16th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2012, Dubai, UAE, 10-12 September 2012

DEFINING NEW PROCESSING PARAMETERS IN LASER CUTTING

Ph.D. Snežana Radonjić, full professor
Technical Faculty Čačak
Svetog Save 65, Čačak, Serbia

Ph.D. Pavel Kovač, full professor
Faculty of Technical Sciences,
Trg Dositeja Obradovića 6, Novi Sad
Serbia

M.Sc. Anđelija Mitrović, assistant
College of Technical Vocational Studies
Svetog Save 65, Čačak, Serbia

ABSTRACT
In a time when modern production has become exposed to strict market demands, in terms of increasing quality, shortening the processing time and reducing the cost of the final product, laser processing has become a necessity in almost all manufacturing industries. Each laser manufacturer, including the Swiss company Bystronic, gives recommended cutting parameters for certain types of materials. The paper presents the process of defining new parameters for cutting parts made of fireproof steel (steel AISI 314) for which the recommended cutting parameters have not been provided by laser manufacturer. Adequate accuracy of the quality and shape of the cut has been reached. Therefore, the obtained parameters are reliable and are further used in the production process.
Keywords: laser, cutting parameters, steel AISI 314

1. LASER CUTTING PROCESS
The process of laser cutting is a type of machining, which entails the interaction between the laser beam, cutting gas and workpiece (Figure 1). The zone in which this process occurs is known as the cutting zone. The main task of the laser power in the cutting zone is to heat the material to the required temperature, thus turning the material from liquid to gaseous state. The cutting zone is a perpendicular surface that heats and melts by absorbing the laser beam. The molten zone progresses in the direction of cutting, which ensures a continuous cut. Many significant processes in laser cutting occur in this zone. The analysis of these processes provides valuable information about laser cutting. For example, it is possible to estimate the cutting speed and account for the formation of characteristic cutting marks.

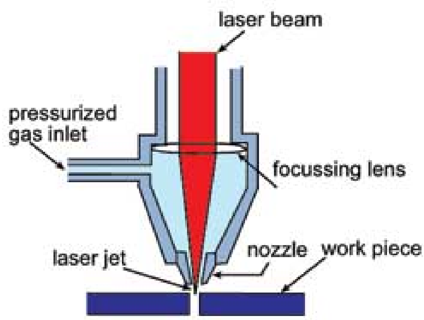

Figure 1. Basic principle of laser cutting

2. CUTTING PARAMETERS

In order to execute the operation of laser cutting it is necessary to know the processing parameters [1]. Processing parameters include the characteristics of the laser cutting process that can be modified to improve the quality of the cutting process and achieve the required results of cutting [2]. The parameters of the laser cutting process can be classified into four major categories: specified parameters of laser cutting, input parameters of laser cutting, operating parameters of laser cutting andoutput parameters of laser cutting.

The specified parameters of laser cutting are: gas type, gas purity, gas pressure, the diameter and shape of the nozzle. Gas pressure and the shape of the nozzle have an effect on the roughness of the cut. The consumption of cutting gas depends on gas pressure and diameter of the nozzle. Cutting by low pressure gas requires the pressure of up to 5 bars, whereas in cutting by high pressure gas, the pressure can reach 20 bars. Conventional nozzles have a circular, conical opening. The distance between the nozzle opening and the surface of the workpiece must be as small as possible. The smaller the distance, the greater the amount of gas that enters the cut. The gap width usually ranges from 0,5 to 1,5 mm.

Operating parameters of laser cutting with which the quality of cutting can be optimized are: focus position, laser power, gas pressure, feed rate and the distance between the nozzle and the cutting surface. Original cutting parameters are optimized to ensure maximum reliability of the process. Each laser is supplied with a set of cutting parameters. Cutting parameters are given for the materials of specific type and thickness. For materials for which the laser manufacturer did not provide the recommended values, new cutting parameters could be set. The paper presents the process of defining new parameters for cutting parts made of fireproof steel (AISI 314) with the achievement of adequate accuracy of the quality and shape of the cut.

3. OPTIMIZATION OF CUTTING PARAMETERS

Cutting parameters are scalar values which have a direct effect on the process of cutting. In order to properly modify the cutting parameters it is important to know how the part has been programmed and which cutting technology is used. The cutting of new material must be preceded by experimental cutting. If any problems concerning the quality of cutting should arise in the experimental phase, they can be fixed by adjusting the original cutting parameters. The optimization of cutting parameters can be derived from the existing samples, and their recommended list [3]. Table 1 shows the order in which cutting parameters should be adjusted depending on the type of cutting gas.

Table 1. Order in which cutting parameters should be adjusted

Step	Cutting with oxygen (O_2)	Cutting with nitrogen (N_2)	Cutting with compressed air (Air) Option
1	Focal position	Focal position	Focal position
2	Laser power	Feed rate ± 10% OK	Feed rate ± 10% OK
3	Gas pressure	Laser power	Laser power
4	Feed rate ± 10% OK	Gas pressure	Gas pressure
5	Nozzle distance	Nozzle distance	Nozzle distance

The reasons for the need of adjusting cutting parameters are: different material composition, variations of tolerances in the thickness of sheet, different nature of the surface and considerable temperature variations in the material used (reference temperature = +20 ° C). The following conditions must be met in order to obtain high quality of the cut: the laser cutting machine and laser beam source must be in perfect condition, the lenses of the cutting head must be flawless, and the cutting head and the nozzle must be consistent with the cutting parameters.

The focal position or focal point denotes the smallest diameter of the laser beam. The maximum power density is concentrated in the focus. The lenses of the cutting head focus the laser beam. The focus position basically depends on the type of gas used. Depending on the material that is cut, the focal point can be located: on the workpiece, in the workpiece and under the workpiece.

