ANALYSIS OF INACCURACY OF CNC LASER CUTTING RESULTS ON STAINLESS STEEL WITH A THICKNESS OF 1.5 MM

Final Project

By:
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Polytechnic Country Batam
2025

Statement of Authenticity of Final Project

I, the undersigned, hereby declare that the contents of my Final Project, entitled "analysis of inaccuracy of CNC laser cutting results on stainless steel with a thickness of 1.5 mm", are entirely my own work, compiled without the use of unauthorised materials, and do not constitute the work of any other party which I have claimed as my own. All sources cited or referred to in this work have been fully listed in the bibliography. Should this declaration prove to be untrue at a later date, I am willing to accept sanctions in accordance with the applicable regulations.

Batam,28,july 2026

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I. AGREEMENT SHEET

That Final Project is arranged to fulfil One from That condition to obtain a degree
Bachelor from Colleague Engineer
(AMd.T.) in
Batam Country Polytechnic

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ABSTRACT

CNC laser cutting machines are widely used in the manufacturing industry because they are capable of producing fast cutting processes and have a high level of precision. However, the quality of the cutting results is greatly influenced by the setting of process parameters so that parameter mismatches can cause dimensional deviations, the appearance of burrs, scale, and poor cut surfaces. This study aims to analyze the effect of cutting parameters on the inaccuracy of CNC laser cutting results on Stainless Steel 316 material with a thickness of 1.5 mm and determine the combination of parameters that produce the best cutting quality. The research method was carried out through literature studies, field observations, and testing of nine specimens with variations in cutting speed, laser power, gas pressure, and focal point parameters. The results showed that the quality of the cutting results increased gradually until Specimen 7 produced the smallest dimensional error value of 0.04 mm with parameters of cutting speed 6500 mm/min, laser power 1200 W, gas pressure 10 bar, and focal point -2.50 mm. In addition to being influenced by cutting parameters, the quality of the results is also influenced by the condition of the machine flatness and the cleanliness of the machine rail. Increasing parameters beyond optimal conditions causes the cutting quality to decrease again due to the increase in heat energy in the cutting area. Therefore, the optimal parameter combination can be used to produce more precise cuts on 1.5 mm thick Stainless Steel 316 material.

Keywords: CNC laser cutting, non-precision cutting, 1.5 mm stainless steel, scrap quality, cutting process

FOREWORD

Praise and gratitude the author expresses to Allah SWT for His abundant mercy, guidance, and blessings, allowing the author to complete the preparation of the final project proposal entitled “Leakage analysis on zero offset butterfly valves with soft seat type focusing on seat ring reliability” properly.

This proposal is prepared as one of the requirements for completing the Manufacturing Electronics Engineering study program at Politeknik Negeri Batam. In the process of preparing this proposal, the author received a lot of assistance, guidance, and support from various parties, both directly and indirectly. Therefore, on this occasion, the author would like to express the sincerest gratitude to:

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3. PT MEGA SYNERGY POWERINDO, which has given the author the opportunity to carry out an internship and conduct research related to the analysis of inaccuracy of CNC laser cutting results on stainless steel with a thickness of 1.5 mm
4. My beloved parents and family, for their prayers, moral support, and endless encouragement, which enabled me to complete this proposal well.
5. Fellow students of Evening Class B, for their companionship, cooperation, and mutual assistance during the learning process and the preparation of this report.

ANALYSIS OF INACCURACY OF CNC LASER CUTTING RESULTS ON STAINLESS STEEL WITH A THICKNESS OF 1.5 MM.

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***Abstract* — CNC Laser Cutting Machines are widely used in the manufacturing industry because they are capable of producing fast cutting processes and have a high level of precision. However, the quality of the cutting results is greatly influenced by the setting of process parameters so that parameter mismatches can cause dimensional deviations, the appearance of burrs, slag, and poor cut surfaces. This study aims to analyze the effect of cutting parameters on the inaccuracy of CNC Laser cutting results on Stainless Steel 316 material with a thickness of 1.5 mm and determine the combination of parameters that produce the best cutting quality. The research method was carried out through literature studies, field observations, and testing of nine specimens with variations in cutting speed, laser power, gas pressure, and focal point parameters. The results showed that the quality of the cutting results increased gradually until Specimen 7 which produced the smallest dimensional error value of 0.10 mm with parameters of cutting speed 6500 mm/min, laser power 1200 W, gas pressure 10 bar, and focal point -2.50 mm. In addition to being influenced by cutting parameters, the quality of the results is also influenced by the condition of the machine flatness and the cleanliness of the machine rail. Increasing parameters beyond optimal conditions causes the cutting quality to decrease again due to the increase in heat energy in the cutting area. Therefore, this optimal parameter combination can be used to produce more precise cuts in 1.5 mm thick 316 stainless steel.**

Keywords: CNC laser cutting, non-precision cutting, 1.5 mm stainless steel, scrap quality, cutting process

II. INTRODUCTION

Modern industrial progress demands continuous innovation in production methods. This is a positive trend, helping to meet product needs more quickly and precisely. Manufacturing systems are increasingly innovative, combining high precision with the ability to produce components with unique configurations. Advanced technology drives industry to achieve optimal results, particularly in manufacturing areas involving machining processes such as cutting.

One of the technologies that is widely used is CNC Laser Cutting, which is a computer-based material cutting machine that is capable of [1] [2] [3] [4] .

to work automatically with digital data. Compared with conventional methods, laser cutting offers many advantages: shorter production cycles, increased efficiency, better product quality, and lower energy consumption. This machine can produce cuts with smooth surfaces, precision up to 1/100 mm, and is suitable for mass production with uniform results [5] [6] [7] .

However, cutting quality is highly dependent on the setting of process parameters, such as laser power, cutting speed, assist gas pressure, and lens focus. If the parameters are not set correctly, the cutting results may suffer from defects such as improper size, non-uniform gap width, or oxidation at the edge. Therefore, a thorough understanding of the influence of each parameter is crucial for optimization [5] [8] [9] [10] .

Previous studies have shown that laser power, cutting speed, assist gas pressure, and laser focus position significantly affect the quality and dimensional accuracy of CNC laser cutting results. However, most previous studies evaluated these parameters individually or only focused on the general cutting quality, while limited studies have comprehensively analyzed the combined influence of cutting parameters along with machine conditions, such as machine flatness and rail cleanliness, on the dimensional accuracy of 1.5 mm Stainless Steel 316. Therefore, this study aims to analyze the factors causing dimensional inaccuracy in CNC laser cutting and to determine the optimal combination of cutting parameters that results in the highest cutting precision and the best cutting quality [11] [12] [13] .

Laser power and cutting speed play a crucial role in determining the width of the cutting gap and the quality of the cut wall surface. Meanwhile, it is emphasized that the pressure and type of assist gas are crucial in helping to remove molten material, resulting in a cleaner and more accurate cut. Furthermore, other studies have confirmed that the laser focus position affects the amount of energy received by the material, which ultimately has a direct impact on the precision of the size and slope of the cut wall. [14] [15] [16] .

