Study on Cutting Quality of Laser Cutting Machine

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Abstract

To research on the influence of technological parameter upon cutting components of ZT- K-30M laser cutting machine, the writer carried out a processing experiment of fiber laser cutting machine upon mild steel plate. On one hand, optimization was implemented to select appropriate processing parameters including laser power, cutting speed and auxiliary air pressure. Then the influence of kerf width, heat affected zone and section roughness driven by focus location variation was drawn attention, so as to obtain the manifestation of kerf width, heat affected zone range and section roughness under appropriated focus location. On the other hand, based on an analysis of micro materials from test pieces for the cutting machine, the writer conducted a research on component change of materials for fiber laser cutting and analyzed the reaction process of cutting, leading to an understanding of how laser cutting machine worked.

Keywords

Focus Location; Kerf Width; Heat Affected Zone; Roughness; Material Analysis.

1. Introductory remarks

Fiber laser output beam is through the medium of pump light source to stimulate, fiber Bragg grating or fiber optic ring as working substance, using the reflection lens and focus. Optical fiber laser cutting its core device for fiber laser, compared with the commonly used CO2 laser cutting technology, as a result of the optical fiber laser cutting laser light routing optical fiber transmission, optical fiber optical path belongs to the flexible light path, easy to realize the fixed length, electro-optical conversion rate is higher. Transmission light road closed, up to the bad working environment, the dust, shock, shock, humidity, high temperature tolerance. Reliable transmission gain effects of optical fiber, laser operation life is long. In addition, the laser costs less, high absorptivity of metal material, cutting speed, can be used for precision cutting [1,2].

Laser cutting parts of the cut surface roughness, the slope and the width of the kerf width and molten debris adhesion conditions represent the cutting quality, range of heat affected zone, kerf width influence the cutting quality of the workpiece.ZT - K - 30 m is mainly studied the influence of process parameters of laser cutting machine for cutting parts.

2. Experimental equipment, materials and methods

Laboratory equipment for ZT - K - 30 m laser cutting machine, laser type as the inter public fiber laser, its maximum output power 500 w, 1064 nm wavelength laser beam, the standard optical fiber 600 microns in diameter, the laser is focused on the focal length is 100 mm, focusing spot diameter of 0.08 mm, equipment cutting nozzle outlet diameter is 1.25 mm. Test materials for 3 mm low carbon steel Q235.Auxiliary gas adopted in the experiment for 99.99% of the oxygen purity, adopt the way of blowing coaxial gas supply way.

Research methods for the cutting power is 450 w, the cutting speed 45 mm/min, the basis of the perforation parameters such as power 150 w, at 0.5 to the interval, by - 10 to + 10 range change focus position, the research focus on the quality of the cutting. Cutting sample Outlines of 50 mm x 30 mm of quadrilateral, quadrilateral outer contour as the observation plane roughness elements; In quadrilateral slab surface, quadrilateral along the length direction, a cutting length 15 mm intervals

for 20 mm line, this line segment as observation slitting slope and the width and the elements of molten debris attached condition.

3. Results and analysis

3.1 The influence of focus position for cutting seam width

From 10 to + 10 when focus position changes in the process of steel plate cutting seam appear different changes. Focus position in 10 to - between 6 and 6 to 10 samples has not been cut through. Focus position for 6 to between 4.5 and 1 to 4 sample, material surface damage is serious, it is not good. Focus position between 4.5 to 1 can successfully complete cutting, slitting morphology have corresponding change. Different focus cut sewn surface sampling is shown in figure 1.Due to different focus cut sewn surface sampling parts have a certain thickness, affected by the upper and lower surface morphology of the kerf width quite different, the surface of the sample under different focus when cutting seam is shown in figure 2.

