



OPTIMIZATION OF LASER CUTTING MODES FOR PARTS MADE FROM SHEET STEEL 12X18H10T

Dmitriy Podashev¹, Anton Kisel'², Ivan Nikolaev³

^{1,2,3} Kaliningrad State Technical University – Kaliningrad, Russia.

¹<http://orcid.org/0000-0001-9112-9253> , ²<http://orcid.org/0000-0002-8014-0550> , ³<http://orcid.org/0009-0007-1206-3489>

Email: dmitrij.podashev@klgtu.ru, anton.kisel@klgtu.ru, ivan.nikolaev@klgtu.ru

ARTICLE INFO

Article History

Received: November 28, 2025

Revised: December 10, 2025

Accepted: January 1, 2026

Published: January 31, 2026

Keywords:

laser cutting,
steel sheets,
processing modes,
surface roughness,
cut geometry,
radiation frequency,
movement speed,
mode optimization

ABSTRACT

This article focuses on the investigation and optimization of laser cutting modes for sheet materials made of corrosion-resistant austenitic steel grade 12X18H10T. The main factors affecting the quality of the cut are examined, including laser power, speed of laser head movement, radiation frequency, and focal point position. A comprehensive analysis of the impact of these factors on surface roughness and the presence of visible defects on the cut edges is provided. The practical significance of this research lies in obtaining specific recommendations for optimal processing modes corresponding to various thicknesses of steel sheets. Applying these recommendations ensures achieving the required quality of processing. Implementation of the developed technology recommendations into serial production can significantly reduce the duration of the manufacturing cycle, eliminate the need for an additional stage of mechanical finishing of parts, and increase the operational efficiency of the used equipment.



Copyright ©2026 by authors and Galileo Institute of Technology and Education of the Amazon (ITEGAM). This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

I. INTRODUCTION

Modern machine-building production is characterized by a wide variety of material processing technologies [1-4], each of which has its own area of economic and technical feasibility. Enterprises use a range of methods for manufacturing parts with complex contours from sheet materials, including mechanical machining (milling and coordinate boring operations), stamping, waterjet cutting, and laser cutting. Each method has historically established niches of application: milling provides high precision in slots and holes, stamping is economically efficient under mass-production conditions, while waterjet cutting is indispensable for materials sensitive to thermal effects. However, within the context of medium- and small-series production tasks, especially when working with alloyed steels, laser cutting appears as the most versatile and promising method. Its advantages are comprehensive in nature and have a direct impact on both economic and operational performance indicators. Among these benefits are high productivity and speed due to non-contact interaction between the tool (laser beam) and the material, eliminating costs associated with specialized cutting tools such as mills or drills that wear out and require regular replacement. Additionally, this technology does not necessitate fabrication of complicated and expensive equipment like dies and molds, significantly reducing preparation time and expenses [5-15]. Furthermore, the ability to process large-format sheet materials without pre-cutting them into smaller blanks allows optimization of layout and minimization of waste, thus improving material utilization efficiency. In Russian Federation's rocket-space industry enterprises, corrosion-resistant steel grade 12X18H10T is widely used in critical structures operating in aggressive environments. This type belongs to the class of austenitic stainless steels. The extensive product line of components made from stainless steels produced using various techniques requires high stability and quality assurance of technological processes, particularly laser cutting [16-19]. Currently, Russian enterprises commonly employ LC MSTD FO3015 laser cutting machines, often having significant service life and experiencing natural wear of their mechanical and optical components. These factors introduce uncertainty into the process since actual beam parameters and positioning accuracy may deviate from specified values.

Moreover, accompanying technical documentation either lacks specific recommendations altogether or contains only general guidelines regarding cutting modes for different materials. Specifically, there is an absence of detailed, practice-verified settings for

12X18H10T steel at varying thicknesses. As a result, operators must empirically determine cutting parameters. Consequently, results vary: acceptable quality is achieved in some cases, whereas others exhibit substantial defects. Therefore, the lack of formalized, scientifically grounded databases for cutting regimes tailored to specific materials and machinery prevents enterprises from fully realizing the potential of laser cutting technology, ensuring high-quality products, and minimizing defective output. This underscores the urgent practical necessity and relevance of targeted research efforts in this direction. The use of laser cutting machines for sheet metal processing involves addressing several technological challenges, central among which is achieving high surface quality of cuts. Current industrial practices rely heavily on subsequent finishing operations, such as manual deburring, to eliminate visible defects and bring the part up to standard condition. However, this approach introduces negative consequences: it increases overall manufacturing lead times, raises labor intensity requiring additional human resources, leading ultimately to higher final product cost. An alternative and technologically superior path would be obtaining a finished component directly during the laser cutting stage itself, avoiding any further mechanical treatment. Achieving this goal is possible only through precise determination and strict adherence to optimal laser cutting regimes unique to each “material-thickness” combination. Thus, the objective of this study is to identify and analyze adjustable technological parameters of the laser cutting process that exert a significant influence on two key metrics: the quality of the formed cut edge (absence of burr and discoloration) and compliance with required roughness specifications according to design drawings for parts manufactured from sheet material (steel 12X18H10T).