A. The Influence of CNC Laser Cutting Parameters on Cutting Stainless Steel 316

1. Effect of laser power
   Laser power is the amount of power generated by a laser source to cut a material. In the process of cutting 316 Stainless Steel, increasing laser power will increase the heat energy received by the material, resulting in a more effective melting process. However, if the laser power is too high, excessive heat energy can cause kerf widening, dross formation, and increased dimensional error. Therefore, optimal laser power settings are necessary to achieve precise cutting results.
2. Effect of Cutting Speed
   Cutting speed determines the duration of interaction between the laser beam and the material. Cutting speeds that are too slow cause heat to accumulate, expanding the Heat Affected Zone (HAZ). Conversely, cutting speeds that are too high result in insufficient laser energy to completely cut the material. Therefore, cutting speeds must be adjusted to the characteristics of 316 Stainless Steel to achieve optimal cutting results.
3. Effect of Gas Pressure
   Gas pressure helps remove molten material from the cutting gap and protects the material surface from oxidation. Nitrogen gas was used in this study because it produces a cleaner cut surface than oxygen. Too low a gas pressure can cause molten material to adhere to the cut edge, while too high a pressure can disrupt the stability of the gas flow and affect cut quality.
4. The Influence of Focus Point
   The focal point is the position of the laser beam's focus on the material surface. Properly setting the focal point results in maximum energy concentration in the cutting area, enabling optimal melting. If the focal point is too high or too low, energy distribution will be uneven, which can result in wider kerfs and increased dimensional error .

B. Relationship between Electrical Parameters and CNC Laser Cutting Quality

In a CNC laser cutting machine, the cutting process is controlled by an electronic system consisting of a CNC controller, laser source, servo driver, servo motor, sensors, and a gas control system. Parameters such as laser power, cutting speed, gas pressure, and focus point are regulated by the electronic control system. Changes in these parameters will affect the laser energy, laser head movement, and heat distribution within the material, resulting in varying cut quality.

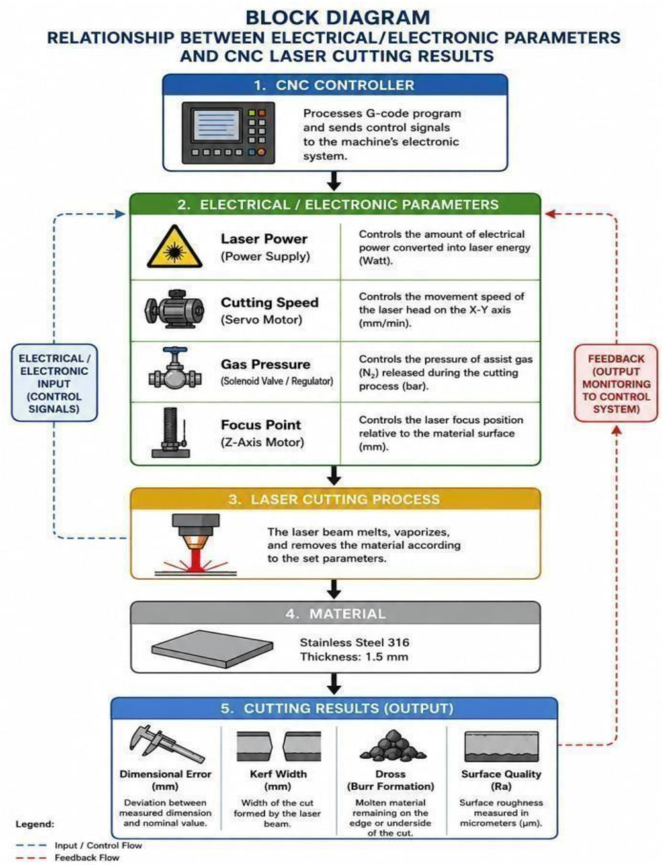


Figure 1 block diagram of the relationship between electronic parameters and CNC laser cutting results

C. Parameter Relationship

Table 1.1 shows the relationship between electronic parameters controlled by the CNC system and the quality of cutting results. Each parameter is set through different electronic components, such as the laser power supply, servo motor, gas regulator, and Z-axis motor. Changes in the value of each parameter will affect the interaction process between the laser beam and the Stainless Steel 316 material, resulting in differences in dimensional error, kerf width, dross, and surface quality. Therefore, proper parameter settings are very important to obtain precise cutting results [15] [17] .

Table 1.1 parameter relationship table

Parameter	Electronic Components	Effect on Material	Measurement results
Laser Power	Laser power supply	Laser energy increases	Dimension error
Cutting speed	Servo motor	Laser interaction time	Dimension error
Gas pressure	Regulator	Melt disposal	dross
Focus point	Z-axis motor	Energy concentration	Cutting accuracy

