International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 14, Issue 11 [November 2025] PP: 01-08

Automatic Timber Cutting and Shaping Equipment

Donglin Huang, Yulong Jin, Jinyang Guo
[1] *School of Electronic and Information Engineering, Changchun University, Changchun 130022, China*
Corresponding Author: Min Li

Abstract: *This paper introduces the key elements and manufacturing conditions of automatic wood cutting and forming equipment, and constructs three-dimensional curve diagrams based on experimental data. Through the analysis of these diagrams, the optimal manufacturing conditions for the equipment are derived. Additionally, the solution methodology for the three-dimensional curve diagrams is elaborated in detail, along with an explanation of the equipment's connotation and significance.*
Keywords: *automation, wood processing, cutting, 3D curve graph*

Date of Submission: 05-10-2025 Date of acceptance: 05-11-2025

I. Preface

In recent years, automatic wood cutting and forming equipment has been increasingly widely used in wood processing. In the wood industry, high-power devices are not necessarily required, and due to the excellent processability of wood compared to laser heat sources, with the increasing demand for factory automation, the wood industry is considered one of the easiest fields to adopt automated laser wood cutting and forming equipment.

The fields of processing using automated equipment include cutting, punching, marking, laser engraving, as well as promoting chemical reactions, laser carbonization, and other aspects, but the main application now is cutting processing. It has been put into practical use in cutting straight lines, curves, and stamping dies for sheet metal, and is also being used in wood carving. It is better than the original processing method in terms of processing accuracy, yield, and variability. If combined with CNC lathes, it is possible to achieve automation and product standardization.

When using lasers in wood processing, there are various methods and processing conditions for the aforementioned processes. Therefore, it is necessary to conduct research, and this article focuses on introducing automated cutting processing.

From the perspective of processing science, it is of great significance to fully utilize the characteristics of lasers for optimal processing. Therefore, it is hoped that corresponding standards and methods can be developed. In order to study the practical best method, a curve graph of experimental data was drawn through experiments. Based on the three-dimensional curve graph, the range suitable for the optimal standard was determined, and the corresponding processing conditions were calculated on the curve graph. The optimal processing conditions for laser cutting of sheet metal can be derived using the three-dimensional graphical method.

For this method, setting standards and handling parameters are key, and when handled appropriately, it becomes an effective approach. Below is a brief description of practical applications centered around cutting processing.

II. Experimental elements and conditions

As shown in Figure 1, based on the characteristics of sheet metal cutting and processing, the characteristic elements when using automated cutting and forming equipment to cut sheet metal are provided. These complex factors are determined by various conditions, which vary depending on the various usage environments of the device.