The central position of the focus varies depending on the condition of the lenses. Dirty or old lenses can shift the focus position upward. This dislocation can be up to several millimeters depending on the age or degree of impurity of the lenses. It is therefore important to regularly clean the lenses. The focus position can be modified by the input of a new numerical value in millimeters. The higher numerical value shifts the focus position downward, the lower numerical value shifts the focus position upward, while the numerical value 0 corresponds to the surface of the sheet.
Laser power is a parameter that defines the power of the laser during continuous operating mode of the laser (cw-continuous wave). It should be noted that there is a difference between continuous wave and pulse wave. In continuous operating mode, the nominal power of the laser beam is continuously available, while in pulse operating mode it is emitted at intervals [4].
Gas pressure depends on the cutting gas and the nozzle used. In oxygen (O_2) assisted cutting, the higher value results in higher cutting temperature and rougher shape of the cut. With the use of nitrogen (N_2) and compressed air, the material is ejected and cooled more easily. In cutting with O_2 the maximum gas pressure is 10 bars, in cutting with N_2 the maximum gas pressure is 24 bars, whereas in cutting with compressed air the maximum pressure is 12 bar.
Feed rate is a parameter that defines the cutting speed during continuous operating mode of the laser (cw). Feed rate is a variable which is dependent on other factors. If it is not possible to achieve the minimum feed rate during the production, the laser machine must be tested by the manufacturer's service personnel. It should be noted that the reduction of the feed rate by 10 - 20% leads to significant improvement of quality and process reliability in almost all cases.
Nozzle distance is a parameter that defines the distance between the nozzle and the surface of the workpiece during the cutting process. This distance affects the flow of gas, which further has a direct effect on cutting performances and cutting quality. If the nozzle distance is larger than 1 mm, significant variations in pressure will occur. It is recommended that the nozzle distance be smaller than the diameter of the nozzle, because greater distance can result in turbulence and considerable changes in pressure in the gap between the nozzle and the workpiece [3]. The nozzle distance <1 mm leads to increased wear and impurity of the nozzle, whereas the nozzle distance >1mm leads to poor quality of the cut.

4. SETTING THE CUTTING PARAMETERS FOR FIREPROOF STEEL AISI 314

Experimental research was conducted on a Byspeed 4020 laser, a product of Bystronic from Switzerland [5] . The recommended values of cutting parameters for materials of specific type and thickness were given by the laser manufacturer. The recommended values for cutting materials made of fireproof steel (AISI 314) were not provided. Therefore, new cutting parameters were defined with the aim of achieving satisfactory quality of the cut. This paper presents an experimental research conducted with the aim of defining new parameters for cutting materials made of fireproof steel AISI 314, sheet thickness 10 mm. Nitrogen N_2 was used for cutting in continuous operating mode of the laser (cw). Figures 2, 3, 4 show the shape of the cut depending on the focus position, gas pressure and feed rate. In order to achieve optimum quality of the cut, the situation and the possible solution have been provided for each parameter. The images are magnified 10 times and this is why the stripes and irregularities can be seen even in the image with the optimal shape of the cut.
Focus position too high. **Situation**: Very sharp rough edge (requires mechanical removal) on the underside of the sheet. A good cut with irregularities from the middle of the cut downwards. **Solution**: Set the position of the focus deeper (7 mm as shown in Figure 2a is too high). Increase gas pressure. The higher the gas pressure, the better the removal of molten material.
Focus position too low. **Situation**: Small beads forming on the underside of the sheet. Rough surface of the cut from the middle of the sheet downwards. **Solution**: Set a greater numeric value of the focus position (3 mm as shown in Figure 2b is too low). Reduce feed rate.

Figure 2a. Focus position too high

Figure 2b. Focus position too low

Gas pressure too high, focus position too low. **Situation**: Laser beam does not cut through the sheet, molten material is driven upward (Figure 3a). The laser beam is light blue in color and there is loud noise during the cutting process. **Solution**: Set focus position less deep. Reduce gas pressure.
Gas pressure too low. **Situation**: Very rough edge on the underside of the sheet. Eroded irregular surface of the cut from the middle of the cut downwards. **Solution**: Increase gas pressure (4 bars as shown in Figure 3b is too low).

Figure 3a. Gass pressure too high, focus position too low

Figure 3b. Gas pressure too low

Feed rate too low. **Situation**: Clean surface of the cut in the upper two-thirds of the cut. Increased stretching in the lower third of the cutting surface. Very rough edge (requires mechanical removal) on the underside of the sheet. **Solution**: Increase feed rate (Figure 4a shows only half of the default value). Increase gas pressure.
Feed rate too high. **Situation**: High quality in the upper half of the cut. Increased roughness and stretching in the lower half of the surface. **Solution**: Reduce feed rate (feed rate shown in Figure 4b is 20% higher than the default value).

Figure 4a. Feed rate too low

Figure 4b. Feed rate too high

Figure 5 shows the optimal shape of the cut surface which should be achieved for nitrogen-assisted cutting of materials made of fireproof steel AISI 314, thickness 10 mm, feed rate 1250 mm/min, laser power 4400 W, focal point 16 mm, gas pressure 17 bars and nozzle distance 7 mm.

Figure 5. Optimal cut for steel AISI 314

5. CONCLUSION

Experimental research carried out during laser processing of AISI 314 resulted in an optimal cut (Fig. 5). The optimal cut is obtained using the following processing parameters: feed rate 1250 mm/min, laser power 4400 W, focal point 16 mm, gas pressure 17 bars and nozzle distance 7 mm.

6. REFERENCES

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