D. *Cause and Effect Diagram of Poor Cutting Results*

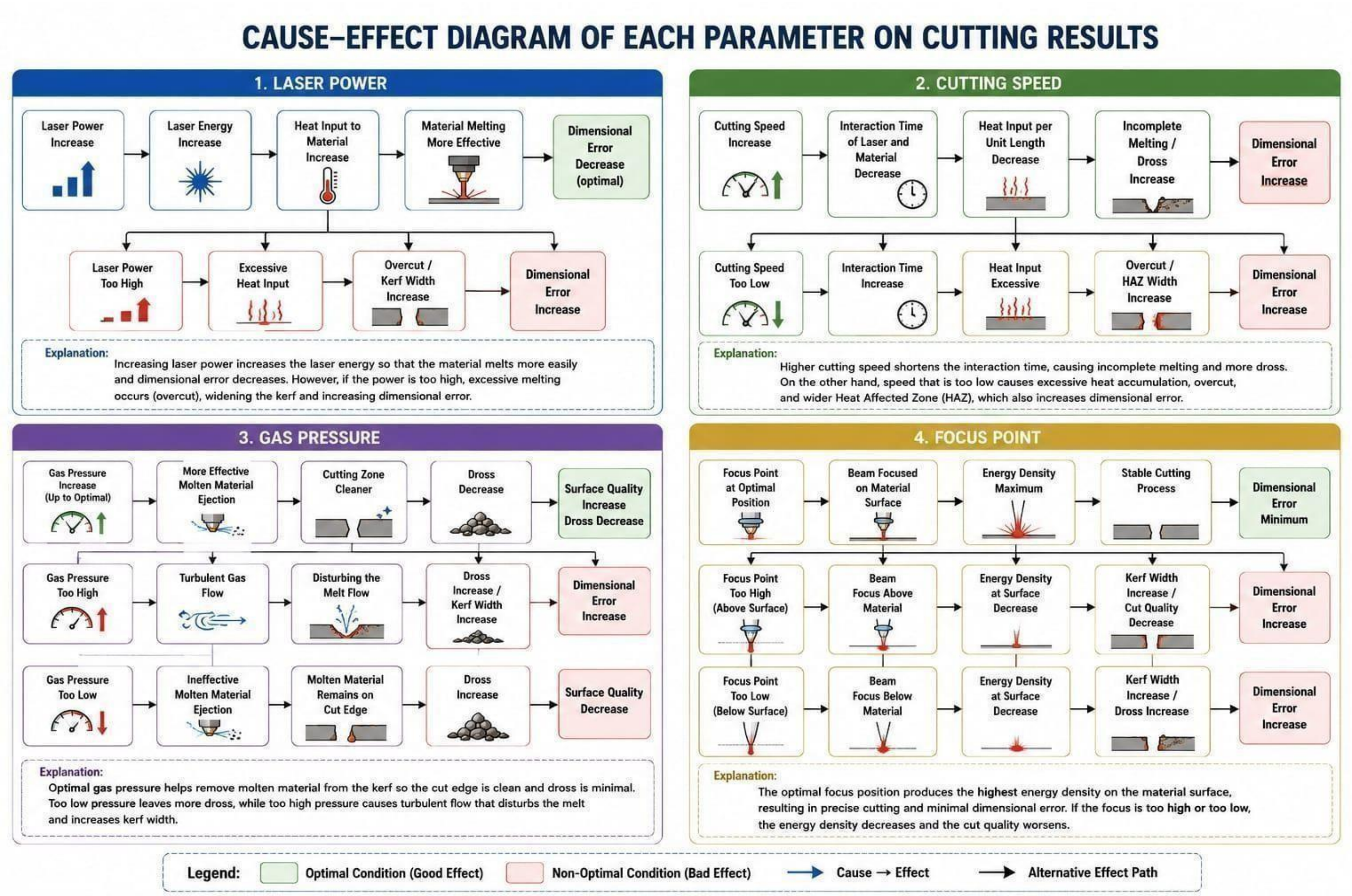


Figure 2 Block Diagram of Cause and Effect of Poor Cutting Results

1. Laser Power

Laser power is a parameter that determines the amount of laser energy delivered to the material during the cutting process. When the laser power is increased to the optimum value, the laser energy increases, thereby increasing the heat input to the material. This increased heat input makes the material easier to melt, making the cutting process more effective. Consequently, the molten metal can be optimally expelled by the assist gas, resulting in a kerf width that meets the design requirements and minimizes dimensional error. Conversely, if the laser power is too high, the material receives excessive heat energy, resulting in overcutting. This condition causes the kerf width to widen and increases dimensional error.

2. Cutting Speed

Cutting speed affects the duration of interaction between the laser beam and the material. If the cutting speed is increased beyond the optimum value, the interaction time becomes shorter, resulting in decreased heat input per unit length. As a result, the material does not melt completely and produces more dross, increasing dimensional error. Conversely, if the cutting speed is too low, the laser interaction time with the material is too long, resulting in excessive heat gain. This condition causes overcuts, widening of the Heat Affected Zone (HAZ), and an increase in kerf width, which ultimately increases dimensional error. Therefore, an optimum cutting speed is required to achieve good cut quality.

3. Gas Pressure

Gas pressure functions to help remove molten metal from the cutting area so that the cut surface is clean. At optimum gas pressure, molten metal can be pushed out effectively so that dross is reduced and surface quality is improved. However, if the gas pressure is too high, the gas flow becomes turbulent, disrupting the flow of molten metal and causing the kerf width to become larger. Conversely, gas pressure that is too low is unable to remove the molten metal completely so that the remaining metal sticks to the cut edge and forms dross. Both of these conditions can increase the dimensional error of the cutting results [18] .

4. Focus Point

The focus point determines the concentration of laser energy relative to the material surface. At the optimum focus position, laser energy is maximally concentrated, resulting in high energy density and a stable cutting process. This results in a kerf width that meets the design requirements and minimizes dimensional error. Conversely, if the focus point is above or below the optimum position, laser energy concentration decreases, resulting in decreased energy density. This results in imperfect material melting, reduced cutting quality, increased kerf width, increased dross, and ultimately higher dimensional error.

CNC Laser Cutting results are influenced by four main parameters, namely laser power, cutting speed, gas pressure, and focus point. Laser power determines the amount of energy received by the material, thus affecting the melting process. Cutting speed regulates the duration of interaction between the laser beam and the material, which impacts the quality of the cut. Gas pressure functions to help expel molten metal from the cutting gap, thereby reducing dross formation and improving surface quality. Meanwhile, the focus point determines the concentration of laser energy on the surface of the material, thus affecting the dimensional accuracy of the cut results. The combination of these four parameters must be optimally adjusted because values that are too low or too high can cause increased dimensional error, changes in kerf width, dross formation, and decreased quality of the cut results .

E. Mathematical Model of the Relationship between Cutting Parameters and Cutting Result Quality

The CNC Laser Cutting process is influenced by combination of cutting parameters such as laser power, cutting speed, gas pressure, and focus point. scientific , relationship between these parameters with quality results cutting can explained using mathematical models simple that describes influence laser energy against change dimensions results cut . This model used as base For analyze connection between process parameters and the obtained dimensional error value from results measurement .

1. Formula Error Dimensions

D *design* = dimensions design (mm)
D *measurement*= dimension results measurement(mm)
Dimensions design-results measurement = result end

III. METHOD

This research begins with a literature review to obtain relevant scientific references, such as journals, books, and statistical data, as a theoretical basis in analyzing the influence of CNC laser cutting machine parameters on the quality of cutting results of 1.5 mm thick stainless steel material. Next, direct field observations were conducted at PT Mega Synergy Powerindo to obtain valid and objective data regarding the cutting process without relying on reports or interpretations of other parties. Observation activities include checking the condition of the CNC laser cutting machine, measuring the cutting results, observing the machine parameters used during the cutting process, and identifying various failures or defects that occur in the cutting results.

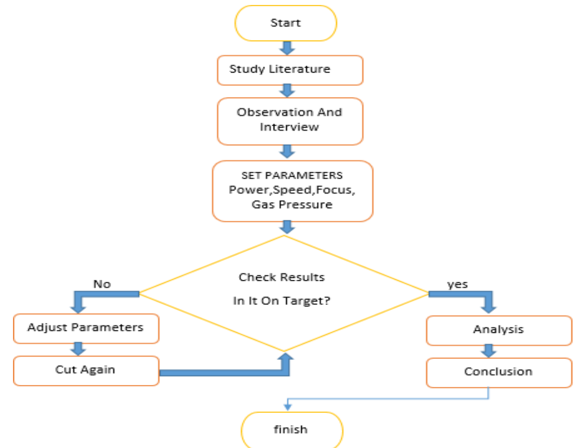


Figure 3 Research Flowchart

This research flow begins from the initial stage as a sign of the start of the activity, then continued with a literature review to review theories, journals, and previous research related to the CNC laser cutting process, cutting parameters, and the quality of the cutting results. After that, observations and interviews were conducted to understand the actual conditions of the machine, the production process, and problems that often arise in the field. Based on the results of the literature review and observations, the parameters of the laser cutting process, both variable and controlled, were determined. The next stage is data collection by carrying out the cutting process according to the predetermined parameters, then measuring the cutting results. The collected data is then processed through preparation, calculation, and tabulation, before entering the analysis stage to evaluate the influence of parameters on the inaccuracy and quality of the cutting results. The results of the analysis are summarized in conclusions that answer the research objectives, and finally the research is closed at the completion stage.

A. Location and Time of Research

This research was conducted at PT. xyz as part of an industrial internship program. The location was chosen because the research topic aligns with the company's production activities, specifically the use of CNC laser cutting machines in the manufacturing process. During the internship, data collection was conducted concurrently with work activities in the industrial environment. The research time included initial observation of the production process, data collection through CNC laser cutting, measurement of cutting results, and data processing and analysis. Aligning the research schedule with the internship activities made the data obtained more representative and in accordance with real conditions in the field.

