

## Optimization of cutting current in CNC plasma cutting for improved bracket fabrication quality

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### Abstract

CNC plasma cutting is widely used in metal fabrication due to its efficiency and versatility; however, parameter optimization is essential to ensure high-quality results. This study investigates the influence of CNC plasma cutting parameters affect the fabrication quality of Revo motorcycle brackets, which are essential for electric motor vehicle conversion. We conducted experiments on 6 mm thick low-carbon steel plates using a JIAXIN JX-1530 machine. The electric current was varied at 50, 52, 54, and 56 A. For each current level, four specimens were prepared and tested while keeping other parameters constant: a cutting speed of 600 mm/min, a gas pressure of 6 bar, and a torch distance of 1–2 mm. We assessed cut quality based on surface roughness (Ra) at two measurement points, dimensional accuracy relative to CAD design, and hardness variations in the Heat-Affected Zone (HAZ) and base material. The results showed that the best conditions were achieved at 50 A, 6 bar gas pressure, and a torch distance of 2 mm, resulting in an average Ra of 5.39  $\mu\text{m}$  and a dimensional deviation of  $\pm 0.3$  mm. Although increasing the current above 50 A improved HAZ hardness, it negatively impacted surface roughness and increased the risk of thermal defects. These findings indicate that the identified optimal parameters support the production of high-precision, cost-effective brackets.

### Keywords:

Plasma cutting, fabrication quality, motorcycle bracket, electric vehicle conversion, heat affected zone

### 1 Introduction

The development of electric vehicle technology in Indonesia is advancing in line with government policies aimed at reducing dependence on fossil fuels. One significant step taken is the program to convert oil-fueled motorcycles into battery-powered electric motorcycles. However, a major challenge in this conversion is the availability of part kits, which are still difficult to find on the market, with most components needing to be imported. The main products of this program include a 2-kW dynamo casing, a lithium battery bracket, and a plug-and-play arm system that can be implemented on both automatic and manual electric vehicles. The key advantage of this kit is its fast and efficient installation process, allowing the conversion of a fuel-powered motorcycle to an electric motorcycle in under four hours. Therefore, this innovation is expected to accelerate the adoption of electric vehicles in Indonesia.

This program aligns with the government's target outlined in Presidential Instruction Number 7 of 2022, which promotes the use of battery-powered electric motor vehicles as operational vehicles for government agencies. Additionally, the conversion of fuel-based vehicles to electric is regulated by the Minister of Transportation

Regulation (Permenhub) Number 65 of 2020. Through this initiative, Indonesia aims to convert 13 million motorcycles by 2030 as part of its strategy to achieve net-zero emissions by 2060.

To support the production of conversion kit parts, this study also examines the use and optimization of CNC plasma-cutting parameters for the manufacture of Revo brackets from low-carbon steel [1]. CNC plasma cutting technology enables more precise, efficient, and faster cutting than conventional methods [2–4]. Optimizing cutting parameters such as cutting speed, electric current, gas pressure, and torch-to-material distance are key factors in producing high-quality brackets suitable for electric vehicle conversion needs. Plasma cutting is the latest technology in steel cutting, capable of cutting across a wide range of thicknesses [5]. Plasma cutting is a process for cutting metal using a plasma torch. In this process, pressurized air is blown at high speed from a nozzle, while an electric arc is formed through the gas from the nozzle to the cut surface, converting some of the gas into plasma [6]. Using plasma, the cutting method becomes highly efficient, offering significant advantages in cutting speed and initial cost compared to oxyfuel and waterjet cutting [7].

Plasma cutting is a metal-cutting process that uses plasma energy emitted from a plasma torch, which is forced out at high speed. Plasma cutting is the process of cutting steel and other metals using a plasma torch [8]. Current strength and gas pressure are two cutting parameters that determine the operation of a plasma cutting tool. Parameters that must be considered in plasma cutting include electrical polarity, current magnitude, gas flow rate, cutting speed, and so on [9]. Non-conventional plasma cutting has become a vital tool in industry, significantly improving cutting accuracy [10,11].