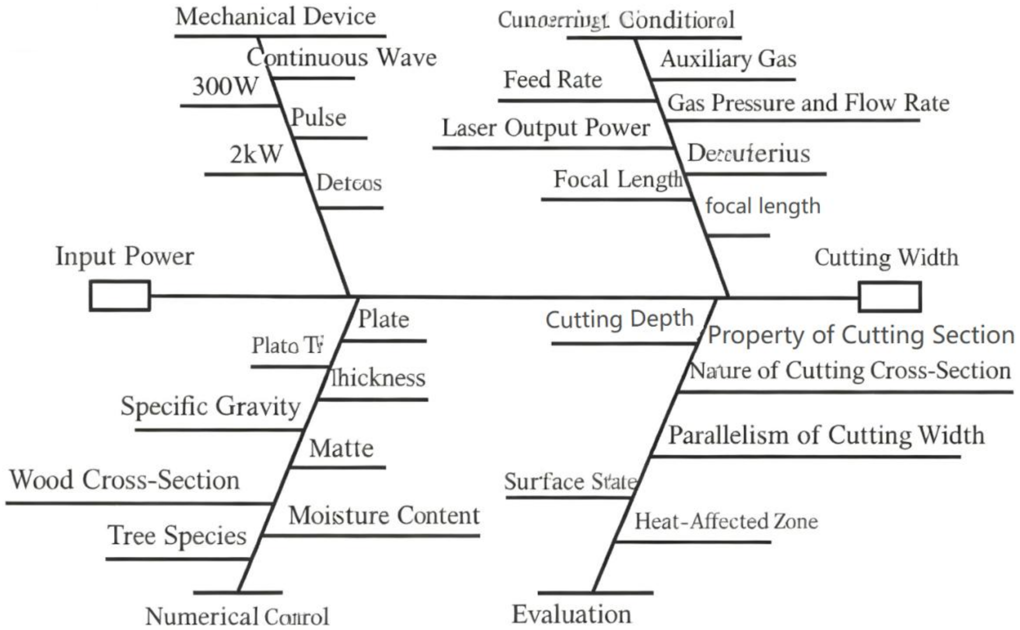

Figure 1 Characteristics Factor Diagram of Laser Cutting Plate

2.1 Experimental apparatus and conditions.

The cutting and forming process adopts a CO_2 laser processing machine with a nominal maximum output power of 300W and continuous oscillation TEM00 mode. Using a GaAs spotlight with a focal length of 130mm, the focus of the laser is on the surface of the sample, just like a typical processing device. As a given processing condition, the laser output power is 50-250W, and it varies in 5 stages per 50W. The feed rate of the processing machine varies in 5 stages within the range of 100-1200mm/min. In order to reduce thermal effects and prevent combustion, N_2 is used as an auxiliary gas; To reduce thermal effects and control cutting width, the optimal gas pressure condition was determined to be 2.4kg/cm based on experimental results (as long as the regulator is changed, both pressure and flow can be adjusted). In addition, when measuring the cutting width, a universal projector that can measure micrometers can be used.

2.2 Experimental Materials

Dried (with a moisture content of u=12%) cinnamon trees were used as experimental materials, with dimensions of 120mm × 40mm × 5mm.

III. Best Processing Conditions

3.1 Setting the Best Standards

There are many factors that can be considered as the best standard for sheet cutting, but this study focuses on the cutting width and parallelism of the cutting groove. When using equipment to process wood, if the output power is high and the feed rate of the processed material is slow, the cutting width will increase. This is due to the high energy power density and long irradiation time. When cutting sheet metal, if the feed rate is slow, due to the flow of auxiliary gas, the cutting width at the bottom will be wider than that at the top. As the feed rate increases, the cutting width at the bottom will become narrower and eventually become a slotted state. This phenomenon may vary in severity depending on the laser device, output power, material thickness, tree species, and board types. Due to the fact that the reduction of thermal effects is almost proportional to the reduction of cutting width, it is required that the cutting width be small; From the perspective of accuracy, it is required that the cutting groove should have good parallelism, which are the best standards for sheet metal cutting and processing. The cutting width W is the average width $(W_1+W_2)/2$ of the upper cutting width W_1 and the lower cutting width W_2; For the parallelism R, for convenience, the ratio W_1/W_2 of the upper cutting width to the lower cutting width is used as the parallelism (as shown in Figure 2).

