JOURNAL OF SCIENTIFIC RESEARCH IN ALLIED SCIENCES
ISSN NO. 2455-5800
Contents available at: www.jusres.com

STUDY OF CHIPS AFTER DRY DRILLING OF 17-4PH STAINLESS STEEL WITH UNCOATED AND COATED SOLID CARBIDE DRILL BITS

Kamlesh Kumar Mandpe[1], Aruna Thakur[2], Sharda Pratap Shrivas[3]
1. M. Tech Scholar, Mechanical Engineering Department, CEC Bilaspur
2. Post Doc. Scholar, Mechanical Engineering Department, IIT Bombay
3. Asst. Prof. Mechanical Engineering Department, CEC Bilaspur

ARTICLE INFO | **ABSTRACT** | **ORIGINAL RESEARCH ARTICLE**

Article History
Received: Aug' 2018
Accepted: Sept' 2018
Keywords:
17-4 PH stainless steel; chip morphology; chip thickness; solid carbide drill bits.

Corresponding Author
*** Mandpe K. K.**

17-4 PH stainless steel is one of the most imperative type precipitation hardened alloy steel. It has excellent property of corrosion resistance and superb mechanical strength, due to this it is used in marine vessels. These properties make that it to be used in salt water applications, including it has many applications like in nuclear industries, paper industries, food processing equipment, turbine blade design and in oil and gas industry. In the current study, the process parameter is feed rate, spindle speed, and type of solid carbide drill bits. The comparison between the performance of uncoated and TiAlN coated solid carbide drill bits are discussed herein. Also studied surface roughness and Chip morphology has been examined thoroughly. The result indicated that side flow of chip of material increases with cutting speed that could be reduced by drilling with a coated drill bit. Also, chip thickness is also decreased with feed.

1. INTRODUCTION

17-4 PH stainless steel is a martensitic Precipitation Hardened stainless steel with a microstructure that is mainly austenitic at high annealing temperature but transforms to the martensitic structure when brought down to room temperature along with a high rate of cooling. This grade of PH stainless steel contains around 4% Nickel and 17% Chromium as its major constituent structure. Its high strength is maintained to approximately 360^0 C. The perfect combination of these properties tend it to be used in the manufacturing of chemical equipment, aircraft parts, petroleum instruments, nuclear reactor parts, food processing equipment, paper industries, turbine blade design, oil and gas industries etc. For considering deep hole drilling with large depth to diameter ratio over 10, drilling force increases significantly with depth due to the friction and pressure reaction between the continuing generated chips and the drill flutes including the hole wall. Generally deep hole drilling process, overlarge drilling depth will cause drill breakage due to the low rigidity of the deep-hole twist drill, while using too small drilling depth is inefficient [15]. A drilling burr formation mechanism was proposed and divided into four stages: initiation, development, pivoting point, and formation stages with cap formation. The burr thickness is largely determined by the distance between the pre-defined machined surface and the pivoting point, while the burr height is determined by the positions of the pivoting point and the cap formation [14]. The shearing of the chips in a thread of the blind hole presents a particular problem in the machining industry. The tap geometry plays an important role in the tool's durability, influencing the forces during the tapping process so that The tap durability was improved, the chip deposition on the rake surface was reduced and the torsion torque has a smaller value compared to the standard tap geometry [13]. Low values of tool life, increased cutting forces and the appearance of un-favorable tough chips are the main characteristics which rank these steels among the group of materials that are difficult to machine [11]. The new chip-breaking theory has been confirmed by vibration drilling experiments using aluminum and stainless steel [10].

The novelty of this paper is to evaluate and identify the influence of feed and spindle speed while drilling with using uncoated and coated solid carbide drills. This paper shows the drilling operation that is carried out the process parameter of 800RPM spindle speed and two different feed rates of 0.10 mm/rev and 0.20 mm/rev. The result shows that the surface finish is degraded at higher feed rate. It is also evident that for the different feed rates the surface finish of drilled surface could not be improved by the TiAlN coated solid carbide drill bit compared to its uncoated carbide drill bit in dry drilling operation of 17-4 PH stainless steel.

