Study on laser cutting process of aluminum alloy explosion suppression material

Zhou Jingzhong, Zhang Zhiwei*, Niu Fang, Lv Jianjun
No.52 Institute of China Ordnance Industry. Inner Mongolia, Baotou, China
* Corresponding author: zhzhwhero@126.com

Abstract. Using laser cutting technology instead of the existing processing process to process aluminum alloy explosion-suppressing material mesh, the effect of laser output power, cutting speed and auxiliary blow pressure on the size of the seam and surface roughness is studied. Inverted optical microscope is used to characterize the shape and physical phase of the cut, and the composition content analysis of residue produced after vibration experiment is carried out using ICP-AES inductively coupled plasma emission spectrometer and CS-744 carbon sulfur analyzer. The results show that aluminum alloy explosion suppression material is prepared by laser cutting process, and the test parameters are laser output power 30W, cutting speed 200mm/s, auxiliary blow air pressure 0.7bar, and its cutting size and surface roughness are optimal. Ultrasonic cleaning can effectively remove patches from the surface of the material after cutting to achieve better surface quality requirements. Laser cutting process compared with the traditional mechanical cutting process has obvious advantages, smooth cutting, high processing accuracy, slag rate significantly reduced.

1. Introduction

Aluminum alloy explosion suppression material is an advanced functional material, it is through the special aluminum alloy foil through the seam, meshing and other processes into a honeycomb-like pore material, filled in a container containing flammable and explosive fluid, when encountering ignition source can effectively prevent the container explosion. Widely used in armored vehicles, aircraft, ships and other military products and even buses, underground oil depots, high-class cars, oil tankers and other civilian products.

With the rapid development and progress of society, people's awareness of security has been qualitatively improved, into the twenty-first century, the international trend is becoming more and more complex, terrorist activities occur from time to time, our troops counter-terrorism, explosion-proof, peacekeeping tasks also increase frequently, so the modern armored vehicles, transport vehicles, tanks, anti-terrorism vehicles and other models of the security protection of combatants put forward higher demand, so the protection of fuel tanks equipped with flammable and explosive fuel tanks also put forward higher requirements. As a more advanced functional material, anti-explosion materials provide adequate protection to solve the safety protection in this field.

As an advanced protective material in the field of safety at present, the key process technology of explosion suppression material is the processing process and filling process of the material. At present, the use of anti-explosion material processing technology mainly includes slit - pull net, ultrasonic cleaning and so on. The seam cutter uses a metal slit knife. This processing method, because it is contact processing, will produce mechanical extrusion, so in the process of cutting mesh will inevitably produce burrs, chips, need to go through a cumbersome follow-up processing to meet the requirements of use.
This experiment uses laser cutting technology to replace the existing processing process to process explosion suppression material mesh, through the focus of high-power density laser beam irradiation work parts, so that the irradiated material quickly melt, vaporization, and with the help of high-speed air flow with the beam blowing out the molten material, explore the preparation process on the product slag rate.

2. Experimental method

2.1. Test preparation of samples
The laser cutting process parameters are set as: laser output power (20W, 30W, 100W), cutting speed (70mm/s, 100mm/s, 200mm/s), auxiliary air pressure (0.5bar, 0.7bar, 0.9bar). The thickness of aluminum alloy foil for the test is specified at 0.05mm ±0.005mm, and the test sample is prepared using the laser metal laser marking mechanism of laser.

2.2. Experimental method
Under certain conditions of other parameters, the three factors of laser output power, cutting speed and auxiliary blow pressure are adjusted respectively. In order to reduce the error in material preparation and measurement process when measuring the width of the seam, multi-point measurement is carried out on the seams in different parts of the sample, and the method of taking the mean after removing a maximum value and a minimum value is used.

| Level | Laser power(W) | Cutting speed(mm/s) | Auxiliary blowing pressure(bar) |
|-------|----------------|---------------------|-------------------------------|
| 1     | 20             | 200                 | 0.5                           |
| 2     | 30             | 100                 | 0.7                           |
| 3     | 100            | 70                  | 0.9                           |

2.3. Ultrasonic cleaning
The JXD type ultrasonic cleaner is injected into the water heating to 60degrees C and maintaining the temperature, add the cleaning agent to make it fully blend with the water, put into the cut aluminum alloy explosion suppression material, the liquid surface height is not over the material 30mm to 50mm, clean 5min, and then wash with clean water twice after drying.

2.4. Vibration experiment
The material after ultrasonic cleaning and the aluminum alloy explosion suppression material prepared by the mechanical cutting process are put into the KS speed control multi-use oscillator for vibration experiment. The quality and volume of the material put in are filled in full accordance with the actual production needs of tank filling.

2.5. Sample profiling and residue composition testing
Sample phase and structural analysis using ZEISS Observer, Germany. A1m inverted optical microscope. The component content analysis of residue produced after vibration experiment was carried out using the Speck ICP-AES inductively coupled plasma emission spectrometer in Germany and the Reco CS-744 carbon sulfur analyzer in the United States.
3. Results and discussion

3.1. Effect of laser power on seam size and surface roughness

Figure 1 is a diagram of laser power and seam size, from which it can be seen that the size of the cut increases with the increase of laser power when the material thickness, cutting speed and gas pressure are certain. According to the formula \( E = P \times t \), when the cutting speed is unchanged, that is, the laser irradiation time \( t \) must, with the increase of laser power \( P \), the energy obtained by the material \( E \) increases, the temperature of the cutting surface increases, so that the alloy at the seam is aggravated by melting gasification, so the size of the cut becomes larger.