B. Tools and materials

This research uses several tools and materials that support the CNC laser cutting process. The tools used include a CNC laser cutting machine as the main tool for carrying out the material cutting process, a CNC computer that functions to operate and control the machine through a cutting program, and AutoCAD software to create designs or patterns for the workpiece to be cut. In addition, an anchor shovel is used to assist in the process of handling or moving the material that has been cut, a power supply as a source of electrical energy for the equipment, a nozzle to direct the laser beam and the flow of cutting gas, and personal protective equipment (PPE) in the form of gloves, protective glasses, aprons, and safety shoes to maintain the safety of the operator during the research process. The materials used consist of a type 316 stainless steel plate with a thickness of 1.5 mm as the main workpiece, and oxygen gas that functions as an auxiliary gas to increase the efficiency of the cutting process and help produce better cutting quality.

In this study, the variables were divided into three groups: independent variables, dependent variables, and control variables. The independent variables included laser power, cutting speed, and assist gas pressure, which were varied to determine their impact on cutting quality and inaccuracy.

The dependent variables are the level of size inaccuracy, namely the difference between the target size and the cutting result, as well as the change in the gap width during the cutting process.

Meanwhile, the control variables included 316 stainless steel material with a thickness of 1.5 mm, the laser focus position, and the type of assist gas used. The control variables were kept constant to ensure that the research results truly reflected the influence of the independent variables.

A CNC laser cutting machine is used as the primary tool for cutting 1.5 mm thick 316 stainless steel. This machine allows for the control of several process parameters, including laser power, cutting speed, gas pressure, and focus point.

Figure 4 Parameter settings position on CNC kaser cutting machine

C. Research Workflow Design

The research procedure begins with material preparation, namely measuring the thickness of the 316 stainless steel plate using a caliper to ensure the thickness is according to specifications, then placing the material on the CNC laser cutting machine table. Next, an inspection and activation of the machine is carried out by checking all machine connections to ensure they are in good condition, activating the emergency stop button as a safety measure, then turning on the machine and the CNC computer. After that, the machine calibration process is carried out by pressing the calibration button to improve position accuracy and cutting results. The next stage is to upload the workpiece design to the CNC system, then set the cutting path with a cutting width (kerf) of 0.25 mm for the outer side and 0.19 mm for the inner side, and determine the guide lines (in and out) to maintain the stability of the cutting process. Next, cutting parameters are set which include cutting speed , nozzle height , gas type , gas pressure , laser power , duty *cycle , pulse frequency, laser turn-on delay* , and *focal point* . In this study, one 3 mm diameter nozzle was used. Before the cutting process begins, the design is properly locked and the cutting process is started by pressing *the start button* on the CNC remote. After the cutting process is completed, measurements and inspections are carried out, including measuring dimensional deviations, observing defects in the cutting results, documenting each specimen in the form of photos, and recording all machine parameters used in each cutting process as research data.

D. Standard Specifications

Table 1.1 shows the standard specifications used to evaluate the precision of CNC laser cutting results based on dimensional deviations from the design dimensions. This classification aims to facilitate the analysis of cutting quality by comparing the deviation values obtained from each specimen against predetermined tolerance limits. The smaller the dimensional deviation value, the higher the level of precision of the resulting cutting result.

Table 1.1 Standard Cutting Specifications

Dimensional deviation from design	Category	Words
0.10 mm	Very good	High precision, cutting results are very close to the design.
0.10-0.40 mm	Good	It still meets the specifications.
>0.40mm	Not good	Notaccurate, need parameter evaluation

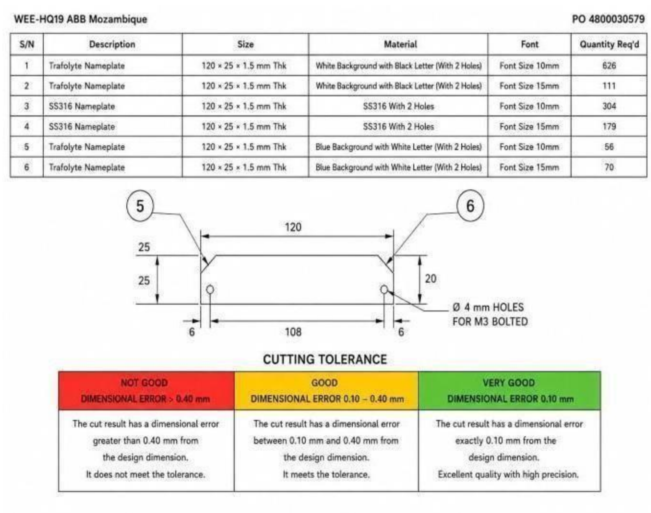


Figure 5 Tolerance criteria for cutting results based on client standards

Table 1.2 shows the test parameters used on nine specimens during the cutting process using a CNC laser cutting machine. Testing was conducted by varying several process parameters, namely cutting speed, gas pressure, power, and focal point.

Furthermore, machine conditions such as machine flatness and machine rail cleanliness were also taken into account because they affect the quality of the cutting results.

The tolerance criteria for cutting results in this study refer to the specifications set by the client PT xyz. Based on these standards, the quality of cutting results is classified into three categories, namely Not Good (dimensional error 0.40 mm and above), Good (dimensional error 0.10–0.40 mm), and Very Good (dimensional error 0.10 mm). These criteria are used as a reference to evaluate cutting results for each parameter variation.

E. Data Analysis Techniques

Data analysis was performed by comparing the cutting results for each parameter variation to determine the relationship between cutting parameters and cutting quality. The obtained data were then compiled in a correlation table containing the relationship between cutting speed, laser power, gas pressure, and cutting quality so that the influence of each parameter could be analyzed more clearly. Next, the types of defects that appeared were identified, such as dimensional inaccuracies, and the factors causing these defects were analyzed. Based on the analysis results, the parameters that had the greatest influence on the level of cutting inaccuracy were determined. The final stage of analysis was carried out by drawing conclusions based on test data and discussions to obtain the most optimal cutting parameters in producing the best cutting quality on Stainless Steel 316 material with a thickness of 1.5 mm.

IV. RESULTS AND DISCUSSION

To obtain optimal cutting parameters on a CNC laser cutting machine, a series of tests were conducted with gradual parameter variations. Tests were conducted on nine specimens by varying the cutting speed, laser power, gas pressure, and focal point according to a predetermined experimental design. Each test result was observed based on the visual quality of the cut and the level of dimensional deviation (dimensional error). The test data were then used to analyze the effect of each parameter on the level of cutting precision and to determine the parameters that produce the best cutting quality.

