M.P. Mazur, Dr. Sc. (Engin.), Professor,
K.S. Sokolan, Cand. Sc. (Engin), Associate Professor,
Department of Mechanical Engineering Technology
Khmelnitskiy National University

DETERMINATION OF LASER CUTTING PARAMETERS OF STAINLESS STEEL USING TAGUCHI METHOD

Today, laser cutting is widely used in automotive, shipbuilding, and other industries where aluminum, low-alloy, and stainless steel are cut. The choice of a laser system for the cutting process is significantly influenced by criteria such as achieving high cutting speeds and maximizing production productivity, which allows for high-quality cuts and eliminates the need for reworking parts. Improving the efficiency of the laser cutting process, as well as its flexibility and quality, reduces production costs.

Mechanical processing of stainless steel is associated with a number of difficulties, which, in turn, are due to the properties of the material. Therefore, one of the most effective methods of processing stainless steel is laser cutting. The quality of manufactured parts is inextricably linked to cutting modes.

The Taguchi method is a statistical method aimed at improving the quality of manufactured parts. These methods have become widely used to improve the quality of manufactured parts in engineering and biotechnology [1]. The Taguchi method offers a systematic and fairly simple approach to optimizing production efficiency. The main goal of applying this method is to improve product quality, regardless of the field of application, or to minimize variations in productivity and processes for achieving target performance indicators.

The Smart 3015 machine [2] was used to obtain experimental results. The research was conducted for the process of laser cutting thick-sheet metal parts. The parameters of the research according to the Taguchi method were selected as the heat-affected zone (HAZ), average surface roughness (R_a), and cut depth (t_a). The control variables selected using the Taguchi method were cutting speed (cm/min), laser power (W), gas pressure (MPa), and laser frequency (Hz).

Experimental studies were carried out on plates made of 08X16H11M3 material, with a width and length of 50 mm and a thickness of 3 mm (Fig. 1, a). A cut was made in the plates with a laser, and after the cut was made, the width of the cut, the roughness of the cut surface, and the HAZ were measured (Fig. 1, b).

Based on the experimental data obtained using the Taguchi method, corresponding orthogonal arrays were constructed. The variables are cutting speed (X1), frequency (X2), gas pressure (X3), and laser power (X4). Three interactions are also investigated: X1 and X4, X3 and X1, and X1 and X2. After that, the experimental values obtained were subjected to variance analysis, which is a mandatory step in using the Taguchi method [1, 3].

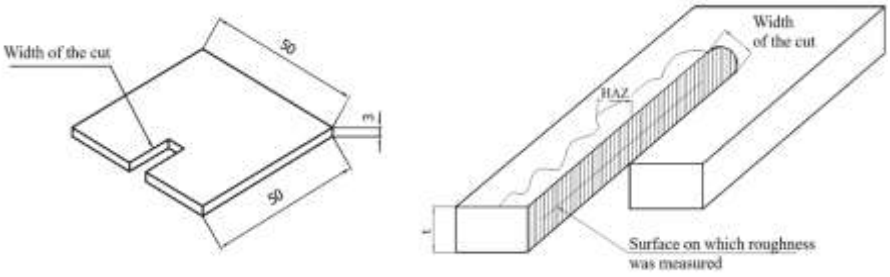

Figure 1 – Sample for research:
a – sample dimensions; b – measurement of opening elements

As a result, the values of the thermal influence zones, roughness, and geometric shape deviation were obtained. The calculation formulas and intermediate values of the parameters are given in [4].

It was established that the reduction of response variables (surface roughness of the slot, geometric shape deviation, and thermal influence zone) using the Taguchi method for all response variables would be most optimal for the control variable X4, which corresponds to the laser power, at a level of 1000 W (Table 1). Similarly, for all response variables, the most optimal value of the control variable X3, which corresponds to gas pressure, is 0.5 MPa.

In the case of cutting speed, it has a negligible effect on the average surface roughness and HAZ parameters, so it can be ignored for these response variables. Therefore, the optimal value is taken to be the value at which the best conicity index of the slot is obtained, i.e., the control variable X1, which corresponds to the cutting speed, at 40 cm/min.

Table 1 - Optimal cutting modes for stainless steel 08X16H11M3, determined using the Taguchi method

Control variables (X)	Response variables (Y)			Optimal cutting parameter
	Conicity	Average roughness	HAZ	
Cutting speed X1, sm/min	40	-	-	40
Frequency X2, Hz	75	25	-	50
Gas pressure X3, MPa	0,5	0,5	0,5	0,5
Laser power X4, W	1000	1000	1000	1000

Conclusions

The work explored the possibility of using the Taguchi method as a tool for optimizing the parameters of laser cutting of 08X16H11M3 stainless steel. Based on the results of the research, the optimal laser cutting modes were established, at which the highest quality of parts is achieved, namely: cutting speed of 40 cm/min, laser power of 1000 W, frequency of 50 Hz, gas pressure of 0.5 MPa.

References:

1. Bendell A. Taguchi Methods. Springer Dordrecht. 2009. 212 p.
2. HGstar Smart3015 machine. URL: https://www.hg-star.com/ru/budget-laser-cutting-machine/
3. Roy K.R. Design of Experiments Using the Taguchi Approach: 16 Steps to Product and Process Improvement Wiley-Interscience. 2001. 560 p.
4. Sokolan, Yu. S., Klyasny N.S., Sokolan K.S. Optimization of stainless steel laser cutting modes using the Taguchi method. *Herald Of Khmelnitskiy National University. Technical Sciences.* No. 1 (239). 2024. pp. 364-369