DINAMIKA REKAYASA
http://dinarek.unsoed.ac.id

Volume 21 Nomor 1 (2025) Hal. 70-76
e-ISSN 2527-6131
http://jurnaldinarek.id

EFEKTIFITAS KECEPATAN PEMOTONGAN MATERIAL SS 316 L TERHADAP KEKASARAN PERMUKAAN PADA PROSES LASER

EFFECTIVENESS OF SS 316 L MATERIAL CUTTING SPEED ON SURFACE ROUGHNESS IN THE LASSER PROCESS

Sigit Arrohman*[1], Andri Sulistyo[1], dan Catur Harsito[2,3]

*Email: sigit.arrohman@umk.ac.id

[1]Jurusan Teknik Mesin, Universitas Muria Kudus,Kudus, Indonesia
[2]Jurusan Teknik Mesin, Sekolah Vokasi Universitas Sebelas Maret, Surakarta, Indonesia
[3]Mechanical, Computer, Industrial Management Engineering Department, Kangwon National University, Samcheok, Republic of Korea

***Abstrak*—** Pemotongan bahan logam menggunakan Laser Cutting dapat menentukan kualitas pemotongan bahan. Hal ini dikarenakan pemotongan laser menggunakan kecepatan tinggi, sehingga dapat meningkatkan kualitas potongan bahan. logam SS 316 L merupakan logam yang digunakan dalam industri manufaktur. Pemilihan logam SS 316 L bertujuan untuk mencegah adanya korosi, kekuatan yang tinggi dan mudah dalam perawatan. Tujuan dari penelitian ini adalah mengetahui parameter kecepatan potong pada pemotongan laser menggunakan bahan SS 316 L. Metode yang digunakan yaitu dengan memvariasikan kecepatan potong mesin laser dengan kecepatan 60 mm/menit, 70 mm/menit, 80 mm/menit, 90 mm/menit, 100 mm/menit. Pengamatan uji kekasaran permukaan dengan dua variasi secara vertikal dan horizontal. Sampel pengujian sebanyak tiga kali untuk masing-masing benda uji. Hasilnya penelitian ini adalah kekasaran permukaan terendah (halus) diperoleh dengan variasi kecepatan potong 100 mm/menit dan tertinggi (kasar) pada kecepatan potong 60 mm/menit baik untuk variasi pengambilan sampel secara vertikal dan horizontal. Sehingga, semakin cepat kecepatan potong mesin laser dapat mengurangi kekasaran permukaan logam SS 316 L.

Kata kunci— Kecepatan potong, Kekasaran permukaan, Laser Cutting.

***Abstract*—** Cutting metal materials using Laser Cutting can determine the quality of the cutting material. This is because laser cutting uses high speed, so it can improve the quality of the cut material. SS316 L metal is a metal used in the manufacturing industry. The choice of SS 316 L metal aims to prevent corrosion, have high strength and be easy to maintain. The aim of this research is to determine the cutting speed parameters in laser cutting using SS 316 L material. The method used is by varying the cutting speed of the laser machine with speeds of 60 mm/minute, 70 mm/minute, 80 mm/minute, 90 mm/minute, 100 mm/min. Observation of surface roughness tests with two variations vertically and horizontally. Test samples three times for each test object. The results of this research were that the lowest (smooth) surface roughness was obtained with a cutting speed variation of 100 mm/minute and the highest (coarse) at a cutting speed of 60 mm/minute for both vertical and horizontal sampling variations. So, the faster the cutting speed of the laser machine can reduce the roughness of the SS 316 L metal surface.

Keywords— Cutting speed, Surface roughness, Laser Cutting.

I. INTRODUCTION

Laser cutting is a technology that utilizes laser beams as the cutting medium, and it has been widely adopted across various manufacturing industries. The application of laser cutting in industrial settings is designed to concentrate a large amount of laser energy into a small area. This is made possible by generating and modifying laser beams so that the laser diameter used for cutting is approximately 0.003 to 0.006 inches [1].

Laser cutting can be applied to both metallic and non-metallic materials. Commonly used metallic materials include iron, stainless steel, and SS 316L. In addition to metals, materials such as acrylic and wood can also be processed using laser cutting. SS 316L, in particular, is widely used in industrial applications, especially in the medical industry, due to its advantageous properties, such as corrosion resistance, high durability, and low maintenance requirements [2].

