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Evaluation of the roundness quality of galvanized steel plate due to variations in cutting speed and nozzle diameter during the laser cutting

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ABSTRACT

Purpose: Generally, laser cutting processes aim to cut materials with high accuracy, as well as precise and near-perfect sizes and results. The purpose of this study is to evaluate the roundness quality of the holes cut by laser cutting on galvanised steel plates; two variations are given, such as cutting speed and nozzle diameter.

Design/methodology/approach: The type of laser used is a fibre laser. The material used is galvanized steel with a thickness of 3 mm with dimensions of 200 mm in length and 200 mm in width. A round profile is good if the distance between the points of the geometric shape is the same distance from the centre point.

Findings: The measurement results show that the smallest radius deviation is with an average value of 20.08 mm at a nozzle diameter of 2.5 mm and a cutting speed of 3 m/min, close to the initial radius value of 20.00 mm.

Research limitations/implications: During the laser cutting process, The best roundness quality is the combination of a nozzle diameter of 2.5 mm and a cutting speed of 3 m/min with a small deviation (the index deviation is 0.4%). At the same time, the biggest deviation in this experiment is the combination of parameters with a nozzle diameter of 3 mm and a cutting speed of 4 m/min (the maximum deviation value is 1%).

Practical implications: The use of the proposed nozzle diameter and cutting speed approach is an important requirement for industrial applications with laser cutting to get the right product for its intended use.

Originality/value: This article presents different nozzle diameters and cutting speeds to reveal the roundness quality due to these variations, where the roundness quality will be adapted for a particular application.

Keywords: Roundness quality, Cutting speeds, Nozzle diameters, Galvanized steel plates, Laser cutting

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MANUFACTURING AND PROCESSING

1. Introduction

Cutting materials with a high level of accuracy and with precise and near-perfect sizes and results can be done with a laser machine. The demand for producing a wide range of products in large quantities has recently increased. The advantage of cutting with a laser machine is that manufacturing components or products will be easier and more efficient, with high product accuracy [1-4]. The production process runs fast because the laser machine can directly receive data ordered by the computer, which can automatically cut complex objects while minimizing material waste through pre-precise design. In addition, another advantage of laser cutting machines is that they can be used on various types of materials such as wood, glass, cardboard, acrylic, plate, and stainless steel [5-6].

A spherical profile is said to be perfectly spherical if the points contained in all geometries are spread the same distance from the centre point to the outermost point or edge. Conversely, a spherical profile is said to be imperfectly spherical if the distance between the points in the geometry from the centre indicates irregularities. ISO/R 1101 defines a roundness tolerance as the tolerance area of a cross-section surrounded by two concentric circles whose radii differ by the tolerance index [7-8]. Dimensional accuracy is required for applications on machining elements where small deviations are required (high accuracy). So choosing an easy, cheap, and efficient material-cutting method is necessary. One of them can be taken over by laser cutting [9]. Quality of other metalworking processes was reported in the following studies, namely: metallurgical characterization of laser welding [10-11], the dimensionless wear behaviour of metal carbide tools in machining operations [12], effect of Selective Laser Melting (SLM) parameters on porosity, hardness, and 316L stainless steel structure [13].

The significant stage in achieving the optimum quality in the cutting process is determining the Laser cutting settings [14,15]. Choosing the right machining parameters can ensure good machining quality while cutting with a laser. According to the findings, cutting speed rapidly declines as sheet thickness increases [16]. Several factors influence the cutting surface quality produced by the laser machine, but the most important keys are assisted gas pressure, focal length, pulse width, and nozzle distance [17]. Power output, gas pressure, and cutting response speed were the process input factors chosen to determine their influence on the cutting process [18]. Based on the background, laser cutting results are typically quite accurate and close to the designed dimensions. The effect of laser-cutting process parameters on the quality of plate products, especially cutting speed and nozzle diameter, has not been reported in some literatures. Therefore, the study aims to evaluate the spherical quality of a fibre laser cutting machine by varying the three cutting speeds and three dimensions of the nozzle used during the cutting process. This parameter will be a reference for the galvanized steel-cutting industry.

