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Investigation of the effects of machining parameters on hole quality in drilling mild steel AISI 1045

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Abstract

The current study shows the effect of machining parameters such as feed rate and spindle speed on the hole quality such as hole size, circularity and surface roughness in drilling AISI 1045. The experiments were performed using high speed steel drill bits. The result indicated that hole size decreases with increasing feed rate and increases with increasing spindle speed. However, circularity decreases with increasing both feed rate and spindle speed. Furthermore, surface roughness increases with increasing feed rate and decreases with increasing spindle speed. Moreover, Analysis of variance deals that feed rate has higher influence on hole size with percentage contribution of 59.16% than spindle speed of 38.37 % on hole size. The percentage contribution of feed rate is greater than spindle speed on circularity 72.40 % and 25.57% respectively. Moreover, the percentage contribution of feed rate on surface roughness is 61.89% greater than spindle speed of 37.14 %.

Keywords: Drilling; AISI 1045; Hole size; Circularity; Surface Roughness.

1. Introduction

Drilling is one of the prominent machining process excessively used manufacturing industries such as aerospace and automotive industries [1-3]. The problems which are related to drilling process such that circularity error, deviation of the holes from the nominal size, burr formation and high surface roughness, which significantly affects the drilling operation [4-7].Therefore, parts are rejected due to rapid tool wear and low hole quality which may lead to increase in total manufacturing cost and time [8-10]. Mild Steel AISI 1045 is low medium carbon alloy widely used for all industrial applications such as gears, shafts, axles, bolts, studs, connecting rods, pins, rolls, spindles, ratchets, crankshafts, torsion bars, rams, sockets, worms, light gears, guide rods and hydraulic clamps. Different analytical and experimental approaches were used to enhance the machinability of mild steel 1045.

The previous literature reveals that there is very limited work done on drilling process of mild steel 1045. Yu Deng et al. [11] measured the Magnetic Barkhaunsen Noise (MBN) for various commercial steels under various parameters such as roughness, hardness and elastic modulus. The results showed a significant influence of MBN parameter on the peak height and average value of structure characteristics of various materials like mild streel AISI 1045, AISI 1045 and AISI 1035. Libo wu et al. [12] investigated the chip geometry, cutting power, chip morphology and chip formation for AISI 1045 mild steel. The results demonstrate that the chip breaking groove can alter the chip flow angle and geometry significantly, and that

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the complicate-grooved insert promotes chip breakage more effectively than the flat rake insert. Ludovic Ngongang et al. [13] investigated the remote measurement and prediction of surface roughness by using turned and milled low carbon steel by using tungsten carbide tool. The quality of the forecasting approaches is mentioned by an overall measurement accuracy of more than 90% and exceptionally low mean square errors. S.V Wong et al. [14] worked on the fuzzy logic optimization by taking two simple inputs and one simple output fuzzy model by means of which one has to select the very optimum parameters out of 10,000 combinations. The result shows the improvement of most complex relationship during cutting machinability data by means of genetic optimization. Chau-Chang Chou et al. [15] investigated the tribological and rheological properties of AISI 1045 mild steel and AISI 1025 mild steel by using nanodiamond-dispersed lubricant. They concluded that nano diamond dispersed lubricants were proficient of reducing metal wear loss.

A large number of studies have been formed on cutting forces in drilling AISI 1045. However, no study is still performed regarding to the hole quality such as hole size (H), circularity error (C) and surface roughness (Ra) in drilling AISI 1045, which needs more investigation. Therefore, this work investigated the effect of drilling process parameters on the hole quality such as H, C and Ra.