In practice, cutting parameters play a crucial role in the laser cutting process, one of which is the cutting speed of the laser cutting machine. The setting of cutting speed can significantly affect the quality of the cut. Materials subjected to laser cutting require high precision; otherwise, defects may occur during the cutting process. Such defects may arise when the laser beam does not accurately target the material, resulting in suboptimal cutting precision. Cutting speed also influences the surface roughness of the material as a result of the cutting process [3]. Variations in cutting speed can help minimize losses in laser cutting, as material defects or damage may occur due to inappropriate cutting parameters [4]. Therefore, in addition to optimizing cutting speed, further study on the behavior of SS 316L under different conditions is essential to determine the effectiveness of laser cutting machines.

The cutting medium used in laser cutting involves the laser beam assisted by a cutting gas, which serves as an auxiliary medium for metal cutting [5]. The purpose of this study is to investigate the effect and effectiveness of varying laser cutting speeds on SS 316L material. The effectiveness examined in this study is based on surface roughness resulting from variations in cutting speed. The significance of this research lies in its contribution to understanding the impact of cutting speed variations on the surface roughness of SS 316L, aiming to identify the optimal cutting parameters for laser processing of this material. This insight is expected to provide a reference for achieving optimal laser cutting conditions for SS 316L.

II. LITERATURE REVIEW

Manufacturing is a process that transforms the shape, properties, dimensions, and characteristics of raw materials into final products through physical and chemical processes. This transformation converts simple materials into more complex products. Machining processes are carried out by removing unwanted material to achieve the desired final shape and specifications. In the manufacturing industry, common machining operations include shaping, milling, grinding, sawing, and turning [1].

Laser cutting is a technique that utilizes a laser beam and CO_2 gas as the cutting medium. This method is widely applied in manufacturing sectors such as the automotive and healthcare industries. Laser cutting employs high-powered lasers in combination with computer-controlled systems to regulate both the laser output and the volume of CO_2 gas used during the cutting process.

There are three main types of lasers used in laser operations. CO_2 lasers are suitable for cutting, drilling, and engraving workpieces. Neodymium (Nd) lasers are used for high-energy drilling applications with low repetition rates. Meanwhile, neodymium-doped yttrium-aluminium-garnet (Nd:YAG) lasers are effective for both drilling and engraving at high power. Additionally, both CO_2 and Nd lasers can also be used for welding processes [6].

Several parameters significantly influence laser cutting processes, including: (a) Nitrogen gas, which is typically used when cutting stainless steel, aluminium, nickel alloy steels, and high-alloy steels. Nitrogen is applied at high pressure to remove molten material generated during the laser melting process. (b) Cutting speed, which refers to the length or duration of cutting that the laser machine can perform within a certain period. Increasing the feed rate of the laser cutter enhances cutting speed and reduces processing time [1], [2].

Computer Numerical Control (CNC) machines are a key component in manufacturing operations. A major advantage of CNC machines is their ability to produce mass-manufactured parts with consistent quality by using pre-programmed settings, eliminating the need for manual adjustments. This allows for high production capacity in a relatively short time [7]. In the manufacturing industry, surface finish is a critical quality attribute, as it directly affects the overall product quality. One common metric used to assess this attribute is surface roughness. Surface roughness may vary depending on the workpiece application and machining process used [8]. SS 316L is an austenitic stainless steel alloy that remains stable in the austenitic phase at room temperature. It offers several advantages, such as being non-magnetic, corrosion-resistant, and having a low carbon content, making it suitable for use in the food and healthcare industries [2].

Surface roughness is defined as the arithmetic average deviation from the mean line of the surface profile. Surface roughness values are used to determine product requirements and standard roughness specifications within companies. Surface roughness quality grades (denoted as N values) range from N1 (0.025 µm) to N12 (50 µm), with each grade corresponding to specific manufacturing standards and product applications.

III. METODS

This study employed an experimental data method. The experimental data used were obtained from surface roughness measurements conducted during the laser cutting process.

The research and sample testing were carried out from January 23, 2023, to March 4, 2023, at the Mechanical Engineering Laboratory, Muria Kudus University.

