

STUDY THE EFFECTS OF THE MULTINITE COAT OF THE HIGH SPEED STEEL DRILL BIT IN DRILLING

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Abstract

Drilling is an important metal manufacturing processes. Drill bits are used in drilling to create holes. Wear of drill bits can have an adverse effect on the quality of the drilling hole. To increase the wear resistance of drill bits, surface modifications have been introduced and studied their effectiveness. Multinite coating is a candidate for surface modification techniques to increase wear resistance of the drill bits. In this study, the effect of multinite coating on the wear resistance of drill bits has been investigated. Two types of 6 mm diameters drill bits, the uncoated high speed steel, and the multinite coated high speed steel drill bits, were used to create the hole with 30 mm in depth on ASTM A36 steel. The drilling parameters were 1,100 rpm of rotation speed and 135 mm/min of the feed rate. The thrust force and the cutting torque during drilling were measured by a force sensor. Flank wear on the drill bits were measured by overlap image technique. Also, the roughness of hole surfaces were investigated. Results showed that the higher surface hardness of multinite coated high speed steel drill bit led to a lower flank wear rate at the beginning of drilling. Consequently, built-up of chip on the multinite coated high speed steel drill bit was less compared to the uncoated one. We conclude that the higher surface hardness of multinite coated high speed steel drill bit improves the wear resistance of drill bit by a decrease of wear rate at the beginning of drilling and a lesser amount of chip built-up on the cutting edge and the surface quality of hole after drilling.

Keywords: Cutting tools, flank wear, thrust force, tool life, torque force, wear

Introduction

The drill bits are essential tools used to create the holes on the parts. They must have high machinability in order to perform the drilling process with the good hole quality requirements. During drilling the drill bits are encountered with the tool wears such as flank wear, crater wear,

margin wear and chisel wear. Flank wear is the most critical wear found in drill bits and is used to define the tool life. Flank wear is caused by the abrasive action between drill bit and chip. Thus, in order to increase the tool wear resistance, the drill bit must exhibits higher surface hardness, low friction

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Table 1. The characters of the drill bit

	Drill bits	
	Multinite Drills	Uncoated Drills
Surface hardness (HV0.1)	1,147.83	722.33
Diameter (mm)	6.49	6.08
Helix angle (degree)	31.5	31.5
Point angle per Teeth (degree)	58.8	59.2
Relief angle (degree)	15	15
Flute width (front), (mm)	4	3.83
Flute width (back), (mm)	3.8	3.59
Run Out (mm)	0.02	0.04
R-Point angle (mm)	4.3	4.66

coefficient, and good toughness. To improve those properties, the coating has been proposed and studied. For example, Harris *et al.* (2003) investigated the using of TiN, Ti1-xAlxN and two relatively high chromium content Ti1-x-yAlxCrN coated drill bits and Braic *et al.* (2010) studied the using of multilayer PVD coated drill bits. They showed that the coating on the drill bits with physical vapor deposition (PVD) both single layer coating and multilayer coating can increase drill bits tool life. However, the physical vapor deposition (PVD) coating process is an expensive process. Thus, the other alternative techniques that can improve wear resistance of drill bits still have been proposed and investigated. Multinite process, a kind of gas sulphur nitriding process, is one of the candidate of alternative techniques to improve wear resistance of drill bits made by high speed steel. The multinite process provides the several outstanding properties for tools such as (1) low friction, (2) improve wear resistance, (3) improve resistance to fatigue, and (4) prevent friction noise, etc. Momose, and Uchida (1987) studied the wear resistance of steel coated by gas-sulphur nitriding process. They found that using gas-sulphur nitriding process can reduce the wear rate of steel compared to that of uncoated steel. However, there are no further research works that have been done to study the feasibility of using the multinite coat to improve wear resistance of drill bits. Therefore, in this study, the effects of multinite coat on wear of the high speed steel drill bit and the hole surface quality was investigated.

Materials and Methods

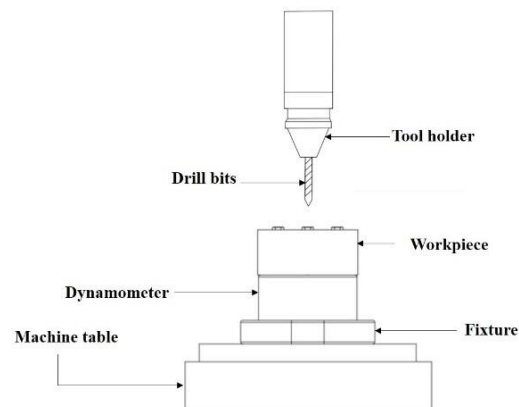
In this study, the high speed steel drill bits made by Nachi Technology Co., Ltd were used. Two types of the high speed steel drill bits were defined into two lots. One was treated by multinite process at Nihon Techno Heat Treatment, Rayong, Thailand. The other was kept as the original high speed steel drill bit.

