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Influences of Al_2O_3 Nanofluid MQL Technological Parameters on Thrust Cutting Force in Hard Turning Using CBN Inserts

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Abstract

*High cutting forces generated at the tool–workpiece interface during hard turning remain a major challenge, which limits the productivity, lowers machined surface quality, and shortens tool life. Among them, the thrust cutting force strongly affects the hard cutting efficiency. The aim of this study is to analyze the thrust force in turning process of hardened 90CrSi steel under Al_2O_3 Nanofluid Minimum Quantity Lubrication (NF MQL) technology using uncoated cubic boron nitride (CBN) inserts. Regression analysis was made to establish the dependence of the thrust force on NF MQL parameters. The results indicate that air pressure has the most significant influence on the thrust forces. The interactions between nanoparticle concentration and air flow rate (NC*Q) and between air pressure and air flow rate (p*Q) also showed the significant effects. The minimal value of thrust cutting force (F_y) could be achieved at Al_2O_3 nanoparticle concentration of 0.8%, air pressure of 4.0 bar, and air flow rate of 250 L/min. Moreover, the analysis results could be used to determine the reasonable set of NF MQL parameters for smaller F_y values in hard turning process.*

Keywords: *Hard turning, Nanofluid, MQL, Al_2O_3 Nanoparticles, Thrust force.*

1. INRODUCTION

For many decades, materials with high hardness (from 45-62HRC) are commonly used in manufacturing industries, including alloy steels, hardened tool steels, white cast iron, heat-treated powder metallurgy parts, super alloy, and so on. Previously, to ensure machining accuracy and surface quality, the grinding process was commonly used to finish the parts with high hardness. However, it has many limitations such as low productivity, high cost, the use of a large amount of cutting oil causing environmental pollution, and so forth. Therefore, the process of machining hard materials with cutting tools with geometrical defined cutting edges including hard turning, hard milling, hard drilling, and so on are increasingly being used as a substitute or replacement solution for grinding process. Hard turning has been proven to exhibit more advantages over grinding process in terms of low sub-surface damage, environmental compatibility, minimum setup time, high flexibility, and chip removal productivity [1]. Many studies have focused on hard turning and explored the different characteristics in comparison the cutting performance of non-heat-treated materials. It could be mentioned by the serrated chip formation due to the very small sliding angle in hard machining compared to conventional machining [2]. Its values increase significantly with the growing work material hardness and are less dependent on the rake angle of the cutting tool. The high cutting forces generated during hard turning are also considered to be a distinguishing feature. The total cutting force in hard machining is not greater than that of traditional cutting, but the thrust force F_y is often much larger than the tangential force due to high friction and pressure between the tool flank face and the newly machined surface. The high values from thrust force are the main causes of reduced surface quality and dimensional accuracy of the machined part [3]. To overcome this problem as well as the high cutting temperature generated from contact zone, some cooling lubrication methods have been studied and utilized in hard machining technology such as Minimum Quantity Lubrication (MQL), Minimum Quantity Cooling (MQC), Minimum Quantity Cooling Lubrication (MQCL), and so on.

