COMPARATIVE ANALYSIS OF PLASMA AND GUILLOTINE CUTTING REGARDING THE TILT ANGLE OF THE CUT SURFACES

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ABSTRACT: The paper presents a comparative study between two cutting methods frequently used in the metallurgical industry – plasma cutting and guillotine cutting – with the aim of evaluating their influence on the quality and geometry of the obtained surfaces. Six different types of metallic materials were analyzed, including both ferrous and non-ferrous alloys, characterized by distinct mechanical and thermal properties. The research focuses on the angle and morphology of the cut surfaces after the cutting process, correlating the experimental results with the technological parameters used. The measurements performed aimed to determine the surface roughness and the geometric deviations of the cut edges, providing a quantitative basis for characterizing the influence of the thermal input and the mechanical forces involved. Through this comparative analysis, the study provides a solid foundation for choosing the optimal cutting method, depending on the industrial application, the material properties and the required dimensional accuracy. The conclusions highlight that the selection of cutting technology significantly influences not only the surface quality, but also the overall performance of the machined parts.

KEYWORDS: cutting, plasma, guillotine, angle

1.INTRODUCTION

In the metalworking industry, cutting processes are a critical step, directly influencing the quality of the final product, the efficiency of the manufacturing process and the costs associated with production. The choice of the optimal cutting method depends on factors such as the type of material, its thickness and the specific requirements of the industrial application. Among the most widely used methods are plasma cutting and guillotine cutting, each with specific advantages and limitations. Recent studies have analyzed these methods in detail, highlighting their impact on the surface roughness, the hardness of the cutting zone and the chemical composition of the material. This comparative analysis aims to consolidate existing knowledge and identify the most suitable cutting methods for different industrial applications. The study will provide concrete data that will help specialists optimize process parameters, reduce operational costs and improve the efficiency of the manufacturing process. The choice of the right cutting method depends not only on the material characteristics, but also on the specific requirements of the application, so optimizing these processes will contribute to a more efficient and sustainable metallurgical industry. The current state of knowledge in the field of metal cutting highlights the advantages and disadvantages of guillotine and plasma cutting, as well as the impact of these processes on the roughness, hardness and chemical composition of materials. Previous works provide a solid basis for the current research, which aims to fill the existing gaps and provide practical recommendations for selecting the optimal cutting method depending on the application requirements.

2. MATERIALS AND METHODS

2.1. MATERIALS USED IN RESEARCH

The study analyzed six types of metallic materials, each with different thicknesses, to cover a wide range of industrial and engineering applications. The selection was designed to include both ferrous and non-ferrous alloys, with distinct mechanical and thermal properties, representative of different technological processes. The materials tested were: C125W2 tool steel – ISO 4957 (M1), C90U tool steel – ISO 4957 (M2), 11SMn30 steel – ISO 683-9 (M3), S235JR structural steel – ISO 630 (M4), X5CrNiMo17-12-2 stainless steel – ISO 4954 (M5) and Al99.0 aluminum alloy – ISO 209 (M6). The choice of these materials allowed for a complex comparative basis, from hard tool steels to light aluminum alloys, facilitating the highlighting of the behavior of each material according to its specific application and the technological requirements of the manufacturing process.

2.2 CUTTING METHODS USED

In this study, two metal cutting methods were used, guillotine cutting and plasma cutting. Each method has advantages and disadvantages depending on the material properties and the final product requirements. This paper aims to compare the two cutting methods on six different materials, analyzing the surface roughness, inclination angle, hardness and chemical composition of the cut areas.

To perform the metal cutting operations, two main pieces of equipment were used: the FDB13x3000 guillotine, fig. 1, and the Mantech 3000x1500 CNC plasma cutting machine, fig. 2. These machines were selected due to their high precision and ability to process various types of materials. For metal sheet cutting operations, the FDB13x3000 industrial guillotine was used, a powerful and precise equipment, figure 3. It is capable of bending metal sheets with thicknesses up to 13 mm and widths of maximum 3000 mm, making it ideal for industrial applications that require high precision.