Then, surface hardness, drill bit diameter, helix angle, point angle per teeth, relief angle, flute width, run out, and radius of point angle of the drill bits were characterized. The surface hardness of both types of drill bits were tested with Future-Tech FM-800 micro-vickers hardness tester. The characteristics of the drill bit are shown in Table 1.

After that, both types of drill bits 1) multinite coated high speed steel drills, 2) uncoated high speed steel drills, were used to drill the ASTM A36 steel of 100 mm diameters and 50 mm of thickness. The drilling machine used in the study was 5-axis DMG Mori DMU-50. The drilling conditions are shown in Table 2.

Table 2. The drilling conditions used in the study

Parameters	Value
Rotation speed (rpm)	1,100
Feed rate (mm/min)	135
Hole depth (mm)	30
Numbers of total holes	120

**Figure 1. Experimental set-up for drilling**

During the drilling, thrust force and torque were measured by Kistler 4-component dynamometer (model:9272). The schematic of dynamometer and workpiece setting is shown in Figure 1. After drilling every 10 holes, wear of the drill bit was observed visually and measured by imaging technique using Olympus SZ61 stereo microscope with C-P3 OPTIKA digital camera. Figure 2 shows the example of drill bit image for wear measurement. The overlap image technique to measure the wear as shown in Figure 3 is same as used in works of Abu-Mahfouz (2003) and Zakeri Mehrabad and Pourmostaghimi (2017) by using the comparison between the wear image before drilling and after drilling of the drill bits.

After drilling, the workpiece was cut as shown the schematic of cutting in Figures 4(a) and 4(b), in

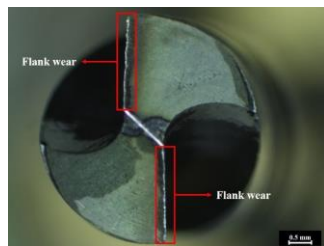


Figure 2. The example of wear image views

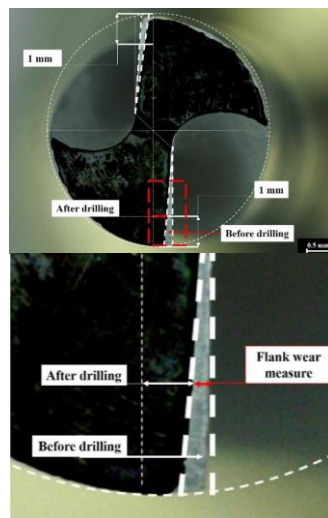


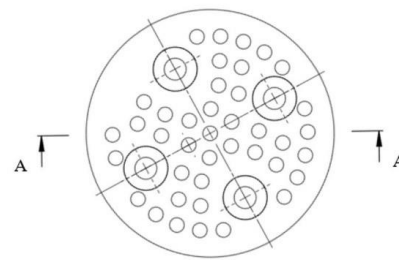
Figure 3. Diagram of wear measurements by overlap image technique

order to measure the surface roughness of the hole surface. The surface roughness testing was performed under ISO1997 with SJ-210 Mitutoyo Surface Roughness Tester.

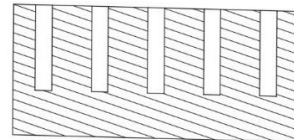
Results and Discussion

Drill Bit Observation

Figure 5 is a set of high magnification front view images of the multinitide coated high speed steel drill bit as in Figure 5(a) and the uncoated high speed steel drill bit as in Figure 5(b) taken before and after drilling with 20, 50, and 120 holes. The cutting edges of the coated and uncoated drill bits were changed from the straight line to jagged line at the beginning of using drill bit. After drilling for 20 holes, the loss of tool material at cutting edge of drill bit was found significantly. Also, the loss of the materials at cutting edge increased with number of drilling holes. Such loss at the cutting edge is known as the flank wear. By comparing between the multinitide coated high speed steel drill bit in Figure 5(a) and uncoated high speed steel drill bit in