2. Materials and methods

The chemical composition of the metal plate used as the roundness evaluation object is shown in Table 1. The dimensions of the galvanized plate are 200 x 200 x 3 mm, respectively length, width, and thickness. The laser cutting machine used is the GWEIKE CNC type LF3015E, a computer-based fibre laser cutting machine with the SC2000 CNC application. Programming is done with CAM (Computer Aided Manufacturing) file format based on DXF. Specifications of the laser cutting machine as shown in Table 2. This experiment begins with determining the dimensions of the sample circle to be cut by a laser cutting machine.

Table 1.
Chemical composition of galvanized steel (wt.%)

Elements	Wt.%
C	0.247
Cr	0.193
Mn	1.23
Mo	0.0085
Al	0.059
Ni	0.036
Si	0.274
Fe	Bal.

Table 2.
Laser cutting machine specifications

Machine model	LF3015E
Laser power	1000W
Dimensions	4600 * 2450 * 1700 mm
Working area	3000 x 1500 mm
Repeat positioning accuracy	± 0.02 mm
Max. speed	60 m/min
Max. acceleration	1.0 G
Voltage and frequency	220 V/ 380 V 50 Hz/ 60 Hz

Furthermore, the sample plate is cut with predetermined parameters. Samples that have been cut will be measured with a vernier calliper and an arc angle to measure the radius of several angles, which measures the radius of the specified angle, where a digital calliper with an accuracy of 0.02 mm and a maximum measurement dimension of 150 mm has been used. The calliper can measure the outside and inside diameter of an object, as well as measure the depth of a gap or hole in an object. The size of the designed hole radius is 20 mm for each hole; deviation radius data is calculated by Equation 1.

$$\Delta r = r_{max.} - r_{min.} \quad (1)$$

where, Δr is the deviation of the radius, $r_{max.}$ is the maximum radius size; $r_{min.}$ is the minimum size of the radius.

Use a digital calliper to assess roundness quality, select round-sectioned from the laser cut; put it on a flat surface; at several locations along the object's length, use the digital calliper to measure the object's diameter; carefully close the calliper jaws around the object; the jaws are ensured parallel to the axis of the object; record the diameter measurements at each point; adding all the measurements and dividing by the total number of measurements, determine the average diameter; the largest and smallest sizes are recorded, then these values are used to get the maximum and minimum diameters; roundness inaccuracies are obtained by subtracting the minimum diameter from the maximum diameter; to calculate the roundness deviation, divide the roundness error by the average diameter; this value indicates the degree of deviation from a perfect cylinder repeat the procedures above numerous times along the length of the object.

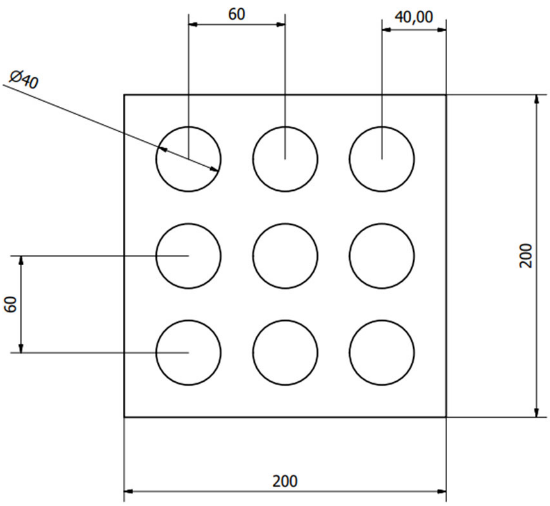

Fig. 1. Sample design for measuring the roundness of laser cut results (in mm)

Cutting speed (v) is the movement of the cutting head towards the workpiece, which is set before the cutting process is carried out. The nozzle used is a subsonic conical type. Two process parameter variations were carried out in this experiment. First, varying the cutting speed such as 2, 3, and 4 mm/min. Second, varying the dimensions of the nozzle size, such as 2.0, 2.5. and 3.0. Oxygen gas at a pressure of 1 bar was used in this experiment. The galvanized steel plate is cut in a circular shape with fibre laser cutting, as shown in Figure 1.