Table 1.2 Testing Parameters for Nine Specimens

Parameter name	Test Parameter Values								
	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5	Specimen 6	Specimen 7	Specimen 8	Specimen 9
Cutting speed (m/min)	5,800	5,800	6,000	6,200	6,300	6,400	6,500	6,600	6,700
Gas pressure (BAR)	7,000	8,000	9,000	9,000	10,000	10,000	10,000	10,000	11,000
Power (WATT)	900	1000	1000	1,100	1,100	1,200	1,200	1,200	1,300
Focalpoint (mm)	-4.50	-4.00	-3.50	-3.00	-2.80	-2.60	-2.50	-2.40	-2.20
Machine balance	Uneven	Uneven	Flat	Flat	Flat	Flat	Flat	Flat	Flat
Cleanliness of the machine rails	Dirty	Dirty	Clean	Clean	Clean	Clean	Clean	Clean	Clean

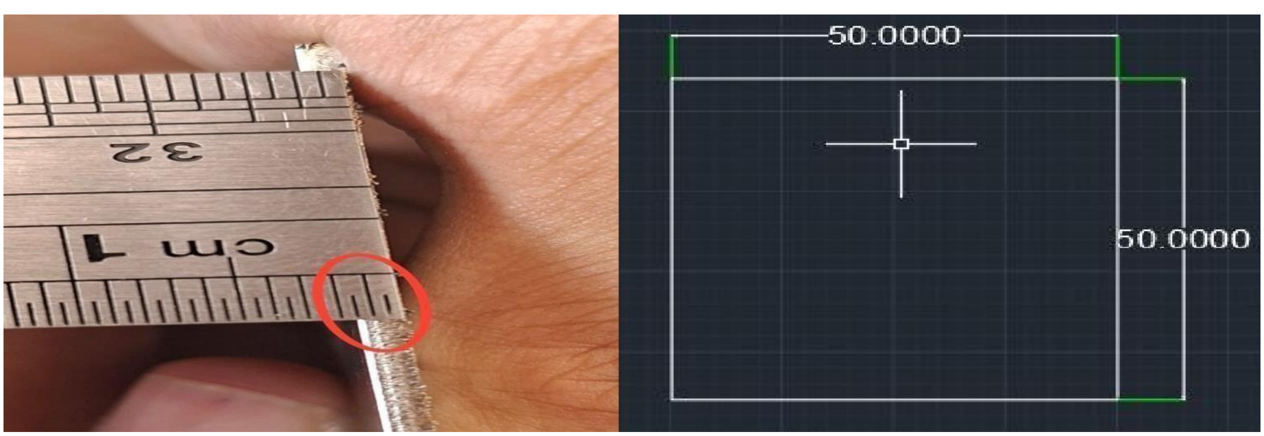
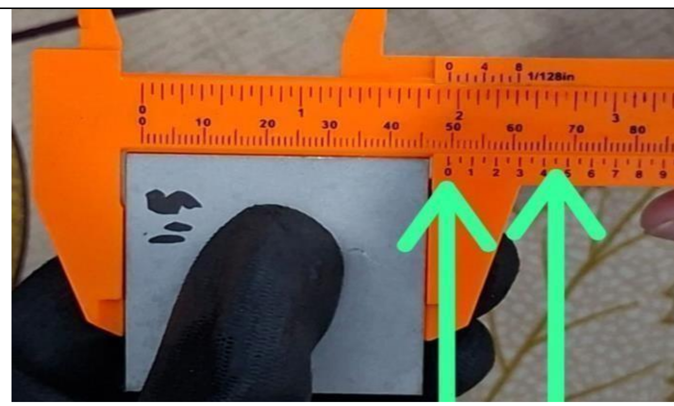


Figure 6 Plate thickness 1.5 mm and sample size 50cm

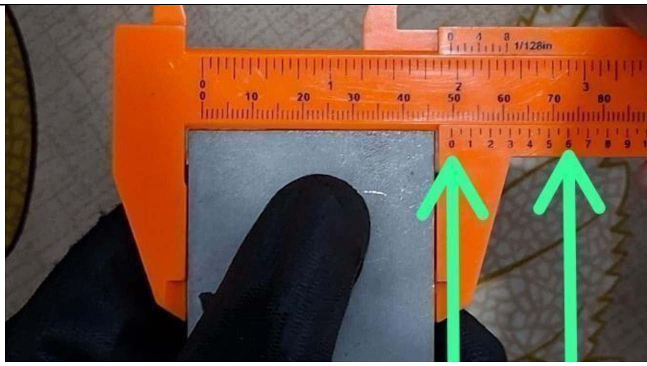
The measurement results for Specimen 1 were obtained by reading the main scale and the vernier scale on the vernier caliper. The main scale shows a value of 49 mm, while the overlapping vernier line is on the 4th line. With a vernier caliper accuracy of 0.05 mm, the vernier scale value is 4 × 0.05 = 0.20 mm. Therefore, the measurement result for Specimen 1 is 49.20 mm.
Main scale = 49.00 mm
Nonius scale = 4 × 0.05 mm = 0.20 mm
Measurement result = 49.00 + 0.20 = 49.20 mm

Calculation results measuring Specimen 2 was performed with read scale main And scale nonius on term sliding scale main show value of 49 mm, while line overlapping nonius is at on 5th line . With accuracy term push of 0.05 mm, the value scale nonius obtained of 5 × 0.05 = 0.25 mm. Therefore Because that , the result measurement Specimen 2 is 49.25 mm.
Scale main = 49.00 mm
Scale nonius = 5 × 0.05 mm = 0.25 mm
Results measurement = 49.25 mm

Calculation results measuring Specimen 3 was performed with read scale main And scale nonius on term sliding scale main show value of 49 mm, while line overlapping nonius is at on 8th line . With accuracy term push of 0.05 mm, the value scale nonius obtained of 8 × 0.05 = 0.40 mm. Therefore Because that , the result measurement Specimen 3 is 49.40 mm.
The calculation :
Scale main = 49.00 mm
Scale nonius = 8 × 0.05 mm = 0.40 mm
Results measurement = 49.40 mm

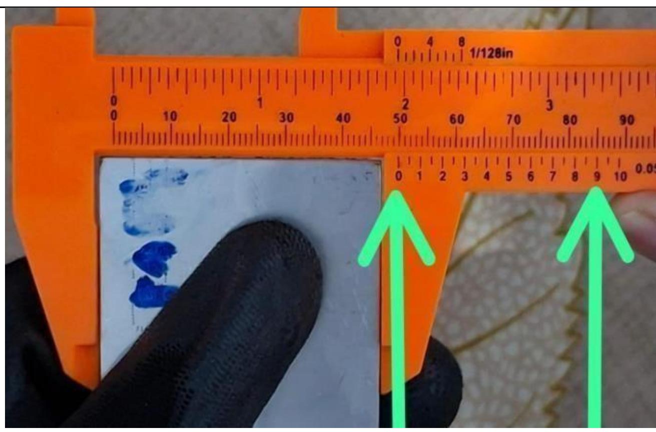


Calculation results measuring Specimen 4 was performed with read scale main And scale nonius on term sliding scale main show value of 49 mm, while line overlapping nonius is at on 9th line . With accuracy term push of 0.05 mm, then mark scale nonius is 9 × 0.05 = 0.45 mm. By Because that , the result measurement Specimen 4 is 49.45 mm.
Calculation :
Scale main = 49.00 mm
Scale nonius = 9 × 0.05 mm = 0.45 mm
Results measurement = 49.45 mm



The measurement results for Specimen 5 were calculated by reading the main scale and the vernier scale on the vernier caliper. The main scale showed a value of 49 mm, while the overlapping vernier line was on the 12th line. With a vernier caliper accuracy of 0.05 mm, the vernier scale value obtained was 12 × 0.05 = 0.60 mm. Therefore, the measurement result for Specimen 5 was 49.60 mm.
Main scale = 49.00 mm
Nonius scale = 12 × 0.05 mm = 0.60 mm
Measurement result = 49.60 mm