Industrialists require tools that support their work effectively. The plate-cutting process demands precision to avoid excessively wide kerfs, which are the gaps created when cutting material. The size of these kerfs can vary due to several influencing factors. To achieve accurate kerfs, it is essential to consider current strength, air pressure, torch height, and cutting speed. Medium carbon steel contains 0.25–0.55% carbon. The cutting process begins with the formation of an arc between the electrode and the workpiece, initiated by the electrical ionization of the cutting gas. This gas is heated by the arc, which raises its temperature and ionizes it, turning it into an electrical conductor. The ionized gas in this state is called plasma, which is then directed through a nozzle to cut the workpiece. The quality of the cut material and the processing time in plasma arc cutting depend on several parameters, including cutting speed, current strength, torch height relative to the cutting surface, gas pressure, and plasma gas flow [12,13].

One parameter that affects plasma arc cutting is current strength. The current strength is a parameter that directly affects the penetration and speed of metal melting. If the current strength is higher, the plasma arc temperature will increase, leading to a faster cutting rate [14,15]. The highly focused heat from plasma arc cutting can increase the cutting width and alter the metal's hardness. This research will focus on optimizing CNC plasma cutting for Revo bracket products made of low-carbon steel [16].

### 2 Research methodology

The research methodology flowchart can be seen in Fig. 1. This study used an experimental approach to optimize CNC plasma cutting parameters for manufacturing a Revo Motorcycle bracket from low-carbon steel with a plate thickness of 6 mm.

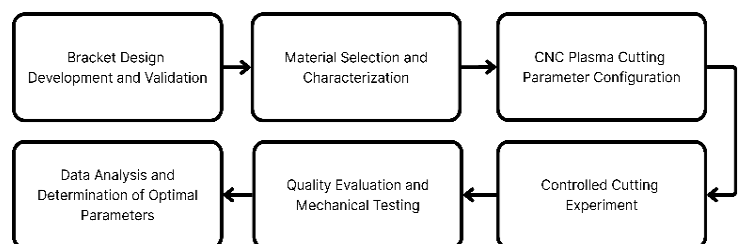


Fig. 1. Research methodology flowchart

## 2.1 Bracket design and material selection

The Revo Motorcycle bracket product design was created according to the requirements of electric vehicle conversion. The design drawing is shown in Fig. 2. The material used is 6 mm thick low-carbon steel, chosen for its mechanical properties suitable for electric vehicle structural applications.

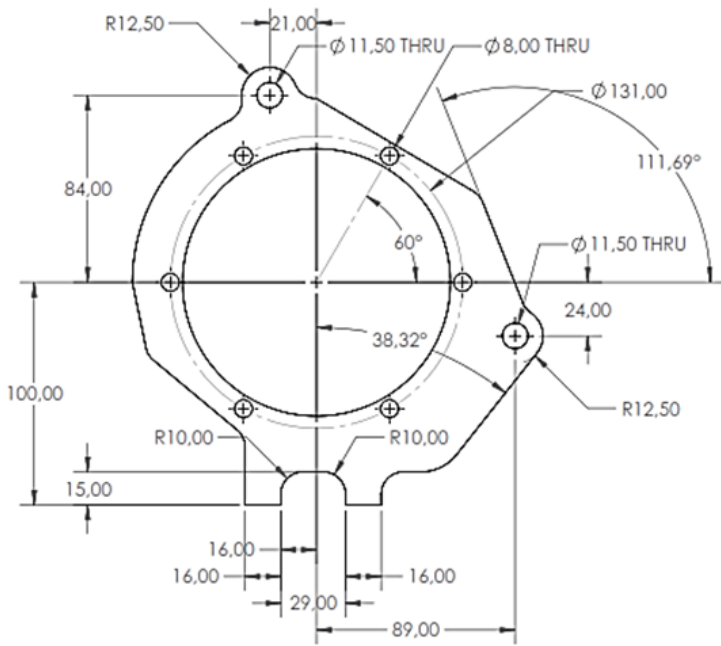


Fig. 2. Detailed engineering drawings

## 2.2 Determining CNC plasma cutting parameters

The CNC Plasma Cutting machine uses a JIAXIN JX-1530, as shown in Fig. 3, with the specifications listed in Table 1. Optimization was carried out by determining the optimal electric current.