2. EXPERIMENTAL DETAILS

A CNC machine has been used conducting this drilling experiment. A rectangular plate of 17-4 PH stainless steel with a dimension of 200 mm length, 100 mm width and 10 mm thickness was used as a job. Figure (1& 2) shows the experimental setup for dry drilling of 17-4 PH stainless steel with uncoated and coated solid carbide drill bits respectively. Also, Figure 3 represents drill bit with tool holder.

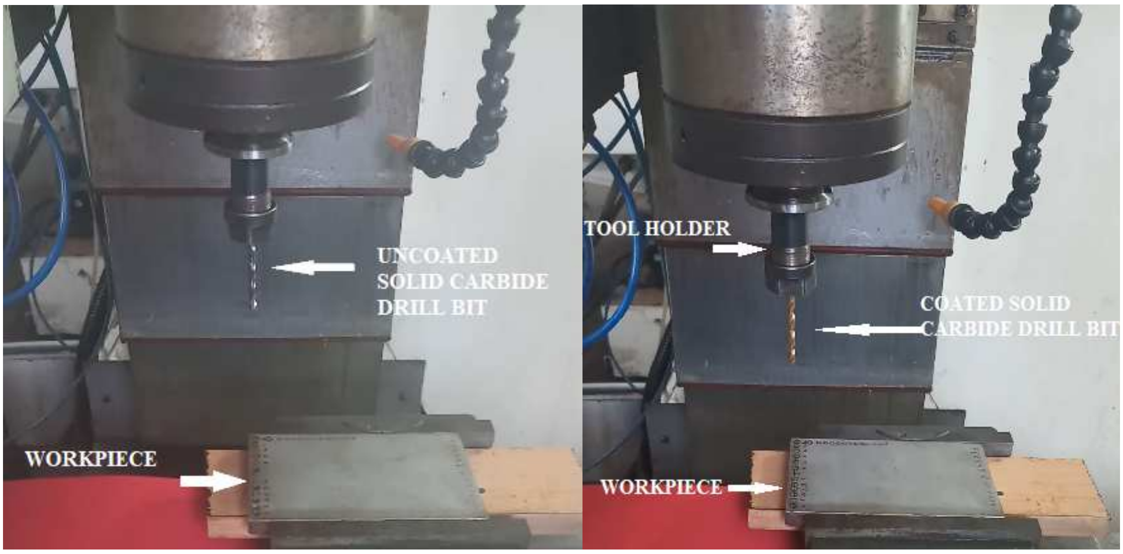


Figure (1&2): Experimental setup

Figure (3): Tool Holder

Table 1 The Chemical composition of the 17-4 PH stainless steel.

Element	Ni	Si	Nb	Zn	Cr	S	P	S	Cu	Mn	C
Weight %	4.26	0.53	0.29	1.2	15.24	0.024	0.038	0.030	3.17	0.56	0.046