In particular, MQL method is considered an environmentally friendly lubrication method because a small amount (10-100 ml/h) of cutting oil is introduced into the cutting area thanks to a stream of high-pressure compressed air [4], resulting the high lubricating performance. As the small amount of cutting oil is introduced into cutting zone, it evaporates almost completely, thereby significantly reducing health problems caused by cutting oil. Furthermore, it is possible to eliminate the other processes such as maintenance, inspection, preparation, and disposal of coolant, thereby also contributing positively to reduce production costs [5]. Although MQL method has many above advantages, its cooling capacity is very low, especially in severe cutting conditions like hard machining. Therefore, the additives of nano-sized solid lubricants to the based cutting oils have been studied to prove that heat transfer is improved and the friction coefficient in the cutting zone is reduced. Numerous types of nanoparticles exhibited diverse morphologies such as spherical shape (Al_2O_3, TiO_2, hBN, and so on), thin sheets (MoS_2, graphite, graphene, etc.), and cylindrical structures (MWCNTs), and so forth. The presence of nanoparticles in cutting zone contributes to reduce friction and enhance machining efficiency [6]. Moreover, the nanoparticles with high thermal conductivity, like MoS_2 and Al_2O_3, contribute to enhance the heat transfer capabilities of the based cutting oils [7]. Consequently, it leads to a reduction in cutting heat and cutting forces. Notably, these nanoparticles typically offer long-term stability, negligible flow hindrance, and minimal pressure drop compared to the particles of millimeter and micrometer scales. An extensive study has been conducted to evaluate the effects of nanoparticles enriched in cutting oils. Sen et al. [8] provided a comprehensive review in 2019 on the utilization of nanoparticles dispersed in minimum quantity lubrication (MQL) base fluids as an effective means of friction reduction in machining processes. Furthermore, the investigations have underscored the suitability of Al_2O_3 nanofluids as the lubricants in cutting processes. Rapeti et al. [9] investigated the machining process of AISI 1040 steel employing sesame oil and canola oil containing the different concentration of MoS_2 nanosheets. Their findings indicated that the addition of MoS_2 nanoparticles enhances the machining efficiency. Also, the coconut oil with 0.5% MoS_2 nanoparticles demonstrates superior machining performance. Eltaggaz et al. conducted a comparative analysis of 4 wt% Al_2O_3 nanoparticles suspended in vegetable oil with pure oil under MQL hard cutting process [10]. The obtained results indicate that the MQL method using nanofluid improved the machining productivity. Hegab et al. formulated 2wt% Al_2O_3 nano cutting oil and 4wt% multi-walled carbon nanotubes (MWCNTs) and evaluated their impact on the machining performance of Inconel 718 [11]. The authors claimed that nanofluids outperformed the base cutting fluid. Vasu and Redy machined Inconel 600 under different cooling/lubrication conditions (dry, MQL, and Al_2O_3 nanofluid MQL) to evaluate their effects on tool wear and cutting force [12]. The results indicated a noticeable reduction in cutting force and tool wear in case of using nanofluid MQL. Additionally, Elansezhian et al. [13] explored the effects of SAE20W40 cutting oil with Al_2O_3, ZnO, and SiO nanoparticles in different weight ratios. The authors concluded that 1.0wt% Al_2O_3 nano cutting oil exhibits the best performance compared to other nanofluids. Gupta et al. [14] demonstrated that MoS_2 and graphite nanofluids bring out the promising results at high cutting speeds, but graphite nanofluids outperform in terms of lubrication and cooling properties, thereby enhancing the machining efficiency of Inconel 800 alloy. Zhang et al. [15] reported that MoS_2 nanofluid MQL produces the very good lubricating performance, due to the high saturated fatty acid content and high film-forming ability of carboxyl groups in palm oil. Also, with the increase of MoS_2 nano concentration in vegetable oils, the viscosity of the nanofluid increased, leading to improve the lubricating property. Gupta and Korkmaz enriched the hexagonal boron nitride (hBN) nanoparticles in MQL based oil for turning process of Bohler K490 steel [16]. The improvement in sustainability and machining performance was reported by using nano-MQL environment. Also, the hBN-enriched nanofluids effectively contribute to reduce the tool wear by up to 26.9% when compared to dry and pure MQL conditions. Similar findings were noted in the study on turning performance of stainless steel 304 under MQL environment using hBN nano particles [17]. The authors also noted the enhancement of machined surface quality in the case of hBN nanofluid MQL compared to dry and flood coolant. Wang et al. [18] reviewed vegetable oil-based nanofluid minimum quantity lubrication utilized in turning process. The comprehensive study was made on the main parameters of nanofluid including the vegetable-based oil, different types of nanoparticles, and preparation of nanofluid. The main lubricating mechanism was deeply pointed out for each type of nanoparticles commonly used and how they interact in the contact zone. The obtained findings revealed that the vegetable oils are suitable for formulating nanofluids and sustainable machining. The discussion all agreed that the application of vegetable oil-based MQL technique improved the cutting performance. Moreover, Madanirad et al. [19] concluded the close relation between the size of nanoparticles and their concentration. The increase in the contact angle goes with the smaller grain size of nanoparticles, but the opposite trend was reported with the larger ones, leading to the steady formation of thin oil film [8]. Cheraghian found that the rheological characteristics of the drilling fluid were improved in the additives of nano particles [20].

Through the literature review, it was reported that Al_2O_3 nano cutting oil in MQL provides better machining performance compared to dry, flood coolant, and MQL with pure oil [21]. However, the studies on the technological parameters of MQL method using Al_2O_3 nano cutting oil are limited. Therefore, the authors are motivated to investigate the influence of Al_2O_3 nanofluid MQL including nanoparticle concentration, air pressure and air flow rate on the thrust cutting force in hard turning of 90CrSi steel using CBN tools.

2. MATERIAL AND METHOD

Hard turning experiments were performed on CS-460x1000 Chu Shing lathe machine (Pin Shin Machinery Company). 90CrSi steel samples were hardened to 60–62 HRC. Table 1 shows the chemical composition of 90CrSi steel. The hard cutting trials were performed under Al_2O_3 nanofluid MQL condition with different nanoparticle concentrations, air pressure, and air flow rate to investigate their effects on the thrust cutting force. The diagram of the experimental model is shown in Figure1.