The measurement results for Specimen 6 were calculated by reading the main scale and the vernier scale on the vernier caliper. The main scale showed a value of 49 mm, while the overlapping vernier line was on the 14th line. With a vernier caliper accuracy of 0.05 mm, the vernier scale value obtained was 14 × 0.05 = 0.70 mm. Therefore, the measurement result for Specimen 6 was 49.70 mm.
Main scale = 49.00 mm
Nonius scale = 14 × 0.05 mm = 0.70 mm
Measurement result = 49.70 mm



The measurement results for Specimen 7 were calculated by reading the main scale and the vernier scale on the vernier caliper. The main scale showed a value of 49 mm, while the overlapping vernier line was on the 18th line. With a vernier caliper accuracy of 0.05 mm, the vernier scale value obtained was 18 × 0.05 = 0.90 mm. Therefore, the measurement result for Specimen 7 was 46.90 mm.
Calculation:
Main scale = 49.00 mm
Nonius scale = 18 × 0.05 mm = 0.90 mm
Measurement result = 49.90 mm

Materials burningNo can measured

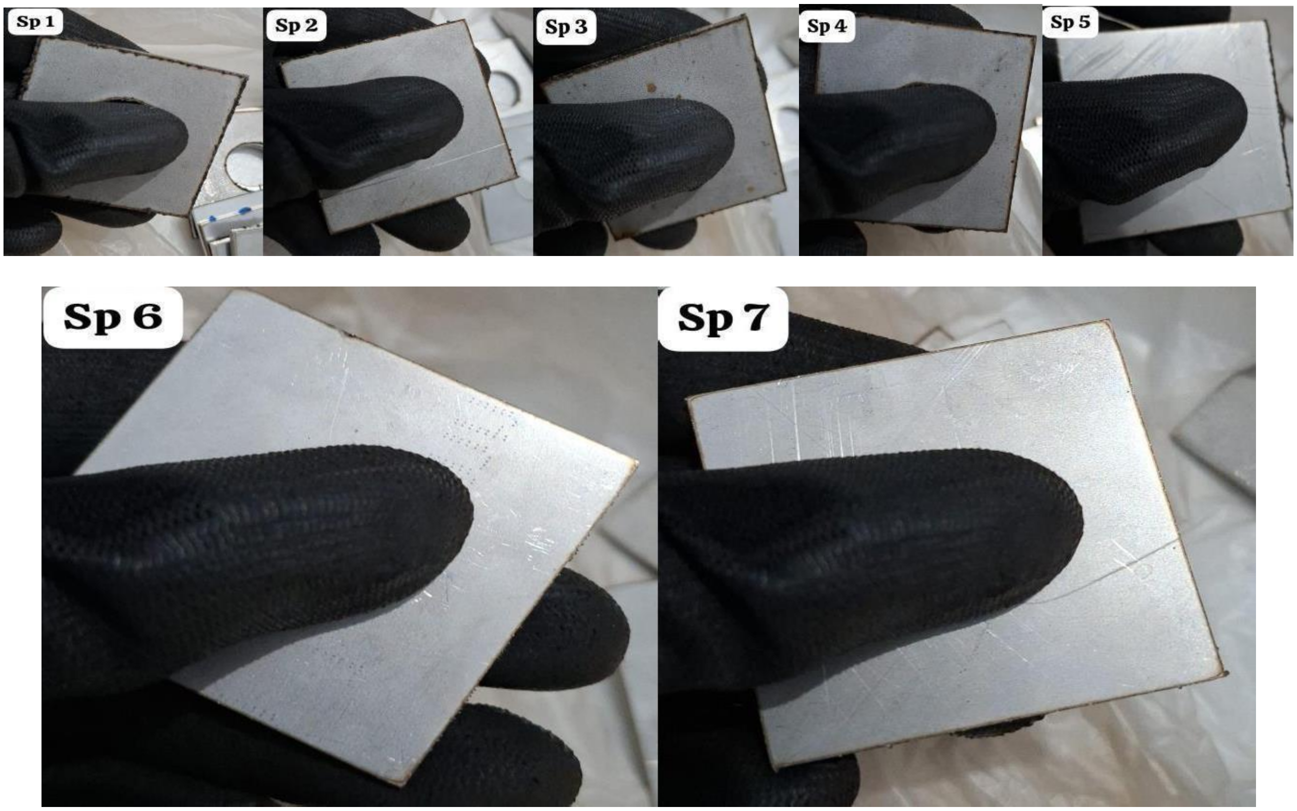
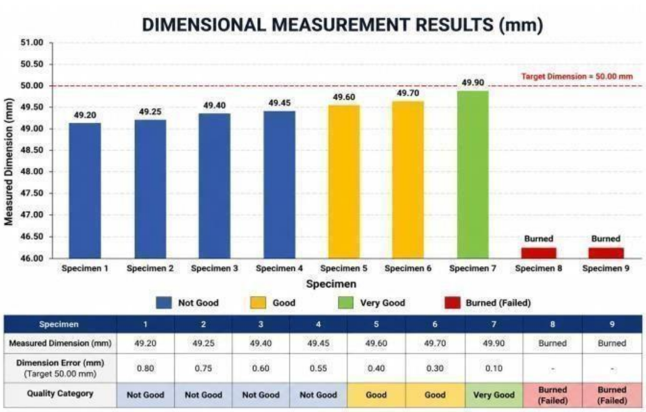


Figure 7 Testing and measurement results of 9 specimens (sp1, sp2, sp3, sp4, sp5, sp6, sp7, sp8, sp9)

A. *Error Dimension Graph on Test Results*



Specimen	1	2	3	4	5	6	7	8	9
Measured Dimension (mm)	49.20	49.25	49.40	49.45	49.60	49.70	49.90	Burned	Burned
Dimension Error (mm) (Target 50.00 mm)	0.80	0.75	0.60	0.55	0.40	0.30	0.10	-	-
Quality Category	Not Good	Not Good	Not Good	Not Good	Good	Good	Very Good	Burned (Failed)	Burned (Failed)

Figure 8 Test Dimension Error

Based on Figure 3, the dimensional error values in the nine specimens show a decreasing trend from Specimen 1 to Specimen 7, then increase again in Specimen 8 and Specimen 9. Specimen 1 has a dimensional error value indicating that the cutting parameters used are not yet capable of producing precise cutting quality. Along with the adjustment of cutting parameters, namely increasing cutting speed, laser power, gas pressure, and changing the focal point, the dimensional error value gradually decreases until it reaches the lowest value in Specimen 7 of 0.10 mm. This result indicates that the combination of parameters in Specimen 7 produces the most optimal cutting conditions, resulting in more precise cuts, smoother edge surfaces, and minimal burrs and slag. After passing this optimal condition, the dimensional error value increases again in Specimen 8 and Specimen 9. This shows that increasing cutting parameters too high does not always result in better cutting quality, because it can cause excessive heat energy in the cutting area which has an impact on reducing the level of precision of the cutting results.

Based on the test results of Specimen 1 with parameters of cutting speed 5800 mm/min, power 900 W, and gas pressure 7 bar, the cutting results still show scratches on the cut edge and slag residue at the bottom of the material. This is caused by low cutting energy so that the material melting process has not taken place optimally. In addition, dusty rail conditions and uneven machine also affect the accuracy of laser head movement so that the cutting results are less precise.

