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Design and Process Parameters Research of Single-Laser Stripping Platform Based on Automatic Double-Position Flipping Mechanism

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Abstract. It is obvious that mechanical stripping is unable to meet the requirements for the stripping of extremely thin wires. Laser stripping has been widely used for its easy integration with electromechanical equipment and high controllability. Currently most laser stripping devices have to utilize double lasers, resulting in high-cost. To solve this problem, a single-laser stripping platform based on automatic double-position flipping is designed. This platform can realize bi-directional stripping with only one laser through automatic double-position flipping. Compared with double-laser stripping platform, the single-laser one can meet the requirements of stripping production with slightly longer stripping time per row of wires but is only half the cost and of the same stripping quality, making it ideal for most medium and small companies. Research has been done on this device of mobile phone antenna stripping. The optimal process parameter has been obtained.

Introduction

Mechanical means such as stripping pliers or knives have always been used in wire stripping. For lines of mass production, mechanical stripping machine with relatively higher automation is adopted [1]. With the rapid development of electronics industry, the stripping of flat wires, HDMI cables, super fine computer wires etc. is needed. It is obvious that traditional ways of mechanical stripping are unable to meet these requirements, so laser has been used in wire stripping industries for its easy integration with electromechanical equipment, high controllability, non-contact process and no cutting force on the work piece. Especially in high-tech fields like aviation and aerospace, the application of laser stripping has been more and more popular for wire harness production [2]. In the meanwhile, some relevant researches have also been made. Previous researches have proved that laser means has absolute advantages over traditional ways of mechanical wire stripping [3-4].

Currently, the commonly used lasers are carbon dioxide and fiber ones. The carbon dioxide laser stripping machine is used for stripping the outer layer of non-metal material because the absorption coefficient of non-metal material for this kind of laser wavelength is high and the absorption coefficient of metal material for this kind of laser wavelength is low, so the metal layer will not be damaged. The YAG laser stripping machine is used for stripping metal shielding layer because the absorption coefficient of metal material for this kind of laser wavelength is high and the absorption coefficient of nonmetal material is low, so the insulation layer will not be damaged [5].

Although laser stripping is the trend of wire stripping industries, there is still plenty of room to lower the cost of wire striping process on the premise of ensuring quality and efficiency home and abroad. In the normally used laser stripping method a special wire stripping clamp with semicircular grooves, which is a little bigger than the wire, is placed on the workbench, first the wires are placed tightly in semicircular grooves and the clamp is transferred to the laser at a fixed speed, then the upper part of these wires will be stripped. After that the clamp is turned manually and the other part of these wires will be stripped. It is traditional to realize bi-directional wire stripping by turning the clamp manually, the disadvantages of which includes bad positioning, low efficiency and high scrap rate, not conductive to realize streamlined operation for modern enterprise.

Some domestic companies have made improvements to solve the problem above. Double lasers are placed up and down to bi-directionally strip the horizontally transferred wires. Although this

method solves the problem of bad positioning and low efficiency, it faces some other problems, for example, a great increase of wire stripping cost because two lasers are needed

So how to lower the cost of wire stripping on the premise of ensuring quality and efficiency becomes an urgent problem currently. A single-laser stripping platform is designed in this paper to solve this problem.

The Design of the Automatic Double-Position Flipping Mechanism

The key part of the single-laser stripping platform is the automatic double-position flipping mechanism as is shown in Fig.1a. The mechanism mainly consists of the mounting substrate, the linear guide way, the guide plate, the flip fixture, the rotary cylinder and the transmission motor. The mounting substrate is fixed on the workbench, the guide plate is fixed on the linear guide way and can move in a straight line powered by the motor, the flip fixture is connected with the rotation axis of the rotary cylinder and is fixed on the guide plate by the bear. There is a semicircular groove on the flip fixture, making it convenient for wires to be clamped tightly. The principle of the platform is that the transmission motor and rotary cylinder is connected with the host by PLC(shown in Fig.1b); The distance that the guide plate moves forward and the rotation angle of rotary cylinder is set in advance; The rotary cylinder and the flip fixture will move forward together, driven by the guide plate after the transmission motor is powered, then the wire is transmitted to the position below the laser head and the upper part of the wire will be stripped; After that, the flip fixture is turned 180 degrees, driven by the rotary cylinder, and the other part of the wire will be stripped; After the wire is stripped, the flip fixture will be turned 180 degrees reversely and the guide plate will be back along the original path. Fig.1c is the picture when the flip fixture is turning; Fig.1d is the picture after the flip fixture turns 180 degrees.