3. Results and discussions

The results of measuring the roundness and deviation of the hole by laser cutting are shown in Figures 2-4; the dimensions of the nozzle and the cutting speed are 2, 3, 4 mm and 2, 2.5, 3 mm/min, respectively. Figure 2a shows the roundness of the results of laser cutting measurements; the biggest deviation occurs at the radius with an angle of 0°, which is 20.69 mm, with parameters 2 mm for cutting speed and 2 mm/min for nozzle size (Fig. 2b). Figure 2c is the roundness measured, then the maximum deviation measured at 0° radius is 20.13 mm (parameters: 3 mm for cutting speed and 2 mm/min for nozzle size, as shown in Fig. 2d). Figure 2e is the roundness that was recorded as well. Figure 2f shows the largest deviation occurs at the radius with 0°, which is 20.60 mm, for the cutting speed variation is 4 mm, and the nozzle size is 2 mm/min.

The results of the hole measurement after laser cutting processes with the cutting speed of 2 mm and the nozzle dimension of 2.5 mm/min, as shown in Figure 3a-b, the deviation measured at an angle of 60° is 20.13 mm. Figure 3c is the roundness measured, and the maximum deviation value measured at angles of 0°, 30°, and 240° is 20.11 mm, as parameters are the cutting speed of 3 mm and the nozzle dimension of 2.5 mm/min (Fig. 3d). Figure 3e is the roundness that was recorded. Then the highest deviation value in the sixth hole is seen at angles of 0°, 30°, and 210°, which is 20.13 mm, with parameters of the cutting speed of 4 mm and the nozzle dimension of 2.5 mm/min (Fig. 3f).

Furthermore, the results of measuring the laser cutting hole are set with the cutting speed of 2 mm and the nozzle dimensions of 3 mm/minute (Fig. 4a shows the roundness of laser cutting measurements), the deviations measured at angles of 0° and 180° are 20.15 mm as shown in Figure 4b. Figure 4c is the roundness measured; the highest deviation measured at angles of 0°, 210°, and 240° is 20.12 mm, as parameters are the cutting speed of 3 mm and the nozzle dimensions of 3 mm/min (Fig. 4d). Figure 4e is the roundness that was recorded as well the maximum deviation value in the ninth hole is seen at an angle of 0° which is 21.43 mm (parameters are the cutting speed of 4 mm and the nozzle dimensions of 3 mm/minute, Fig. 4f).

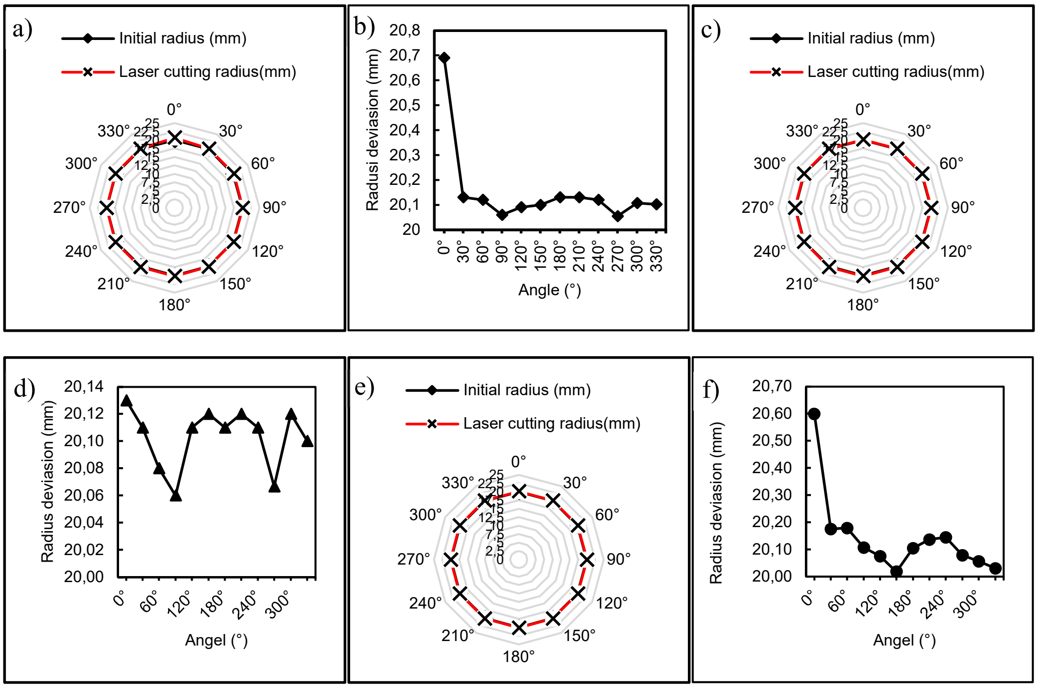

Fig. 2. Measurement results: a) roundness and b) deviation (for nozzle dimensions is 2 mm and cutting speed is 2 mm/min); c) roundness and d) deviation (for nozzle dimensions are 3 mm and cutting speed is 2 mm/min); e) roundness and f) deviation (for nozzle dimensions is 4 mm and cutting speed is 2 mm/min)

