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AN EXPERIMENTAL STUDY ON CUTTING TEMPERATURE AND CHIP FORMS IN DRILLING CARBON BLACK REINFORCED HDPE COMPOSITE

***Alper Uysal**
Yildiz Technical University
Besiktas, Istanbul, Turkey

Erhan ALTAN
Yildiz Technical University
Besiktas, Istanbul, Turkey

Keywords: carbon black; HDPE; drilling; cutting temperature; chip forms; drill point angle
** Corresponding author: Alper Uysal, Phone:+902123832807, Fax: +902123833024*
E-mail address: auysal@yildiz.edu.tr

ABSTRACT

In various areas, the usage of polymer materials increases and some additives such as fibers, carbon nanotubes, graphite, metal oxides, carbon black etc. are used to improve the mechanical properties of these materials. Although different manufacturing processes were applied in the manufacturing of these materials, drilling process is one of the most applied methods. For this reason, in this experimental study, cutting temperature and chip forms were examined in drilling of pure and carbon black reinforced HDPE (High Density Polyethylene) materials. In drilling operations, three different cutting speeds, feeds, and drill point angles were selected as drilling parameters. According to the experimental results, the cutting temperature decreased and the desired chip forms were obtained when drilling at low cutting speed and high feed with drill tool having small point angle (80°) for both materials.

INTRODUCTION

The reinforcing fillers such as multi-walled carbon nanotubes, graphene, carbon black, graphite, various fibers etc. are widely used in polymeric matrices to improve the mechanical, optical and/or electrical properties [1,2]. In industry, fiber reinforced polymer composite materials have been mostly preferred but the use of the other fillers increase day by day. Additionally, these fillers have influence on the machining characterization of polymer materials and researches on this issue have been continued. Drilling is one of the most applied machining processes on pure and reinforced polymer materials and it is known that the cutting temperature damages the polymer matrix, melts it near the cutting edge and so causes distortion [3]. During drilling, an increase in cutting speed causes higher cutting temperature due to low thermal conduction and low glass transition temperature of polymer materials [4-7]. Thus, the polymeric matrix softens due to the generating heat by friction between the major and minor cutting edges and the polymer material [8-10]. Besides, drill tool wear growths at higher cutting temperatures occurring at higher cutting speeds [11]. When investigating the effects of feed on the cutting temperature, it is shown that lower feeds cause high frictional heating and so higher cutting temperatures are measured [12,13]. Carbon black fillers were preferred to reach the required physical and mechanical performance and to improve the processing and curing rate [14]. Therefore, carbon black reinforced polymer materials are used in many applications such as automobile housing, fuel filters, electronic parts etc. However, there is a lack of knowledge on their machining. In this experimental study, the effects of drilling parameters (drill point angle, feed, cutting speed) on the cutting temperature and chip forms were investigated in drilling of pure and carbon black reinforced HDPE (High Density Polyethylene) materials.

EXPERIMENTAL STUDIES

Pure HDPE (High Density Polyethylene, BPC) and carbon black reinforced HDPE (CBR-HDPE, PRE-ELEC® PE 1296) polymer materials were selected and produced by injection molding process. Their material properties can be seen in Table 1. The wokpiece materials were injection molded in dimensions of 150x150x10 mm by using the mould as seen in Figure 1. Firstly, the polymer granules were dried at 60°C for 2 hours. After that, the dried granules were melted at 230°C in plastic injection machine and the polymer workpiece materials were manufactured by applying injection pressure of 90 MPa in a mould at 50 °C.

Table 1. Material properties of pure and carbon black reinforced HDPE

Properties	Pure HDPE	CBR-HDPE
Specific gravity (gr/cm^3)	0,95	1,12
Yield strength (MPa)	23	24
Flexural modulus (MPa)	800	1100
Elongation at break (%)	>50	40
Elongation at yield (%)	9	12
Impact strength, notched Izod (4 mm thickness, 23°C) (kJ/m^2)	12	29
Deflection temperature (0,45 MPa) (°C)	60-82	80
Volume resistivity (Ωcm)	$\geq 10^{14}$	$<10^3$
Surface resistance (Ω)	$\geq 10^{14}$	$<10^5$