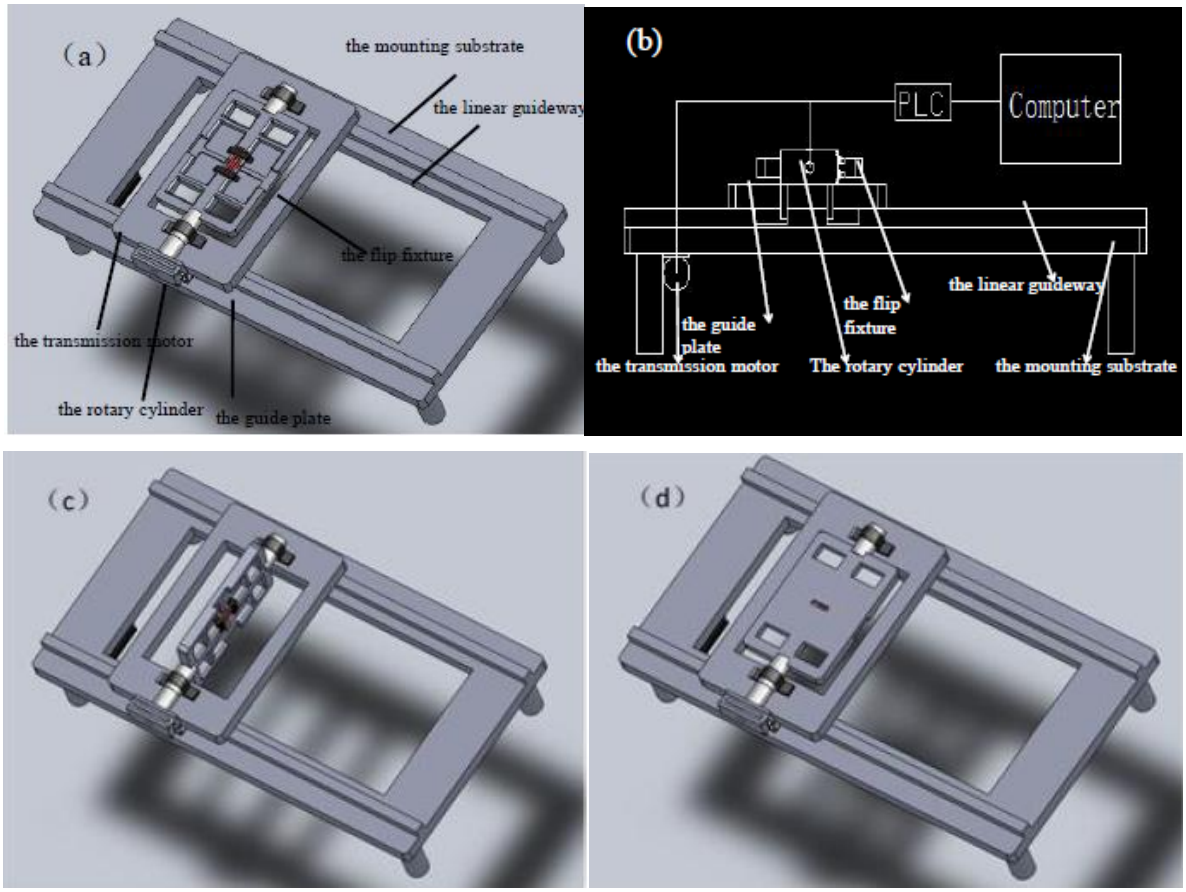

Figure 1. (a) The structure Fig.of this platform: (b) the side view of this platform: (c) he Fig.when the flip fixture is turning: (d) the picture after the flip fixture turns 180 degrees.