Fig. 3. CNC plasma cutting JIAXIN JX-1530 machine

Table 1. Specifications of the JIAXIN JX-1530 CNC plasma cutting machine

Description	Specification
Technology	Plasma
Material	For aluminum, for stainless steel, for steel, for wood
Control type	CNC
Associated function	Engraving
Phase	Three-phase
Other characteristics	High-precision, high-speed, CE, linear, ISO plasma
Cutting speed	Max.: 8,000 mm/min (5.249 in/s) Min.: 0 mm/min (0 in/s)
Laser power	8,500 W
Overall length	1,500 mm (59 in)
Overall width	3,000 mm (118 in)
Weight	1,200 kg (2,645.55 lb)

## 2.3 Experiments and testing

Various combinations of CNC plasma-cutting parameters were tested to find the configuration that produced the best cut quality, minimal thermal distortion, and high production efficiency. The observed process parameters included electric currents of 50, 52, 54, and 56 Amperes. The tests measured the surface roughness of the cuts, the hardness of the base material, and the Heat Affected Zone (HAZ). Fig. 4 shows a Brushless DC (BLDC) support bracket designed for vehicles converting fuel-powered motors to electric motors. This bracket must be precisely sized to fit the BLDC motor, which drives the wheels of the converted vehicle.



Fig. 4. BLDC support bracket for electric vehicles

## 2.4 Experimental procedure

This study conducted a series of experimental tests on the cutting process of a Revo Motorcycle bracket using a JIAXIN JX-1530 CNC Plasma Cutting machine. The material used was low-carbon steel, 6 mm thick. The process parameters are summarized in Table 2.

Table 2. CNC plasma cutting parameters

Experiment setup	Specification
Cutting speed	600 mm/min
Electrical current	40 A, 45 A, 50 A, and 55 A
Gas pressure:	6 bar
Torch distance to material	2 mm

## 3 Results and discussion

Visualization of the results of cutting the bracket with various electric current settings is shown in Fig. 5. To determine the quality of the results, surface roughness testing was carried out at specific points illustrated in Fig. 6.

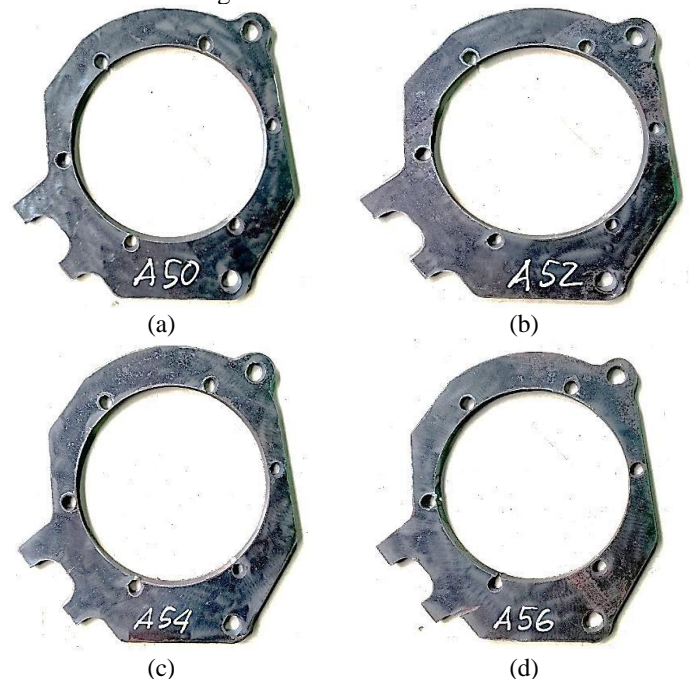


Fig. 5. CNC plasma cutting results with current variations: a) 50 A, b) 52 A, c) 54 A and d) 56 A

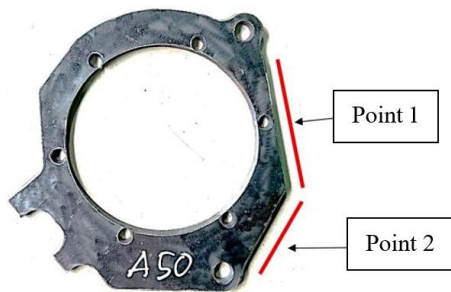


Fig. 6. Test points for the surface roughness of cutting results

The test results are shown in Table 3, showing that the best parameters were obtained at a current of 50 A, a gas pressure of 6 bar, and a torch distance of 2 mm. This combination produced an average roughness value of 5.38  $\mu\text{m}$ .