II. MATERIALS AND METHODS

Austenitic stainless steel 12X18H10T is extensively utilized in Russian rocketry because it possesses capabilities to operate under extreme mechanical loads, thermal stresses, and aggressive environments. The chemical composition of material 12X18H10T is presented in Table 1.

Table 1: Chemical composition of steel 12X18H10T.

Element	Content, %
Carbon (C)	≤ 0.12
Silicon (Si)	≤ 0.8
Manganese (Mn)	≤ 2.0
Copper (Cu)	≤ 0.3
Nickel (Ni)	9.0–11.0
Sulfur (S)	≤ 0.02
Titanium (Ti)	0.5–0.8
Phosphorus (P)	≤ 0.035
Chromium (Cr)	17.0–19.0

Source: Authors, (2026).

Steel 12X18H10T belongs to highly carbonated (from 0.6% to 1.0%) and complex-alloyed cryogenic stainless steels. Chromium and nickel serve as primary alloying elements, preventing corrosion, providing the metal with cryogenic properties (resistance to cooling) and excellent workability. Mechanical properties of steel 12X18H10T are controlled upon release of billets and are listed in Table 2.

Table 2: Mechanical properties of steel 12X18H10T.

Parameter	Value
Ultimate tensile strength	550-650 MPa
Yield strength	225-315 MPa
Density	7.92 g/cm ³
Brinell hardness	170-190 HB
Elongation	35%
Fatigue limit	530 MPa

Source: Authors, (2026).

Table 3 presents analogues of steel 12X18H10T used by industries in various countries.

Table 3: Analogues of Steel 12X18H10T.

USA	AISI 321, AISI 321H, S32100, S32109
Germany	1.4541, 1.4878, X10CrNiTi18-10, X12CrNiTi18-9, X6CrNiTi18-10
Japan	SUS321
France	Z10CNT18-10, Z10CNT18-11, Z6CNT18-10, Z6CNT18-12
United Kingdom	321S31, 321S51, 321S59, LW18, LW24, X6CrNiTi18-10
Italy	X6CrNiTi18-11, X6CrNiTi18-11KG, X6CrNiTi18-11KT
China	0Cr18Ni10Ti, 0Cr18Ni11Ti, 0Cr18Ni9Ti, 1Cr18Ni11Ti, H0Cr20Ni10Ti
Bulgaria	0Ch18N10T, Ch18N12T, Ch18N9T, X6CrNiTi18-10
Hungary	H5Ti, KO36Ti, KO37Ti, X6CrNiTi18-10
Poland	0H18N10T, 1H18N10T, 1H18N12T, 1H18N9T
Czech Republic	17246, 17247, 17248
Austria	X6CrNiTi18-10KKW, X6CrNiTi18-10S
South Korea	STS321, STS321TKA, STSF321

Source: Authors, (2025).

Figure 1 shows examples of parts produced by the Russian space-rocket industry using laser cutting.



Figure 1: Parts obtained by laser cutting.
Source: Authors, (2026).

To address the task set forth in this study, we propose investigating the effect of diverse laser cutting modes and conditions on the quality characteristics of manufactured parts. The quality of the part's edge obtained via laser cutting plays a crucial role in subsequent stages of the production process [20]. For experimental studies, we employed the LC MSTD FO3015 laser cutting system (Russia), equipped with a precise coordinate system, CNC control, and an adaptive laser head featuring a sensor for monitoring clearance from the part. This setup is depicted in Figure 2.



Figure 2: Laser Cutting Machine LC MSTD FO3015.
Source: Authors, (2026).

As a result of analyzing the design documentation used at enterprises, steel sheets made from grade 12X18H10T steel were selected for experiments, which are most commonly used to manufacture parts, namely:

- Sheet 0.8 mm thick, 12X18H10T according to GOST 19903-2015/GOST 5582-75;
- Sheet 1.0 mm thick, 12X18H10T according to GOST 19903-2015/GOST 5582-75;
- Sheet 1.5 mm thick, 12X18H10T according to GOST 19903-2015/GOST 5582-75;
- Sheet 2.0 mm thick, 12X18H10T according to GOST 19903-2015/GOST 5582-75;
- Sheet 3.0 mm thick, 12X18H10T according to GOST 19903-2015/GOST 5582-75;
- Sheet 5.0 mm thick, 12X18H10T according to GOST 19903-2015/GOST 5582-75;
- Sheet 8.0 mm thick, 12X18H10T according to GOST 19903-2015/GOST 5582-75.