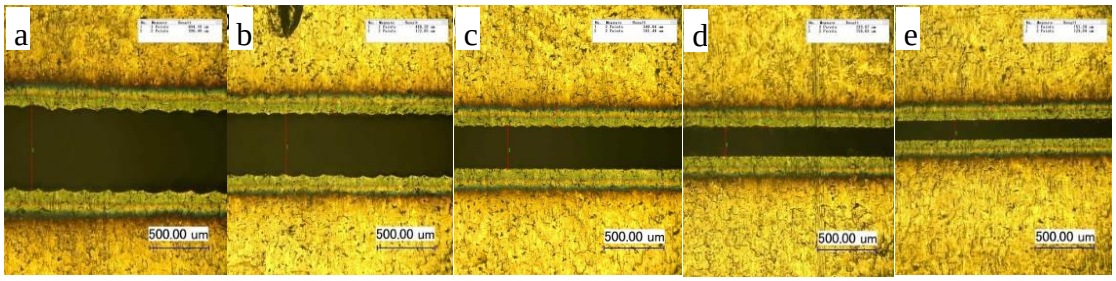


Figure 1: cutting sew on the top surface with different focus a -4.5, b -3.5,c -2.5, d -2, e -1.5

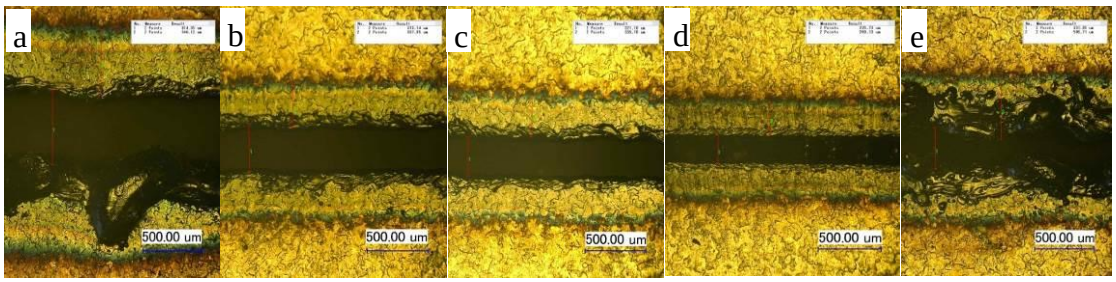


Figure 2: cutting sew on the bottom surface with different focus a -4.5, b -3.5,c -2.5, d -2, e -1.5

Figure 1 and figure 2 are respectively the focal length of laser cutting machine - 4.5, - 3.5, - 2.5, - 2, up and down on the surface of the kerf width - 1.5 parts. Because of the influence of cutting thickness dimension on the cutting seam location below appear different changes. When focus position changes from - 4.5 to - 1.5, the width of cut sewn surface gradually narrowed, kerf edge is also more and more flat and clean. Cutting seam under surface along the cutting seam, the change rule of different focus position in - 4.5 and - 1.5, the sample surface under the kerf presents the uneven size of tumor, no visible uniformity good kerf width, kerf width under the surface of the serious damage cannot be used. Focus in other place, the surface quality of the cutting seam under gradually increase, kerf edge presents a periodic wave form, when the focus position is - 2 kerf width is relatively uniform, no tumor substance.

Through the above analysis, the focus position when - 2 a disease-free synthesis, focus position when - 3 and - 2.5, no significant melting residue, take a focal length of laser cutting machine - 4.5, - 4, - 3.5, - 1.5, - 1, watched cutting molten debris as shown in figure 3.

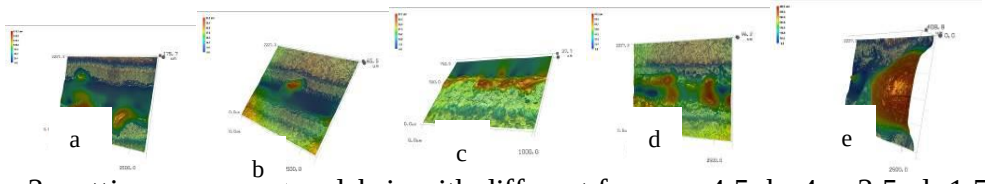


Figure 3: cutting seam molten debris with different focus a -4.5, b -4,c -3.5, d -1.5, e -1

As shown in figure 2, 3, in the focus position in - 4.5, - 1.5 and - 1, was badly damaged by the surface of the kerf width, have larger tumors appeared. The focus position under - 4.5, surface cutting seam 3 in larger tumors, maximum height can reach 175.7 microns.In the focus position when - 4 and - 3.5, the surface quality of the kerf width increase gradually, when in the focus position - 4, no obvious melting residue, highlight the slag can be 1, height can reach 65.5μm.Focus on - 3.5, melting residues attached is relatively uniform, height between 26.9μm - 37.7μm.Thus, the focus position from - 4.5 to - 2, cutting the molten debris situation gradually improved.