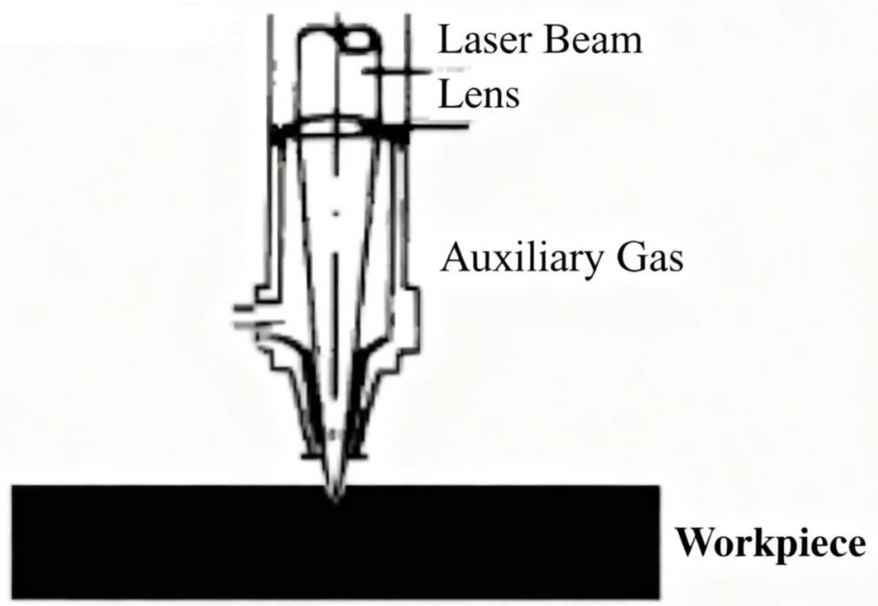

Figure 2 Schematic Diagram of Laser Cutting Principle

3.2 Calculation method for optimal processing conditions

three-dimensional graphical method Processing machinery often processes based on mechanical variables (output power, feed rate, etc. when using laser processing) as given processing conditions, and obtains corresponding processing "results". Seeking the optimal processing conditions is to determine the mechanical variables that can achieve the best results. For ease of explanation, the following will be presented in the form of a model based on the actual data obtained from the experiment. According to the experiment, the relationship curve between the average cutting width W (mm) and the feed rate F (mm/min) under certain output power conditions, as well as the relationship curve between the parallelism R of the cutting groove and the change in F, can be obtained separately. Taking the common F-axis as the center, these two curves can be transformed into a three-dimensional image, as shown in Figure 3. That is to say, the curve formed by the intersection of the F-W surface and the F-R surface in the three-dimensional coordinate system is projected onto the W-R plane. By using this method, the W-R curve (weighted function) can be obtained.

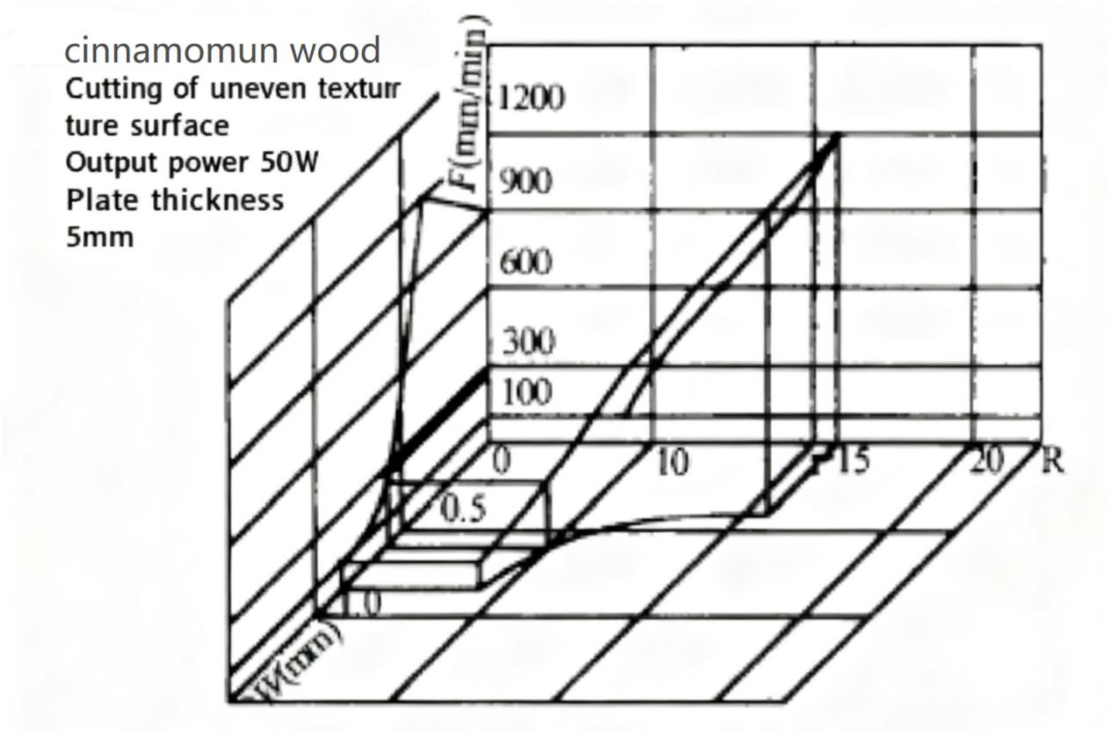

Figure 3 Three-dimensional curve diagram for determining the optimal conditions when the output power is fixed

Based on the obtained three-dimensional curve graph, according to the optimal criteria, determine a certain optimal range or point from the W-R curve group, and by paralleling the corresponding range or point, find the optimal processing condition that can achieve the result, that is, the optimal feed rate F_m.Their relationship is as follows:

$$F_m = F[W(R)] \quad (1)$$

Although W(R) can also be regarded as R(W) , to facilitate the selection of R, W is defined here as a function of R. The F-W curve can generally be derived from the following formula:

$$W = k_1 \exp(-k_2 F) \quad (2)$$

In the formula, $k_1$and$k_2$are constant coefficients. In order to predetermine the three-dimensional curve graph from the curves in the W-R plane, that is to say, to find the corresponding F after determining W, the following formula can be used:

$$F = \frac{1}{k_2} \log\left(\frac{k_1}{W}\right) \quad (3)$$

According to Figure 3, in the above formula, the relationship between \(W \) and \(R \) is roughly as follows:

$$WR = k \quad (4)$$

In the formula, k is a coefficient.