The cutting speed parameter was varied to evaluate the effectiveness of the laser cutting machine, with speed settings of 60 mm/min, 70 mm/min, 80 mm/min, 90 mm/min, and 100 mm/min. The nozzle specifications were as follows: 2 mm in diameter, a perpendicular cutting angle (90°), and gas pressure of 21 bar. The research flowchart is shown in Figure 1.

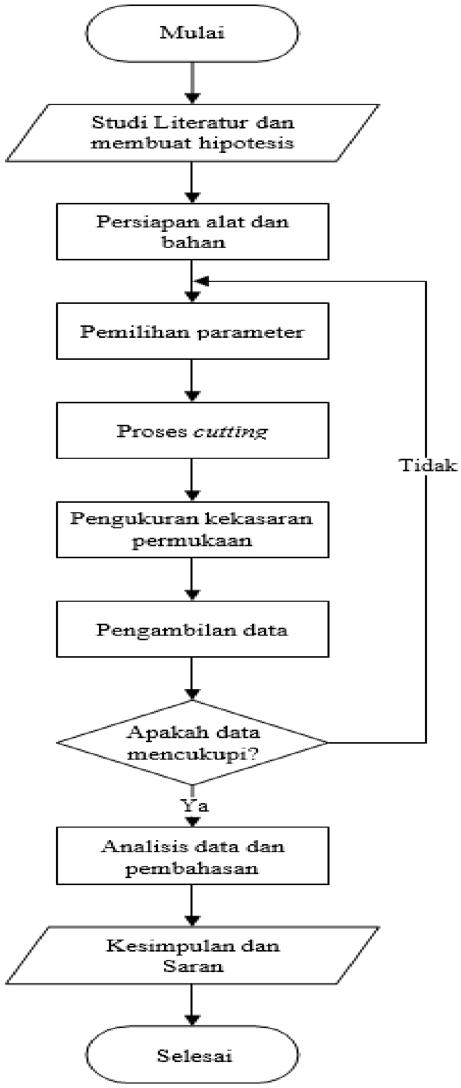

Figure-1. Research Flowchart

The tools and materials used in this study are as follows:

1. Laser Cutting Machine
   The laser cutting process was carried out using the machine shown in Figure 2.

Figure-2. Laser Cutting Machine

Specifications of the laser cutting machine:

Model : GS-3015 C

Cutting area	: 3000 X 1500 mm
Laser power	: 3000 W
Serial number	: PCC03000000002274
X-axis length	: 1510 mm
Y-axis length	: 3020 mm
Z-axis length	: 120 mm
Maximum speed	: 80000 mm/min
CNC system	: Cyput
Maximum load	: 900 kg
Machine weight	: 4,5 ton
Total installed power	: 9-20 kw
Power protection class	: IP54

2. Surface Roughness Testing Instrument

Used to measure the surface roughness of SS 316L workpieces. The device used was a Mitutoyo SJ-2100 surface roughness tester.

Figure-3. Mitutoyo SJ-2100 Surface Roughness Tester

3. SS 316 L

The material used was SS 316L stainless steel in sheet form with a thickness of 2 mm.

Figure-4. SS 316 L Sheet

Specifications of SS 316L

UTS	: 558 Mpa
Hardness	: B79
Density	: 7,99 g /cm3
Specific Heat	: 0,50 KJ/kg.K
Thermal Conductivity	: 16,2W/m.K
Modulus Elastisitas	: 193x103 Mpa

A. Sample Collection with Horizontal Point Variation

Horizontal point variation sampling refers to the method of collecting surface roughness data across horizontally aligned points. The mechanism for horizontal sampling is illustrated in Figure 5.

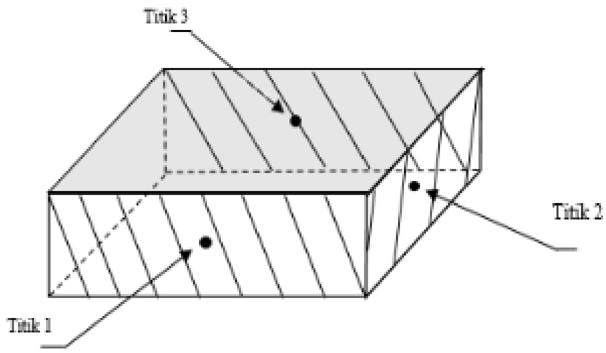

Figure-5. Horizontal Sampling of Test Specimens

Figure 5 shows the mechanism used to collect data from three different measurement points across horizontally aligned positions on the SS 316L workpiece.