The Single-Laser Stripping Platform and Analysis

The single-laser stripping platform consists of laser host, control system and the automatic double-position flipping mechanism designed as above (Fig.1). The laser host contains a neck into which laser can be rapidly installed and exchanged between carbon dioxide laser and fiber laser to strip metal and nonmetal material according to different customer's requirements. The platform combines the laser stripping with PLC, which makes it easy to adjust laser position with higher degree of automation. In this way, it can realize bi-directional stripping using just one laser.

The process parameter of laser stripping should be inputted at first, including average power, pulse width, frequency, scanning speed and scanning times; Then the wire is fixed on the clamp of the automatic double-position flipping mechanism; After the installation, with the starting of the button, the flip fixture is transmitted to the position below the laser head; Then the upper part of the wire will be stripped; After that, the flip fixture is turned 180 degrees, driven by the rotary cylinder, and the other part of the wire will be stripped; After the wire is stripped, the flip fixture will be turned 180 degrees reversely and the guide plate will be back along the original path.

According to the process above, the time of the whole stripping process is; The is the time; it takes for the flip fixture to move from the outermost position to the position below the laser head. The is the time period the flip fixture turns 180 degrees; The is the time period the flip turns 180 degrees reversely; The is the time period the flip fixture moves away from the laser head; The is the time it takes for stripping the upper or the lower part of the wire. According to the experiment, we got the data as the Table 1.

Table 1. Different time in the stripping process

t_1(s)	t_2(s)	t_3(s)	t_4(s)	t_5(s)	T(s)
2	2	1	2	3	13

For the double lasers, we just need to move the fixture to the middle position of the two lasers at a fixed speed so it can bi-directionally strip the wires one-time. The time of the whole stripping process is; The total process time of the stripper with two lasers is 6 seconds less than the stripper with one laser. However, it can meet most companies' requirements when the time that finishing a row of wires is small than 20s.

The enterprise-used laser stripper is normally YAG fiber laser of 20W, the unit price of which is 180000 Yuan; The cost of stripper with one laser is 180000 Yuan while the stripper with two lasers is 360000 Yuan. It's a large budget for most small and medium companies. So stripper with one laser is a prior choice for most small and medium companies on the premise of ensuring the processing efficiency.

The Single-Laser Stripping Platform and Analysis

The Theoretical Analysis of Laser Stripping

The principle of laser stripping is that the laser beam can be focused to a light spot whose diameter is smaller than 0.1mm and the power near the focal point can reach megawatt. When the work piece is irradiated by the focused laser beam, it will be heated to gasification temperature rapidly [6]. Belonging to laser cutting, the laser stripping also has the advantages of rapid cutting speed, narrow kerf width and large range of application [7] .

Laser cutting can be divided into the models of gasification cutting [8], fusion cutting [9] and reaction gas assisted cutting [10]. Laser stripping includes gasification and melting at the same time. The key of getting high stripping quality is to get appropriate energy density by adjusting process parameters of laser. When the energy density is too low to reach the threshold energy of wire, the wire sheath cannot be removed; But if the energy density is too high, the wire core will be damaged.

The energy density is as below [11]

$$q = \frac{4P}{\pi D^2} \cdot \frac{D}{v} = \frac{4P}{\pi D v} \tag{1}$$

In the formula, the is average power. The is the diameter of spot. The is scanning speed.

According to the formula above, energy density will increase when the average power increases and the diameter of light spot and scanning speed decreases.

Besides, the influence of frequency and pulse width should also be considered when stripping wires with pulsed laser. So the process parameters that influence the stripping effect are average power, diameter of light spot, scanning speed, pulse width and frequency. How to find an optimal combination of these stripping parameters and get each parameter's influence rules on laser stripping are the main proposes of the laser stripping experiment.