2. Material and Methods

In current study, the experimentations were carried out on vertical milling machine (Model: Victoria-Elliott U2, London, UK). The f used was 0.1, 0.2 and 1.3 and n were 330, 410 and 510 as shown in Table 5. The work piece material was AISI 1045 mild steel with 20 mm × 10 mm and a thickness of 20 mm as shown in Table 3. The high-speed steel (HSS) dormer twist drill bits having a point angle of 130º and a helix angle of 30º were used as shown in Table 4. All the experiments were carried out under dry drilling conditions due to environmental hazard. The coordinate measuring machine (CMM, Taichung, Taiwan) was used to measure the C and H as shown in table 2. The Ra was measured by using a surface roughness tester Mitutoyo (SJ-201, Kawasaki). For true measurement of Ra, each hole was cleaned using high-pressure air to eliminate tiny particles from the hole wall. The design of experiment is a statistical technique for finding process variables that have a significant influence on the outcome variable [16-18]. To properly analyze each factor, a factorial approach was used. Minitab software was used to build a full factorial experiment with two input factor, f and n, each have three levels. ANOVA is a statistically- based, objective decision-making tool for detecting difference in the average performance of groups of objects that have been examined [19-22]. ANOVA aids in officially analyzing the relevance of the key components and their interactions by comparing the mean square against an estimate of the experimental errors at specific confidence levels [23-26]. The response variables that were recorded in each experimental run were Ra, C and H. The mechanical and thermal properties of AISI 1045 are as shown in Table 1.

Table 1. Mechanical and thermal properties of workpiece material AISI 1045

Parameters	**Values**
Density	6.858 g/cm^3
Tensile strength	470 MPa
Elastic modulus	180 GPa
Specific heat capacity	498 J/kg-K
Thermal conductivity	41.9 W/mK
Shear Modulus	90 GPa

Table 2. Equipment detail and experimental conditions

Experimental details	
Drilling condition	Dry conditions
Machine tool	Vertical milling machine
Hole size and circularity error	Coordinate measuring machine (CMM) Mitutoyo 7106
Surface roughness	Surface roughness tester Mitutoyo SJ-201

Table 3. AISI 1045 workpiece parameters

Work-piece parameters	Description
Material	Mild steel 1045
Geometrical shape	cylindrical
Thickness	20 mm

Table 4. Drill bit material and geometrical descriptions

Drill bit parameters	Description
Manufacturer	Norseman drill and tool (USA)
Material	High speed steel
Helix angle	30º
Point angle	130º
Diameter	10 mm

Table 5. Cutting parameters of drilling

Level	1	2	3
Spindle speed (rpm)	102	223	397
Feed rate (mm/rev)	0.3	0.97	1.86

3. Results and Discussion

3.1. Analysis of hole quality

Ra, H, C are all factors that influence hole quality. Poor hole quality in final assembly causes high rejection rates of aviation components that can exceed 60 %. As a result, the quantity of components rejected owing to poor quality must be kept under control [27].

3.2. Surface roughness

The Ra of holes determined under various drilling conditions is shown in figure 1. In the current study, Ra has an inverse relationship with n, with one reason being that the material is in contact with the tool-tip for a shorter period of time, another reason could be that the work piece surface temperature rises, softening the materials and reducing the resistance offered by the material against the tool [28]. Ra was also influence at higher f, where friction between the tool and the work piece increased as the material removal rate increased, resulting in increased the Ra. Moreover, from ANOVA table 6, it is shown that feed rate has a percentage contribution of 61.89 % higher than cutting speed of 37.14 %.