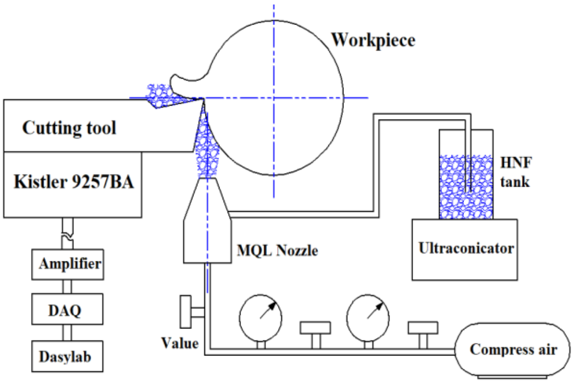


Figure 1. *Diagram of the experimental set up*

CBN cutting inserts can provide good shock resistance and very high wear resistance and have been widely applied for machining hardened steel, sintered metals and high temperature alloys. Accordingly, the CBN inserts (CCGW09T308S01020H) made by Sandvik were used in this work for hard turning of 90CrSi steel (60-62HRC) (Figure 2). The specifications of CBN tools are given in Table 2. Based on the manufacturer's recommendations and the previous work [22], the cutting parameters were chosen and fixed at V=160m/min, f = 0.12 mm/rev, a_p = 0.12mm.

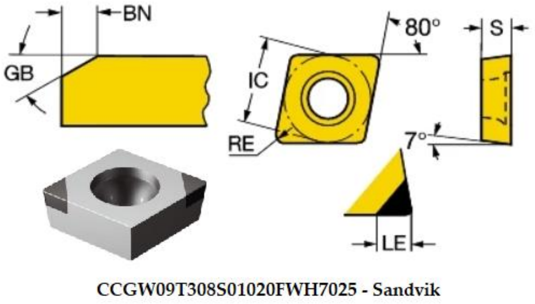


Figure 2. *CBN inserts*

Table 1. *Chemical composition in wt% of 90CrSi steel*

C	Si	Mn	Ni	S	P	Cr	Mo	W	V	Ti	Cu
0.85–0.95	1.20–1.60	0.30–0.60	Max 0.40	Max 0.03	Max 0.03	0.95–1.25	Max 0.20	Max 0.20	Max 0.15	Max 0.03	Max 0.3

Table 2. *Technical specifications of CBN inserts*

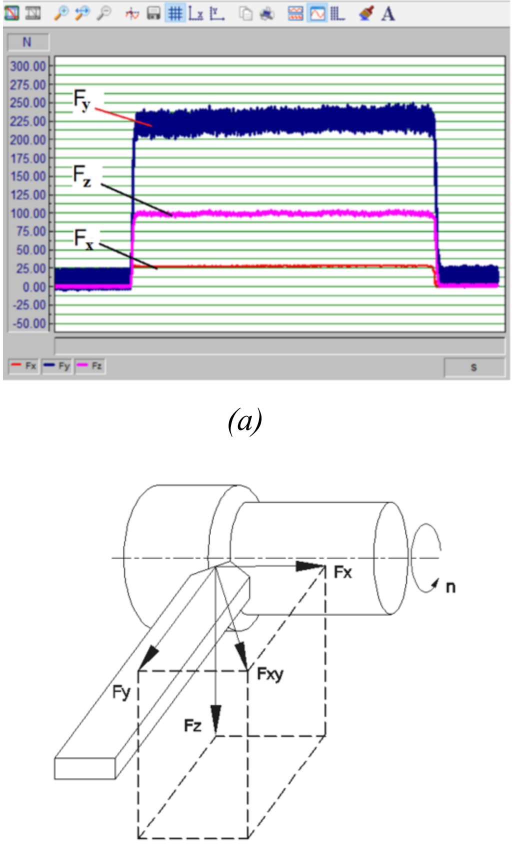
Shape	Available corners	Nose R (mm)	s (Chip thickness)(mm)	Material type	Tip relief angle(°)	Negative land angle(°)	Negative land width(mm)
C (80° Diamond-Shape)	2	0.8	3.97	7025	7	20	0.1

Table 3. *Surveyed parameters and their levels*

No.	Parameters	Symbols	Low	High
1	Nanoparticle concentration (%)	NC	0.5	1.5
2	Air pressure (Bar)	P	4	6
3	Air flow rate (L/min)	Q	150	250

The NOGA MiniCool MC1700 MQL nozzle was set up to directly spray the flank face of CBN cutting tool. Gamma-aluminum oxide (Al_2O_3) nanoparticles with the purity 99.5+% and grain size of 30 nm were enriched to the vegetable-based cutting oil. Al_2O_3 nano cutting oil with three different concentrations (0.5%, 1.0%, and 1.5%) was formulated by using the Ultrasons-HD ultrasonic homogenizer (JP Selecta, Abrera (Barcelona), Spain) in one hour at 40 kHz frequency and 600 W maximum power to obtain a homogeneous mixture. The investigated parameters including nanoparticle concentration (NC), air pressure (p), and air flow rate (Q) and their levels were summarized in Table 3.