Substitute formula (4) into formula (3), and the following formula is obtained:

$$F_m = \frac{1}{k_2} \log\left(\frac{k_1 R}{k}\right) \quad (5)$$

Since this method adopts the graphical method, it does not necessarily need to be expressed by a mathematical model. It is only necessary to directly convert the original curve graph obtained from experiments into a three-dimensional graph and specify the optimal range and points that can be translated on the W-R plane.

Needless to say, for the usual optimal point, W and R can also be arbitrarily selected as the optimal point or optimal range according to the required requirements. The characteristic of this method is that the obtained range is flexible. For example, under the condition of considering processing efficiency, a method with a fast feed rate can be selected, and so on.

IV. Experimental Results and Analysis

4.1 Experimental results

Firstly, the results obtained under the given processing conditions are given. That is to say, using the output power of the automation equipment as a parameter, the relationship between the workpiece feed rate F and the average cutting width W (F-W curve) and the relationship between F and parallelism R under the same conditions (F-R curve) are calculated. As shown in Figure 4, due to the sharp decrease in cutting width with the increase of feed rate, the F-W curve roughly becomes an exponential function curve. Within the experimental range, it can be considered that as the feed rate increases, the F-R curve increases linearly (as shown in Figure 5). That is to say, when the feed rate is slow, the lower cutting width is larger than the upper cutting width ($W_1<W_2$), and as the speed increases, the upper cutting width will become larger than the lower cutting width ($W_1>W_2$). When the cutting widths above and below are equal (i.e. $W_1=W_2$) and the parallelism R=1, a straight cutting groove is displayed.

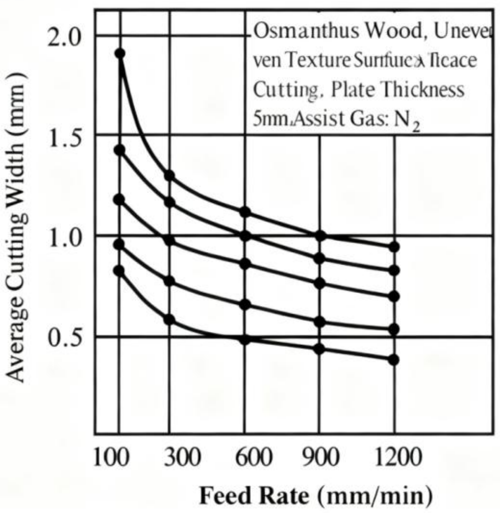

Figure 4 Relationship Between FeedRate and Average Cutting Width (F—W Curve)

4.2 Three dimensional Curve Chart

As mentioned earlier, using F as the center can enable the resulting F-W curve and F-R curve to achieve a three-dimensional image. According to this processing, the W-R curve formed by the intersection of the F-W surface and the F-R surface can be projected onto the W-R plane. Figure 6 shows the weighted function group obtained on the W-R plane. According to the design criteria of optimal conditions, select the weighted function group of W-R plane that has a smaller cutting width W and can make the cutting groove a function of parallelism.

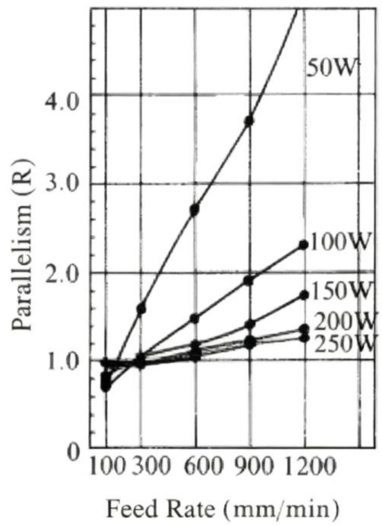

Fig. 5 Relationship between Feed Rate and Parallelism of Cutting Width (*F*— R Curve)