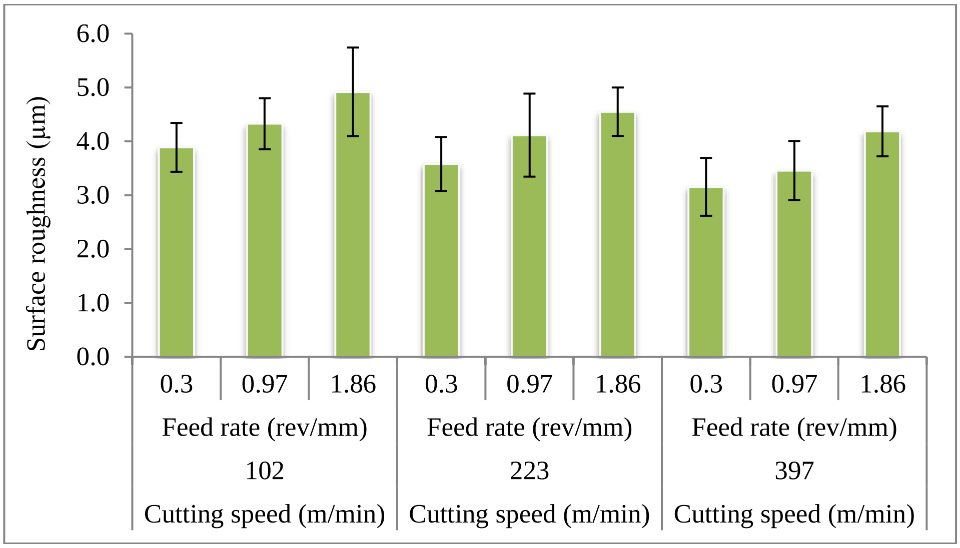

Fig. 1 Surface Roughness

Table 6. Analysis of Variance for surface roughness

Surface roughness							
Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Model	4	2.47029	99.03 %	2.47029	1.235146		
Linear	4	2.47029	99.03 %	2.47029	1.235146		
Cutting speed	2	0.92649	37.14 %	0.92649	0.463246	77.19	0.001
Feed rate	2	1.54380	61.89 %	1.54380	0.771900	128.62	0.000
Error	4	0.02401	0.96 %	0.02401	0.006001	-	-
Total	16	2.49430		-	-	-	-

3.3. Hole size

Figure 2 demonstrates the average H and percentage deviation from nominal size. Within decrease in f and an increase in n, a noticeable increase in diameter has been observed. However, increasing f increases the dimensional accuracy. This might be owing to the high chip thickness at a faster feed rate, which makes the cutting process unstable and causes constant jerks [29]. At a low f, shear cutting is the primary process, resulting in segmented chips and low cutting force, hence, the hole size is obtained with minimum deviation. Spindle speed has a substantial impact on hole dimensions accuracy as shown in figure 2. As the n increase, the H increase. This is most likely due to the increase in temperature at the tool-tip and hole surface contact, which softens the materials and enables for a more stable and smooth operation. Furthermore, it is observed from ANOVA table 7 that feed rate has a percentage contribution of 59.16 % higher than that cutting speed of 38.37 %.

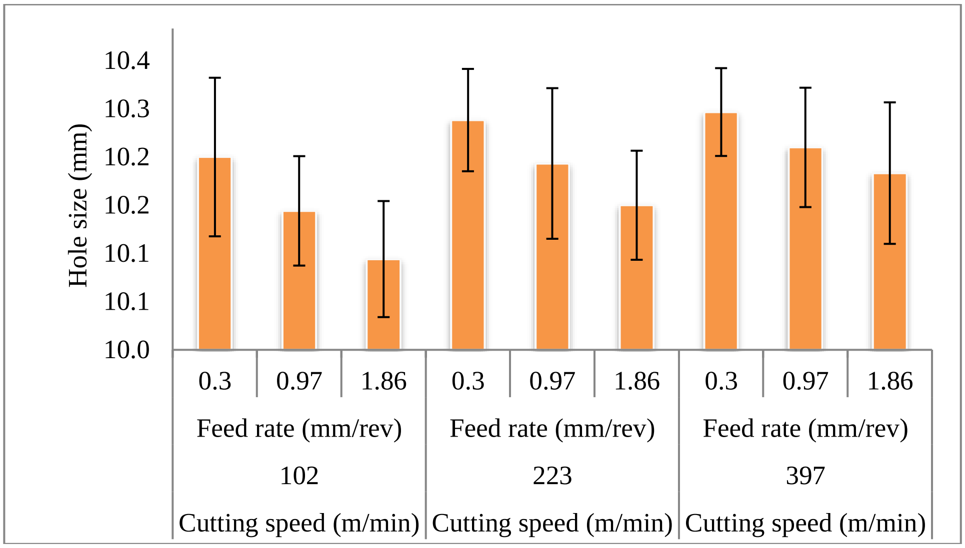

Fig. 2 Hole Size

Table 7. Analysis of Variance for hole size

Hole size							
Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Model	4	0.026277	97.53 %	0.026277	0.013138		
Linear	4	0.026277	97.53 %	0.026277	0.013138		
Cutting speed	2	0.010339	38.37 %	0.010339	0.005169	31.08	0.004
Feed rate	2	0.015938	59.16 %	0.015938	0.007969	47.91	0.002
Error	4	0.000665	2.47 %		0.000166	-	-
Total	16	0.026942	100 %	-	-	-	-