From figure 1, figure 2 can get up and down surface visible kerf width as shown in table 1.Analysis of the surface morphology of the kerf width, when focus position setting of - 3.5 to -2, below the surface cutting seam breakage degree gradually improved, the kerf edge, present a periodic wave form of wave form reflects the pulse laser cutting out the light, if every wave curve chemotaxis to rules under the condition of half round curve, the trend of its present a smaller radius value, it can reflect the actual focal point position of rising process, until the focus position is - 2.5 to - 2, the wave curve closer to a straight line, when in the focus position - 2, no visible gap after the split of kerf width;In addition, the cutting seam width value increase as the focus position, the kerf width on the decline.

Table 1 Top and bottom surface of the kerf width（Unit：μm）

Focus Position	Top Surface	Bottom Surface	Differentials
-4.5	694.16		
-4	593.95		
-3.5	499.28	373.14	126.14
-3	443.59	321.10	122.49
-2.5	348.94	285.86	63.08
-2	233.87	235.73	-1.86
-1.5	152.20		
-1	81.69		

Analysis on the surface morphology of the kerf width, the kerf width on the numerical value with the improvement of the focus position, the decline in its value, the focus position - 1 reach the kerf width on the upper surface of the minimum value, namely 81.69 mu m, tend to focus on spot value of 0.08 mm in diameter, the cutting seam width of topography as shown in figure 4.Visible, when the focus position is set to "1", its practical focus on the specimens of the above.

Figure 4: Kerf width focus in - 1 position

Combination of upper and lower surface cutting seam width values comparative analysis, reflect the actual cutting seam section has a certain slope, with the focus location up to - 2, the difference in surface cutting seam width, up and down seam cutting slope in decreases, and thus reflects the actual focal point showed a trend of rising movement, when the upper and lower surface cutting seam width value is relatively close, slitting slope most hours, at this time the focus position is more appropriate position.

3.2 Focus position for slitting the effect of heat affected zone

Similar to analyze cutting seam width, also taking the focus position in - 4.5 to - 1, using super depth of field of 3 d microscopy heat affected zone, its heat affected zone amplitude values as shown in Table 2, cite specific heat affected zone morphology can be seen in figure 1, 2.

Table 2 Heat affected zone amplitude value change（Unit：μm）

Focus Position	Top Surface	Bottom Surface	Differentials
-4.5	200.49	540.12	339.63
-4	193.03	432.47	239.44
-3.5	182.65	373.14	200.49
-3	176.33	339.70	163.37
-2.5	161.49	298.82	137.33
-2	159.63	269.13	109.50
-1.5	129.94	506.71	376.77
-1	116.93	631.08	514.15

Can be seen from table 2, the surface of the heat affected zone amplitude value is bigger; Below the surface, when the focus position from - 2.5 to 0, heat affected zone amplitude gradually narrowed, focal point position by -1.5 to - 1, the heat affected zone range to dramatically expand trend; On the surface, the heat value were small; Combination, its heat amplitude difference in focus position at - 2 smaller, shows that the air flow more smoothly, combined with the table 1 shows that the slope is minimum, kerf width edge closer to the surface.

3.3 The effects of focus position on the cut surface roughness

On the quality of cutting seam at the same time, the roughness of the section is also an important index of laser cutting quality. The surface roughness is refers to the machining surface with small spacing and small peak valley roughness. The surface roughness is mainly influence the wear resistance, with stability, fatigue strength, corrosion resistance, impermeability, contact stiffness and accuracy of measurement. In addition, the surface roughness of the parts plating coating, thermal conductivity and contact resistance, reflection and radiation performance, liquid and gas flow, the resistance of the conductor surface current flow will have different degrees of influence [3].Using precision roughness measuring instrument measuring experiment in front of the cutting seam complete cut surface roughness, as shown in figure 5.