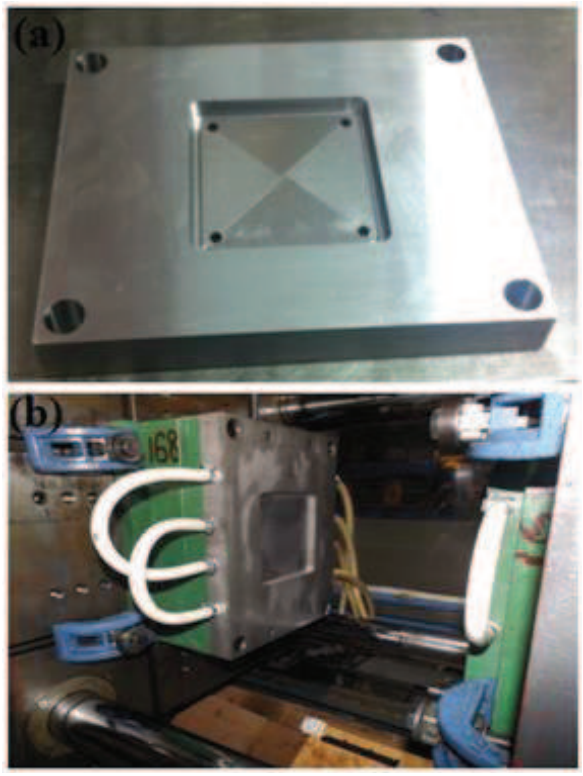


Figure 1. Manufacturing the polymer workpieces a) plastic injection mould, b) plastic injection process

The drilling operations were conducted in a CNC machining center with HSS (High Speed Steel) twist drill tools having three drill point angles as 80°, 120°, and 80°-120° (double-angled) at drilling parameters given in Table 2. The drill diameter was 8 mm and drill tools can be seen in Figure 2.

Table 2. Drilling parameters

Material	HDPE, CBR-HDPE
Drill point angle, α (°)	80° / 120° / 80°-120°
Cutting speed, V (m/min)	40 / 80 / 120
Feed, f (mm/rev)	0,1 / 0,2 / 0,3

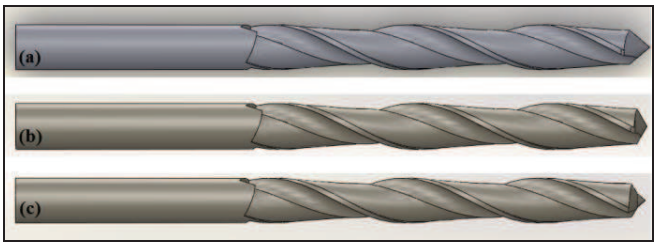


Figure 2. Twist drill tools having point angle a) 80°, b) 120°, c) 80°-120° (double-angled)

During drilling process, the cutting temperatures (T) were measured by using Optris® CTlaser LT two-wire infrared thermometer having measurement range of -50°C to 975°C with ±1% measurement accuracy and response time of 9 ms. The measured temperature values were processed via Compact Connect software. The infrared temperature measurements have been utilized in various machining operations and presents advantages such as non-contacting, rapid responding, no negative effects on the material etc. [15,16]. The laser beam was focused on the drill tool tip and temperature measurements were performed during the process as seen in Figure 3. The chip images were taken by SOIF XLB45-B3 digital stereo microscope and 3 MP MD30 camera at x7 magnification.

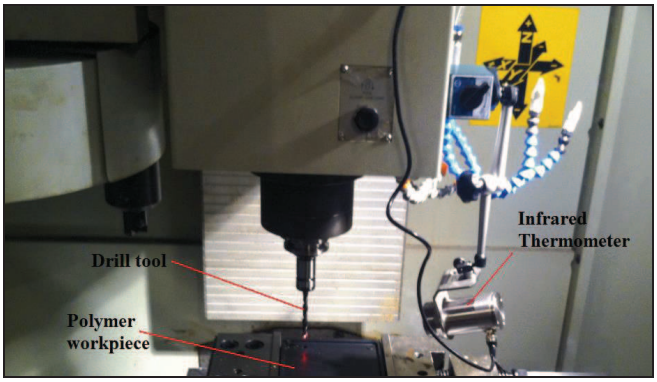


Figure 3. Cutting temperature measurement during drilling operation

EXPERIMENTAL RESULTS AND DISCUSSION

The cutting temperature increased with increase of cutting speed due to occurring higher friction between drill tool and polymer workpiece material during drilling process (Figure 4 and Figure 5). The heat accumulates on the surface of polymer material in the drilling operation due to having low thermal conductivity [17] and more heat is conducted through drill tool due to having more thermal conductivity than polymer material. Therefore, less heat conduction occurs in the direction of feed and this is the case for pure polymer materials. Some of the friction-based heat is transferred to the polymer material from the drill tool during the process and the drill tool transmits more heat when the feed increased at a constant cutting speed. Therefore, the cutting temperature decreased with increase of feed as seen in Figure 6 and Figure 7. When the effects of drill point angle on the cutting temperature was investigated, less