The test samples used were squares measuring 20×20 mm. The processing quality requirements specify surface roughness not exceeding Ra 6.3 as per the design documentation. For visual inspection and measurement of surface roughness, the following measuring instruments were employed:

1. Portable profilometer Mitutoyo Surftest SJ-410 (Figure 3).
2. Control and measurement machine KIT-MSM-32 (Figure 4).



Figure 3: Portable profilometer Mitutoyo Surftest SJ-410.
Source: Authors, (2026).



Figure 4: Control and measuring machine KIT-MSM-32.
Source: Authors, (2026).

III. RESULTS AND DISCUSSIONS

The main parameters under investigation that affect cut quality include laser power, speed of laser head movement, emitter frequency, and lens position. These parameters will be variable during the experimentation process. During the study, it was found that these parameters have an equal effect on metal thickness values of $S = 0.8$ mm, $S = 1$ mm, and $S = 1.5$ mm. Therefore, it was decided to combine them into one experimental group. Parameter changes occurred through the control panel of the laser machine using the Unicut software. Dependencies of surface roughness R_a on focal distance of the lens for different sheet thicknesses are shown in Figure 5.

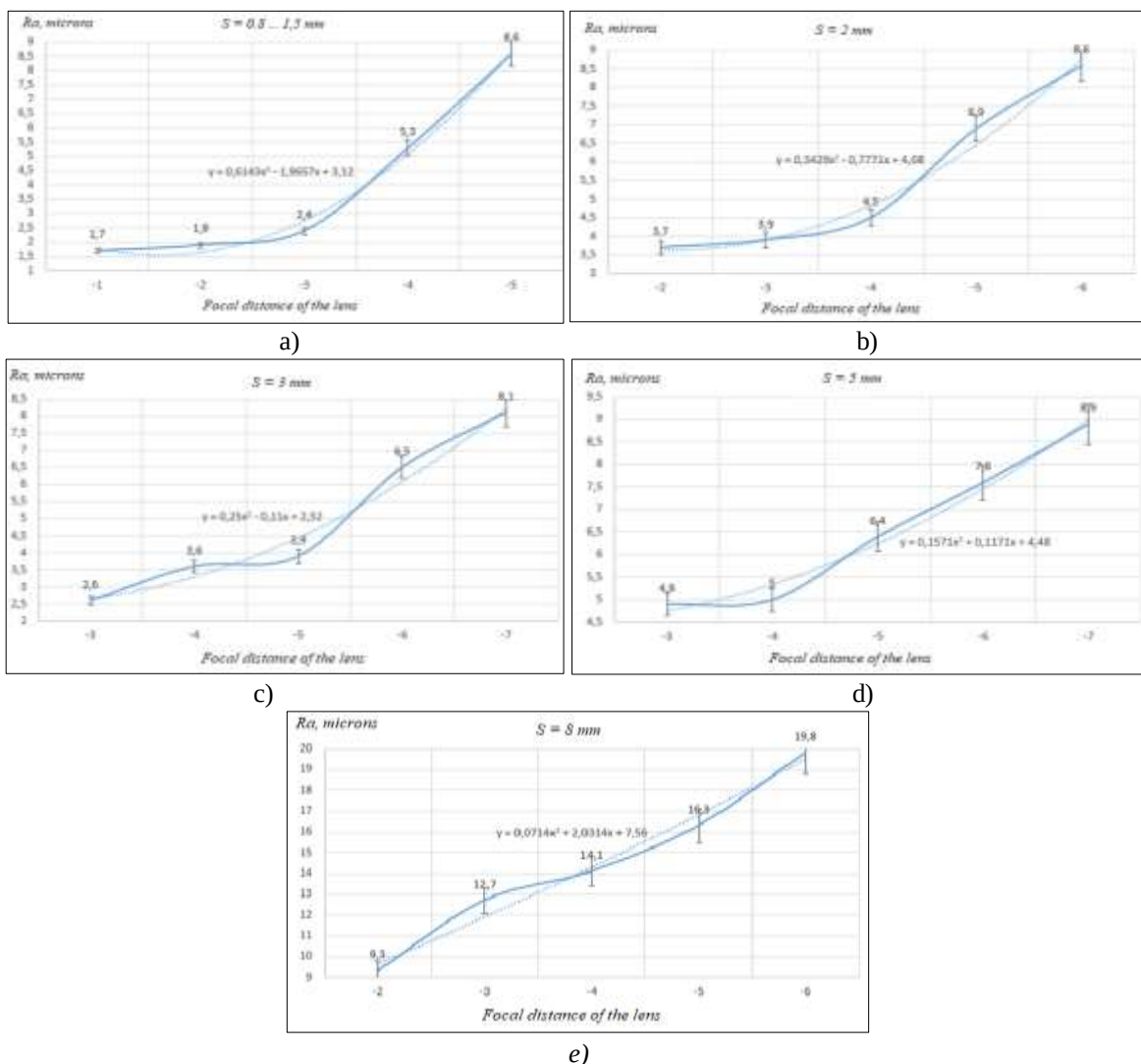


Figure 5: Dependencies of surface roughness R_a on lens focal distance for different sheet thicknesses:
a) for sheet thickness $S = 0.8-1.5$ mm; laser power $P = 4000$ W; laser head travel speed 7000 mm/min; frequency $F = 5000$ Hz;
b) for sheet thickness $S = 2$ mm; laser power $P = 4000$ W; laser head travel speed 7000 mm/min; frequency $F = 5000$ Hz;