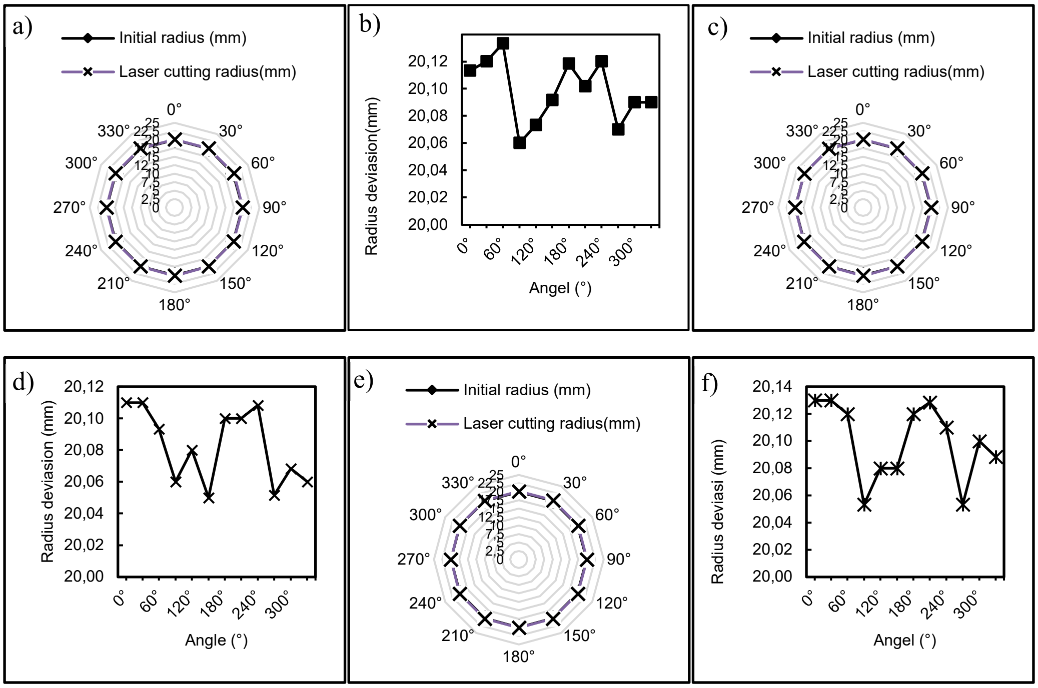

Fig. 3. Measurement results: a) roundness and b) deviation (for nozzle dimensions is 2 mm and cutting speed is 2.5 mm/min); c) roundness and d) deviation (for nozzle dimensions is 3 mm and cutting speed is 2.5 mm/min); e) roundness and f) deviation (for nozzle dimensions is 4 mm and cutting speed is 2.5 mm/min)