Three components of cutting forces (F_x, F_y, F_z) were directly measured by 9257BA Kistler dynamometer (Germany) connected to A/D data collection and DQA N16210 data acquisition system. The measurement signals of cutting forces were processed by Dasylab 10.0 software and the obtained results are illustrated in Figure 3. It can be observed that the cutting force F_y (thrust force) has the largest value among three components, which is consistent with the study on cutting force during hard turning [1]. Moreover, it causes the greatest influence on machined surface quality and has the tight relation with flank wear [23].



(a)

(b)

Figure 3. *(a) Measured cutting force components, (b) The force designation during hard turning*

Box-Behnken experimental design with the help of Minitab 19 software was used to investigate the effects of nanoparticle concentration (NC), air pressure (p) and air flow rate (Q) on the thrust force in hard turning process (Table 4). The cutting trials were carried out by following the experimental matrix shown in Table 4.

3. RESULTS AND DISCUSSION

ANOVA analysis for the data set of the thrust force was performed to observe the relationship between the objective function F_y and NF MQL parameters and build a regression model for predicting F_y. The results of ANOVA analysis with the significance level $\alpha = 5\%$ (95% confidence level) for F_y are shown in Table 5. Based on the measured data of F_y values, the experimental model is suitable and statistically significant.

The influence level of investigated factors is shown on the Pareto chart (Figure 4) and evaluated through the standard influence coefficient (standardized effect). The air pressure is found to be the most significant factor while nanoparticle concentration and air flow rate cause little effects on thrust cutting force F_y. The interactions between nanoparticle concentration and air flow rate (NC*Q) and between air pressure and air flow rate (p*Q) also exhibit the significant influences.

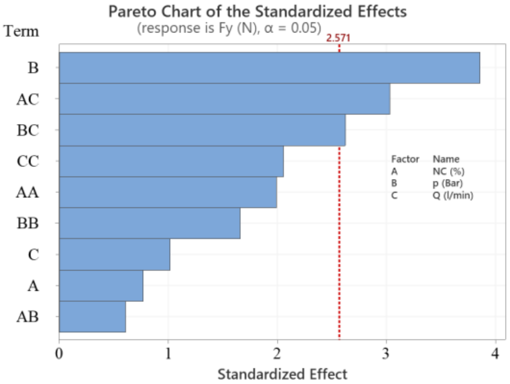


Figure 4. *Pareto chart of the standardized effects of investigated factors on thrust force F_y*

Table 4. *Experimental matrix and measured results*

StdOrder	RunOrder	PtType	NC (%)	p (Bar)	Q (L/min)	F_y (N)
7	1	2	0.5	5	250	170.98
13	2	0	1	5	200	109.89
4	3	2	1.5	6	200	266.77
15	4	0	1	5	200	118.87
5	5	2	0.5	5	150	280.77
10	6	2	1	6	150	213.28
8	7	2	1.5	5	250	236.75
14	8	0	1	5	200	187.95
1	9	2	0.5	4	200	156.97
9	10	2	1	4	150	230.61
11	11	2	1	4	250	105.63
3	12	2	0.5	6	200	247.96
6	13	2	1.5	5	150	145.91
2	14	2	1.5	4	200	135.37
12	15	2	1	6	250	261.98

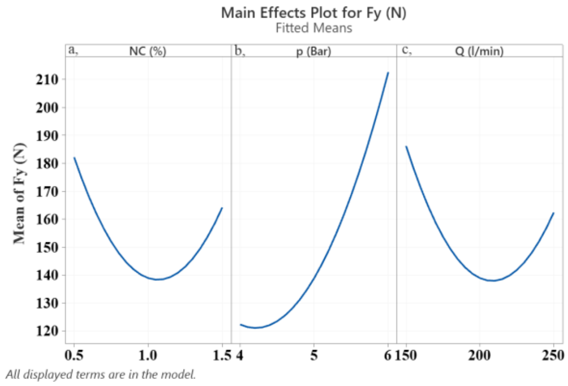
Table 5. *Results of ANOVA analysis for the thrust force F_y*