3.4. Circularity error

Many applications rely on C in measurement. The circular cross section is one of the most significant and fundamental form in engineering. In the current study, coordinate measuring machine is used for measuring the C in the hole. The C increases with n and because the vibratory displacement of the drilling tool increases with cutting parameter, causing dynamical instability. It occurs most frequently due to the instability of the drilling tool entrance. However, in the current study C decreases with increasing both f and n as shown in figure 3. Moreover, ANOVA table 8 shows that the feed rate has a percentage contribution of 72.40 % higher than cutting speed of 25.57 %.

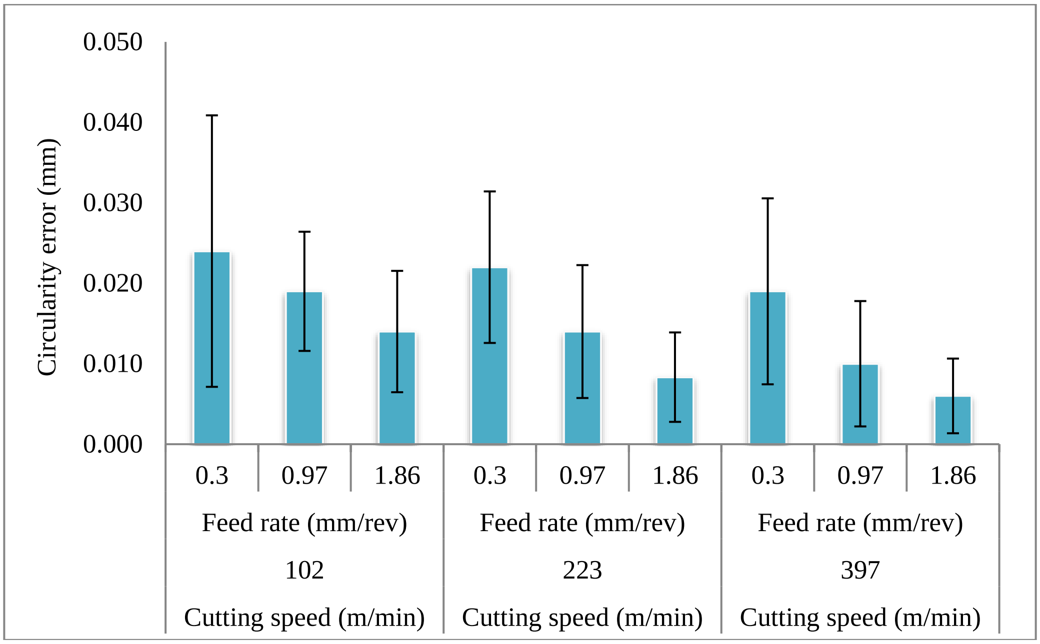

Fig. 3 Circularity

Table 8 Analysis of Variance for circularity error

Circularity error							
Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Model	4	0.000313	97.97 %	0.000313	0.000156		
Linear	4	0.000313	97.97 %	0.000313	0.000156		
Cutting speed	2	0.000082	25.57 %	0.000082	0.000041	25.31	0.005
Feed rate	2	0.000231	72.40 %	0.000231	0 0.000115	71.66	0.001
Error	4	0.000006	2.02 %	0.000006	0.000002	-	-
Total	16	0.000319	100 %	-	-	-	-

4 Conclusions

In the present work, the assessment of hole quality in the drilling of AISI 1045 was determined the main conclusions are as follows:

It was investigated that feed rate has higher influence on hole size than spindle speed. Hole size decreases with increases in feed rate and increases with increases in spindle speed. The percentage contribution of feed rate has higher influence on hole size with percentage contribution of 59.16% than spindle speed of 38.37 %. Moreover, circularity decreases with increasing both feed rate and spindle speed. The percentage contribution of feed rate is greater than spindle speed on circularity 72.40 % and 25.57% respectively. Moreover, surface roughness increases with increases in feed rate and decreases with increases in spindle speed. Moreover, the percentage contribution of feed rate on surface roughness is 61.89% greater than spindle speed of 37.14 %.