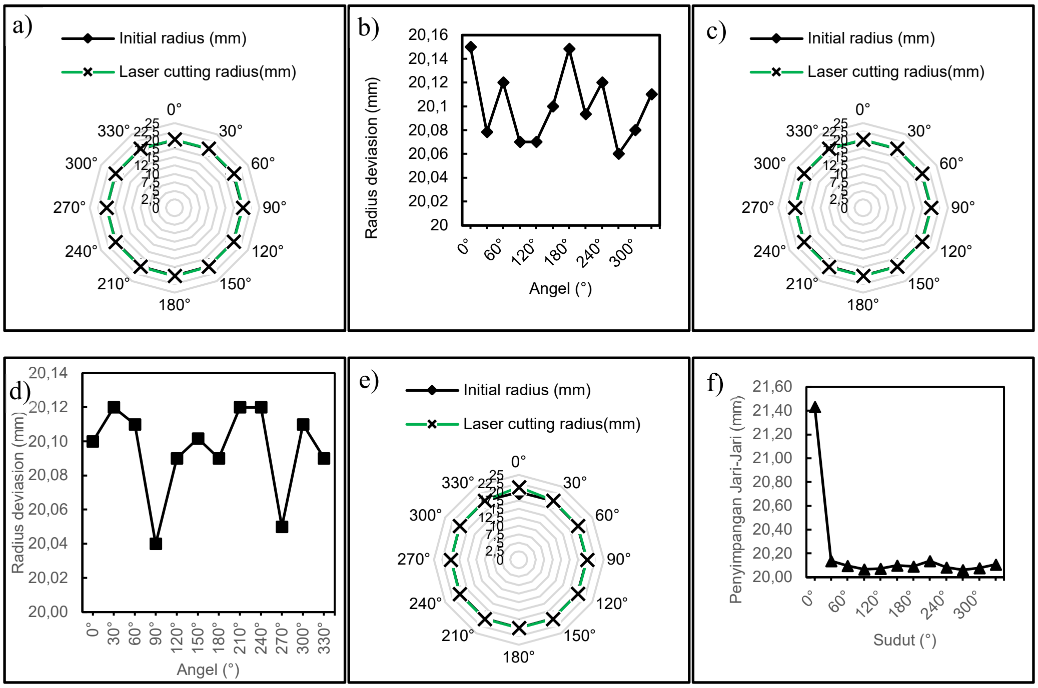

Fig. 4. Measurement results: a) roundness and b) deviation (for nozzle dimensions is 2 mm and cutting speed is 3 mm/min); c) roundness and d) deviation (for nozzle dimensions is 3 mm and cutting speed is 3 mm/min); e) roundness and f) deviation (for nozzle dimensions is 4 mm and cutting speed is 3 mm/min)

Table 3.
Roundness quality of laser cutting results due to variations in nozzle diameter and cutting speed.

Nozzle diameter, mm	Laser cutting speed, mm/min	Roundness quality, mm	Deviation, %
2	2	20.15	0.75
2	3	20.10	0.50
2	4	20.14	0.70
2.5	2	20.09	0.45
2.5	3	20.08	0.40
2.5	4	20.09	0.45
3	2	20.10	0.50
3	3	20.09	0.45
3	4	20.20	1

Parameters of nozzle diameter and cutting speed can affect the deviation of the roundness of the cutting hole from the galvanized plate (Tab. 3). The maximum deviation is shown at a cutting speed of 4 mm/min and a nozzle diameter of 3 mm, which is 20.2 mm. At the same time, the minimum deviation is 20.08 mm in cutting conditions with a nozzle dimension of 2.5 mm and a cutting speed of 3 mm/minute. Therefore from the results of this experiment, these cutting parameter conditions are recommended to reduce product deviation by fibre laser cutting.

The selection of the nozzle diameter is determined by the type of material and the thickness of the material to be cut [19]. A higher nozzle diameter may cause turbulence phenomena, worsening the cutting product quality. Micro-structural studies also illustrate that turbulence can hamper the quality of product components [20,21].

Several things affect the roundness of the cutting results with fibre laser cutting, including wear and tear on the spindle bearing of the CNC machine or grinder used. The service life of laser cutting also causes shifts or deviations during cutting, so it needs to be recalibrated [22]. It can also be caused by bending in the work-piece or machine tool when a force is applied [23]. The cutting part is quite large and wide. Clamp centre position error. Stress on retaining or clamping devices on thin-walled components. There is chatter in the cutting process. Material deviations occur in the cutting process without a centre point [24].

4. Conclusions

The cutting parameters with laser cutting greatly affect the quality of the roundness of the hole. Parameters such as nozzle diameter and cutting speed have been evaluated in this experiment so that conclusions can be drawn. Variations in nozzle diameter of 2.5 mm with a cutting speed of 3 m/min obtained a variation with the best roundness quality compared to variations in nozzle diameter with other cutting speeds. This parameter has a radius deviation value of 20.08 mm, the smallest difference from the initial radius of 20.00 mm. The parameter of nozzle diameter of 3 mm with the cutting speed of 4 m/min is considered the variation with the worst roundness quality compared to variations of nozzle diameter with other cutting speeds. This parameter has a measured radius of 20.20 mm compared to an initial radius of 20.00 mm.

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