(a) Top view of workpiece



(b) A-A section view of workpiece

Figure 4. The schematic of cutting workpiece

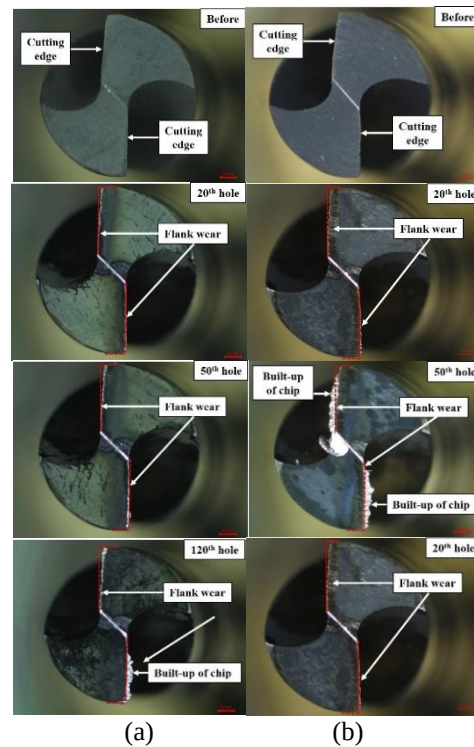


Figure 5. The front view images of the drill bit taken before using and after using with 20, 50, and 120 drilling holes at (a) multinitide coated high speed steel drills and (b) uncoated high speed steel drills

Figure 5(b), it was found that the flank wear of the multinitide coated high speed steel drill bit was less than that of uncoated high speed steel drill bit when using for ASTM A36 steel drilling.

Figure 6 is a set of front view images of the drill bits, showing the built-up of chip at cutting

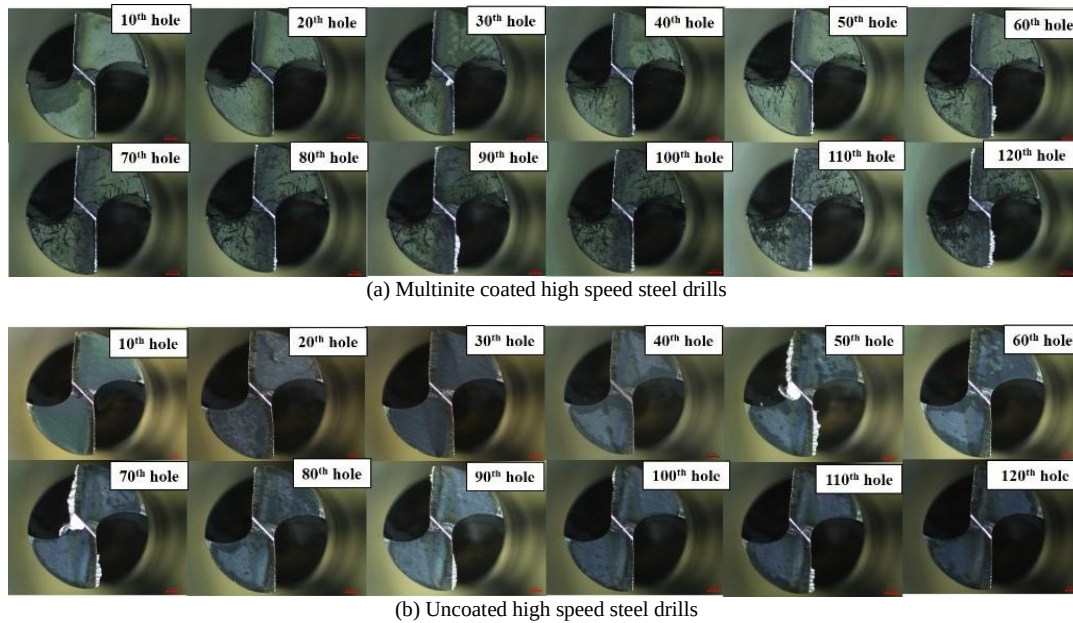


Figure 6. The built-up of chip at cutting edge of (a) multinite coated high speed steel drills and (b) uncoated high speed steel drills at various drilling progress

edge. It was found that the white layer stuck on the cutting edge of the drill bit. This white layer is the built-up of chip at cutting edge, observed the built-up of chip on cutting edge of multinite coated high speed steel drill bit as shown in Figure 6(a) and uncoated high speed steel drill bit as shown in Figure 6(b) after using drill bit for drilling at 50th hole. However, the multinite coated high speed steel drill bit exhibits less built-up of chip on the cutting edge compared to the uncoated high speed steel drill bit.