B. Sample Collection with Vertical Point Variation

Vertical point variation sampling refers to the method of collecting surface roughness data from vertically aligned points. The sampling procedure is illustrated in Figure 6.

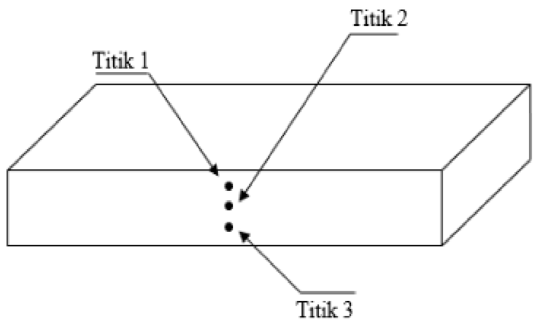

Figure-6. Vertical Sampling of Test Specimens

Figure 6 shows the mechanism for vertical data collection, where measurements are taken at three different vertically aligned positions on the SS 316L workpiece. The sampling was repeated three times for accuracy.

IV. RESULTS AND DISCUSSION

A. Horizontal Test Results

The horizontal surface roughness test was conducted using various cutting speeds on SS 316L material. The surface roughness measurements obtained from the horizontal testing are presented in Table 1.

Table 1. Surface Roughness of SS 316L with Varying Cutting Speeds (Horizontal Direction)

No	Cutting speed (Cs) (mm/min)	Surface Roughness (µm)			Total ∑(µm)	Average (µm)
		Point 1	Point 2	Point 3		
1	60	3,794	3,266	3,524	10,584	3,528
2	70	4,486	4,181	3,805	12,427	4,157
3	80	5,265	4,353	4,604	14,222	4,741
4	90	5,404	4,486	5,508	15,398	5,133
5	100	5,692	5,975	5,593	17,26	5,753

The surface roughness data in Table 1 is analyzed to determine the relationship between cutting speed and surface roughness of SS 316L. Figure 7 illustrates this relationship based on the horizontal measurements.

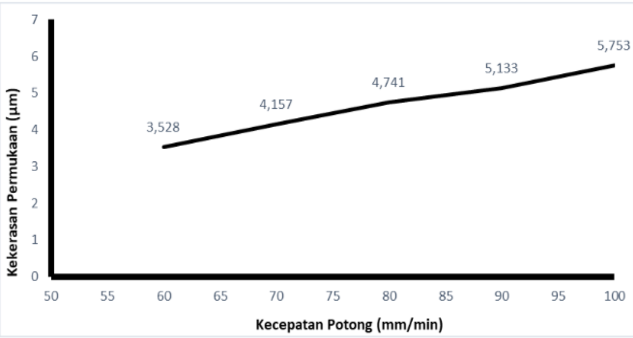

Figure-7. Relationship between Cutting Speed and Surface Roughness (Horizontal Direction)

Figure 7 shows the effect of cutting speed on the horizontal surface roughness values. Cutting speeds were varied from 60 mm/min to 100 mm/min, and the results indicate a consistent increase in surface roughness with increasing cutting speed. This increase is influenced not only by cutting speed but also by spindle rotation, feed rate, and depth of cut [9][10]. At a cutting speed of 60 mm/min, the average horizontal surface roughness (Ra) was 3.528 µm. When the cutting speed increased to 70 mm/min, the Ra value rose to 4.157 µm, and further increased to 5.753 µm at 100 mm/min.

The estimated explanation for this phenomenon is that surface roughness increases with higher cutting speeds. In laser cutting processes, an increase in cutting speed shortens the interaction time between the laser and the workpiece. This results in suboptimal heat energy transfer to the cutting area and causes the assist gas distribution to become increasingly uneven as cutting speed rises. The findings of this study indicate that variations in cutting speed lead to progressively higher surface roughness values as the cutting speed increases.