![Fig 1 The relation between laser power and kerf size](image)

Figure 2 is a map of the surface roughness of the material under different laser power, from which it is not difficult to see that the roughness of the seam surface increases with the increase of laser power. Because when the cutting speed is certain, the time of laser irradiation on the surface of the material does not change, with the increase of power, the luminous intensity of the focus center increases, the energy obtained on the surface of the material also increases accordingly, under the action of gas pressure, the high temperature melting or gasification material diffuses indirectly melting part of the alloy to both sides, so that the surface roughness increases.

![Fig 2 The surface roughness maps of materials under different laser powers](image)

3.2. Effect of cutting speed on seam size and surface roughness

The relationship between cutting speed and cut size is shown in Figure 3, and the experiment finds that the width of the cut becomes smaller with the increase of the cutting speed, which can be analyzed from the mechanism of cut formation: in low-speed cutting, because the cutting speed can not keep up with the oxidation reaction speed, the excess reaction heat makes the cut over-melt, thus forming a wider and uneven cut.
Figure 4 shows that the surface roughness of the material decreases as the cutting speed increases. With the increase of cutting speed, the laser beam's forward speed is the same as the melting speed of the slag, and under the impetus of auxiliary blowing gas, it can be understood that the slag flow is flowing down in a string, so that the incision does not adhere to the slag, the cutting surface becomes smoother.

3.3. Effect of auxiliary blow pressure on seam size and surface roughness

Figure 5 is a diagram of the dimensions of the auxiliary blow air pressure and the seam, which shows the trend of decreasing and then slightly increasing the size of the seam as the gas pressure increases. This is because as the gas pressure increases, the gas flow increases and the slag energy increases, so the cutting quality is improved. However, if the pressure over the General Assembly makes the gas flow disorder, the formation of an untidy incision, the width of the cut is therefore wider, so choose the appropriate auxiliary blow gas pressure to get a more ideal cutting quality.
Figure 6 shows that the surface roughness of the material with the increase of gas pressure shows a trend of decreasing first and then slightly increasing, the reason is similar to the effect of gas pressure on the width of the seam, which is not repeated here.

3.4. Ortho experimental results analysis
At the same time, some studies show that the cutting speed increases with the increase of cutting power, and then combined with the above-mentioned different parameters on the shape of the cut edge and the size of the cut, the optimal test parameters are determined to be laser output power 30W, cutting speed 200mm/s, auxiliary blow pressure 0.7bar. Figure 7 is a micromorphic map of the optimal test parameters of laser-cut aluminum alloy foil, which clearly shows that the size of the cut and the roughness of the surface are the optimal items.
3.5. Effect of ultrasonic cleaning on the material after cutting

Figures 8 and 9 are before and after ultrasonic cleaning, from which it can be seen that there is white powder on the surface of the cutting material before cleaning, and that there are some macular spots at the end of the seam, which disappear completely after cleaning.

![Fig 8 before cleaning](image)

![Fig 9 after cleaning](image)

3.6. Comparison of laser cutting process with mechanical cutting process

As can be seen from Figure 10 and Figure 11, the aluminum alloy explosion suppression material prepared by the laser cutting process does not change much at the edge of the cutting seam before and after the vibration test, while the aluminum alloy explosion suppression material prepared by the mechanical cutting process is significantly reduced compared to the cutting edge burrs before cleaning.

Description Laser cutting process to prepare aluminum alloy explosion-suppressing materials can reduce the production of burrs and slag chip removal phenomenon, the process is better than the traditional mechanical cutting process.

| Serial NO. | Laser power(W) | Cut speed (mm/s) | Auxiliary blowing pressure(bar) | The size of the seams | Surface roughness |
|------------|----------------|-----------------|---------------------------------|-----------------------|-----------------|
| 1          | 20             | 200             | 0.5                             | 57.7                  | Smaller         |
| 2          | 20             | 100             | 0.7                             | 71.5                  | Smaller         |
| 3          | 20             | 70              | 0.9                             | 134.7                 | Medium          |
| 4          | 30             | 200             | 0.7                             | 42.8                  | Smaller         |
| 5          | 30             | 100             | 0.9                             | 85.4                  | Medium          |
| 6          | 30             | 70              | 0.5                             | 135.6                 | Larger          |
| 7          | 100            | 200             | 0.9                             | 73.2                  | Medium          |
| 8          | 100            | 100             | 0.5                             | 108.1                 | Larger          |
| 9          | 100            | 70              | 0.7                             | 172.3                 | Larger          |

**Cut**: K1 88.0 57.9 100.5

**Sew**: K2 87.9 88.3 88.3

**Feet**: K3 117.9 147.5 97.8

**Inch**: R 30.0 89.6 12.2

![Fig 10](image)
The solution filtered, grayed out, dissolved, hydrochloric acid leached, and ICP after the vibration experiment was determined to determine the residual content, the specific value of which can be found in Table 3.

Table 3 shows that the residual content detected after the vibration experiment is 1.60 mg/L, while the residual content detected by the mechanical cutting process after the vibration experiment is 12.06 mg/L, which is significantly higher than the former. This shows that the laser cutting process processed aluminum alloy explosion-suppressing material slag rate is obviously very low.

4. Conclusion

4.1. The aluminum alloy explosion suppression material is prepared by laser cutting process. The current optimal test parameters are laser output power of 30W, cutting speed of 200mm/s, auxiliary blow air pressure of 0.7bar, its seam size and surface roughness are optimal.

4.2. Ultrasonic cleaning effectively removes white and yellow patches from the surface of the cut material to meet better surface quality requirements.

4.3. Laser cutting process compared to the traditional mechanical cutting process has obvious advantages, smooth seam cutting, high processing accuracy, slag rate significantly reduced.

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