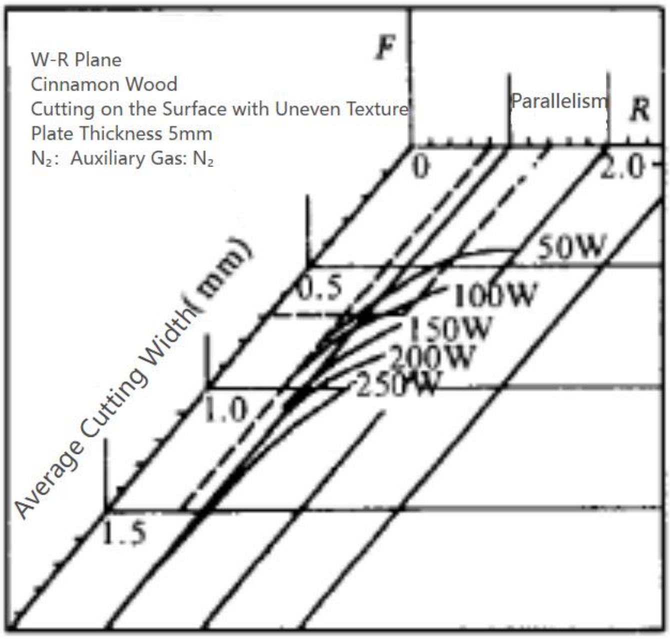

Figure 6 Group of Weighting Functions Projected onto the W-R Plane (with Output Power as a Parameter)

4.3 Optimal Machining Conditions and Their Changes

If based on the optimal criteria and focusing on good parallelism, the points on the R = 1 line can be found from the curve graph in Figure 6. As shown in Figure 3, by translating this point in the three-dimensional curve graph in the direction indicated by the arrow, the corresponding optimal feed rate F_m can be obtained, and the result is shown in Figure 7. If only the requirement of good parallelism (R = 1) is emphasized, an optimal feed rate of approximately 280 ~ 350 mm/min can generally be obtained. However, it does not consider the situation where the average cutting width increases with the increase of output power.Assuming W = 1 and R = 1 as the optimal range, then in the W—R curve group (Figure 6), the range enclosed by the R = 1 and W = 1 lines will become the corresponding optimal range. As shown in Figure 3, by translating to find their upper and lower limit points, the corresponding optimal feed rate range can be determined. It can be seen from Figure 7 that the part where the output power is above 200 W is not included in this range. However, if the plate thickness increases, it is estimated that these high-power parts may become the effective range.

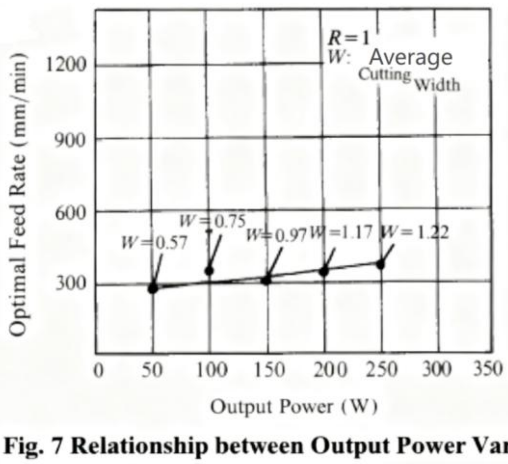

Fig. 7 Relationship between Output Power Variation
and Optimal Feed Rate when $R = 1$

When using laser to process punch dies, the standard cutting width is 0.7mm. Figure 8 shows the variation of the optimal feed rate with the output power when W = 0.7 and W = 1 are taken as standards. The numbers in parentheses are the parallelism at that time. The greater the output power, the faster the feed rate for optimal processing. When the cutting width is smaller, the processing efficiency is higher.

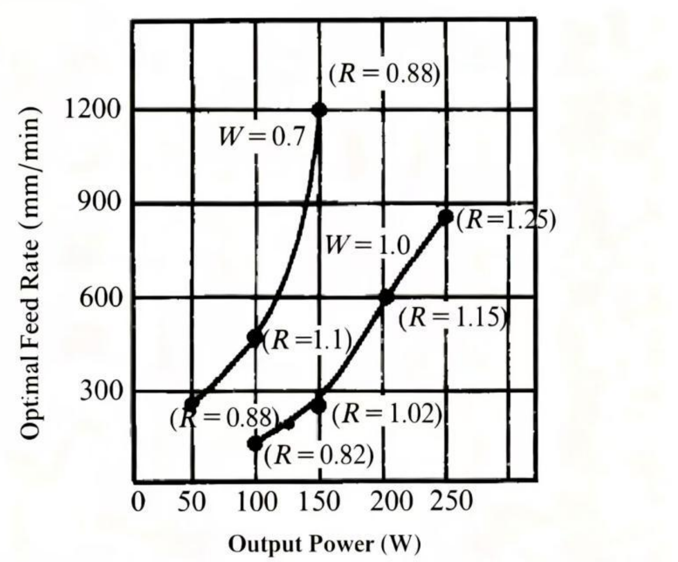

Figure 8 Relationship between Output Power Variation and Optimal Feed Rate when W=0.7 and W=1.0

