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Iterative improvement of light curing printing all-in-one machine

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Abstract

As photopolymerization 3D printing technology matures and finds increasing applications in the manufacturing of everyday goods, with an expanding market, numerous equipment manufacturers are enhancing printer performance to boost printing efficiency and improve the quality and yield of photopolymerization prints. However, among the various factors affecting the quality of printed products, many manufacturers still rely on manual transportation to connect the post-processing steps for newly printed parts, such as part removal, cleaning, and curing. This approach has a impact on the quality, yield rate, and working environment of the final products. This article will delve into the processes and post-optimization strategies for post-processing integrated machines.

Keywords

Photopolymerization printing; iteration; photopolymerization printing post-processing; rapid prototyping manufacturing; precision machining

1. Introduction

In photopolymerization printing technology, the printing platform contacts the UV screen of the printer and uses liquid photosensitive resin as the unprinted medium to scan and solidify the resin based on the layered cross-sectional information of the parts, forming a certain thickness layer to complete one printing. Then, the platform is lifted and lowered by a certain height for the next printing. This process is called photopolymerization printing. Due to its high model accuracy, precise structure, and complex shape, this technology is widely used in fields such as medical, construction, automotive, and figurines.

But photopolymerization printing is not just about the shiny surface, there are also post-processing steps such as scraping, transportation, cleaning, and curing. Shovel

is the process of removing printed parts from the printing platform, while cleaning involves placing the removed parts in an ultrasonic cleaning tank with high concentration alcohol for cleaning. Afterwards, the cleaned parts are placed in a space illuminated by ultraviolet light for post curing. The above steps are collectively referred to as post-processing of photopolymerization printing. In order to ensure the accuracy of printed materials, post-processing work is usually carried out by the same person in a fixed location, minimizing the impact of post-processing on printed materials as much as possible.

In this project, the team conducted research on the structural design and overall construction of a light curing post-processing integrated machine, compared it with market competitors, and conducted surveys on potential customers to identify the shortcomings of previous concepts. In order to improve the efficiency of light curing printing, the team conducted iterative improvement research on the original light curing printing post-processing equipment.

1.1. Market Competitor Analysis

At the beginning, the structural design and construction of the integrated post-processing machine for photopolymerization printing were carried out, but there was still no product on the market that integrated multiple post-processing devices into one machine. But there is a similar machine in the market, and Zongwei Cube has launched a photopolymerization printing post-processing equipment called "Wash&Cure3". Its characteristic is that it has a large internal volume of 15.1L, which is an all-in-one machine that combines cleaning and curing as previously mentioned. Among them, the machine uses a spray type to clean the parts that have completed the photopolymerization printing, thereby saving alcohol. It is equipped with an "automatic mode" for the entire process of spraying, immersion, and curing, thus achieving one-stop photopolymerization printing cleaning and curing, fully automatic and contactless. This machine is very in line with the team's previous concept of a light curing printing post-processing integrated machine. However, compared to it, the team's concept machine not only realizes one-stop processing for cleaning and curing, but also integrates the functions of scraping and transportation. After the light curing printing machine completes printing, the machine can perform scraping operations and transport to the cleaning and curing module without manual intervention, reducing the risk of accidental breakage of parts caused by manual transportation, oxidation caused by prolonged exposure to air, and damage to the health of transport workers. It can better interpret the modern innovative manufacturing industry of "one-stop", "unmanned", "intelligent" and promoting "high-end".

1.2. Customer Research

After completing the structural design and construction of the photopolymerization

printing post-processing integrated machine, the team simulated the operation of each module of the integrated machine through the modeling process and conducted relevant discussions with potential customers. It is understood that the current UV curing printing market has expanded to the manufacturing of daily necessities due to continuous expansion, so the market demand for UV curing printing post-processing all-in-one machines will be very huge. During the research, the client also mentioned that they hope to refine the cleaning module of the post-processing machine, optimize its transportation, and reduce mechanical conflicts that may occur during operation.