Table 2 Properties of 17-4 PH stainless steel

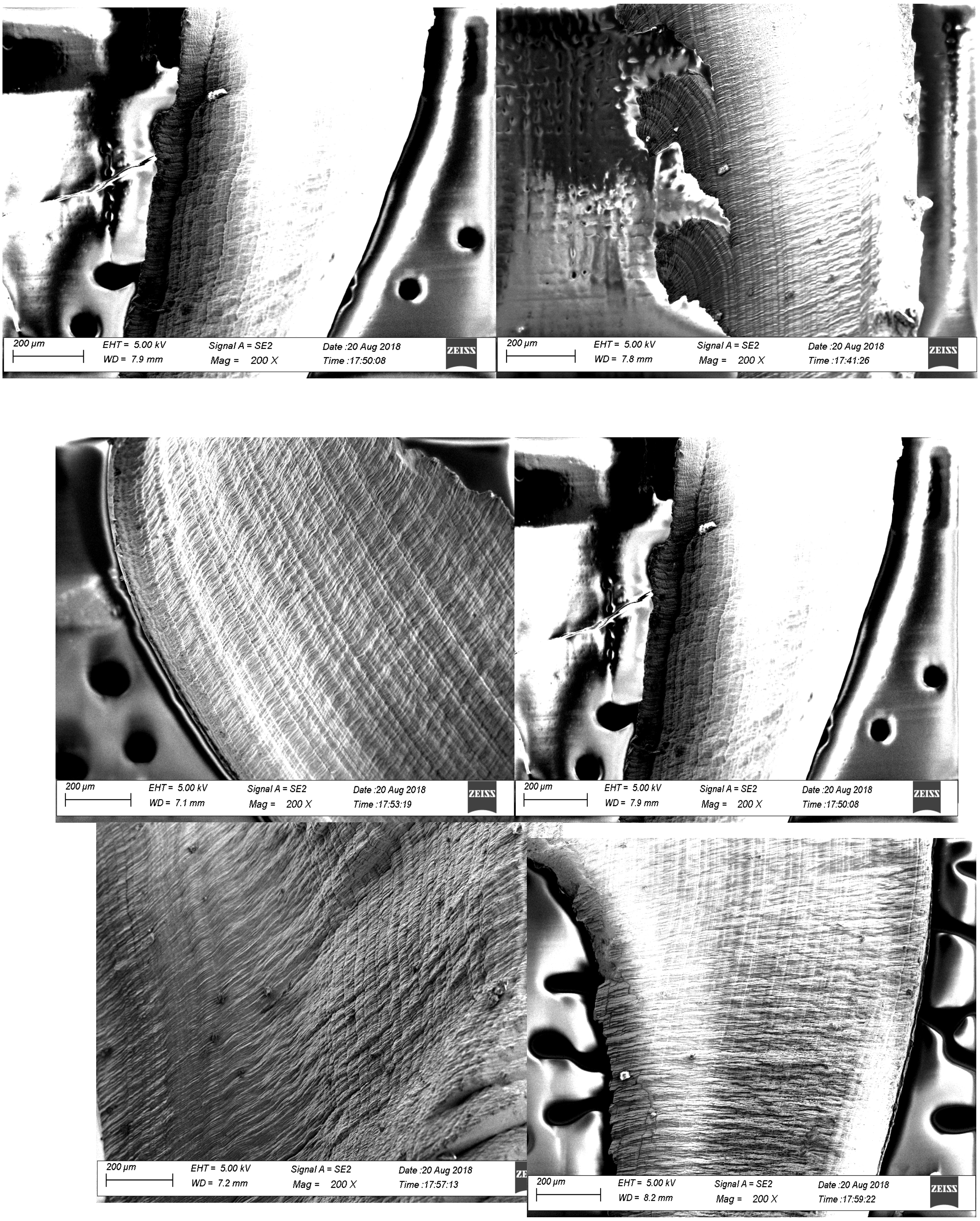
Density, g/cm^3	7.78
Specific Heat (J/kg)	460
Poisson's Ratio	0.272
Modulus of Rigidity (GPa)	67
Thermal expansion co-efficient (µm/m°C)	10.3
Elastic modulus (GPa)	197
Mean coefficient of thermal expansion (µm/mK)	10.4

Table 1 shows the chemical composition of the 17-4 PH stainless steel. Table 2 represents the properties of 17-4PH stainless steel. The chip morphology was analyzed by scanning electron microscopy (SEM, Make: JEOL JSM-7600F), IIT, Bombay, and surface roughness have been measured by Taylor Hobson Surtronic3+ Surface Finish Tester Profilometer, NIT, Rourkela, shown in Figure 4 & 5 respectively. Such plan of the experiment would also enable understanding of the influence of cutting duration on various aspects of machining of 17-4 PH stainless steel while comparing to the performance of uncoated and coated solid carbide drill bits. To get the better statistical accuracy of measured responses each experiment run was repeated thrice.

Figure (4): Scanning electron microscopy (SEM), IIT, Bombay.

Figure (5): Taylor Hobson Surtronic3+ Surface Finish Tester Profilometer, NIT, Rourkela.