cutting temperature values were measured due to the fact that small point angle (80°) facilitated the cutting of polymer [18] and temperature values increased with increase of drill point angle (Figure 4 – Figure 7). The double-angled (80°-120°) drill tool design was more effective in reducing the cutting temperature than standard drill tool (120°) but was not effective as much as drill tools having small point angle (80°). The carbon black reinforcement increases the hardness, strength, electrical conductivity and thermal conductivity of polymer materials. Therefore, more heat is occurred during the machining process and less heat is transmitted from the drill tool to the polymer material. As seen in Figure 4 – Figure 7, higher cutting temperatures in drilling of CBR-HDPE was measured than that in drilling of pure HDPE.

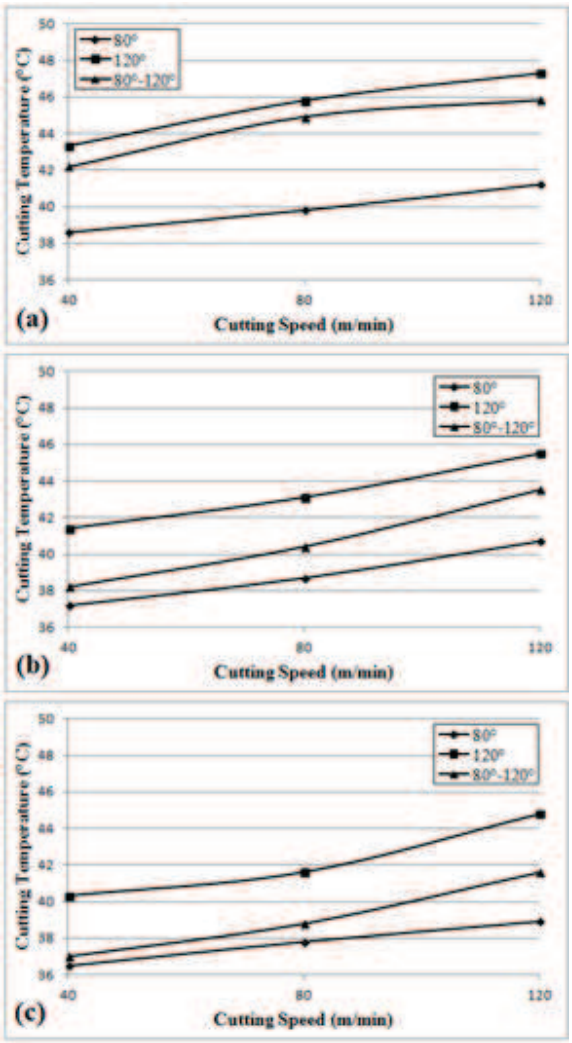


Figure 4. The variation of cutting temperature with cutting speed and drill point angle for pure HDPE a) f= 0,1 mm/rev, b) f= 0,2 mm/rev, c) f= 0,3 mm/rev