2.1. Overview of current plan

At present, the team's post-processing solution for the all-in-one machine is as follows: 1. The basket frame in the all-in-one machine is supported by the "Poselier Lipkin" mechanical structure and moved to wait under the parts to be shoveled 2、The spring steel sheet stored in the tank like ammunition chain storage mechanism extends forward, and the parts that have just completed the photopolymerization printing are scooped down from the photopolymerization printer platform, which is supported by a basket frame at the bottom; 3、 After removing the parts, the gravity sensing mechanism senses the weight of the parts, and the "Poselier Lipkin" mechanical structure moves backwards, causing the basket frame to come near the U-shaped clamp and be clamped by the U-shaped clamp, while detaching from the "Poselier Lipkin" mechanical structure; 4、 The bottom bevel gear rotates, driving the screw and basket frame to rotate and descend, transferring the basket frame to the cleaning and solidification module area; 5、 In the cleaning and solidification area, a stainless steel cleaning tank filled with 95% industrial alcohol is used. The parts are immersed in the cleaning alcohol and the ultrasonic oscillator is activated for ultrasonic cleaning 6、After cleaning, determine whether to perform secondary curing with ultraviolet radiation based on whether the parts are transparent, slender, hollow, or solid. The above is the current operating mode of the post-processing all-in-one machine. Figure 1 shows the current design modeling of the team.

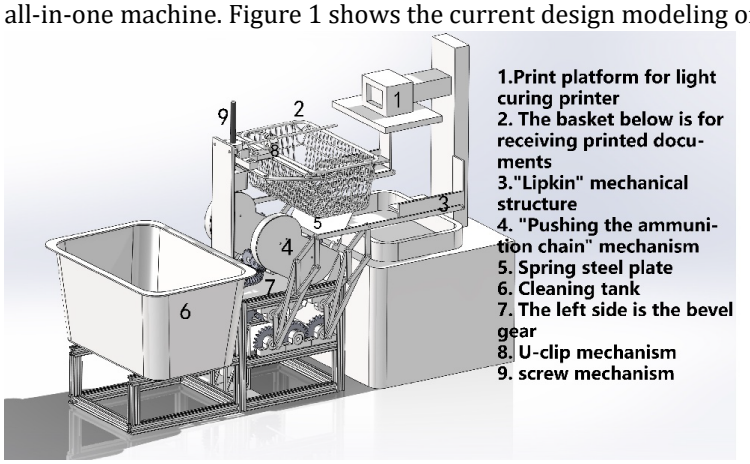

Figure 1. Modeling diagram of the original photopolymerization printing post-processing integrated machine

2.2. Analysis and iteration of shovel transport module

After completing the structural design of the integrated machine for post-processing of photopolymerization printing, the team quickly simulated the actual operating environment. The shovel mechanism is composed of a push-pull chain structure and spring steel. Based on the push-pull chain, the connection and transmission mechanism of the spring steel are similar to the automatic loading machine carried by tanks and self-propelled artillery, which saves space and completes the movement mode of the shovel mechanism design. However, during the shoveling process, it was found that the parts printed by the photopolymerization printer are generally firmly attached to the printing platform, requiring multiple, rapid, and sufficient forces to remove the parts. Therefore, the iteration for the shovel mechanism is to replace the spring steel plate with a tougher and thinner one, reduce the contact area, increase the pressure on the cutting surface, and use a motor with higher horsepower and torque to drive the push-pull chain mechanism, so that the spring steel can move back and forth more quickly, while also increasing the shovel force to prevent the shovel process from being unable to be completed due to fatigue.

In addition, it was found in the simulation that the parts were dropped into the basket by gravity, and the impact force in contact with the basket could easily damage the newly printed parts, especially the slender rods and parts with complex details. Therefore, in response to this deficiency, the team proposes to optimize the printing support for parts by adding a "protective frame" (as shown in the figure2) to protect internal parts during modeling or slicing for parts with special requirements. This protective frame can provide a certain buffer in the event of falling, avoiding damage to the parts. Not only in the post-processing process, but also in the transportation of parts, due to the existence of the "protective frame", the parts can be stored and transported in various sizes of storage boxes through sponge protection, reducing secondary damage.

