasticity of consumables due to the excessive tension, which is not conducive to printing, but also avoids the bad line disk forming and the disorder of consumables due to the too small tension. The winding system is controlled by servomotor, which has strong load resistance and stability. The cooled wire, through the winding device, will eventually roll the converted wire into a tube of well-formed, compact 3d-printed wire.

![Figure 2. Schematic diagram of the silk making system](image)

2.3. Linkage printing system
The 3D printer can also be directly connected to the silk system. The data communication is established between the main control board of the 3D printer and the control board of the silk making system, and the wire is imported to the feed port of the 3D printer (see figure 4-b). By reading the printing speed and printing state of the 3D printer, the main control board of the silk making system can adjust the rotation speed of the screw and the traction speed of the traction roller, and finally match the output quantity of the wire. In the process of 3D printing by 3D printer, the wire will not break, nor will excessive wire accumulation lead to blockage, so as to evenly feed and print smoothly.

![Figure 3. Function diagram of winding device](image)
3. System material and manufactured wire

Figure 5 is the screw extruder, which pushes the particle waste through the screw, and the extruder is the extruder heating device outside the screw. The particle waste is heated to a molten state during the process of propulsion.

As shown in figure 6, the device for controlling the diameter of wire is the linear potentiometer as the sensor element. The material is inserted into the measuring hole and the slider is attached to the material with a spring. The diameter of the material is determined by measuring the resistance value of the potentiometer. The stepper motor is used to drive the winding shaft to turn the reel to collect the printed material, and the winding speed is adjusted according to the measured material diameter to achieve the purpose of controlling the diameter. Practical tests were conducted on PLA, ABS and PETG, three commonly used 3D printing materials, and the final consumable diameter precision was up to 0.05mm. The actual consumables are shown in figure 7.
Figure 6. control wire diameter device

Figure 7. diameter of consumables

As shown in figure 8, thread rolling machine for reciprocating adjusting device, to avoid the machine in the same position in the process of constant winding wire entanglement, flow device according to the extrusion machine and thread rolling automatic reciprocating shaft speed adjustment, through the actual test results, making the device does not stretch the diameter of the wire change wire, squeeze out the distribution of the filament is neat.

Figure 8. winding device
4. Conclusion
The waste recycling 3D printing and silk-making system can generate a variety of 3D printed wires of different sizes through the silk-making part and store them or use them directly in conjunction with the 3D printer. With the rapid development of 3D printing, this system is also suitable for small and medium-sized 3D printing manufacturing in all walks of life. It can directly use waste and particle raw materials for 3D printing. On the one hand, it can relieve energy and environmental pressure, on the other hand, it can bring certain economic benefits. As today's energy and pollution problems have been taken seriously, this system has a certain practical significance.

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