- c) for sheet thickness $S = 3$ mm; laser power $P = 4000$ W; laser head travel speed 7000 mm/min; frequency $F = 5000$ Hz;
 d) For sheet thickness $S = 5$ mm; laser power $P = 4000$ W; laser head travel speed 4000 mm/min; frequency $F = 1000$ Hz;
 e) For sheet thickness $S = 8$ mm; laser power $P = 4000$ W; laser head travel speed 2000 mm/min; frequency $F = 1000$ Hz.
 Source: Authors, (2026).

Figure 6 shows the dependence of surface roughness R_a on the frequency of the laser emitter.

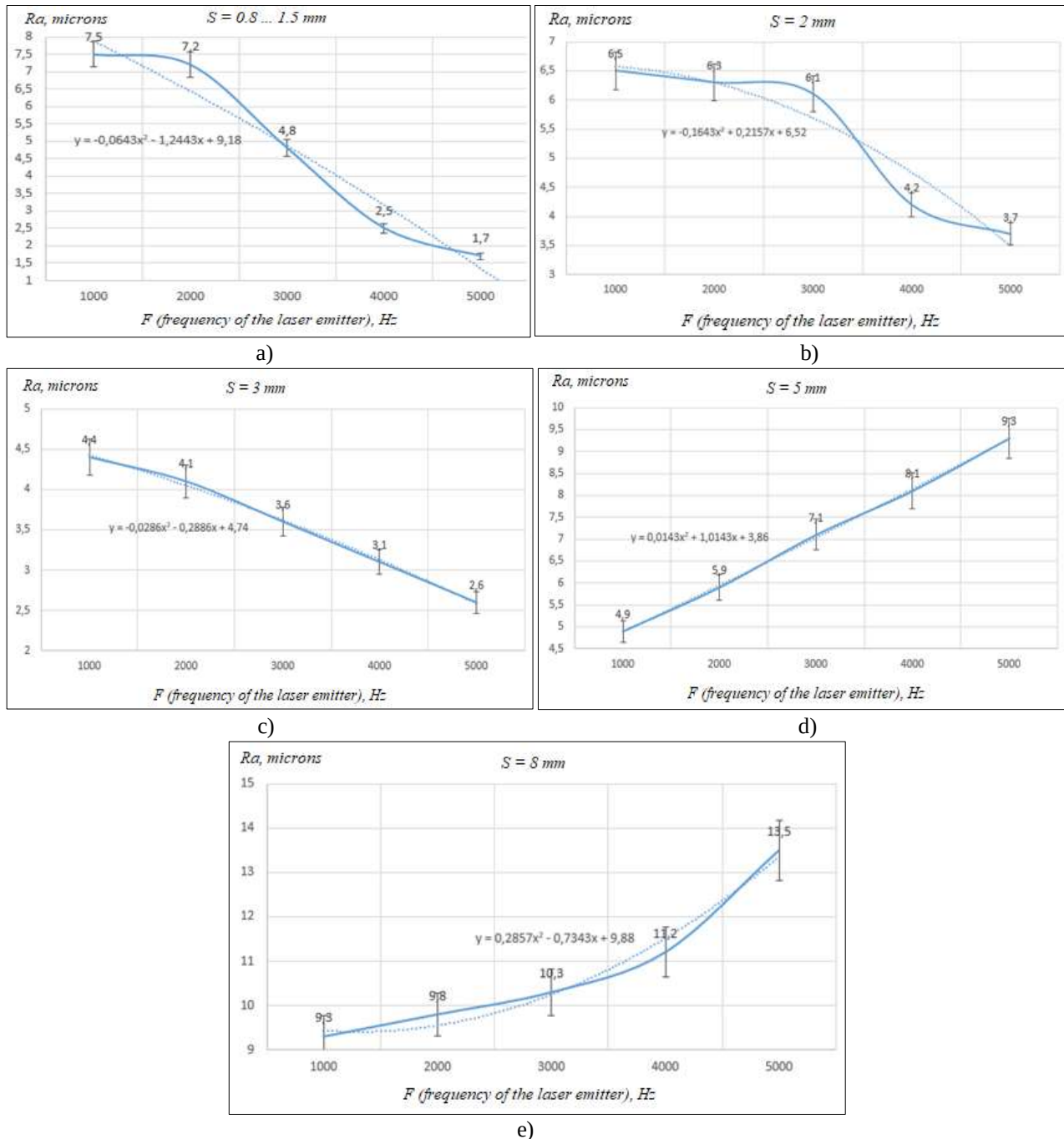


Figure 6: Dependence of surface roughness R_a on laser radiation frequency for:

- a) sheet thickness $S = 0.8 \dots 1.5$ mm; laser power $P = 4000$ W; laser head speed = 7000 mm/min; lens position (focus) = -1.0 ;
 b) sheet thickness $S = 2$ mm; laser power $P = 4000$ W; laser head speed = 7000 mm/min; lens position (focus) = -2.0 ;
 c) sheet thickness $S = 3$ mm; laser power $P = 4000$ W; laser head speed = 7000 mm/min; lens position (focus) = -3.0 ;
 d) sheet thickness $S = 5$ mm; laser power $P = 4000$ W; laser head speed = 4000 mm/min; lens position (focus) = -4.5 ;
 e) sheet thickness $S = 8$ mm; laser power $P = 4000$ W; laser head speed = 2000 mm/min; lens position (focus) = -6.0

Source: Authors, (2026).

Dependences of surface roughness R_a on the speed of laser head movement for different thicknesses of cut sheets are shown in Figure 7.

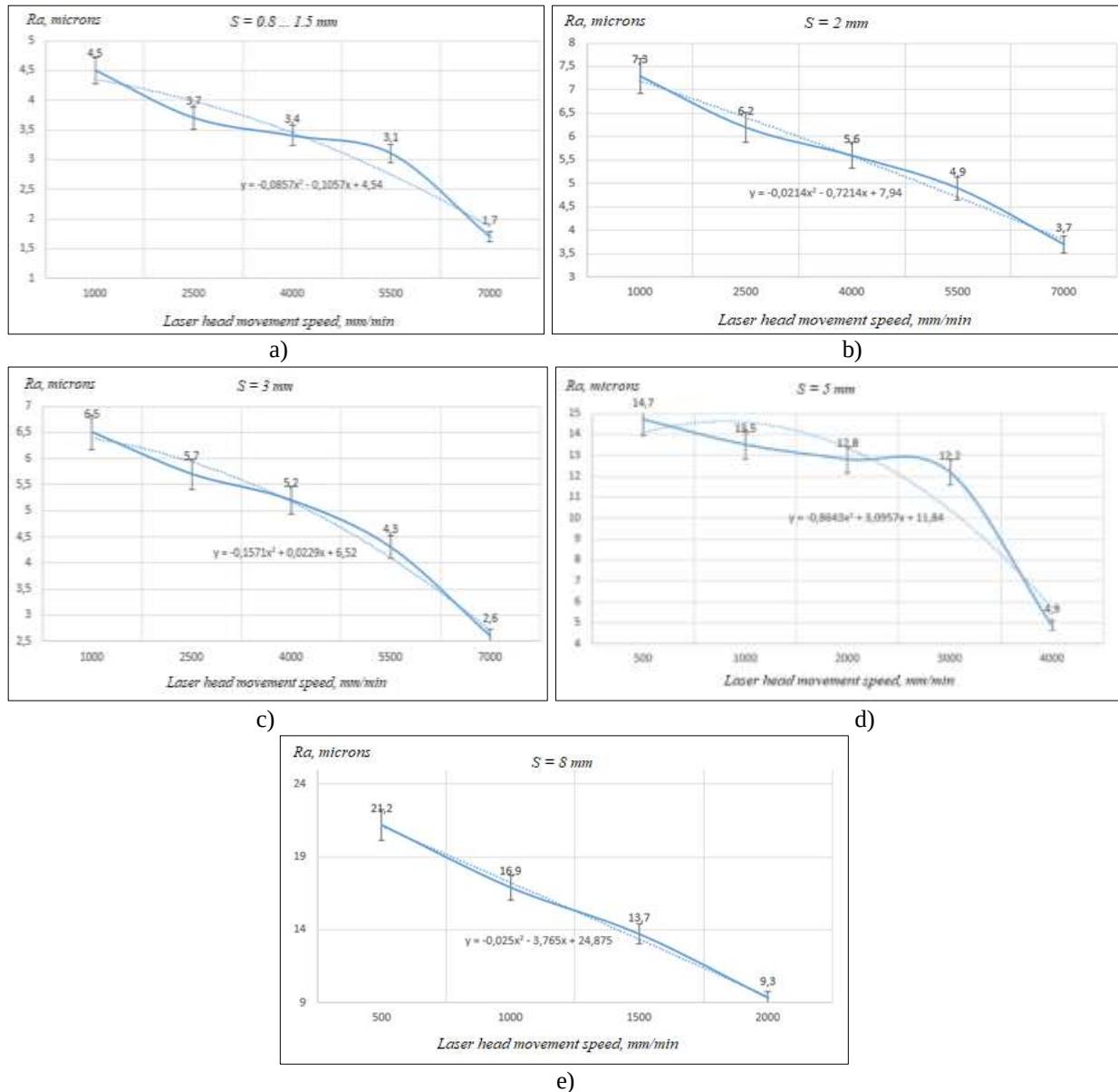


Figure 7: Dependence of surface roughness R_a on laser head movement speed at:

- a) sheet thickness $S = 0.8 \dots 1.5 \text{ mm}$; laser power $P = 4000 \text{ W}$; laser emitter frequency = 5000 Hz; lens position (focus) = -1.0;
- b) sheet thickness $S = 2 \text{ mm}$; laser power $P = 4000 \text{ W}$; laser emitter frequency = 5000 Hz; lens position (focus) = -2.0;
- c) sheet thickness $S = 3 \text{ mm}$; laser power $P = 4000 \text{ W}$; laser emitter frequency = 5000 Hz; lens position (focus) = -3.0;
- d) sheet thickness $S = 5 \text{ mm}$; laser power $P = 4000 \text{ W}$; laser emitter frequency = 1000 Hz; lens position (focus) = -4.5;
- e) sheet thickness $S = 8 \text{ mm}$; laser power $P = 4000 \text{ W}$; laser emitter frequency = 1000 Hz; lens position (focus) = -6.0

Source: Authors, (2026).

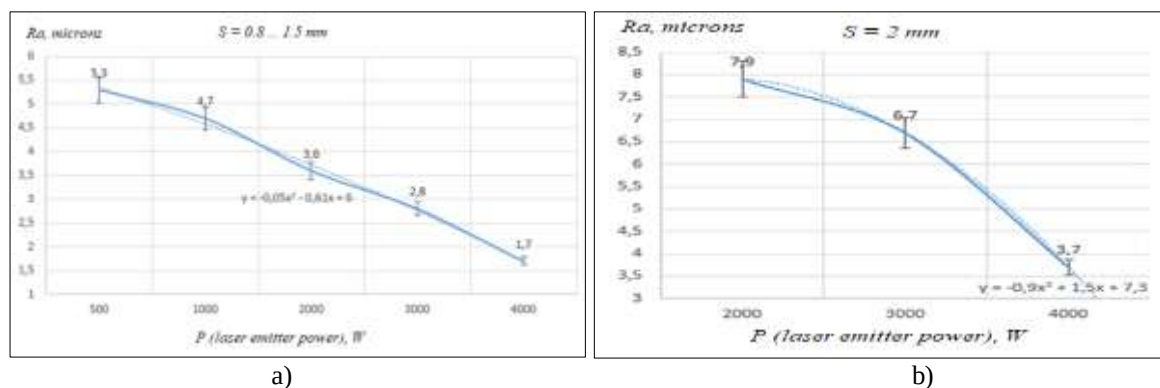


Figure 8: Dependence of surface roughness R_a on laser emitter power at:

- a) sheet thickness $S = 0.8 \dots 1.5 \text{ mm}$; laser head movement speed = 7000 mm/min; laser emitter frequency = 5000 Hz; lens position (focus) = -1.0;
- b) sheet thickness $S = 2 \text{ mm}$; laser head movement speed = 7000 mm/min; laser emitter frequency = 5000 Hz; lens position (focus) = -2.0.

Source: Authors, (2026).

In Figure 8, the dependencies of surface roughness Ra on the laser emitter power are presented. It should be noted that further experiments to reduce the laser power were not carried out when the sheet thickness was 2 mm (see Fig. 8, b), because with a further reduction in laser power, the material did not penetrate. For the same reason, no experiments were conducted to reduce the laser power for sheets thicker than 3 mm, as reducing the laser power by more than 5% resulted in insufficient penetration during one pass. As an example, Figure 9 shows images of processed surfaces after cutting sheets of 5 mm and 8 mm thickness. During visual inspection, such defects as scale formation and heat-affected zones have been identified, i.e., changes in color—from straw yellow to blue and violet along the cut line. This is particularly critical for stainless steel components since chromium can burn off in the heat-affected zones, thereby reducing corrosion resistance.