Higher cutting speeds in laser cutting may reduce the cutting duration, but this also leads to inefficient heat transfer to the material and contributes to surface irregularities on the SS 316L specimen. The results of this study demonstrate that increasing the cutting speed consistently results in higher surface roughness values [11], [12], [13].

B. Vertical Test Results

The vertical surface roughness test was performed by varying the cutting speed during the vertical cutting of SS 316L material. The results are summarized in Table 2.

Table-2. Surface Roughness of SS 316L with Varying Cutting Speeds (Vertical Direction)

NO	Cutting Speed (mm/min)	Surface Roughness of SS 316 L (µm)		
		Top Point	Middle Point	Bottom Point
1	60	0.735	0.907	0.917
2	70	1.024	1.035	1.197
3	80	1.425	1.608	1.927
4	90	2.431	2.721	2.913
5	100	3.873	3.905	3.930

Table 2 presents surface roughness values measured at three vertical positions: top, middle, and bottom. Each position exhibited varying degrees of roughness, indicating that vertical position influences surface finish.

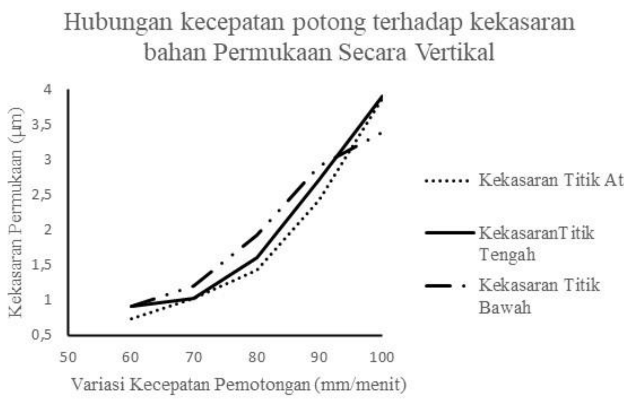

Figure 8. Relationship between Cutting Speed and Surface Roughness (Vertical Direction)

Figure 8 illustrates the relationship between cutting speed and vertical surface roughness for SS 316L. As cutting speed increased from 60 mm/min to 100 mm/min, surface roughness values also increased consistently across all vertical measurement points. The increase in cutting speed leads to shorter interaction time and less effective heat and energy transfer, which results in rougher surface finishes. Furthermore, the constant gas pressure during prolonged cutting duration contributes to decreased laser effectiveness, increasing surface irregularities [14][15].

For example, at a cutting speed of 60 mm/min, the top-point Ra value was 0.735 µm, the middle point was 0.907 µm, and the bottom point was 0.917 µm. As the cutting speed increased, the surface roughness also increased in all three positions. This suggests that the deeper the cutting penetration, the longer the laser-material interaction time, and with constant gas pressure, this reduces the effective cutting force and energy, thereby increasing surface roughness.

V. Conclusion

A. *Conclusions*

- In laser cutting, surface roughness in the horizontal direction is influenced by variations in cutting speed. The lowest horizontal roughness was observed at a cutting speed of 60 mm/min, while the highest occurred at 100 mm/min.
- In vertical cutting, the lowest vertical roughness at a cutting speed of 60 mm/min was recorded at point 1 (upper region). The highest roughness was observed at point 3 (lower region). Furthermore, for each cutting speed, surface roughness increased consistently from point 1 to point 3.

A. *Recommendations*

Further studies are recommended to optimize the use of CO_2 gas, investigate a wider range of cutting speeds, and assess different material thicknesses of SS 316L.

Acknowledgments

The author extends sincere gratitude to all parties who contributed to the research process and the preparation of this report and journal.

References

[1] Z. Arifin, "Pengaruh variasi cutting speed terhadap kekasaran permukaan SUS 304 pada proses laser cutting menggunakan gas N2," Universitas Brawijaya, 2018.

[2] R. M. Ogana, "Pengaruh Variasi Cutting Speed Terhadap Kekasaran Permukaan SS316l pada Proses Laser Cutting," Universitas Brawijaya, 2018.

[3] A. A. Almorshedi, "Optimization of Parameters of Laser Non-Linear Inclined Cutting on Stainless Steel Metal," Universiti Tun Hussein Onn Malaysia, 2014.