Table 3. Surface roughness test

Specimen	Ra point 1 ( $\mu\text{m}$ )	Ra point 2 ( $\mu\text{m}$ )	Average Ra ( $\mu\text{m}$ )
A50a	6.936	3.840	5.38
A50b	6.928	3.850	5.38
A50c	6.924	3.835	5.37
A50d	6.940	3.855	5.39
Average specimen A50	6.932	3.845	5.39
A52a	6.743	4.733	5.73
A52b	6.677	4.799	5.74
A52c	6.667	4.717	5.69
A52d	6.753	4.815	5.78
Average specimen A52	6.710	4.766	5.73
A54a	8.388	4.514	6.45
A54b	8.500	4.734	6.61
A54c	8.518	4.648	6.58
A54d	8.370	4.600	6.48
Average specimen A54	8.444	4.624	6.53
A56a	17.441	12.140	14.79
A56b	17.681	12.580	15.13
A56c	17.671	12.274	14.97
A56d	17.617	12.446	15.03
Average specimen A56	17.561	12.360	14.96

Surface roughness test results indicate that varying the electric current significantly affects the surface quality. The lowest average roughness (Ra) value was obtained for specimen A50 (current 50 A) at 5.39  $\mu\text{m}$ , while the highest value was found for specimen A56 (current 56 A) at 14.96  $\mu\text{m}$ . The graph of surface roughness test results can be seen in Fig. 7.

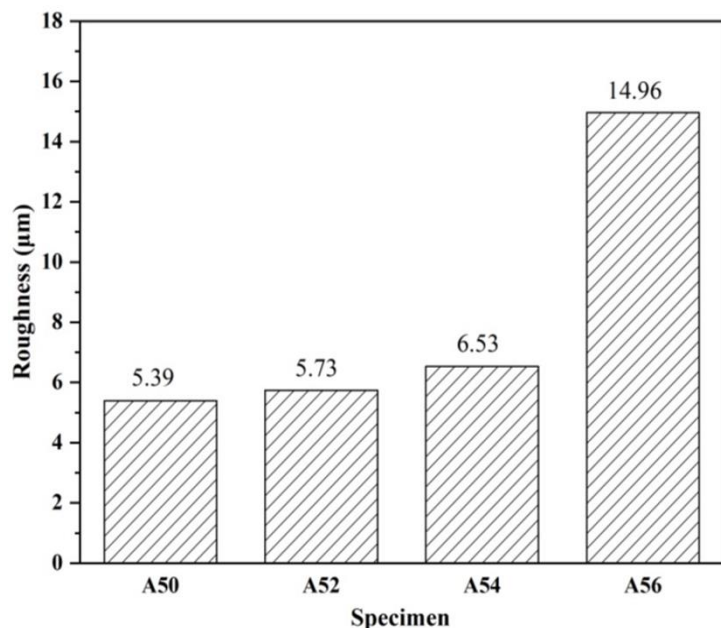


Fig. 7. Surface roughness test results

Increasing the electric current tends to raise the plasma arc temperature, accelerating the cutting process but also increasing the likelihood of overcuts, molten metal splashes, and irregularities at the cut edge. This is consistent with the findings of Sami Abbas and Gunawan Budi [16,17], who stated that increasing the current

increases penetration and cutting speed, but can reduce surface quality if not balanced with other parameters such as cutting speed and gas pressure. The high roughness value at 56 A indicates that excessive current causes plasma instability and increased slag formation, leading to a rough surface. Conversely, a current of 50 A strikes a balance between thermal energy and plasma stability, resulting in a cleaner, more precise cut.

### 3.1 The surface roughness results

Hardness testing was performed to assess how varying electric currents affect the mechanical properties of materials, particularly in the HAZ and the base material. The results indicated that hardness values in the HAZ were generally higher than those in the base material across all current variations. The highest hardness value in the HAZ was recorded for specimen A56 at 81.5 Brinell Hardness Number (BHN), while the lowest value in the base material was found in specimen A54 at 74 BHN, as shown in Table 4. Fig. 8 illustrates the graph of the hardness test results.