References

[1] Aamir, M., Tolouei-Rad, M., Giasin, K., & Nosrati, A. (2019). Recent advances in drilling of carbon fiber–reinforced polymers for aerospace applications: A review. The International Journal of Advanced Manufacturing Technology, 105, 2289-2308.

[2] Aamir, M., Sharif, A., Zahir, M. Z., Giasin, K., & Tolouei-Rad, M. (2023). Experimental assessment of hole quality and tool condition in the machining of an aerospace alloy. Machines, 11(7), 726.

[3] Güldibi, A. S., Köklü, U., Koçar, O., Kocaman, E., & Morkavuk, S. (2023). The effects of aging process after solution heat treatment on drilling machinability of corrax steel. Experimental Techniques, 1-19.

[4] Koklu, U., Morkavuk, S., Featherston, C., Haddad, M., Sanders, D., Aamir, M., ... & Giasin, K. (2021). The effect of cryogenic machining of S2 glass fibre composite on the hole form and dimensional tolerances. The International Journal of Advanced Manufacturing Technology, 115(1-2), 125-140.

[5] Habib, N., Sharif, A., Hussain, A., Aamir, M., Giasin, K., Pimenov, D. Y., & Ali, U. (2021). Analysis of hole quality and chips formation in the dry drilling process of Al7075-T6. Metals, 11(6), 891.

[6] Sharif, A., Hussain, A., Habib, N., Alam, W., Hanif, M. I., Noon, A. A., & Khan, M. I. (2023). Experimental investigation of hole quality and chip analysis during the dry drilling process of Al6061-T6. Journal of Materials and Manufacturing, 2(1), 21-30.

[7] Köklü, U., Koçar, O., Morkavuk, S., Giasin, K., & Ayer, Ö. (2022). Influence of extrusion parameters on drilling machinability of AZ31 magnesium alloy. Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering, 236(5), 2082-2094.

[8] Aamir, M., Tolouei-Rad, M., Giasin, K., & Vafadar, A. (2020). Feasibility of tool configuration and the effect of tool material, and tool geometry in multi-hole simultaneous drilling of Al2024. The International Journal of Advanced Manufacturing Technology, 111, 861-879.

[9] Hussain, A., Sharif, A., Habib, N., Ali, S., Akhtar, K., Ahmad, F., ... & Ishaq, M. (2021). Effect of Drilling Process Parameters on Brass Alloy 272 Through Experimental Techniques. Journal of Mechanical Engineering Research and Developments, 44(11), 222-234.

[10] Sharif, A. (2022). Study on burr formation, tool wear and surface quality in machining Al6063. Journal of Materials and Manufacturing, 1(2), 1-9.

[11] Deng, Y., Li, Z., Chen, J., & Qi, X. (2018). The effects of the structure characteristics on Magnetic Barkhausen noise in commercial steels. Journal of Magnetism and Magnetic Materials, 451, 276-282.

[12] Wu, L., Liu, J., Ren, Y., Yang, Z., Wang, G., Sun, J., ... & Liu, X. (2020). 3D FEM simulation of chip breakage in turning AISI1045 with complicate-grooved insert. The International Journal of Advanced Manufacturing Technology, 108, 1331-1341.

[13] Ngongang, L., Kanaa, T., Njeugna, E., & Ateba, A. Remote Monitoring of Surface Roughness on Turned and Milled Carbon Steels with High-Speed Steel and Tungsten Carbide Tools.

[14] Wong, S. V., & Hamouda, A. M. S. (2002). Development of genetic algorithm-based fuzzy rules design for metal cutting data selection. Robotics and Computer-Integrated Manufacturing, 18(1), 1-12.