Spindle speed = 800 RPM & Feed rate = 0.10 mm/rev	
Uncoated	**Coated**



Spindle speed = 800 RPM & Feed rate = 0.20 mm/rev	
Uncoated	**Coated**

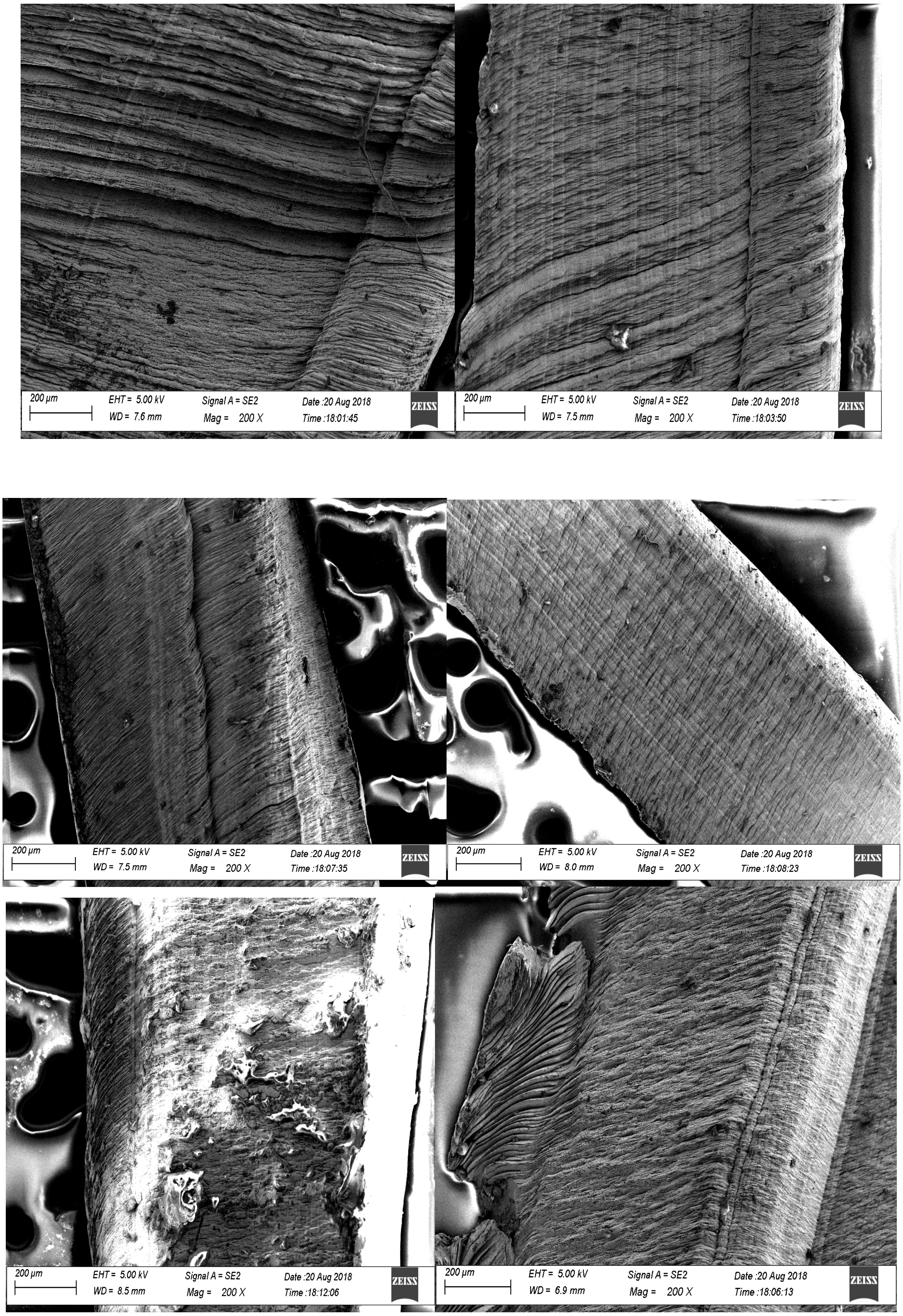


Figure (6): SEM images of chips produced by uncoated and coated drill bits at a constant spindle speed of 800 RPM and at variable feed rates of 0.10 mm/rev and 0.20 mm/rev.