The Experimental Study on Stripping Parameters and the Result Analysis

Some experimental studies about the stripping process parameters of mobile phone antenna are done based on the theory above and the single-laser stripping platform. Mobile phone antenna is extremely thin wire with three layers. Its outer layer is the insulating material and the second layer is the metal braid, and the innermost layer is the wire core. The purpose of the experiment is to find an optimal combination of these stripping parameters and get each parameter's influence rules on laser stripping when stripping the outer two layers of the mobile phone antenna.

The laser head used in the experiment is a YAG fiber laser whose average power is 20W, and different average powers can be obtained by adjusting the percentage. The stripping material is mobile phone antenna whose diameter is 1mm, wire core is 0.6mm. The light spot is focused to 0.1mm which is the minimum value to get high output energy. The process parameters that need to be set are average power, scanning speed, frequency, pulse width and scanning times. Different process parameters chosen in the experiment are shown in table 1. According to the normally enterprise used laser stripping parameters; The average power is chosen from 8W—18W; The scanning speed is chosen from 15mm/s to 100mm/s; The frequency is chosen from 10kHz to 40kHz; The pulse width is chosen from 1us to 6us; The scanning times is chosen from 3 times to 6 times.

Table 2. Design of experimental parameters

Test P No.	Average Power (W)	Cutting velocity(mm/s)	Frequency (kHz)	Pulse width(us)	scan times(n)
1	8	100	20	3	3
2	8	50	10	2	3
3	10	50	20	3	6
4	10	50	40	6	3
5	12	50	10	1	3
6	12	50	20	1	3
7	12	50	40	1	3
8	12	50	40	2	3
9	12	50	40	3	3
10	12	35	40	3	3
11	12	15	40	3	3
12	16	15	40	3	3
13	18	15	40	3	3

Fig.2a shows that when the average power is less than 10W, the insulating material of the outer layer cannot be cut thoroughly no matter how other parameters change, which is shown in table 2; It shows that the energy density above is too small to cut the outer layer thoroughly. Fig.2b is the stripping picture when the average power is 12W; Although the insulating material of the outer layer has been cut thoroughly, the metal braid still has not been cut thoroughly; Comparing the samples of 5, 6 and 7 in Fig.2b, the depth of laser cutting increases with the increasing of the frequency, the reason may be that although the peak power will decrease when the frequency is increased, its effect on the material removal is not obvious; However, the times of laser actions on wire per unit will increase when the frequency increased; So the heat accumulating effect will be very obvious and the removal of wire's material is accelerated; Comparing the samples of 7, 8and 9 in Fig.2b, the depth of laser cutting increases with the increasing of the pulse width; The reason should be that when the pulse width is increased, the time of laser actions on wire in single pulse is increased; So the heat accumulating effect is obvious and plays a leading role on the stripping depth; Comparing the samples of 9, 10 and 11, the stripping effect of sample 11 is the best; It shows that the slower of the scanning speed is, the deeper of the cutting depth is; The scanning speed is chosen as 15mm/s, considering the efficiency of production companies. The average power is 16W in the sample 12 of Fig.2c; Comparing with sample 11, the cutting depth is deeper, but the metal braid still cannot be cut thoroughly; The average power is 18W in the sample 13; Comparing with sample 12, the cutting depth is deeper and both the insulating material and the metal braid of outer layers are cut thoroughly without damaging the wire core of mobile phone antenna; So the sample 13 is chosen as the best match of these stripping parameters; Comparing the samples of 11, 12 and 13, we can see that the material will get more energy when the average power is increased or the cutting depth is deeper. The optimal combination of these stripping parameters gotten in the experiment is that the average power is 18W, the scanning speed is 15mm/s, the frequency is 40kHz, the pulse width is 3us and the scanning times is 3times. Fig.2d is final rendering of laser stripping.