[15] Chou, C. C., & Lee, S. H. (2008). Rheological behavior and tribological performance of a nanodiamond-dispersed lubricant. Journal of materials processing technology, 201(1-3), 542-547.

[16] Habib, N., Sharif, A., Hussain, A., Aamir, M., Giasin, K., & Pimenov, D. Y. (2022). Assessment of hole quality, thermal analysis, and chip formation during dry drilling process of gray cast iron ASTM A48. Eng, 3(3), 301-310.

[17] Sharif, A., Tipu, J. A. K., Arif, M., Abbasi, M. S., Jabbar, A. U., Noon, A. A., & Siddiqi, M. U. R. (2022). Performance Evaluation of a Multi-Stage Gravitational Water Vortex Turbine with optimum number of Blades. J. Mechan. Engin. Res. Develop, 45, 35-43.

[18] Ullah, I., & Sharif, A. (2022). Novel Blade Design and Performance Evaluation of a Single-Stage Savanious Horizontal Water Turbine. Journal of Technology Innovations and Energy, 1(4), 42-50.

[19] Sharif, A., Siddiqi, M., & Muhammad, R. (2020). Novel runner configuration of a gravitational water vortex power plant for micro hydropower generation. Journal of Engineering and Applied Sciences, 39(1), 87-93.

[20] Shoukat, A. A., Noon, A. A., Anwar, M., Ahmed, H. W., Khan, T. I., Koten, H., ... & Sharif, A. (2021). Blades Optimization for Maximum Power Output of Vertical Axis Wind Turbine. International Journal of Renewable Energy Development, 10(3).

[21] Ullah, I., Siddiqi, M. U. R., Tahir, M., Sharif, A., Noon, A. A., Tipu, J. A. K., ... & Habib, T. (2022). Performance investigation of a single-stage savanious horizontal water turbine with optimum number of blades. J. of Mechanical Engineering Research and Developments, 45(2), 29-42.
[22] Noon, A. A., Arif, M., Tipu, J. A. K., Jabbar, A. U., Siddiqi, M. U. R., & Sharif, A. (2021). Performance enhancement of centrifugal pump through cavitation reduction using optimization techniques. International J. of Thermofluid Science and Technology, 8(4), 080404.
[23] Tipu, A. K., Arif, M., Sharif, A., & Siddiqi, M. U. R. (2021). Implementing Truss Elements for Ensuring Structural Integrity on the Blade of Up-scaled Gravitational Water Vortex Turbine. J. Mechan. Engin. Res. Develop, 44, 115-122.
[24] Sharif, A., Siddiqi, M. U. R., Tahir, M., Ullah, U., Aslam, A., Tipu, A. K., ... & Sheikh, N. A. (2021). Investigating the Effect of Inlet Head and Water Pressure on the Performance of Single Stage Gravitational Water Vortex Turbine. Journal of Mechanical Engineering Research and developments, 44(11), 156-168.
[25] Muhammad, R., Sharif, A., & Siddiqi, M. R. (2022). Performance investigation of a single-stage gravitational water vortex turbine accounting for water vortex configuration and rotational speed. Journal of Engineering and Applied Sciences, 41, 44-55.
[26] Sharif, A., Khan, H., Bashir, N., & Alam, W. (2023). Parametric optimization and evaluating mechanical properties of poly lactic acid proceed by FDM additive manufacturing. Journal of Materials and Manufacturing, 2(1), 11-20.
[27] Arul, S. V. L. M. S., Vijayaraghavan, L., Malhotra, S. K., & Krishnamurthy, R. (2006). The effect of vibratory drilling on hole quality in polymeric composites. International Journal of Machine Tools and Manufacture, 46(3-4), 252-259.
[28] Zhang, J. Z., & Chen, J. C. (2009). Surface roughness optimization in a drilling operation using the Taguchi design method. Materials and manufacturing processes, 24(4), 459-467.
[29] Son, N. H., & Nguyen, N. T. (2020). Prediction of surface roughness and optimization of machining parameters in drilling process of aluminum alloy Al6061. International Journal of Trend in Scientific Research and Development, 4(3), 397-401.