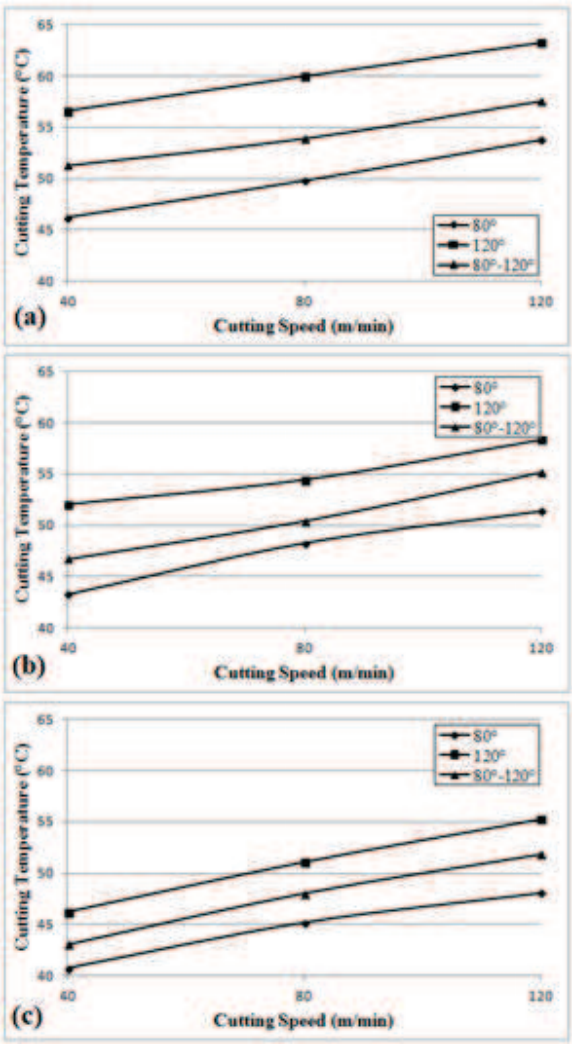


Figure 5. The variation of cutting temperature with cutting speed and drill point angle for CBR-HDPE a) f= 0,1 mm/rev, b) f= 0,2 mm/rev, c) f= 0,3 mm/rev

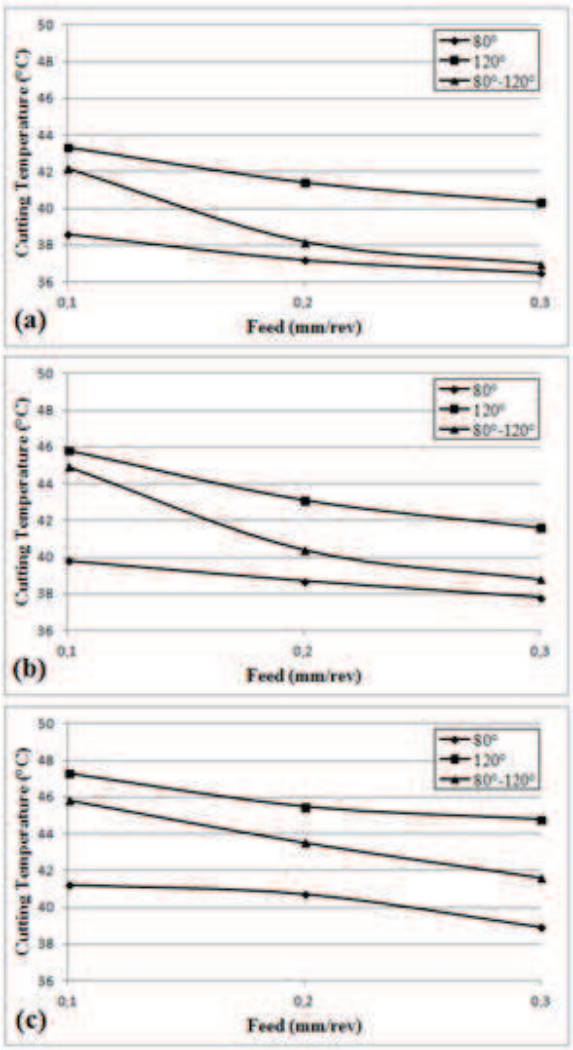


Figure 6. The variation of cutting temperature with feed and drill point angle for pure HDPE a) V= 40 m/min, b) V= 80 m/min, c) V= 120 m/min