In Specimen 2, the cutting quality improved compared to Specimen 1. Increasing the power to 1000 W and the gas pressure to 8 bar facilitated the removal of molten material, reducing slag. However, slight jagging was still observed on the cut edge, making these parameters less than optimal.

In Specimen 3, the cut quality was good. Increasing the cutting speed to 6000 mm/min and the gas pressure to 9 bar resulted in cleaner and more precise cut edges. However, slight dimensional deviations remained, requiring further parameter optimization.

In Specimen 4, the cutting results showed significant improvements. The combination of a cutting speed of 6200 mm/min, a power of 1100 W, and a gas pressure of 9 bar resulted in a smoother cut surface with less slag than in the previous test.

In Specimen 5, the cut quality was good. The 10 bar gas pressure helped clear the cutting area of any remaining molten material, resulting in a cleaner and more precise cut.

Specimen 6 achieved near-optimal cutting results. The combination of a cutting speed of 6400 mm/min, a power of 1200 W, and a gas pressure of 10 bar resulted in smooth cut edge quality and reduced dimensional deviations.

Specimen 7 achieved the best cutting quality. The cutting speed parameters of 6500 mm/min, power of 1200 W, and gas pressure of 10 bar produced clean cut edges with minimal burrs and the highest level of precision compared to the other specimens.

In Specimen 8, the cutting quality began to decline. Increasing the cutting speed to 6600 mm/min caused the laser energy to act more quickly, resulting in a slight decrease in precision compared to Specimen 7.

In Specimen 9, the cut quality decreased again. The combination of a cutting speed of 6700 mm/min, a power of 1300 W, and a gas pressure of 11 bar resulted in increased heat in the cutting area, which led to the appearance of heat marks on the edge material.

Table 1.4 presents the results of dimensional inaccuracy measurements on nine specimens that have been made with various cutting parameters using a CNC Laser Cutting machine. Measurements were carried out to determine the magnitude of dimensional deviation between the cutting results and the design size as an indicator of the precision level of each specimen. The dimensional error values obtained were then classified based on predetermined specification standards so that the quality of the cutting results on each specimen could be determined and the cutting parameters that produce the best level of precision could be determined.

B. *Discussion Cutting Parameter Changes*

Cutting parameter changes for each specimen were carried out in stages with the aim of obtaining a parameter combination that yields the best precision level for 1.5 mm thick 316 Stainless Steel. Parameter selection refers to theory and previous research stating that cutting speed, laser power, gas pressure, and focus point are the main parameters that affect the quality of laser cutting results. Therefore, each parameter change was evaluated based on the results of dimensional error measurements until the most optimal parameters were obtained. Parameter interval changes are not made randomly, but rather based on evaluation results from previous tests. If measurement results still show high dimensional error, the parameters are readjusted to improve cutting quality. Once a downward trend in dimensional error is observed, parameter changes are continued in stages until the optimum parameter combination is found. This approach aims to clearly observe the effect of each parameter change on cutting quality without exceeding the optimum condition.

Based on the test results, the dimensional error value decreased from Specimen 1 to reach the smallest value in Specimen 7. This shows that increasing parameters gradually can improve the accuracy of the cutting results. However, in Specimens 8 and 9 the error value increased again, which shows that increasing parameters beyond the optimum conditions does not always result in better cutting quality. The optimum parameters were obtained at a cutting speed of 6500 mm/min, laser power of 1200 W, gas pressure of 10 bar, and focus point of -2.50 mm, with a dimensional error value of 0.10 mm. [19]

Table 1.4 Dimensional Inaccuracy Measurement Results

Example	Dimensional error (mm)	Design size(mm)	Category
1	49.20	50.00	Not good
2	49.25	50.00	Not good
3	49.40	50.00	Not good
4	49.45	50.00	Not good
5	49.60	50.00	Good
6	49.70	50.00	Good
7	49.90	50.00	Very good
8	Burnt	50.00	Rejected
9	Burnt	50.00	Rejected

C. *Discussion*

a. Discussion of specimen 1

Based on the test results on Specimen 1, the quality of the cutting results was poor with a dimensional error value of 0.80 mm. The cutting results showed scratches on the edges of the material and slag residue at the bottom of the cut. This condition is thought to be caused by the combination of cutting speed parameters of 5800 mm/min, power of 900 W, and gas pressure of 7 bar which were unable to produce a stable cutting process. In addition, the dusty condition of the machine rail and the uneven position of the machine caused the movement of the laser head to be less precise, thus increasing the dimensional deviation of the cutting results.

b. Specimen Discussion 2

In Specimen 2, the dimensional error value decreased to 0.75 mm. Increasing the power to 1000 W and gas pressure to 8 bar helped the melting and material removal process, resulting in better cutting quality compared to Specimen 1. However, burrs were still found on the cut edge, so the parameters used did not produce optimal cutting quality.

c. Specimen Discussion 3

In Specimen 3, the dimensional error decreased again to 0.60 mm. Increasing the cutting speed to 6000 mm/min and the gas pressure to 9 bar resulted in smoother cut edges and reduced slag formation. Furthermore, the cleaning rail and leveling machine helped improve the accuracy of the laser head movement, resulting in better cutting precision.

d. Specimen Discussion 4

Test results on Specimen 4 showed a dimensional error of 0.55 mm. Increasing the power to 1100 W provided more stable cutting energy, resulting in a smoother cut surface. However, the measurement results were still above the good category limit, requiring further parameter optimization.

e. Specimen Discussion 5

Specimen 5 achieved a dimensional error of 0.40 mm. The 10 bar gas pressure helped remove residual molten material from the cutting area, significantly reducing the amount of slag. The resulting cut quality appeared cleaner and closer to optimal conditions.

f. Specimen Discussion 6

In Specimen 6, the dimensional error was reduced to 0.30 mm. The combination of a cutting speed of 6400 mm/min and a power of 1200 W achieved a balance between laser energy and cutting speed, resulting in better edge quality. These results indicate that the parameters used are close to optimal conditions.

g. Specimen Discussion 7

Specimen 7 produced the smallest dimensional error value, namely 0.10 mm. The cutting speed parameters of 6500 mm/min, power 1200 W, and gas pressure 10 bar resulted in a stable and precise cutting process. The cutting results were clean, with minimal burrs, and had the best edge quality compared to all specimens. Therefore, the parameters in Specimen 7 can be categorized as optimal.

h. Specimen Discussion 8

In Specimen 8, the dimensional error increased, increasing the cutting speed to 6600 mm/min caused the laser energy to work faster, resulting in a slight decrease in cutting accuracy compared to Specimen 7.

i. Specimen Discussion 9

In Specimen 9, the dimensional error increased by 1 mm. Increasing the cutting speed to 6700 mm/min, the power to 1300 W, and the gas pressure to 11 bar resulted in increased thermal energy in the cutting area. This resulted in the appearance of heat marks on the material edge and a decrease in cut quality compared to the previous specimen.