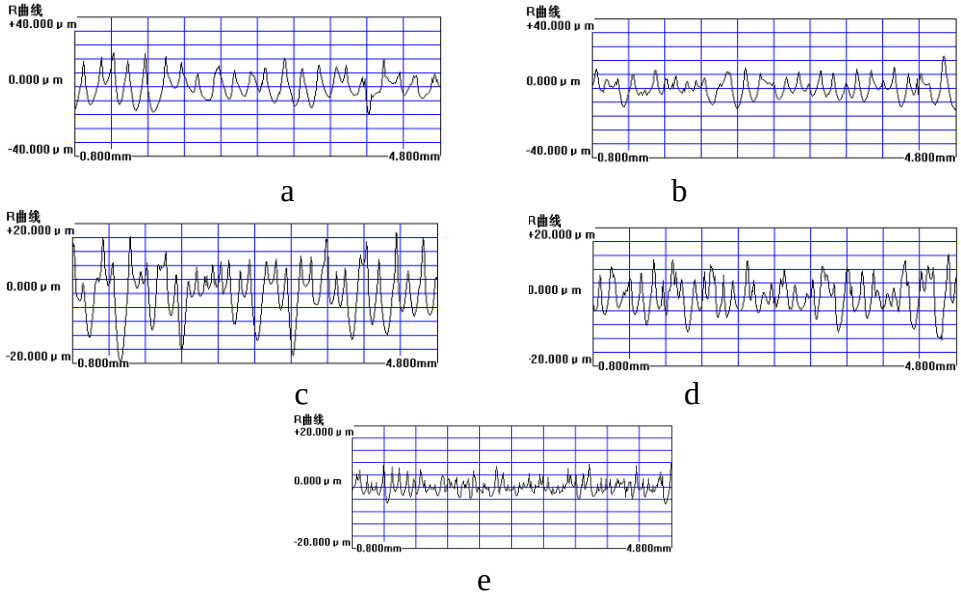


Figure 5: Cut surface roughness with different focus a -4, b -3.5, c -3, d -2.5, e -2

By measure the roughness of the curve, contour offset in the length of the sampling arithmetic average of the absolute value, thus obtains the tangent plane of Ra value as shown in table 3.

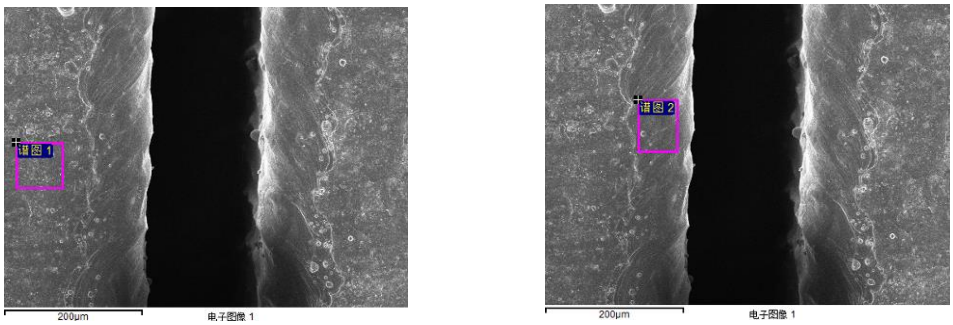
Table 3 cut surface roughness Ra value（Unite：μm）

Focus Position	Cut Surface Ra
-4	5.8656
-3.5	5.7375
-3	4.2957
-2.5	3.8739
-2	1.8170

Can be seen from table 3, in between - 4.5 to -2 focus position, with the focus position, its roughness Ra showed a trend of decline, the focus position when - 2, minimum value.

3.4 Cutting mechanism research

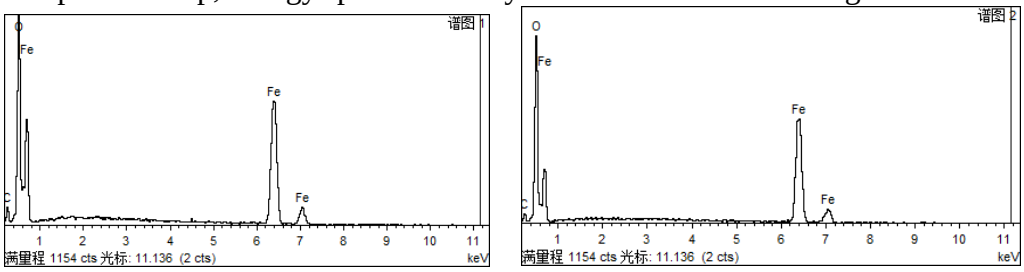
Through the Zeiss IGMA/HD scanning electron microscope energy spectrum analysis, the sample is shown in figure 6.



a. Sample from heat affected zone around b. Sample from heat affected zone

Figure 6: Sample schematic diagram

In the form of plane sweep, energy spectrum analysis results are shown in figure 7.



a. Element content surround heat affected zone b. Element content in heat affected zone

Figure 7 Energy spectrum analysis results

After 3 times analysis to $CaCO_3$ as standard sample of C, with SiO_2 as standard sample of O, with Fe as standard samples of Fe, billet body surface and section of material analysis results as shown in table 4.