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	46527	5169.7	4.72	0.051
Linear	3	18106.6	6035.5	5.51	0.048
NC (%)	1	645.8	645.8	0.59	0.477
p (bar)	1	16327.1	16327.1	14.9	0.012
Q (L/min)	1	1133.6	1133.6	1.03	0.356
Square	3	10407.9	3469.3	3.17	0.123
NC (%)*NC (%)	1	4342.9	4342.9	3.96	0.103
p (bar)*p (bar)	1	3013.5	3013.5	2.75	0.158
Q (L/min)*Q (L/min)	1	4627.9	4627.9	4.22	0.095
2-Way Interaction	3	18012.5	6004.2	5.48	0.049
NC (%)*p (bar)	1	408.2	408.2	0.37	0.568
NC (%)*Q (L/min)	1	10063.1	10063.1	9.19	0.029
p (bar)*Q (L/min)	1	7541.2	7541.2	6.88	0.047
Error	5	5477.8	1095.6		
Lack-of-Fit	3	1829.1	609.7	0.33	0.807
Pure Error	2	3648.7	1824.3		
Total	14	52004.8			

The regression model of thrust force F_y is given in Equation 1 with $R^2 = 89.47\%$, proving that the experimental model well fits with the experimental data.

$$F_y(N)=2767-795NC-434p-12.25Q+137.2NC*NC+28.6p*p+0.01416Q*Q+20.2NC*p+2.006NC*Q+0.868p*Q \quad (1)$$

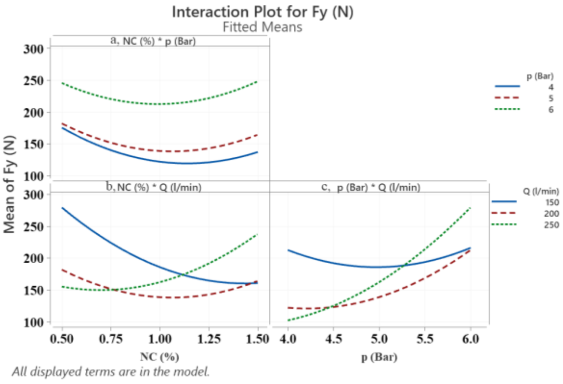
The cutting force F_y is the largest among three components in the hard turning process, and greatly affects dimensional accuracy and machined surface quality. The increase of F_y indicates that the friction generated between the tool flank face and the machined surface is large. Therefore, it is important to study the effect of NF MQL parameters on the thrust force. The helpful guides will be provided in selecting the technology conditions in the manufacturing industry. The influences of NF MQL parameters on the thrust force are shown in Figure 5. In Figure 5a, the average thrust force values decrease when increasing the nanoparticle concentration from 0.5% to 1.1%, but they tend to gradually go up as the nanoparticle concentration (NC) reaches to 1.5%. It can be explained that Al_2O_3 nanoparticles have high hardness and the nearly spherical structure, so they will act as "ball rollers" on the friction contact surface [24]. Hence, at reasonable concentrations, they can effectively reduce cutting forces [25]. However, the high level of Al_2O_3 nanoparticle concentration leads to collision and agglomeration of nanoparticles, causing the growth of cutting forces [26]. It is also clearly shown in the interaction graph between Q and NC (Figure 6b).



All displayed terms are in the model.

Figure 5. *Main effects of input parameters on the thrust force F_y*

From Figure 5b, it can be seen that the air pressure greatly affects the thrust force F_y. When air pressure increases from 4 to 5 bar, F_y values rise slightly but climb up as air pressure reaches to 6 bar. The influence of air pressure p is also clearly shown in the interaction diagram in Figure 6a, F_y values at p=4-5 bar are much smaller than those at p= 6 bar. In addition, the interaction p*Q also greatly affects F_y. In Figure 5c, the air flow rate also causes the significant effect on F_y. When air flow rate is about 200 L/min, F_y reaches the smallest value. This can be explained that the initial growth of Q contributes to increase the amount of nano cutting oil in the cutting zone, decreasing cutting heat and friction, resulting in the reduction of cutting force. However, when the amount of nano cutting oil is large enough, a large number of Al_2O_3 nanoparticles appear in the cutting zone, which leads to clustering and increases cutting force [27]. In addition, the interaction between air pressure and air flow rate also greatly affects the cutting force value (Figure 6c). When Q is small, the air pressure has little effect on F_y, but with the large air flow, the small values of air pressure should be used to help reduce cutting force.