Wear Measurement

After drill bit observation, the image of drill bit was processed to determine the flank wear by using overlap image technique. The relationships between number of the drilled holes and the flank wear of both drill bits are shown in Figure 7. It was found that the flank wear of multinite coated high speed steel drill bit was lower than that of the uncoated high speed steel drill bit at the same number of drilling. Also, the flank wear curves can be divided into 3 stages according to the difference in the wear rate. At the first stage, the flank wear was progressed at almost constant high wear rate. After 20th drilling holes, drill bit was slightly worn at very close to zero wear rate and this is defined as the 2nd stage. Finally, the 3rd stage is defined after 50th-70th drilling holes. At this stage the flank wear rate increased. Comparing between coated and uncoated drill bits,

in first stage, the flank wear rate of uncoated high speed steel drill bit was higher than that of multinite coated high speed steel drill bit. For other stages, both drill bit types were worn at the similar wear rate. Moreover, the 2nd stage of wear of the multinite high speed steel drill bit was longer than that of uncoated high speed steel drill bit. Lower wear rate and longer of the 2nd stage in multinite high speed steel drill bit may be resulted by higher surface hardness of multinite high speed steel drill bit, similar to the results worked of by Nuclear-power, (2002); Luyckx and Love (2004) and Dhokey *et al.* (2021).

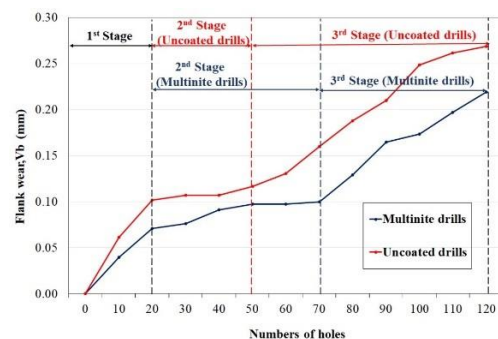


Figure 7. The flank wear of multinite coated high speed steel drills and uncoated high speed steel drills as a function of the number of holes

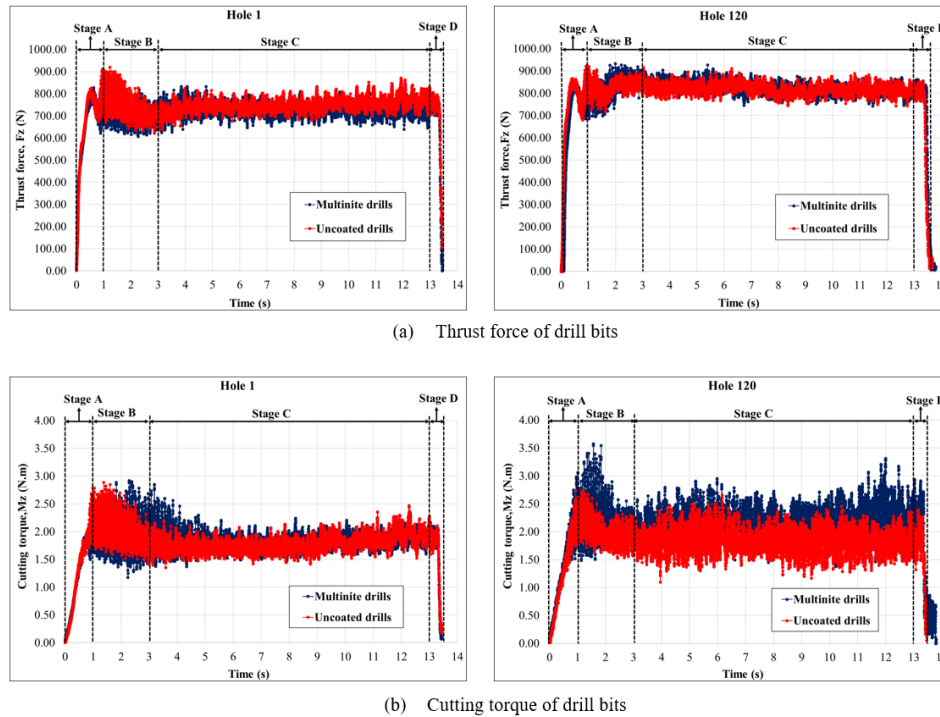


Figure 8. Thrust force and cutting torque of drill bits at 1st hole and 120th hole