3. RESULT AND DISCUSSION

CHIP MORPHOLOGY

The chip morphology of chip formation after drilling operation is represented by SEM images shown in Figure 6. 17-4 PH stainless steel usually characterized by serrated and continuous type ribbon like chips. Chip serration is primarily characterized to normal plastic deformation and shear localization. It is evident that degree of serration was also found to be more in drilling with a coated drill bit at a high feed rate of 0.20 mm/rev and at a spindle speed of 800 rpm compare to the uncoated counterpart. The SEM images also depicted that the free surface of chips after drilling 17-4 PH stainless steel is characterized by the two imperative features i.e. shear cracks and lateral flow. During chip flow, little consideration will indicate that the side flow of the material increases with feed rate and that could be reduced by drilling with coated solid carbide drill bits.

MACHINED SURFACE ROUGHNESS

The variation of surface roughness is obtained after drilling at a constant spindle speed of 800 RPM and variable feed rate is shown in Figure 7. The result indicated that the surface roughness of the machined surface after drilling at a feed rate of 0.20 mm/rev is quite more as compare to drilling at lower feed rate i.e. at 0.10 mm/rev. Also, it indicates that the surface roughness could not be reduced by drilling with coated carbide drill bits compare to uncoated counterparts.

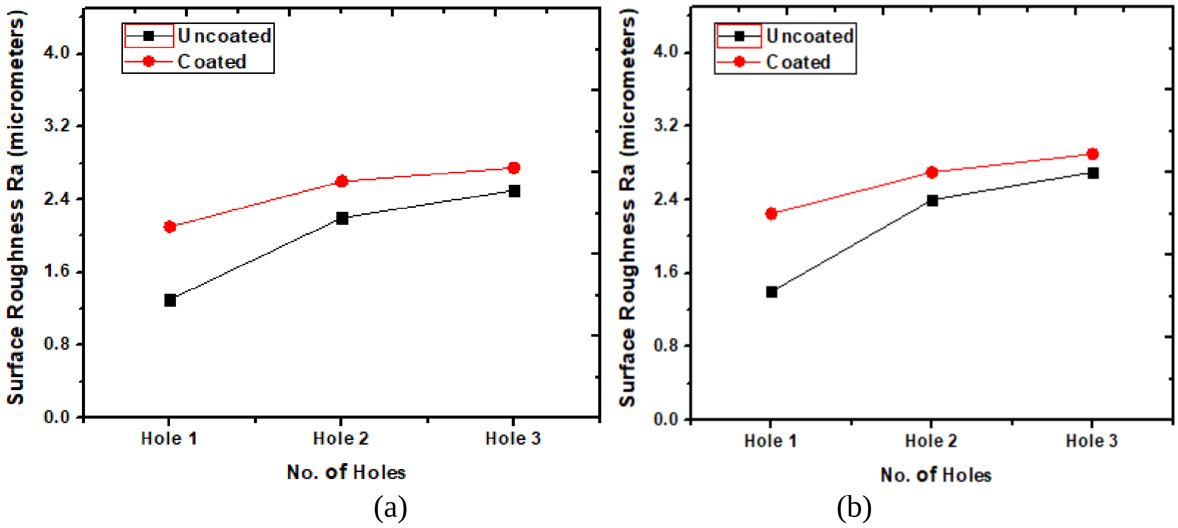


Figure (7): Variation in surface roughness with two feed rates and constant speed for successive holes. (a) At feed 0.10 mm/rev, (b) At feed 0.20 mm/rev

4. CONCLUSION

The present research work evaluated the effect of tool coating and variable feed rates on surface roughness and chip formation during dry drilling of 17-4 PH stainless steel by simulation and experimentation. The following conclusions can be drawn from this study as follows:

1) Chip morphology depicted the type of chips produced during dry drilling of 17-4PH stainless steel on the basis of that it can be concluded that adequate machining parameter for the drilling operation that is the feed rate should be 0.10 mm/rev or lower than that should be applied at a spindle speed of 800 RPM. The also solid coated drill bit should be preferred to the uncoated counterpart.
2) Elevation in feed rate leads to raised in surface roughness. Also, it could not be improved by using a TiAlN coated drill at specific machining conditions which were taken.