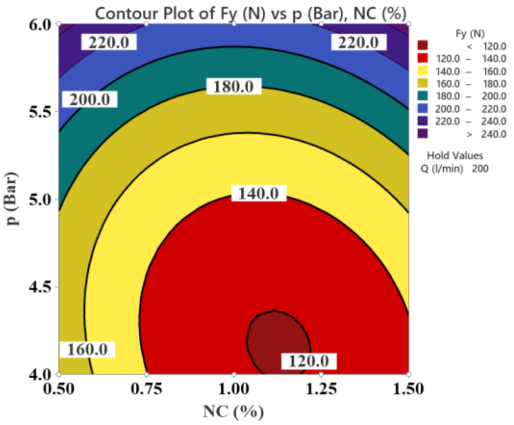


All displayed terms are in the model.

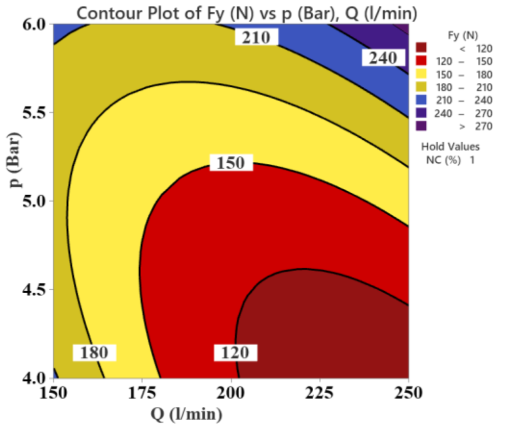
Figure 6. *Interaction plots of effects of investigated factors on thrust force F_y*

The interactive influences of two factors on the objective function are shown on the contour charts in Figure 7. The contour charts help to predict and choose the reasonable ranges of the input parameters for lower cutting force F_y values. In Figure 7a, for Q= 200 L/min, nanoparticle concentration NC=1.1% and air pressure p= 4.0 bar should be used for the smaller cutting force F_y (<120N). From Figure 7b with the nanoparticle concentration NC=

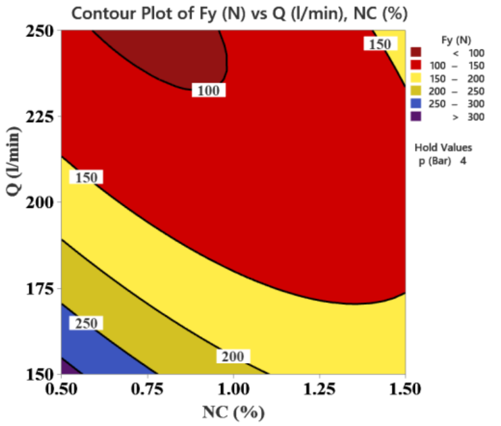
1.0%, F_y is less than 120N with air pressure in the range of 4.0÷4.5 bar and air flow rate of about 200-250 L/min. From Figure 7c, in order to achieve smaller F_y (<100N), nanoparticle concentration of about 0.9% and air flow rate of about 240-250 L/min should be suggested.



*(a) p*NC with Q=200 L/min*



*(b) p*Q with NC=1%*



*(c) Q*NC with p=4 bar*

Figure 7. *Contour plots of influences of input factors on the cutting force F_y*

The optimization result for F_y is shown in Figure 8. The thrust force F_y reaches the smallest value at about 95.34N with nanoparticle concentration NC= 0.8%, air pressure p=4 bar, and air flow rate Q=250 L/min.

4. CONCLUSION

In this work, the effects of Al_2O_3 NF MQL parameters on thrust cutting force F_y in hard turning of 90CrSi steel using CBN inserts were studied. The impacts of nanoparticle concentration, pressure, and air flow rate were investigated by using the Box-Behnken experimental design and ANOVA analysis. The results are summarized as follows:

- The thrust cutting force is significantly influenced by air pressure, and the interactions NC*Q (nanoparticle concentration and air flow rate) and p*Q (air pressure and air flow rate).
- The variation in air flow rate and nanoparticle concentration leads to distinct effects on F_y.
- Based on the optimization result, the minimum value for thrust cutting force F_y is attained at nanoparticle concentration of 0.8%, air pressure of 4 bar, and air flow rate of 250 L/min.

In future work, more investigations should be focused on the tool wear, tool life, and lubricating mechanism of Al_2O_3 nano cutting oil.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest

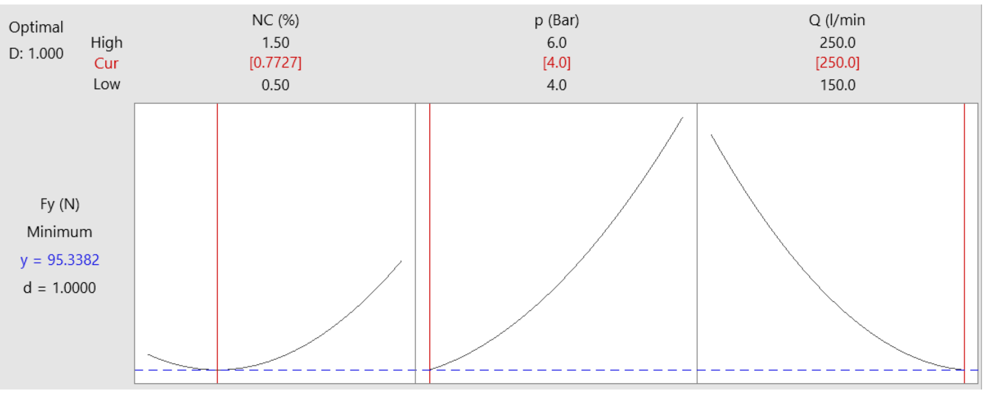

Figure 8. *Optimization result for the thrust force F_y*

REFERENCES

1. Davim, J. P., "Machining of Hard Metals", *Springer-Verlag London Limited,* (2011), https://doi.org/10.1007/978-1-84996-450-0.
2. Čep, R., Neslušan, M., Barišić, B., "Chip formation analysis during hard turning", *Strojarstvo*, 50(6) (2008) 337- 345.
3. Milutinović, M., Tanović, L., "Cutting forces in hard turning comprising tool flank wear and its implication for the friction between tool and workpiece", *Tehnički vjesnik,* 23(5) (2016) 1373-1379, doi:10.17559/TV-20140903224947.
4. Pereira, O., Martín-Alfonso, J., Rodríguez, A., Calleja-Ochoa, A., Fernández-Valdivielso, A., de Lacalle, L.L., "Sustainability analysis of lubricant oils for minimum quantity lubrication based on their tribo-rheological performance", *J. Clean. Prod.*, 164 (2017) 1419–1429, doi:10.1016/j.jclepro.2017.07.078.
5. He, T., Liu, H., Xia, H., Wu, L., Zhang, Y., Li, D., Chen, Y., "Progress and trend of minimum quantity lubrication (MQL): A comprehensive review", *Journal of Cleaner Production*, 386(1) (2023), https://doi.org/10.1016/j.jclepro.2022.135809.
6. Junankar, A. A., Parate, S. R., Dethe, P. K., Dhote, N. R., Gadkar, D. G., Gadkar, D. D., Gajbhiye, S. A., "A Review: Enhancement of turning process performance by effective utilization of hybrid nanofluid and MQL", *Materialstoday: Proceedings*, 38(1) (2021) 44-47.
7. Ali, S. H., Yao, Y., Wu, B., Zhao, B., Ding, W., Jamil, M., Khan, A., Baig, A., Liu, Q., Xu, D., "Recent developments in MQL machining of aeronautical materials: A comparative review", *Chinese Journal of Aeronautics*, 38(1) (2025) 102918, https://doi.org/10.1016/j.cja.2024.01.018.
8. Sen, B., Mia, M., Krolczyk, G. M., Mandal, U. K., Mondal, S. P., "Eco-friendly cutting fluids in minimum quantity lubrication assisted machining: A review on the perception of sustainable manufacturing", *Int. J. Precis. Eng. Manuf. Technol.*, 8 (2021) 249-280, http://dx.doi.org/10.1007/s40684-019-00158-6.
9. Rapeti, P., Pasam, V. K., Gurram, K. M. R., Revuru, R. S., "Performance evaluation of vegetable oil based nano cutting fluids in machining using grey relational analysis-A step towards sustainable manufacturing", *J. Clean. Prod.*, 172 (2016) 2862-75, http://dx.doi.org/10.1016/j.jclepro.2017.11.127.
10. Eltaggaz, A., Hegab, H., Deiab, I., Kishawy, H. A., "Hybrid nano-fluid-minimum quantity lubrication strategy for machining austempered ductile iron (ADI)", *Int. J. Interact. Des. Manuf.*, 12 (2018) 1273-1281, http://dx.doi.org/10.1007/s12008-018-0491-7.
11. Hegab, H., Umer, U., Soliman, M., Kishawy, H. A., "Effects of nano-cutting fluids on tool performance and chip morphology during machining Inconel 718", *Int. J. Adv. Manuf. Technol.*, 96 (2018) 3449-58, http://dx.doi.org/10.1007/s00170-018-1825-0.
12. Vasu, V., Reddy, P. K. G., "Effect of minimum quantity lubrication with Al_2O_3 nanoparticles on surface roughness, tool wear and temperature dissipation in machining Inconel 600 alloy", *Proc. Inst. Mech. Eng. N. J. Nanoeng. Nanosyst.*, 225 (2011) 3-16, http://dx.doi.org/10.1177/17403499 11427520.
13. Anburaj, R., Elansezhian, R., "Investigation on influence of nano fluid in machining of inconel 718", *Asia. Pacific. J. Res.*, 1 (2016) 154-60.
14. Gupta, M. K., Jamil, M., Wang, X. J., Song, Q. H., Liu, Z. Q., Mia, M., Hegab, H., Hegab, H., Khan, A. M., Collado, A. G., Pruncu, C. I., and Imran, G. M. S., "Performance evaluation of vegetable oil-based nano-cutting fluids in environmentally friendly machining of Inconel-800 alloy", *Materials*, 12(17) (2019) 2792, doi.org/10.3390/ma12172792.
15. Zhang, Y., Li, C., Jia, D., Zhang, D., Zhang, X., "Experimental evaluation of MoS_2 nanoparticles in jet MQL grinding with different types of vegetable oil as base oil", *Journal of Cleaner Production*, 87 (2015) 930-940, doi: 10.1016/j.jclepro.2014.10.027.