In addition, due to different emphases during processing, the optimal standards also differ. For example, taking the optimal processing conditions obtained by this method as the benchmark for processing tests, selecting the point where R = 1 and W = 1 from Figure 6, the corresponding optimal feed rate is 320 mm/min, and the output power is 150 W. Under the conditions of an output power of 150 W and a feed rate of 320 mm/min, when processing 5 mm thick osmanthus wood with a cutting width of about 12 mm, the central part is narrower due to the influence of the laser beam, and it is cut almost in a straight line. If the conditions such as material and plate thickness are the same, roughly the same effect can be obtained. At present, the research on automated cutting technology has made progress, and it is already possible to cut with a small cutting width.

V. Conclusions

When using automated equipment to process sheet metal, it is generally desirable to have a small cutting width and a straight cutting groove. If these conditions are taken as the best standards, then the optimal processing conditions must be determined in order to achieve the best processing results. The method provided in this article is to transform the curve graph obtained from experiments into a three-dimensional curve graph, in order to obtain the relevant functions, and then determine the optimal point consistent with the best standard based on this result. This article only discusses the laser cutting effect of 5mm plate thickness. When the feed rate is slow, the plate thickness will have a significant impact on the cutting width; When the feed rate is fast, the impact is not significant. That is to say, when the feed rate is around 100mm/min, the thickness of the plate has a significant impact on the cutting width; When the thickness of the board increases, the cutting width will decrease. If the feed rate is above 600mm/min, even if the plate thickness increases, the cutting width may slightly decrease, but the change will not be too significant. If the feed rate is 100mm/min and the output power is high, the irradiation time will be prolonged due to the slow feed rate; The output power density will also increase, so as the heat affected layer expands, the surface quality will also decrease. Above 200W, the feed rate should not be less than 100mm/min. Assuming in advance that the gas type and pressure used for cutting the sheet are optimal, and given two optimal criteria for the final processing problem, namely the average cutting width and its parallelism. When using other standards instead of this standard, sometimes it cannot be well applied due to the completely different trend of the curve graph it represents. But if this method does not use mathematical formulas to represent, but appropriately specifies the optimal standard, and the curve graph obtained based on experimental data is made into a three-dimensional curve graph, a plane containing the required evaluation function can be obtained. If the best point can be selected based on the given optimal criteria within this plane, the optimal processing conditions for achieving the best results can be determined, and two optimal factors can be simultaneously grasped to determine the optimal "range". Wood is not a uniform material, and it varies slightly depending on the species, board thickness, and types of plywood, specialty plywood, etc. Therefore, it is necessary to compare with the actual situation and accumulate a large amount of experimental data. Here, only one practical experimental method is introduced.

Annotation

This article is based on the College Students' Innovation and Entrepreneurship Training Program Project (Project Number: 2025GJ008)

REFRENCES

[1]. Zhao Lianfeng. The Application of Artificial Intelligence Technology in Electrical Automation

[2]. Yang Chunmei, Liu Qingwei, Li Xiang, Miao Qian, Ma Yan, Doumbia Bakary, Ren Changqing. Theoretical Process Parameter Calculation and Experimental Verification of Laser Cutting Veneers

[3]. Wang Xinming, Ma Xiaoxin, Kang Kai. Research on Laser Cutting Technology

[4]. Li Rongrong, Xu Wei, Xiong Xianqing, Fang Lu, Fang Xiaoyang. The Effect of Laser Processing Parameters on Wood Machining Performance

[5]. Li Zhaohua, Zhang Baoyuan, Wang Chunjing. Factors affecting laser cutting

[6]. Lin Junyao. Automation Transformation of Wood Processing Machinery Equipment

[7]. Luo Shunming, Wei Jianjun. Discussion on the Application of Automated Timber Processing Production Lines in Production