[4] K. B. W and A. I. Juniani, "Optimasi Parameter Mesin Laser Cutting Terhadap Kekasaran Dan Laju Pemotongan Pada Sus 316l Menggunakan Taguchi Grey Relational Analysis Method," *Jati Undip: Jurnal Teknik Industri*, vol. 11, no. 2, pp. 97–106, 2016.

[5] M. A. Hidayat, A. Farid, and P. Suwandono, "Analisa parameter pada pemotongan plate menggunakan CNC fiber laser cutting terhadap kekasaran permukaan," *Turbo: Jurnal Program Studi Teknik Mesin*, vol. 10, no. 2, 2021.

[6] N. Satyawardhana, M. S. Y. Lubis, and D. 2022, "Optimasi Parameter Proses Laser Cutting Terhadap Kekasaran Permukaan Material Acrylictype Clear Dengan Menggunakan Metode Taguchi," in *Seminar Nasional Teknik (SEMNASTEK) UISU*, 2022, pp. 5–10.

[7] R. D., M. Subhan, and I. R. Pratiwi, "Analisis Kekasaran Permukaan Baja Aisi 1045 Pada Proses Pemesinan Bubut Cnc Dengan Metode Taguchi," in *Seminar Nasional Inovasi Teknologi Terapan*, 2021, pp. 42–48.

[8] R. A. Mahendra, M. R. A. Anggara, K. E. Kapel, A. M. Mifthahudin, K. I. Pratama, and F. Rahmadianto, "Analisa Efektifitas Uji Kekasaran Permukaan Baja ST 42 Dengan Variabel Mekanik Mesin Dengan Metode Taguchi," *Jurnal Mesin Material Manufaktur dan Energi*, vol. 1, no. 1, pp. 5–8, 2020.

[9] S. Apreza, Z. Kurniawan, and M. Subhan, "Optimasi Kekasaran Permukaan Proses Pembubutan Baja ST. 42 Dengan Menggunakan Metode Taguchi," *Manutech: Jurnal Teknologi Manufaktur*, vol. 9, no. 01, pp. 73–78, 2017.

[10] S. Syach, A. S. Nurrohkayati, and S. H. Pranoto, "Optimasi parameter untuk kekasaran permukaan pada proses pembubutan baja ST 37 dengan menggunakan metode Taguchi," *TEKNOSAINS: Jurnal Sains, Teknologi dan Informatika*, vol. 9, no. 2, pp. 113–120, 2022.

[11] E. P. Purwanti and B. W. Karuniawan, "Optimasi Parameter Proses Pemotongan Acrylic terhadap Kekasaran Permukaan Menggunakan Laser Cutting Dengan Metode Response Surface," in *Proceedings Conference on Design Manufacture Engineering and its Application*, 2017, pp. 316–323.

[12] W. Wildan and A. S. Nurrohkayati, "Analisis parameter proses pembubutan terhadap kekasaran permukaan baja ST 37 menggunakan metode taguchi," *JTTM: Jurnal Terapan Teknik Mesin*, vol. 4, no. 1, pp. 28–35, 2023.

[13] M. S. Y. Lubis, A. Wiyoso, H. Wibowo, and S. Ariyanti, "Penentuan Parameter Proses Laser Cutting Terhadap Kekasaran Permukaan Material Acrylyc," *IRA Jurnal Teknik Mesin dan Aplikasinya (IRAJTMA)*, vol. 2, no. 2, pp. 19–28, 2023.

[14] J. Supriyandi, E. Yudo, and A. Satria, "Optimasi Kekasaran Permukaan Proses CNC Turning Baja Skd-11 Dengan Menggunakan Metode Taguchi," *Jurnal Syntax Admiration*, vol. 2, no. 7, pp. 1284–1293, 2021.

[15] A. Nugroho, A. S. Hutama, and C. Budiyantoro, "Optimasi keakuratan dimensi dan kekasaran permukaan potong material akrilik dengan proses laser menggunakan metode Taguchi dan PCR-TOPSIS," *JMPM (Jurnal Material dan Proses Manufaktur)*, vol. 2, no. 2, pp. 75–82, 2018.