5. REFERENCES-

[1]. Akhtar, W., Sun, J., Sun, P., Chen, W., & Saleem, Z. (2014). Tool wear mechanisms in the machining of Nickel-based super-alloys: A review. *Frontiers of Mechanical Engineering, 9* (2), 106–119.

[2]. Alabdullah, M., Polishetty, A., Nomani, J., & Littlefair, G. (2017). Effect of Microstructure on Chip Formation during Machining of Super Austenitic Stainless Steel. *International Journal of Materials Forming and Machining Processes, 4* (1).

[3]. Altin, A., Nalbant, M., & Taskesen, A. (2007). The effects of cutting speed on tool wear and tool life when machining Inconel 718 with ceramic tools. *Materials & Design , 28* (9), 2518-2522.

[4]. Aslan, F., Langlois, L., Mangin, P., & Balan, T. (2018). Identification of Drilling Parameters during the Flow Drill Screw Driving Process. *Key Engineering Materials, 767* (1), 465-471.

[5]. Bressan, J. D., Daros, D. P., Sokolowski, A., Mesquita, R. A., & Barbosa, C. A. (2008). Influence of hardness on the wear resistance of 17-4 PH stainless steel evaluated by the pin-on-disc testing. *Journal of Materials Processing Technology, 205* (1-3), 353-359.

[6]. Chen, W. C., & Liu, X. D. (2000). Study on the various coated twist drills for stainless steels drilling. *Journal of Materials Processing Technology, 99* (1-3), 226-230.

[7]. Chen, Y. C., & Liao, Y. S. (2003). Study on wear mechanisms in the drilling of Inconel 718 superalloy. *Journal of Materials Processing Technology, 140* (1-3), 269–273.

[8]. Chinchanikar, S., & Choudhury, S. K. (2013). Investigations on machinability aspects of hardened AISI 4340 steel at different levels of hardness using coated carbide tools. *International Journal of Refractory Metals and Hard Materials, 38* (1), 124-133.

[9]. Cicek, A., Uygur, I., Kıvak, T., & Ozbek, N. A. (2012). Machinability of AISI 316 Austenitic Stainless Steel With Cryogenically Treated M35 High-Speed Steel Twist Drills. *Journal of Manufacturing Science and Engineering, 134* (6), 1-6.

[10]. Deyuan, Z., & Lijiang, W. (1998). Investigation of the chip in vibration drilling. *International Journal of Machine Tools and Manufacture, 38* (3).

[11]. Dolinsˇek, S. (2003). Work-hardening in the drilling of austenitic stainless steels. *Journal of Materials Processing Technology, 133* (1-2), 63-70.

[12]. Dornfeld, D. A., Kim, J. S., Dechow, H., Hewson, J., & Chen, L. J. (1999). Drilling Burr Formation in Titanium Alloy, Ti-6Al-4V. *CIRP Annals-Manufacturing Technology, 48* (1), 73-76.

[13]. Faur, A. S., Popa, M. S., Luca, B. C., Voina, I. D., & Bizubac, D. (2018). Research on the influence of a new tap drill geometry on C45, 42CrMo4, and X5CrNi8 steel processing. *International Conference on Innovative Manufacturing Engineering and Energy, 178* (1), 1-6.

[14]. Guo, Y. B., & Dornfeld, D. A. (1999). Finite Element Modeling of Burr Formation Process in Drilling 304 Stainless Steel. *Journal of Manufacturing Science and Engineering, 122* (4), 612-619.

[15]. Han, C. H., Zhang, D., & Luo, M. (2018). Chip evacuation force modeling for deep hole drilling with twist drills. *The International Journal of Advanced Manufacturing Technology, 98* (9-12), 3091–3103.