Table 4. Hardness test results

Hardness results (BHN)	Specimen			
	A50	A52	A54	A56
HAZ area	79.5	80	80.1	81.5
Base material	76.5	75.5	74	75

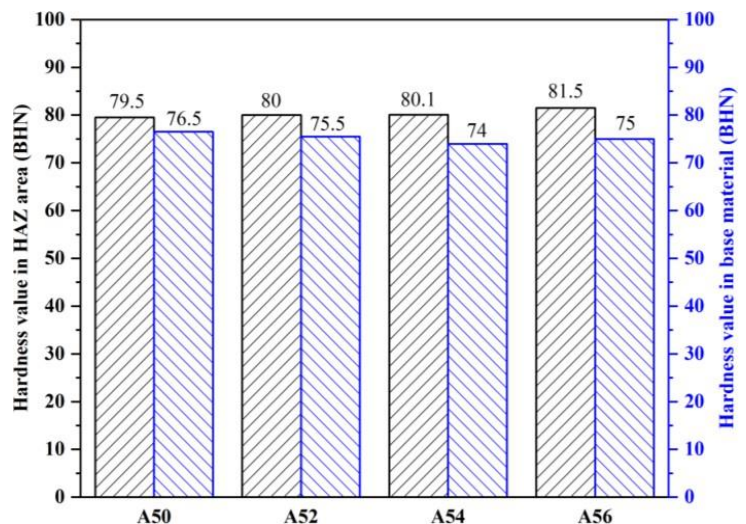


Fig. 8. (a) Hardness distribution in the HAZ; (b) BHN comparison of the base material and the HAZ region

The increase in hardness in the HAZ at Fig. 8 is due to the high heat concentration in the plasma arc, which induces microstructural changes, such as the formation of martensite or a denser ferrite-pearlite structure. The higher the electric current used, the higher the plasma-arc temperature, which expands the HAZ and increases hardness due to rapid cooling after cutting. However, if the current is too high, as in specimen A56, although the hardness increases, the risk of microcracking or undesirable structural changes also increases [5,16].

These findings align with research [18], which states that increasing current and gas pressure in the CNC plasma cutting process can increase hardness in the HAZ zone due to microstructural phase transformation. Furthermore, [16,19] also emphasized that rapid thermal changes in the plasma cutting process affect local mechanical properties, particularly material hardness and toughness. Therefore, although increasing current can increase hardness, a balance between mechanical strength and the risk of thermal defects must be considered to ensure optimal structural and functional cutting results. This can have dual consequences: on the one hand, the material becomes harder and better able to withstand mechanical loads; on the other hand, excessive hardness increases the toughness and increases the risk of microcracking due to thermal residual stresses.

The results of this study emphasize the importance of controlling process parameters, particularly gas flow and pressure, to achieve a balance between hardness and toughness. While increasing flow can

provide the advantage of higher mechanical strength, if not balanced with appropriate gas pressure and cutting speed settings, the risk of thermal defects such as distortion, cracks, or unevenness in the cut surface increases [19,20]. Structurally and functionally, optimizing plasma cutting parameters is key to ensuring that the cut not only meets mechanical strength standards but also maintains good surface quality and material integrity. Therefore, this study emphasizes the need for a holistic approach to process parameter management, accounting for interactions among flow, gas pressure, cutting speed, and the material being cut [21,22].

#### 4 Conclusions

The experimental investigation demonstrated that variations in CNC plasma cutting current significantly influence the fabrication quality of Revo motorcycle brackets for electric vehicle conversion. The best results were achieved at 50 A, with a gas pressure of 6 bar and a torch distance of 2 mm. This setup yielded an average surface roughness of 5.39  $\mu\text{m}$  and a dimensional accuracy within  $\pm 0.3$  mm. Increasing the current beyond 50 A enhanced hardness in the HAZ due to microstructural transformations, it simultaneously deteriorated surface quality and increased the risk of thermal defects. This finding emphasizes the need to balance mechanical strength with cutting precision. These results highlight that careful control of plasma cutting parameters can produce high-precision, cost-efficient brackets for electric vehicles. Future research should explore variations in cutting speed, gas pressure, and material thickness to create a more comprehensive framework for optimizing plasma cutting processes in various industrial settings.

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