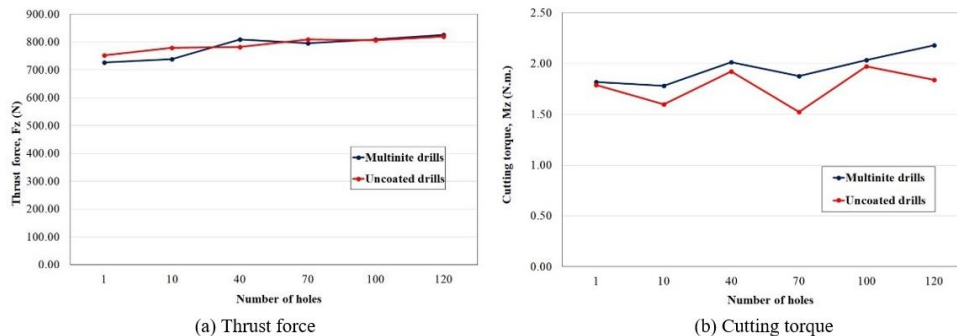


Figure 9. Average of (a) thrust force and (b) cutting torque at 3-13 sec

Thrust Force and Cutting Torque

The thrust force and the cutting torque during drilling 1st hole, and 120th hole were shown in Figures 8(a) and 8(b), respectively. The thrust force and the cutting torque were progressed in four main the stages. Firstly, in stage A, the thrust force and cutting torque were increased rapidly until maximum thrust force and cutting torque. It is occurred when the drill bits start to touch the workpiece surface until of the tip of drill bit was fully penetrated to workpiece. Secondly, in stage B, the thrust force and the cutting torque were decreased until reaching to the steady state of the thrust force and the cutting torque. Then, in stage C, the thrust force and cutting torque was constant until

the drill reaches the assigned drilling depth. Fourthly, in stage D, the thrust force and cutting torque was decreased rapidly due to moving out of the drill bits from the workpiece.

From the stages of forces, we are interested in stage C which was the steady state of drilling process. Thus, the average thrust force and cutting torque at 3-13 sec in various number of drilling holes were shown in Figure 9. From Figure 9(a), it was found that at the initial the thrust force of multinited coated high speed steel drills was lower than that of uncoated high speed steel drills. After 20th hole drilling, thrust force of the multinited coated high speed steel drills was similar to that of uncoated high speed steel drills. Moreover, from Figure 9(b),

it was found that the cutting torque of multinite coated high speed steel drills was slightly higher than that of uncoated high speed steel drills. The slightly lower thrust force of multinite coated high speed steel drill bit may be caused by higher hardness of multinite coated high speed steel drill bit. When the cutting edge and face of drill bit were changed, the thrust forces in both drill bits were changed to similar level. However, due to low friction of multinite coated high speed steel drill bit, the less cutting heat generation may be obtained (Stachowiak and Batchelor, 1993; Amiri and Michael, 2010). The less heat generation was recognized by slightly high cutting torque ever thought low built-up of chip found. The less heat generation may affect the loss of strength of workpiece which resulted in an easy to cut. Thus, the hardness of multinite coat may be important on wear resistance of high speed steel drill bit by reducing the wear rate at the beginning and decreasing built-up of chip in later stage of drilling process.

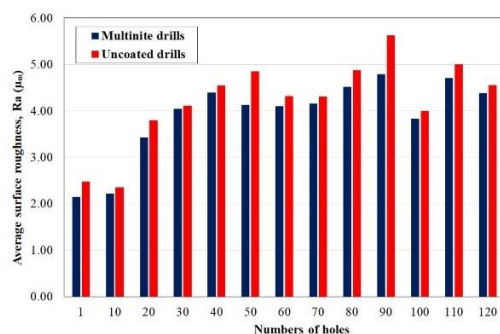


Figure 10. Average surface roughness of holes surface drilled by multinite coated and uncoated high speed steel drills at various number of hole drilling

Surface Roughness of Holes

In term of the hole quality, the surface roughness of the hole surface was measured. Figure 10 shows the hole surface roughness at various number of hole drilling by multinite coated high speed steel drill bit and uncoated high speed steel drill bit. It showed that drilling by the multinite coated high speed steel drill bit produced lower hole surface roughness than by the uncoated high speed steel drill bit.

Also, in first 20th drill holes, the surface roughness of drilled holes were significantly lower than that of drilling more holes. The lower of surface roughness of hole surface drilling by the multinite coated high speed steel drill bit may caused with higher hardness and lesser built up of chip in the

multinite coated high speed steel drill bit. Previous study Ramaswami (1971); Kümmel *et al.* (2015), and Oliaei and Karpat (2016) showed that the built-up of chips on the cutting edge is main cause of flank wear of cutting tools, and affected to the surface quality of the workpiece. Thus, in this study we refer that the multinite coating increases the surface hardness of drill bit and improve wear resistance as well as the quality of hole surface.