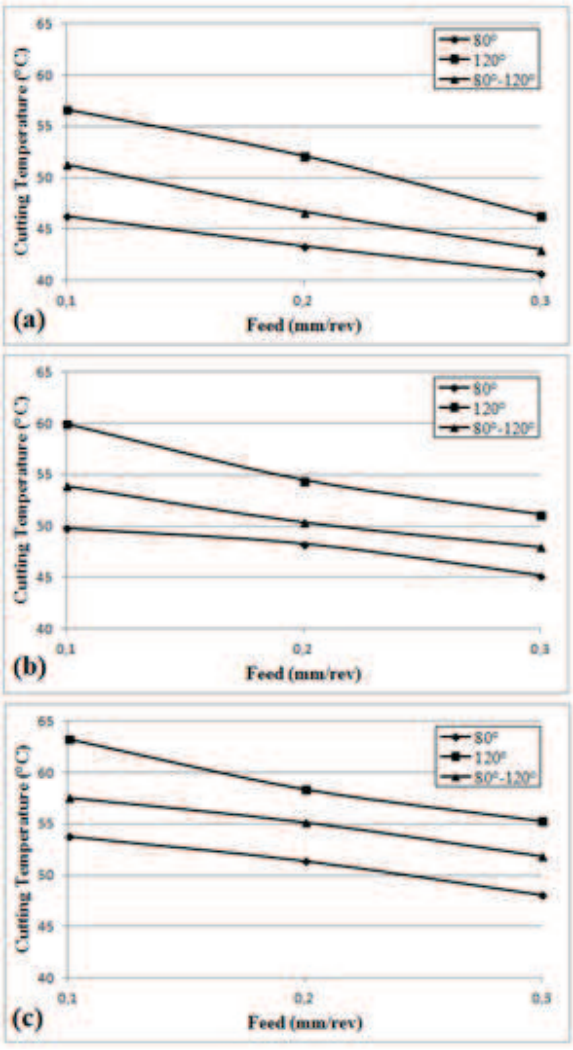


Figure 7. The variation of cutting temperature with feed and drill point angle for CBR-HDPE a) V= 40 m/min, b) V= 80 m/min, c) V= 120 m/min

The changing of chips according to cutting speed, feed and drill point angle were given in Figure 8 – Figure 11 for both polymer materials. As increasing the cutting speed and decreasing the feed, more deformed, non-uniform, mixed and long chips were obtained due to occurring more friction-based heat. Additionally, it was seen that drill tools having small point angle formed more uniform chips due to making easier the cutting of polymer material. The most unfavorable chips were obtained with standard drill tools. As is known that some of heat is transmitted by chips and more heat is accumulated on the surface of pure HDPE. Therefore, the chips were more deformed and mixed in the drilling of pure HDPE than that in the drilling of CBR-HDPE.

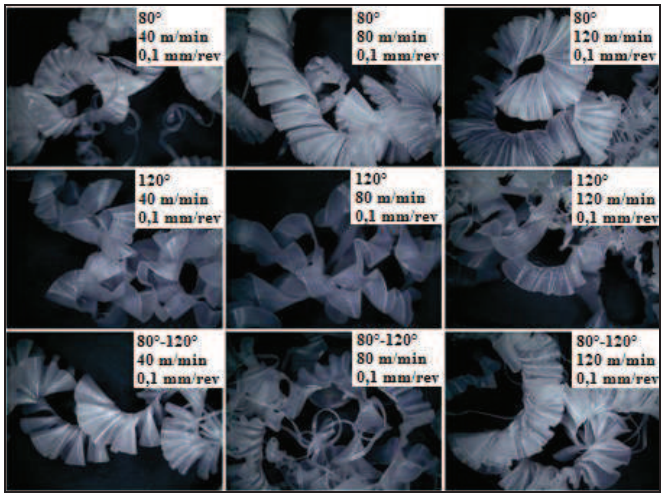


Figure 8. The changing of chips according to cutting speed and drill point angle for pure HDPE

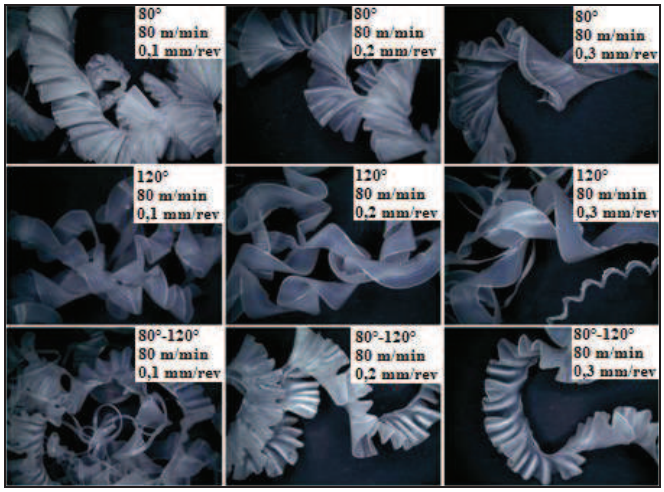


Figure 9. The changing of chips according to feed and drill point angle for pure HDPE