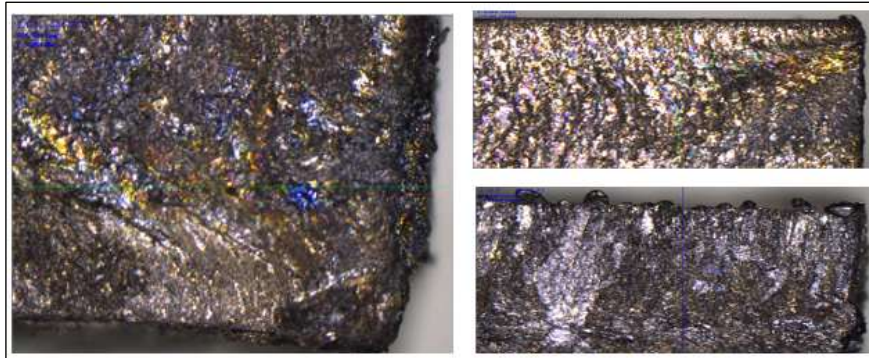


Figure 9: Images of obtained edges when cutting sheets of thickness 5 mm.

Source: Authors, (2026).

IV. CONCLUSIONS

The work performed has yielded comprehensive scientific-practical results in optimizing the modes of laser cutting of corrosion-resistant austenitic steel grade 12X18H10T using the LC MSTD FO3015 equipment. Quantitative relationships between technological parameters and quality characteristics of cuts have been established. Analysis of these relationships allows us to draw the following conclusions:

1. The optimal focus position value is found to be a critical parameter determining the geometry of the cut. For thin sheets (0.8-1.5 mm), the optimum value is -1.0 mm (surface focus), providing minimum surface roughness Ra of 1.7 microns. As the thickness increases, it becomes necessary to shift the focus deeper into the material (-4.5 mm for 5 mm, -6.0 mm for 8 mm) to ensure uniform energy input across the depth of the cut.
2. Non-linear dependencies of the optimal laser emitter power on material thickness have been revealed. For sheet thicknesses up to 2 mm, it is possible to reduce the power down to 2000 W without compromising quality, whereas for 3 mm or greater, even a slight decrease in power (to 3000 W, which represents a drop of only 25%) leads to incomplete cuts and sharp deterioration in edge quality.
3. It has been proven that increasing the speed of the laser head movement up to 7000 mm/min improves processing quality when cutting thin sheets, while for thicker ones (5-8 mm), optimal speeds range from 2000 to 4000 mm/min. Further increase in speed causes dross formation and degradation of surface quality in terms of roughness.
4. The frequency of the laser emitter exerts its most significant influence on thin sheets, where high-frequency mode (5000 Hz) ensures process stability. For thicknesses of 5-8 mm, low frequency (1000 Hz) proves optimal, promoting more effective melting and removal of material. It has been determined that a 4 kW laser emitter configured with air has the following application areas for cutting sheet materials made of 12X18H10T:

thicknesses of 0.8-2.0 mm: high-quality cutting with parameters meeting design documentation requirements;

thicknesses of 3.0-5.0 mm: limited applicability requiring subsequent mechanical treatment;

thicknesses over 5 mm: technologically unfeasible due to unsatisfactory edge quality and geometric accuracy.

For sheet thicknesses ranging from 0.8 to 2.0 mm, the recommended optimal regimes include:

laser emitter power: 4000 W;

laser head travel speed: 7000 mm/min;

frequency: 5000 Hz;

lens focal distance: -1.0...-3.0.

Under these conditions, expected surface roughness values fall within the range of Ra 1.7-3.7 microns. For thicknesses from 3.0 to 5.0 mm, recommendations include:

reducing speed to 2000-4000 mm/min;

shifting the focus to -4.5...-6.0 mm;

using pulsed mode with a frequency of 1000 Hz.

Mandatory subsequent mechanical finishing. Implementation of these recommended regimes enables elimination of manual dross removal operations, shortening of the manufacturing technology cycle, reduction of operator subjectivity, and increased utilization efficiency of the equipment.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Dmitriy Podashev, Anton Kisel, Ivan Nikolaev.
Methodology: Dmitriy Podashev, Anton Kisel, Ivan Nikolaev
Investigation: Anton Kisel.
Discussion of results: Dmitriy Podashev, Anton Kisel, Ivan Nikolaev.
Writing – Original Draft: Anton Kisel, Ivan Nikolaev.
Writing – Review and Editing: Dmitriy Podashev, Anton Kisel, Ivan Nikolaev.
Resources: Dmitriy Podashev, Anton Kisel, Ivan Nikolaev.
Supervision: Anton Kisel.
Approval of the final text: Dmitriy Podashev, Anton Kisel, Ivan Nikolaev.