Conclusions

Higher surface hardness of multinite coated high speed steel drill bit reduces the flank wear rate at the beginning of drilling. Then, due to low wear on the drill bit in case of multinite coated high speed steel drill bit, built-up of chip on the drill bit was less compared to uncoated high speed steel drill bit. Thus, it was concluded that higher surface hardness of multinite coated high speed steel drill bit led to low wear rate on beginning of drilling and less built-up of chip on the cutting edge in later which affects to improves the wear resistance of drill bit and the surface quality of hole after drilling.

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References

- Abu-Mahfouz, I. (2003). Drilling wear detection and classification using vibration signals and artificial neural network. *International Journal of Machine Tools and Manufacture*, 43(7):707-720. [https://doi.org/10.1016/S0890-6955\(03\)00023-3](https://doi.org/10.1016/S0890-6955(03)00023-3).
- Amiri, M. and Khonsari, M.M. (2010). On the thermodynamics of friction and wear. *Entropy*, 12(5):1021-1049. <https://doi.org/10.3390/e12051021>.
- Braic, V., Zoita, C.N., Balaceanu, M., Kiss, A., Vladescu, A., Popescu, A., and Braic, M. (2010). TiAlN/TiAlZrN multilayered hard coatings for enhanced performance of HSS drilling tools. *Surface and Coatings Technology*, 204(12-13):1925-1928. <https://doi.org/10.1016/j.surfcoat.2009.08.011>.
- Dhokey, N.B., Maske, S.S., and Ghosh, P. (2021). Effect of tempering and cryogenic treatment on wear and mechanical properties of hot work tool steel (H13). *Materials Today: Proceedings*, 43(5):3006-3013. <https://doi.org/10.1016/j.matpr.2021.01.361>.
- Harris, S.G., Doyle, E.D., Vlasveld, A.C., Audy, J., and Quick, D. (2003). A study of the wear mechanisms of TiAlN and TiAlCrN coated high-speed steel twist drills under dry machining conditions. *Wear*, 254(7-8):723-734. [https://doi.org/10.1016/S0043-1648\(03\)00258-8](https://doi.org/10.1016/S0043-1648(03)00258-8).
- Kümmel, J., Braun, D., Gibmeier, J., Schneider, J., Greiner, C., Schulze, V., and Wanner, A. (2015). Study on micro texturing of uncoated cemented carbide cutting tools

- for wear improvement and built-up edge stabilization. *Journal of Materials Processing Technology.*, 215:62-70. <https://doi.org/10.1016/j.jmatprotec.2014.07.032>.
- Luyckx, S. and Love, A. (2004). The relationship between the abrasion resistance and the hardness of WC-Co alloys. *Journal of the Southern African Institute of Mining and Metallurgy*, 104(10):579-582.
- Momose, O. and Uchida, S. (1987). Gas sulphonitriding steels in a CS₂ and NH₃ atmosphere. *Wear*, 116(1):19-24. [https://doi.org/10.1016/0043-1648\(87\)90263-8](https://doi.org/10.1016/0043-1648(87)90263-8).
- Nuclear-power. (2002). Surface Hardness and Wear Resistance. US, United States: Nuclear-power. Available from: www.nuclear-power.com. Accessed date: Mar 28, 2022.
- Oliaei, S.N.B. and Karpas, Y. (2016). Investigating the influence of built-up edge on forces and surface roughness in micro scale orthogonal machining of titanium alloy Ti₆Al₄V. *Journal of Materials Processing Technology*, 235:28-40. <https://doi.org/10.1016/j.jmatprotec.2016.04.010>
- Ramaswami, R. (1971). The effect of built-up-edge (BUE) on the wear of cutting tools. *Wear.*, 18(1):1-10. [https://doi.org/10.1016/0043-1648\(71\)90059-7](https://doi.org/10.1016/0043-1648(71)90059-7).
- Stachowiak, G.W. and Batchelor, A.W. (1993). *Engineering Tribology*. 1st ed. Elsevier Science, Amsterdam, Netherlands, 871p.
- Zakeri Mehrabad, V. and Pourmostaghimi, V. (2017). Tool Wear Modeling in Drilling Process of AISI1020 and AISI8620 using Genetic Programming. *International Journal of Advanced Design and Manufacturing Technology*, 10(1):93-100.