16. Gupta, M. K., Korkmaz, M. E., “A conceptual framework for sustainability impact assessment in machining bohler tool steel under hBN-enriched nano cutting fluids environment”, *Sustainable Materials and Technologies*, 37 (2023), https://doi.org/10.1016/j.susmat.2023.e00669.
17. Prasanth, P., Sekar, T., Vijay, M., “Experimental investigation on CNC turning of SS304 using nano particle based minimum quantity lubrication”, *Materials Today: Proceedings*, (2023), https://doi.org/10.1016/j.matpr.2023.01.089.
18. Wang, X., Li, C., Zhang, Y., Ding, W., Yang, M., Gao, T., Cao, H., Xu, X., Wang, D., Said, Z., Debnath, S., Jamil, M., Ali, H. M., “Vegetable oil-based nanofluid minimum quantity lubrication turning: Academic review and perspectives”, *Journal of Manufacturing Processes*, 59 (2020) 76–97, doi:10.1016/j.jmapro.2020.09.044.
19. Madanirad, Z., Akbari, M., Shariaty-Niassar, M., Abadi, K. A. V., “Effects of Graphene Oxide Size on PES Ultrafiltration Hydrophilicity and Pure Water Flux”, *International Journal of Nanoscience and Nanotechnology*, 19(2) (2023) 121-134, doi: 10.22034/ijnn.2023.2001625.2372.
20. Cheraghian, G., “Application of Nano-Particles of Clay to Improve Drilling Fluid”, *International Journal of Nanoscience and Nanotechnology*, 13(2) (2017) 177-186.
21. Günan, F., Kıvak, T., Yıldırım, Ç. V., Sarıkaya, M., “Performance evaluation of MQL with Al_2O_3 mixed nanofluids prepared at different concentrations in milling of Hastelloy C276 alloy”, *J. Mater. Res. Technol.*, 9 (2020) 10386-10400, https://doi.org/10.1016/j.jmrt.2020.07.018.
22. Ngoc, T. B., Duc, T. M., Tuan, N. M., Long, T. T., “Influence of Al_2O_3/MoS_2 hybrid nanofluid MQL on surface roughness, cutting force, tool wear and tool life in hard turning”, *Forces in Mechanics*, 16(2024) 100285, https://doi.org/10.1016/j.finmec.2024.100285.
23. Klocke, F., “*[RWTH edition] Manufacturing Processes 1”*, *Springer-Verlag Berlin Heidelberg,* (2011), e-ISBN 978-3-642-11979-8, doi:10.1007/978-3-642-11979-8.
24. Sharma, A. K., Tiwari, A. K., Dixit, A. R., “Mechanism of Nanoparticles Functioning and Effects in Machining Processes: A Review”, *Materials Today: Proceedings*, 2(4-5) (2015) 3539-3544, doi:10.1016/j.matpr.2015.07.331.
25. Luo, T., Wei, X., Huang, X., Huang, L., Yang, F., “Tribological properties of Al_2O_3 nanoparticles as lubricating oil additives”, *Ceramics International*, 40(5) (2014) 7143–7149, doi:10.1016/j.ceramint.2013.12.05.
26. Duc, T. M., Long, T. T., Dong, P. Q., “Effect of the alumina nanofluid concentration on minimum quantity lubrication hard machining for sustainable production”, *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, 233(17) (2019) 5977-5988, doi:10.1177/0954406219861992.
27. Duc, T. M., Tuan, N. M., Long, T. T., Ngoc, T. B., “Machining feasibility and Sustainability study associated with air pressure, air flow rate, and nanoparticle concentration in Nanofluid minimum quantity lubrication-assisted hard milling process of 60Si2Mn steel”, *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, 236(23) (2022) 11256-11269, doi:10.1177/09544062221111253.