D. Comprehensive Analysis of Parameter Influence

Based on the test results of nine specimens, it can be seen that gradually increasing the parameters can improve the quality of the cutting results until it reaches the optimal condition in Specimen 7. After passing this parameter, the quality of the cutting results decreases again due to the excessive increase in heat energy. Therefore, the optimal parameters are obtained at a cutting speed of 6500 mm/min, a power of 1200 W, a gas pressure of 10 bar, and a focal point of -2.50 mm.

V. CONCLUSION

Based on the results of testing and analysis that have been carried out on the cutting process using a CNC Laser Cutting machine on Stainless Steel 316 material with a thickness of 1.5 mm, it can be concluded that cutting parameters have a very significant influence on the level of precision of the cutting results. Changes in the values of cutting speed, laser power, gas pressure, and focal point produce differences in cutting quality and dimensional error values on each test specimen. The results show that the dimensional error value decreases gradually from Specimen 1 to Specimen 7, with the largest error value of 0.80 mm on Specimen 1 and the smallest error value of 0.10 mm on Specimen 7. The most optimal cutting parameters were obtained on Specimen 7 with a combination of cutting speed of 6500 mm/min, laser power of 1200 W, gas pressure of 10 bar, and focal point of -2.50 mm, which produces the best cutting quality with smoother cut edges, minimal burrs, and has a higher level of precision than other specimens. This study also shows that the inaccuracy of cutting results is influenced by several factors, including mismatched cutting parameters, dirty or dusty machine rail conditions that interfere with the movement of the laser head, uneven machine position that affects cutting accuracy, and improper focus point settings on the material surface. In addition, increasing cutting parameters too high does not always result in better cutting quality. This is evidenced in Specimen 8 and Specimen 9 which experienced an increase in dimensional error values due to increased thermal energy in the cutting area, thus indicating that an optimal combination of parameters is needed to obtain cutting results with the best level of precision.

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Job Assignment Matrix

Company Name: Mega Synergy Powerindo
Department: Electrical
Effective Date: 26 November 2025- 25 July 2026

No.	Employee Name	Department	Job Title	Assigned Work / Responsibility
	Hendra	Electrical	DIRECTOR	Supervised the laser marking process. Monitored machine, parameter settings (power, speed, and frequency). Ensured product quality met company standards.
	Aluwih	Electrical	FORMENT	Assisted in monitoring the laser marking process. Guided operators in machine operation and parameter settings.
	Renaldi	Electrical	ASISSTANT QC INSPECTOR	Operated laser marking machine, set process parameters, inspected marking quality, and recorded production data.

Prepared By	Approved By
Name:Digo Suagnad Position: Assisten QC INSPECTOR Date:25 July 2026	Name:Hendra Position:Director Date: 25 July 2026

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No.FO.5.3.1-V5 Format Berita Acara Penyerahan

08 September 2021

BERITA ACARA PENYERAHAN HASIL PROYEK

Nomor: -

Tanggal 25 juli 2026

PELAKSANAAN KEGIATAN

MAGANG DAN PROYEK AKHIR

Pada hari ini sabtu tanggal 25 bulan juli tahun 2026 yang bertandatangan di bawah ini:

1.	Nama	:	Digo Suganda
	Jabatan	:	Assisten Qc inspeksi
	Alamat	:	B17,Unnamed Road, Tanjung Sengkuang, Batu Ampar, Batam City, Riau Islands

Selanjutnya dalam hal ini disebut **PIHAK KESATU**

2.	Nama	:	Riwan Antonia Nadeak
	Jabatan	:	HRD
	Alamat	:	B17,Unnamed Road, Tanjung Sengkuang, Batu Ampar, Batam City, Riau Islands

Selanjutnya disebut sebagai **PIHAK KEDUA**

Pihak kedua menerima dari Pihak Pertama berupa :

- √ Laporan proyek akhir
- √ Laporan magang
- ☐ Hasil proyek :
  - ☐ Produk
  - ☐ Layanan
  - √ Prosedur
- ☐ ....

Demikian Berita Acara ini dibuat dan ditandatangani dalam rangkap 2 (dua) untuk dipergunakan sebagai mestinya.

Pihak Kesatu	Pihak Kedua
Digo Suganda	**Riwan Antonia Nadeak**
NIM. 3222311061	ID No. ...HC004...

BORANG LOKBOOK REVISI PROPOSAL/ PROYEK AKHIR

Nama	:	Digo suganda
NIM	:	3222311061
Judul	:	Analisis ketidakakuratan hasil pemotongan laser cnc pada baja tahan karat dengan ketebalan 1,5 mm
Pembimbing 1	:	Mishthafiyatillah S.Si., M.Sc
Penguji 1	:	Ir. Vivin Octowinandi, S.Tr.T., M.Sc.
Penguji 2	:	Dr. Ir. Basuki Rachmatul Alam

No.	Pemberi saran/komentar/catatan revisi	Catatan perbaikan saat seminar	Perbaikan yang dilakukan	Paraf pembimbing / Tanggal acc	Paraf penguji / Tanggal acc
1.	penguji 1	1. acuan standar 2. sediakan gambar mesin yang menunjukkan posisi dari parameter yang ganti 3. narasikan jurnal parameter di material 4. kenapa interval parameter berubah 5. berikan hasil pengukuran yang bisa menyokong bahwa memang masuk rentang 0.05mm	1. Menambahkan acuan standar toleransi pemotongan berdasarkan spesifikasi/drawing dari klien sebagai acuan evaluasi hasil pemotongan CNC Laser Cutting. 2. Menambahkan gambar mesin CNC Laser Cutting beserta posisi pengaturan parameter yang diubah, yaitu laser power, cutting speed, gas pressure, dan focus point, serta penjelasan masing-masing parameter. 3. Menambahkan kajian pustaka dari jurnal yang membahas pengaruh parameter laser cutting terhadap material Stainless Steel 316 serta menghubungkannya dengan hasil penelitian. 4. Menambahkan penjelasan bahwa perubahan interval parameter dilakukan secara bertahap berdasarkan hasil uji sebelumnya dan referensi jurnal untuk memperoleh kombinasi parameter yang paling optimal. 5. Menambahkan tabel		

			hasil pengukuran setiap spesimen menggunakan jangka sorong, perhitungan error dimensi, grafik hasil pengukuran, serta pembahasan yang menunjukkan spesimen dengan error dimensi terkecil sebesar 0,04 mm.		
2.	Penguji 2	Minim aspek sains - tech elektronik - teknik elektro - di jurnal laser cnc cutting - tidak ada relasi parameter elektrik / elektronika thd hasil laser cutting (model / algoritma matematik vs hasil / parameter mekanik hasil cutting : perhitungan & hasil pengukuran)	Menambahkan penjelasan parameter elektrik/elektronika laser (power, duty cycle, pulse frequency, delay, focal point). Menjelaskan hubungan parameter elektrik/elektronika dengan hasil pemotongan laser. Menambahkan model atau algoritma matematis hubungan parameter laser terhadap hasil cutting. Menambahkan perhitungan energi/daya laser sebagai dasar analisis. Menghubungkan parameter elektrik dengan parameter mekanik hasil pemotongan (error dimensi, kerf, dross, HAZ). Menambahkan analisis hasil pengukuran berdasarkan perhitungan dan data eksperimen. Menambahkan referensi jurnal yang membahas hubungan parameter elektrik/elektronika terhadap kualitas laser cutting.		