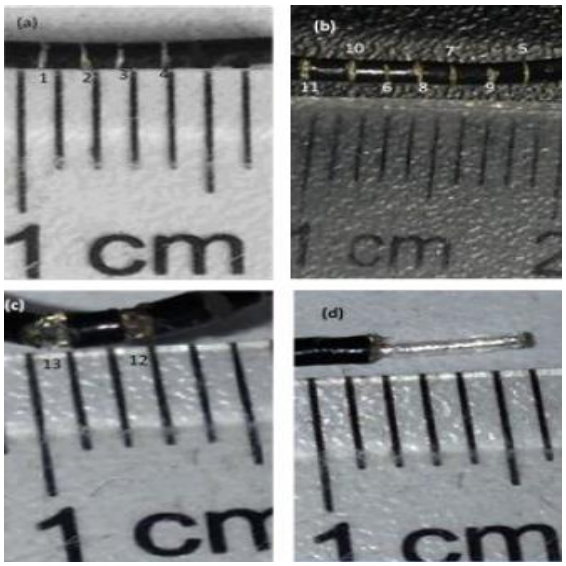

Figure 2. The Fig.2 of laser stripping: (a) the samples of 1,2,3,4: (b) the samples of 5,6,7,8,9,10,11: (c) the samples of laser stripping12, 13: (d) the final rendering of laser stripping.

According to the experimental results above, the changing rule of the average power and the scanning speed is consistent with the theoretical equation of the energy density, which means the energy density will increase when the average power is increased or when the scanning speed is lowered and the outer material of the wire can get more energy. The number of times that laser acts on wire per unit time will increase when the frequency is increased. Also the time of laser acts on wire in a single pulse will be increased when the pulse width is increased. Both of these can cause very obvious heat accumulating effect thus lead to the accelerated removal of wire's material and better stripping effect.

The Quality Comparison between the Stripper with One Laser and the Stripper with Two Lasers

The mobile phone antenna is separately stripped by stripper with one laser and stripper with two lasers using the optimal parameter. The rendering of the wires is shown in Fig.3.

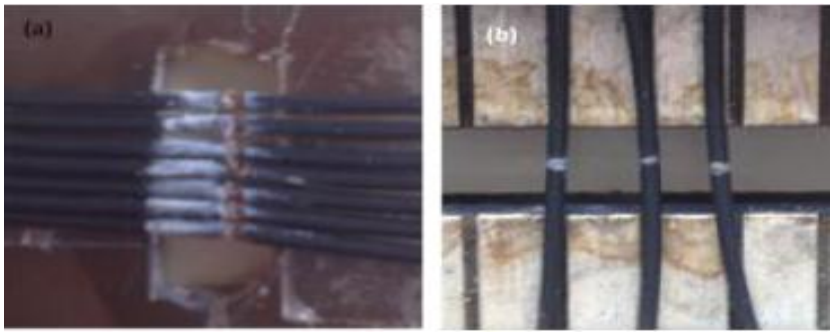

Figure 3. The rendering of laser stripping: (a) processed by stripper with one laser: (b) processed by stripper with two lasers.

Comparing Fig.3a and 3b, we can see the stripping quality of the stripper with one laser is almost the same as the stripper with two lasers and can meet the requirements of companies' stripping quality.

Conclusion

The single-laser stripping platform based on automatic double-position flip mechanism can replace double-laser stripping platform. Although its stripping time per row of wires is 6s longer than that of double-laser one, the total time of 13s per row of wires already meets the production requirement. In the meanwhile, the single-laser stripping platform is only half the cost of the double-laser one but of the same stripping quality, making it ideal for most medium and small companies.

Some experimental studies on the process parameters of mobile phone antenna stripping were done on the single-laser stripping platform and the appropriate energy density and the optimal combination of these stripping parameters have been obtained. The stripping quality is high, meeting the requirements of most companies. The results of the stripping process parameter study in this paper have reference value for other kind of wires. Besides, the changing rule of the average power and the scanning speed is consistent with the theoretical equation of the energy density, which means the energy density will increase when the average power is increased or when the scanning speed is lowered and the outer material of the wire can get more energy. The number of times that laser acts on wire per unit time will increase when the frequency is increased. Also, the time of laser acts on wire in a single pulse will be increased when the pulse width is increased. Both of these can cause very obvious heat accumulating effect thus lead to the accelerated removal of wire's material and better stripping effect.

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