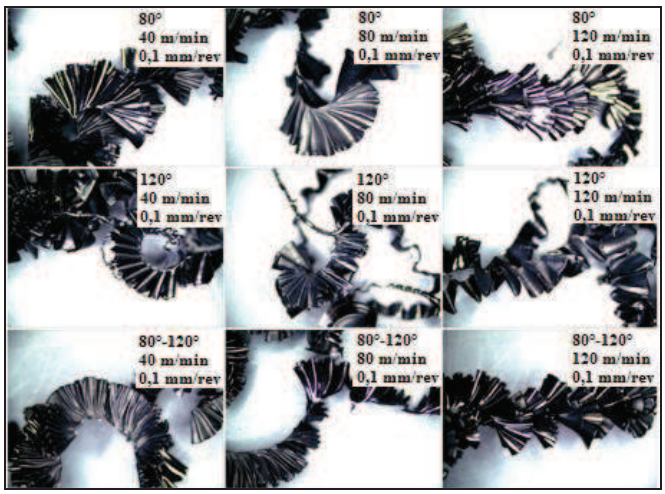


Figure 10. The changing of chips according to cutting speed and drill point angle for CBR- HDPE

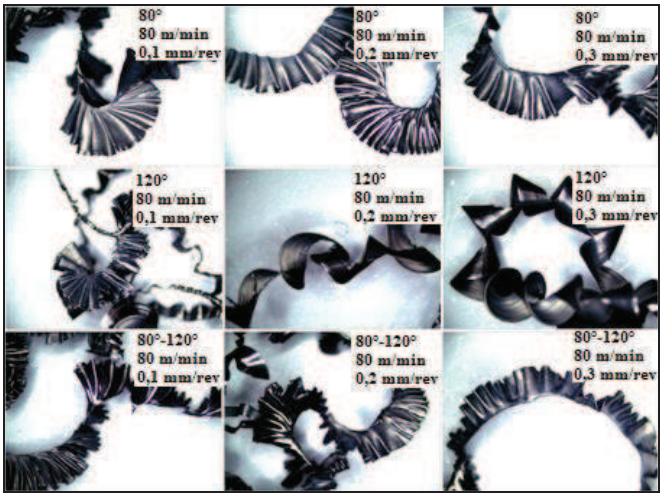


Figure 11. The changing of chips according to feed and drill point angle for CBR-HDPE

CONCLUSION

In this experimental study, the drilling of pure and carbon black reinforced HDPE polymer materials with three cutting speeds, feeds and drill point angles were performed and cutting temperature and chips were investigated. Depending on investigations, the following results were obtained.

- The cutting temperature increased with increase of cutting speed due to occurring higher friction between drill tool and polymer workpiece materials.
- Higher cutting temperatures were measured at low feed values due to occurring more friction-based heat.
- Less cutting temperatures were occurred in the drilling with drill tools having small point angle (80°) due to facilitating the cutting of polymer material and the cutting temperature increased when the drill point angles were increased.
- It was specified that the double-angled (80°-120°) drill tool design had advantages on the standard drill tools (120°) but the most effective drill point angle was 80°.
- The cutting temperatures measured in the drilling of CBR-HDPE were higher than that occurred in the drilling of pure HDPE due to the fact that the carbon black addition increased the hardness, strength, electrical conductivity and thermal conductivity of polymer materials.
- The chips were much more deformed and non-uniform and long chips were obtained at high cutting speed and low feed due to increasing friction between drill tool and polymer material.
- The desired chips were formed in the drilling with drill tools having small point angle (80°) and the undesirable chips were occurred in the drilling with standard drill tools (120°).

- The chips of pure HDPE were affected from the heat and much more deformed than the chips of CBR-HDPE and so they were non-uniformly formed.

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NOMENCLATURE

CBR	Carbon Black Reinforced
f	Feed
HDPE	High Density Polyethylene
HSS	High Speed Steel
T	Cutting Temperature
V	Cutting speed
α	Drill point angle

REFERENCES

[1] Li, Z.H., Zhang, J., and Chen, S.J., 2008. Effects of carbon blacks with various structures on vulcanization and reinforcement of filled ethylene-propylene-diene rubber. *eXPRESS Polymer Letters*, 2(10), pp. 695-704.