The guillotine operates with a pressure of 200 tons and is equipped with an advanced hydraulic system, which allows for uniform and precise bending. The computer numerical control (CNC) ensures automatic adjustment of bending angles and depth, providing an accuracy of ±0.1 mm. The power supply is three-phase, at 380V, with a consumption of 15 kW, which allows stable and efficient operation of the equipment in industrial conditions. Among the special features of the guillotine is the possibility of setting the bending angles to various values, including for bending at complex angles. The digital control panel facilitates automatic operation and intuitive programming of working parameters. The equipment is also equipped with integrated safety devices, designed to protect the operator and reduce the risk of accidents during operation.

By using these two advanced equipment, the metal materials processing process benefited from a high level of precision, efficiency and safety, thus optimizing the final results.

Fig.1 FDB13x3000 guillotine
CNC Mantech 3000x1500

Fig.2 Plasma cutting machine

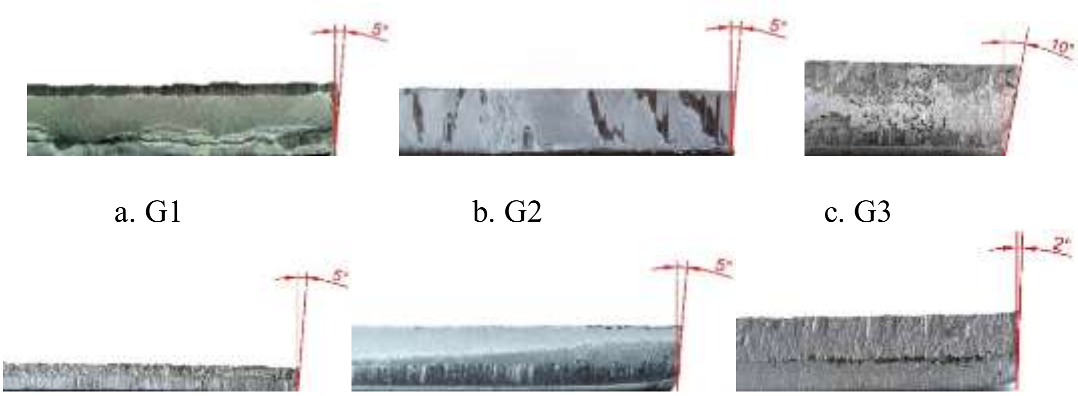
The Mantech 3000x1500 CNC Plasma is a high-performance equipment designed for fast and precise cutting of large metal materials. With a generous working surface of 3000 x 1500 mm, this machine allows the processing of metal sheets of various sizes and thicknesses. The maximum cutting capacity varies depending on the material: 25 mm for carbon steel, 20 mm for stainless steel and 15 mm for aluminum.
The power of the equipment is supported by a cutting current of 85A, which ensures fast and precise cutting, and the high-quality plasma source guarantees stable arc control, resulting in clean and well-defined cuts.
The machine control system is computer numerically controlled (CNC), allowing advanced programming and precise operation. Its interface is compatible with CAD/CAM files (DXF, DWG), facilitating the direct import of complex models from design software .
The machine's accuracy is remarkable, with a positioning tolerance of ±0.1 mm, ensuring high-quality cuts. The cutting speed can reach 15,000 mm/min, thus optimizing productivity without compromising processing quality.
The equipment's electrical consumption is between 10 and 15 kW, and the power supply is three-phase at 380V, which gives it stability and energy efficiency in industrial environments.
The machine also has several special features designed to improve the safety and efficiency of the cutting process. The cooling system prevents overheating during prolonged use, and the integrated safety device allows automatic shutdown in the event of interruptions or obstacles on the work surface. In addition, a ventilation and dust extraction system

2.3. ANALYSIS OF THE INCLINATION ANGLES OF CUT SURFACES

The rake angles are an important aspect in the analysis of cutting processes, as they influence the quality of the cut edges and can have implications for the subsequent applications of the materials. The rake angles are measured for both guillotine and plasma cutting. Photographs of the cut areas were taken and entered into the Autocad design program where the rake angles were measured.