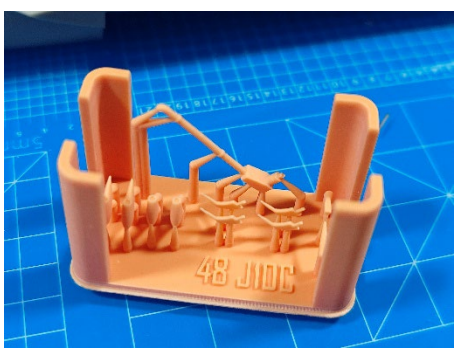

Figure 2. shows the installation of a "protective frame" style component

2.3. Analysis and iteration of cleaning and solidification module

In response to the requirements for cleaning and curing, the team also compared the "Wash&Cure3" photopolymerization printing post-processing equipment launched by Vertical Cube. The spray cleaning method in this device can not only conveniently and accurately clean the parts of photopolymerization printing, but also save the use of cleaning alcohol. However, due to the complexity of details and the presence of multi-faceted structures inside and outside, some exposed surfaces of the parts may not be cleaned by spray alcohol, resulting in residual alcohol. On the other hand, immersion based alcohol ultrasonic cleaning can allow the parts to be soaked in alcohol on every exposed surface before being immersed in alcohol, allowing for thorough cleaning and reducing the presence of residual resin on the surface due to insufficient cleaning or blind spots.

At the same time, the team found in the simulation that the parts still have diversity, but the original concept of the all-in-one machine only used external ultrasonic oscillators for cleaning. There may be resin residue caused by insufficient cleaning or excessive cleaning for different parts, which can damage the surface of the parts and reduce their original performance. Therefore, in the iteration of the cleaning module, it is particularly necessary to set the cleaning intensity of the oscillators in the cleaning module to "high, medium, and low" levels to meet the cleaning needs of different parts. The cleaning intensity of the "high, medium, and low" three gears is mainly adjusted by a knob. The working frequency of the three gears is between 20-40kHz, and the output power density is selected between 0.3-0.6w/cm2. The cleaning frequency can be adjusted to reduce the waste of excess energy in ultrasonic cleaning, improve the efficiency of the cleaning module, and reduce damage to parts.

In the secondary curing module after cleaning, due to the special nature of photosensitive resin, some light cured printed parts with special colors and shapes do not require secondary curing. Otherwise, white or transparent parts may oxidize and turn yellow due to exposure to ultraviolet light, and slender rod-shaped parts may bend and break. But for other parts without special requirements, secondary curing is needed to achieve the performance required for the parts to meet the working requirements. In the original concept of all-in-one machines, this module was not included. Therefore, in the iteration, it was decided to upgrade and add a secondary curing module. A UV irradiation lamp will be placed above the cleaning tank to wait for the parts to be cleaned before the secondary curing can be carried out. In order to enhance intelligence, machines can make judgments on whether secondary solidification is necessary based on the part information input by employers before post-processing.

After completing the secondary curing of the parts, the post-processing process of photopolymerization printing of the parts ends here.

2.4. Summary of Current Iteration Plans

In response to the previously proposed concept of an integrated light curing printing post-processing machine, through simulation and customer research, it was found that the machine still has shortcomings. Currently, there is an iterative solution: firstly, using high-power motors and thinner spring steel sheets to improve shovel efficiency; 2、 Set up a "protective box" for printed copies to reduce damage to parts caused by post-processing; 3、 Introduce a cleaning frequency that switches between high, medium, and low levels to reduce damage caused by ultrasonic cleaning; 4、 Add a secondary curing module and improve the post-processing procedures.

3. Outlook for post-processing machine iterations

Nowadays, with the rise of photopolymerization printing and the continuous expansion of the market, many small and medium-sized model studios are gradually introducing photopolymerization printers to improve the efficiency of model production. Therefore, the assembly line production of photopolymerization printing, a rapid prototyping technology, is also about to emerge, and the integrated post-processing machine will face greater challenges in terms of post-processing requirements. However, as the country accelerates the promotion of new industrialization, cultivates and strengthens advanced manufacturing clusters, and promotes the high-end, intelligent, and green development of manufacturing, the integrated post-processing machine not only needs to iterate on efficiency, but also needs to iterate on functional integration, interactive capabilities, and green friendliness.

4. Conclusion

Through the structural design and construction concept of the original photopolymerization printing and post-processing integrated machine, as well as the emergence of the vertical cube "Wash&Cure3" photopolymerization printing and post-processing equipment in the market, a deficiency analysis was conducted on the team's original concept. The research identified four iterative directions, which also clearly point to the needs of today's market, providing us with a good opportunity. By studying the direction of product iteration, we have come to understand that machines are not created once and for all, but rather require continuous understanding of customer needs, market competitors, manufacturing development plans, and iterative improvements to our own products in order to stand out in the market

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