[2] Marinho, B., Ghislandi, M., Tkalya, E., Koning, C.E., and de With, G., 2012. Electrical conductivity of compacts of graphene, multi-wall carbon nanotubes, carbon black, and graphite powder. *Powder Technology*, 221, pp. 351-358.

[3] Rubio, J.C., Panzera, T.H., Abrao, A.M., Faria, P.E., and Davim, J.P., 2011. Effects of high speed in the drilling of glass whisker-reinforced polyamide composites (PA66 GF30): statistical analysis of the roughness parameters. *Journal of Composite Materials*, 45(13), pp. 1395-1402.

[4] Khashaba, U.A., 2004. Delamination in drilling GFR-thermoset composites. *Composite Structures*, 63, pp. 313-327.

[5] Rubio, J.C., Abrão, A.M., Faria, P.E., Correia, A.E., and Davim, J.P., 2008. Delamination in high speed drilling of carbon fiber reinforced plastic (CFRP). *Journal of Composite Materials*, 42, pp. 1523-1532.

[6] Gaitonde, V.N., Karnik, S.R., Rubio, J.C., Abrão, A.M., Correia, A.E., and Davim, J.P., 2012. Surface roughness analysis in high-speed drilling of unreinforced and reinforced polyamides. *Journal of Composite Materials*, 46(21), pp. 2659-2673.

[7] Khashaba, U.A., El-Sonbaty, I.A., Selmy, A.I., and Megahed, A.A., 2010. Machinability analysis in drilling woven GFR/epoxy composites: Part I - Effect of machining parameters. *Composites: Part A*, 41, pp. 391-400.

[8] Rubio, J.C., Panzera, T.H., Abrao, A.M., Faria, P.E., and Davim, J.P., 2011. Effects of high speed in the drilling of glass whisker-reinforced polyamide composites (PA66 GF30): statistical analysis of the roughness parameters. *Journal of Composite Materials*, 45(13), pp. 1395-1402.

[9] Abrão, A.M., Rubio, J.C.C., Faria, P.E., and Davim, J.P., 2008. The effect of cutting tool geometry on thrust force and delamination when drilling glass fibre reinforced plastic composite. *Materials and Design*, 29, pp. 508-513.

[10] Palanikumar, K., Rubio, J.C., Abrao, A.M., Correia, A.E., and Davim, J.P., 2008. Influence of drill point angle in high speed drilling of glass fiber reinforced plastics. *Journal of Composite Materials*, 42(24), pp. 2585-2597.

[11] Lin, S.C., and Chen, I.K., 1996. Drilling carbon fiber-reinforced composite material at high speed. *Wear*, 194, pp. 156-162.

[12] Durão, L.M.P., Gonçalves, D.J.S., Tavares, J.M.R.S., de Albuquerque, V.H.C., Vieira, A.A., and Marques, A.T., 2010. Drilling tool geometry evaluation for reinforced composite laminates. *Composite Structures*, 92, pp. 1545-1550.

[13] Gaitonde, V.N., Karnik, S.R., Rubio, J.C.C., Leite, W.D.O., and Davim, J.P., 2014. Experimental studies on hole quality and machinability characteristics in drilling of unreinforced and reinforced polyamides. *Journal of Composite Materials*, 48(1), pp. 21-36.

[14] Vargas, C.A., Sierra, J.D., Posada, J.C., Garcia, L.A., and Zapata, L.J., 2016. Reinforcement effect of carbon black in Colombian natural rubber: Benchmarking with Guatemala rubber. *Journal of Elastomers & Plastics*, (2016) DOI: 10.1177/0095244316645953.

[15] Abukhshim, N.A., Mativenga, P.T., and Sheikh, M.A., 2006. Heat generation and temperature prediction in metal cutting: A review and implications for high speed machining. *International Journal of Machine Tools & Manufacture*, 46, pp. 782-800.

[16] Davoodi, B., and Hosseinzadeh, H., 2012. A new method for heat measurement during high speed machining. *Measurement*, 45, pp. 2135-2140.

[17] Ahmad, J.Y.S., 2009. *Machining of Polymer Composites*. Springer: New York.

[18] Uysal, A., Altan, M., and Altan, E., 2012. Effects of cutting parameters on tool wear in drilling of polymer composite by Taguchi method. *International Journal of Advanced Manufacturing Technology*, 58, pp. 915-921.