2.3.1 ANALYSIS OF THE TILT ANGLES OF SURFACES CUT WITH A GUILLOTINE

Figure 10 shows the inclination angles of materials cut with a guillotine.



a. G1 b. G2 c. G3

d. G4 e. G5 f. G6

Fig.10 Tilt angles of materials cut with a guillotine

Table 3 presents the inclination angles of the materials in the guillotine cut area.

Table 3 Tilt angles of materials in the guillotine cut area

Materials / Angle	G1	G2	G3	G4	G5	G6
Angle [^{o}]	5	5	10	5	5	2

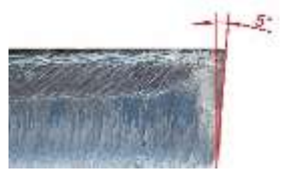
The bevel angles are relatively small, indicating precise and controlled cutting. Thicker material (G3) tends to have a larger angle (10°), which can be attributed to the force applied during cutting. The G6 material has the smallest bevel angle (2°), suggesting a more uniform and precise cut.

2.3.2 ANALYSIS OF THE TILT ANGLES OF PLASMA JET CUT SURFACES

Figure 11 shows the inclination angles of materials cut with a guillotine.

a. P1

b. P2



c. P3

d. P4

e. P5

f. P6

Fig.10 Tilt angles of materials cut with a guillotine

Table 4 shows the angles of the materials in the guillotine cut area.

Table 4 Tilt angles of materials in the plasma jet cut area

Materials / Angle	P1	P2	P3	P4	P5	P6
Angle [^{a}]	7	7	5	7	7	10

The tilt angles are generally greater than in guillotine cutting, which can be attributed to the nature of the plasma cutting process, which involves high temperatures and partial melting of the material. Material M6 (P6) has the largest tilt angle (10°), which may be an indicator of thermal deformation or edge melting due to high temperature.

2.3.3 COMPARISON BETWEEN GUILLOTINE CUTTING AND PLASMA JET CUTTING

When cutting with a guillotine, the bevel angles are generally lower in the case of guillotine cutting, which suggests a more precise and controlled cut. This is beneficial for applications that require smooth edges and precise angles. Plasma cutting produces higher rake angles, which can be attributed to the thermal effects of the process. This can lead to edge distortion and poorer cut quality, especially on thinner materials. This rake angle analysis complements the general study of cutting processes, providing valuable information for selecting the optimal cutting method based on application requirements.

3.CONCLUSIONS

This paper has conducted a detailed comparative analysis between plasma cutting and guillotine cutting, applied to six different types of metallic materials, with the main aim of evaluating the impact of these methods on the angle of inclination of the cut and the quality of the resulting surfaces. The research was based on rigorous experimental measurements, through which it was monitored how the technological parameters and material properties influence the geometry of the cut and the stability of the process.

The results obtained highlight significant differences between the two processes:

Guillotine cutting generated low inclination angles, with values between 2° and 10°, indicating a stable mechanical process, characterized by a direct contact between the blade and the material, without additional thermal effects. This type of cutting ensures high precision and good repeatability, especially for thin and medium materials. It was found that the smallest angles correspond to thin sheets, where plastic deformation is minimal, while thick materials showed a slight inclination gradient due to shear stresses.

Plasma cutting, on the other hand, produced larger inclination angles, ranging from 5° to 15°, presenting a higher variability determined by thermal effects and local melting of the material. The non-uniform temperature distribution and high arc energy cause the appearance of marginal deformations and a heat-affected zone (HAZ), which can lead to a loss of dimensional accuracy and the need for additional grinding or finishing operations.

For industrial applications that require smooth edges, precise cuts and tight dimensional tolerances – such as the construction of metal structures, the automotive industry or the processing of thin sheets – the guillotine method has proven to be superior, due to the low inclination angles and the absence of thermal effects.

However, plasma cutting offers advantages in other technological contexts: the process can induce a superficial hardening of the cut edges, improving local hardness and wear resistance. Thus, in the case of components that require increased mechanical strength in the cutting area, plasma cutting may be a more appropriate choice.

Regarding the material thickness, it has been observed that, for thick sheets, the larger angles resulting from plasma cutting are technologically acceptable, as they do not significantly affect the functionality of the part.

On the other hand, for thin materials, guillotine cutting remains the most appropriate solution, as it prevents deformation and maintains the flatness of the cut surface.