[16]. Hsiao, C. N., Chiou, C. S., & Yang, J. R. (2002). Aging reactions in a 17-4 PH stainless steel. *Materials Chemistry and Physics, 74* (1), 134–142.

[17]. Liew, P. J., Syahida, M. A., Ainusyafiqah, S., Amri, S. M., & Izamshah, R. R. (2018). Investigation of Effects of Carbon Nanofiber Nanofluid in Drilling of AISI 304 Stainless Steel. *Journal of advanced manufacturing technology*, *12* (1(2)), 491-500.

[18]. Lin, T. R. (2002). Cutting Behaviour Using Variable Feed and Variable Speed when Drilling Stainless Steel with TiN-Coated Carbide Drills. *The International Journal of Advanced Manufacturing Technology, 19* (9), 629-636.

[19]. Lin, T. R. (2002). Experimental design and performance analysis of TiN-coated carbide tool in face milling stainless steel. *Journal of Materials Processing Technology, 127* (1), 1-7.

[20]. Lin, X., Cao, Y., Wu, X., Yang, H., Chen, J., & Huang, W. (2012). Microstructure and mechanical properties of laser forming repaired 17-4PH stainless steel. *Materials Science and Engineering A, 553* (1), 80-88.

[21]. Minevich, A. A., Eizner, B. A., Gick, L. A., & Popok, N. N. (2008). Case Studies on Tribological Behavior of Coated Cutting Tools. *Tribology Transactions, 43* (4), 740-748.

[22]. Mohanty, A., Gangopadhyay, S., & Thakur, A. (2016). On Applicability of Multilayer Coated Tool in Dry Machining of Aerospace Grade Stainless Steel. *Materials and Manufacturing Processes, 31* (7), 869-879.

[23]. Murayama, M., Hono, K., & Katayama, Y. (1999). Microstructural Evolution in a 17-4 PH Stainless Steel after Aging at 400C. *Metallurgical and Materials Transactions A, 30* (2), 345-353.

[24]. OZCELIK, B., KURAM, E., DEMIRBAS, E., & ¸SIK, E. (2013). Effects of vegetable-based cutting fluids on the wear in drilling. *Sadhana, 38* (4), 687–706.

[25]. Schönbauer, B. M., Yanase, K., & Endo, M. (2017). The influence of various types of small defects on the fatigue limit of precipitation-hardened 17-4PH stainless steel. *Theoretical and Applied Fracture Mechanics, 87* (1), 35-49.

[26]. Sultan, A. Z., Sharif, S., & Kurniawan, D. (2015). Chip Formation When Drilling AISI 316L Stainless Steel using Carbide Twist Drill. *Procedia Manufacturing, 2* (1), 224-229.

[27]. Thakur, A., Gangopadhyay, S., & Maity, K. P. (2014). Effect of cutting speed and CVD multilayer coating on machinability of Inconel 825. *Surface Engineering, 30* (7), 516-523.

[28]. Thakur, A., Gangopadhyay, S., & Mohanty, A. (2015). Investigation on Some Machinability Aspects of Inconel 825 during Dry Turning. *Materials and Manufacturing Processes, 30* (8), 1026-1034.

[29]. Thakur, A., Gangopadhyay, S., Mohanty, A., & Maity, K. (2016). Experimental assessment on the performance of TiN/TiCN/Al2O3/ZrCN coated tool during dry machining of Nimonic C-263. *International Journal of Machining and Machinability of Materials, 18* (5-6), 452-465.

[30]. Uzhanfeng, L., & Uquantai, L. (2018). Experimental study on deep hole drilling of 17-4PH material. *Materials Science and Engineering, 307* (1), 1-6.

[31]. Viswanathan, U. K., Banerjee, S., & Krishnan, R. (1988). Effects of Aging on the Microstructure of 17-4 PH Stainless Steel. *Materials Science and Engineering, 104* (1), 181 - 189.

[32]. Yao, J., Wang, L., Zhang, Q., Kong, F., Lou, C., & Chen, Z. (2008). Surface laser alloying of 17-4PH stainless steel steam turbine blades. *Optics & Laser Technology , 40* (6), 838-843.