VI. REFERENCES

- [1] S. Tursunbaev, D. Umarova, M. Kuchkorova, A. Baydullaev, "Study of machining accuracy in ultrasonic elliptical vibration cutting of alloyed iron alloy carbon with a germanium", *Journal of Physics: Conference Series*, no. 1, p. 012053, 2022.
- [2] J. Chen, Ya. Fan, L. Wan, W. Wu, "Surface properties of laser-woven magnesium alloys based on dot-matrix processing", *Journal of Physics: Conference Series*, vol. 2790, no. 1, p. 012011, 2024.
- [3] C. Oliveira, R. Hamano, T. Chuvas, H. Costa, "Influence of cutting parameters on surface integrity and machining forces in top milling of metallic spraying metal coatings", *ITEGAM-JETIA*, no. 8(35), pp. 4-13, 2022.
- [4] R. Hamano, H.R. Costa, T. Chuvas, "Evaluation of machining forces and surface integrity on AISI 304 steel top milling process under different cutting conditions", *ITEGAM-JETIA*, no. 5(20), pp. 166-171, 2019.
- [5] Hu, Sh. "4KW Laser Tube Cutting in Metal Fabrication—TP7535M Fiber Laser Tube Cutting System", *Engineering Advances*, vol. 3, No. 6, pp. 505-509, 2024.
- [6] V. B. Shulyatyev, "Laser-plasma cutting of aluminum-lithium alloys", *AIP Conference Proceedings: ACTUAL PROBLEMS OF CONTINUUM MECHANICS: EXPERIMENT, THEORY, AND APPLICATIONS*, Novosibirsk, Russia, 20–24 september 2021, vol. 2504, AIP PUBLISHING, p. 030056, 2023.
- [7] P. Wen, X. Tan, J. Shan [et al.], "Numerical simulation of effect of laser power and assistant gas on laser cutting ability", *Transactions of the China Welding Institution*, vol. 34, no. 4, p. 57-60, 2013.
- [8] H. Niino, Y. Kawaguchi, T. Sato [et al.], "Laser cutting of carbon fiber reinforced thermo-plastic (CFRTP) by IR laser irradiation", *Journal of Laser Micro Nanoengineering*, vol. 9, no. 2, p. 180-186, 2014.
- [9] D. Rajamani, M. Siva Kumar, E. Balasubramanian, A. Tamilarasan, "Nd: YAG laser cutting of Hastelloy C276: ANFIS modeling and optimization through WOA", *Materials and Manufacturing Processes*, vol. 36, no. 15, pp. 1746-1760, 2021.
- [10] G. Nenad, J. Meško, R. Nigrovič [et al.], "Laser cutting of ductile cast iron", *Materialpruefung*, vol. 62, no. 8, pp. 820-826, 2020.
- [11] A. Shaparev, A. Mirzayev, M. Qarayev [et al.], "The influence gas jet on the quality laser cutting metals", *Reliability: Theory & Applications*, vol. 20, no. S7(83), pp. 310-319, 2025.
- [12] J. Pocorni, J. Powell, J. Frostevarg, A. F. H. Kaplan, "Investigation of the piercing process in laser cutting of stainless steel", *Journal of Laser Applications*, vol. 29, no. 2, p.022201, 2017.
- [13] R. Kristianto, C.N. Rosyidi, P. W. Laksono, "The Cutting Parameter Optimization of CO2 Laser Cutting with Taguchi-Grey Relational Analysis Method", *Nanotechnology Perceptions*, vol. 20, no. S11, pp. 164-174, 2024.
- [14] D. J. Thomas, "The effect of laser cutting parameters on the formability of complex phase steel", *The International Journal of Advanced Manufacturing Technology*, vol. 64, no. 9-12, p. 1297-1311, 2013.
- [15] Ya. Zhang, Ch. Wang, W. Xu [et al.], "Laser Cutting of Titanium Alloy Plates: A Review of Processing, Microstructure, and Mechanical Properties", *Metals*, vol. 14, no. 10, p. 1152, 2024.
- [16] M. T. E. Kassim, E. T. Karash, A. M. Mahmood, Ja. N. Sultan, "Mechanical Property Enhancement of Stainless Steel 12X18H10T Through nc-TiN Coating: A Simulation Study", *Annales de Chimie: Science des Matériaux*, vol. 48, no. 2, pp. 163-176, 2024.
- [17] A. M. Molodets, A. A. Golyshev, "Electrophysical Properties of Stainless Chromium–Nickel Steel at High Pressures and Temperatures at Stepwise Shock Compression", *Physics of Metals and Metallography*, vol. 125, no. 6, pp. 571-578, 2024.
- [18] D. S. Makashin, A. G. Kisel', "Determination of the Range of Effective Grinding Modes and Grinding Wheel Materials for Processing 95Kh18 Steel", *Russian Metallurgy (Metally)*, vol. 2024, no. 7, pp. 1495-1500, 2024.
- [19] F. Bader, L. Bathelt, E. Djakow [et al.], "An Approach for an Innovative 3D Steel Strip Straightening Machine for Curvature and Saber Compensation", *Key Engineering Materials*, vol. 926, pp. 2391-2396, 2022.
- [20] L. Łatka, E. Jonda, T. Kielczawa, "The influence of the laser cutting process parameters on the quality of the cut edge", *Journal of Physics: Conference Series*, vol. 2676, no. 1, p. 012001, 2023.