In conclusion, the choice of cutting method should be made depending on the purpose of the application, the material thickness and the desired level of precision. Guillotine cutting is recommended for operations where geometric accuracy and surface quality are a priority, while plasma cutting is advantageous in situations requiring high processing speed, flexibility and increased resistance of the cut edges. The study demonstrates that a correct approach, based on correlating technological parameters with material characteristics, allows for process optimization and achieving a balance between precision, productivity and costs.

REFERENCES

[1] Peko , I., et al. Modeling of Surface Roughness in Plasma Jet Cutting Process of Structural Steel . Tribology in Industry, 2016.
[2] Duplák , J., Hatala , M., Dupláková , D., Botko , F. Prediction Model of Surface Roughness Parameters of Structural Steel Created by Plasma Arc Cutting . Materialwissenschaft wave Materials Technology , 2019.
[3] Rajeshkannan , A., et al. Optimizing the Processor Parameters in Plasma Arc Cutting Against Surface Roughness . Materials Today : Proceedings , 2020.
[4] Karthick , M., et al. Optimization of Plasma Arc Cutting Parameters on Inconel 718 for Least Surface Roughness . Advances in Materials Science and Engineering, 2022.
[5] Lazarević , A., et al. Effects of Plasma Arc Cutting Processor Parameters on the Surface Roughness . Journal of Manufacturing Processes , Elsevier, 2022.
[6] Bhowmick , S., et al. Experimental Study of Plasma Arc Cutting of AISI 304 Using Taguchi Method . Materials Today : Proceedings , 2018.
[7]Das, MK, et al. Optimization of Process Parameters in Plasma Arc Cutting of EN31 Steel. Procedia Engineering, 2014.
[8]Peko, I., et al. Modeling and Optimization of Cut Quality Responses in Plasma Jet Cutting of Aluminum Alloy . International Journal of Mechanical Engineering and Applications , 2021.
[9]Slătineanu, L., et al. Surface Roughness at Plasma Cutting . Journal of Unconventional Technologies, 2017. Versus Ra and Taper . Compendium Paper Asia, 2024.
[10] Hang, PT, et al. An Investigation on the Effect of Cutting Parameters in CNC Plasma Cutting on Surface Quality (Ra, Slag , Cut Angle). Vietnam Journal of Agricultural Sciences, 2020.
[11] Jamsari , NS, et al. Optimization of Cut Surface for CNC Plasma Machine Considering Speed , SOD and Pressure
[12] Abdulnasser , B., et al. Plasma Arc Cutting Optimization Parameters Using Taguchi Method . AIP Conference Proceedings , 2016.
[13] Tsiolikas , A., Kechagias , J., Salonitis, K. Optimization of Cut Surface Quality During CNC Plasma-Arc Cutting. NAUN Proceedings , 2016.
[14] Slătineanu, L., et al. Surface Roughness Analysis at Plasma Cutting of Structural Steel St52-3N. Nonconventional Technologies Review, 2020.
[15] Choudhury , MR, et al. Optimization of Process Parameters in Plasma Arc Cutting of Commercial -Grade Aluminum Plate. High temperatures Materials and Processes , 2024.
[16] Gani , A., et al. Optimization of Cutting Parameters and Surface Deformation of Thin DCO1 Sheet Processed by Plasma Arc Cutting . Advances in Mechanical Engineering, 2021.
[17] Salonitis , K., et al. Experimental Investigation of the Plasma Arc Cutting Process : Power, Speed , Height and Gas Pressure vs. Quality. CIRP Proceedings , 2012.
[18] Gupta, R., et al. Performance Analysis and Optimization of Plasma Arc Cutting for Stainless Steel Using MRR and Ra Minimization . Propulsion & Power Research Journal, 2025.
[19] Komusi , G., et al. The Influence of Technological Parameters of Plasma Cutting on the Quality and Surface Roughness When Cutting Thick Steel Sheets . ResearchGate Preprint, 2024.
[20] Duplák, J., et al. Prediction Model of Surface Roughness Parameters via Full-Factor Experiment in Plasma Cutting. Procedia Manufacturing, 2019.