Table 4 Material analysis results

	Weight percentage surround heat affected zone	Weight percentage in heat affected zone	Atomic percent surround heat affected zone	Atomic percent in heat affected zone
Fe K	69.14	71.06	37.65	40.36
C K	5.84	3.47	14.78	9.17
O K	25.02	25.46	47.57	50.48

By table 4 shows that the process of laser cutting, sheet metal body gradually by oxygen oxidation of Fe element, can produce three types of exothermic reaction, Fe element part of the generally exists in

the form of oxide.In the process of laser cutting, there are two kinds of reaction of heat affected zone, is a kind of oxidation reaction, material surface under the laser beam heats up quickly to the ignition temperature, intense combustion reaction with oxygen, emit a lot of calories;Is a kind of hot melt reaction, under the effect of the heat generated by the oxidation reaction, the material forming inside the hole filled with steam, and holes surrounded by molten materials around [4].Produce because of heat affected zone, carbon steel plate absorption of laser energy, after reaction with oxygen, temperature reaches above the melting point, near the cutting seam surface produced by melting peaks, generally after solidification, high kerf edge, using super depth 3 d can be observed under the microscope.

Therefore,carbon steel plate laser cutting, from the microcosmic point of view can be seen as the combination of the oxidation reaction and hot melt, which belongs to the macroscopic melt oxidation of cutting and cutting on the continuum.

4. Conclusion

Articles in ZT-K-30M the influence of process parameters of laser cutting machine for cutting parts as the research object, through the kerf width, kerf heat affected zone, the cut surface roughness and cutting mechanism of research, draw the following conclusions.

1) As the focus position to rise to the right focus position, kerf width decreases, kerf edge slope gradually decreases, and the appropriate focus position is located in the upper and lower surface cutting seam width of approximately equal circumstances.

2) As the focus position to rise to the right focus position, the heat affected zone amplitude decreases gradually, show that in the focus of the appropriate location, the air flow is relatively smooth, minimum heat affected zone.

3) As the focus position to rise to the right focus position, its roughness Ra showed a trend of decline, the focus in the right position, the minimum value.

4) During the process of laser cutting, plate ontology of Fe elements gradually by oxygen oxidation, generally exists in the form of oxide.In the process of laser cutting, there are two kinds of reaction of heat affected zone, is a kind of oxidation reaction, material surface under the laser beam heats up quickly to the ignition temperature, intense combustion reaction with oxygen, emit a lot of calories;Is a kind of hot melt reaction, under the effect of the heat generated by the oxidation reaction, the material forming inside the hole filled with steam, and holes around surrounded by molten materials.

References

[1] Shen Haiping, Chen Xin, Chen Yang. Fiber laser cutting technology [J]. Electric welding machine, 2013, (7):51-56.

[2] Sun Wei. TC1 plate laser cutting process parameters on the influence of the cutting quality of the research [D]. Institute of Aeronautical Engineering Shenyang, 2009.

[3] Hu Ronghua. Tolerance and fit and measurement [M]:Tsinghua University Press,2005.

[4] Jin Gang. Diagram for the laser processing practical technology [M].Beijing: Metallurgy Industry Press,2013.

[5] Chen Cong, Gao Ming, Gu Yunze. Fiber laser cutting aluminum alloy sheet process characteristics research [J]. Chinese Laser,2014, (6):0603004.

[5] Yuan Wei. Laser cutting thin plate technology research [D]. University of Science and Technology Changchun,2014.

[6] Tan Xianfeng, Yang Junhua, Geng Yanqing. From coke deposition and laser drilling hole size relations of experimental research [J]. Applied Laser,2011,(3):244-247.