DRILL TOOL FLANK WEAR IN DRILLING OF PURE AND CARBON BLACK REINFORCED HIGH DENSITY POLYETHYLENE

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Abstract: Polymer materials are preferred in various industrial areas such as automotive, manufacturing, aeronautic etc. and their material properties are improved by reinforcing carbon black, carbon fiber, graphite, carbon nanotubes, metal oxides etc. to enhance their usage areas. Additionally, in application areas, drilling operations are required for assembly processes. Therefore, in this experimental study, drill tool flank wear was investigated in drilling of pure and carbon black reinforced HDPE (High Density Polyethylene) materials. In experiments, two cutting speeds, feeds, and drill point angles (120° and 80°-120°) were selected as drilling parameters. Depending on the results, drill tool flank wear increased with increase of cutting speed and decreased with increase of feed. The maximum tool wear values were measured in drilling with standard drill tools (120°) and the double-angled (80°-120°) drill tool design reduced the tool wear. In addition, the carbon black addition improved the material properties of HDPE and this caused an increase in drill tool flank wear during drilling process.
Keywords: Carbon Black, HDPE, Drilling, Drill Tool Wear

Introduction

Polymer materials are consumed more than steel materials and their usage continues to grow so rapidly due to their material properties such as non corrosive nature, high impact resistance, being lighter, good strength to weight ratio etc. (Alauddin et al., 1995, Gulrez et al., 2014). Among the polymer materials, polyethylene has excellent chemical resistance and mechanical properties and it is electrically insulating material. However, the electrical conductivity can be increased by using various conductive fillers to enhance their usage in other applications such as in manufacturing computer chip, fuel tankers, automotive housing etc. In general, carbon black, carbon fibers, metal fibers and carbon nanotubes are commonly preferred to improve the electrical conductivity and these fillers can enhance the modulus and strength of matrix material (Gulrez et al., 2014, Hopmann et al., 2014, Zhijun et al., 2009). Polymer materials are usually shaped using methods such as plastic injection, extrusion etc. but the demand for the machining of them increases. Drilling is one of the most important machining operations that applied on polymer and composite materials to prepare them for joining and assembly (Ahmad, 2009). During drilling of polymer and composite materials, drill tool wears and so drilled part quality is reduced. Lin and Chen (1996) studied the effects of increasing cutting speed on tool wear when drilling carbon fiber reinforced composite material with both multifacet drill and twist drill. Drill tools are worn quickly at high cutting speeds and the multifacet drill tool was not superior when compared with the twist drill. Inoue et al. (1997) carried out drilling experiments in glass fiber reinforced composite material under various feed rates and cutting speeds and the relationship between tool wear and drilled hole quality was examined. Depending on the results, a great number of holes at a constant quality were obtained at high feed rates. Khashaba et al. (2010) performed an experimental study on the effect of drill pre-wear and machining conditions in drilling glass fiber reinforced glass epoxy composites. The results showed that thrust force and surface roughness were affected by the drill pre-wear and this effect became more significant at high cutting speed and feed which increased peel-up and push-out delaminations. Uysal et al. (2012) investigated the effects of cutting parameters on tool wear in drilling of sheet molding compound composite material. Feed was found as the most effective parameter while cutting speed was the least significant parameter on drill tool wear. Wang et al. (2013) aimed to investigate the wear of uncoated, diamond coated and AlTiN (Aluminium Titanium Nitride) coated carbide drills in drilling of carbon fiber reinforced composite material. The diamond coating reduced the edge rounding wear while the AlTiN coating was not effective on reducing the wear due to its oxidation during drilling. Gaugel et al. (2016) performed drilling experiments with uncoated and diamond coated tungsten carbide hard metal twist drills in carbon fiber reinforced polymer laminates. According to the measurement results, it was figured out that there was a correlation between drill tool wear and delamination damage. Uysal and Altan (2015) investigated drill tool wears in drilling of pure and carbon black reinforced polypropylene and polyamide materials with drill tools having different drill point angles. The minimum drill tool wear was observed in drilling with drill tool having small point angle (80°) and it increased with increase of cutting speed. Additionally, drill tool wears were higher in drilling of carbon black reinforced polymer materials than that observed in drilling of pure polymer materials. In literature, the studies about drill tool wears have been generally performed on drilling carbon or glass fiber reinforced polymer composite materials and there are no further works on particle reinforced polymer composite materials. However, in this experimental study, drill tool flank wear was investigated in drilling pure and carbon black reinforced HDPE

(High Density Polyethylene) materials. In experiments, two cutting speeds, feeds and drill point angles were selected as drilling parameters and their effects on the drill tool flank wear were examined.

Experimental Studies

In experimental studies, BPC brand pure HDPE (High Density Polyethylene) and Premix brand PRE-ELEC® PE 1296 model carbon black reinforced HDPE (CBR-HDPE) materials were the workpiece materials and their material properties were given in Table 1.

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)	$\geq 10^{14}$	$<10^5$

The polymer workpiece materials were injection molded from pure HDPE and CBR-HDPE granules in dimensions of 150x150x10 mm. Before the injection molding process, the granules were dried at 60°C for 2 hours. During the molding process, the granules were melted at 230°C, the mold temperature was 50 ºC and injection pressure was 90 MPa.

Drilling operations were performed by First MCV-300 CNC machining center with HSS (High Speed Steel) twist drill tools as seen in Figure 1. The drilling parameters were given in Table 2.

Figure 1. Drilling operation with HSS twist drill tool using CNC machining center.

Table 2: Drilling parameters.

Parameters	Value	
Cutting speed, V (m/min)	40	120
Feed, f (mm/rev)	0,1	0,2
Drill point angle, α (°)	120°	80°-120° (double-angled)

The drill diameter was 8 mm and the drill point angles were selected as 120°, and 80°-120° (double-angled) as given in Figure 2.

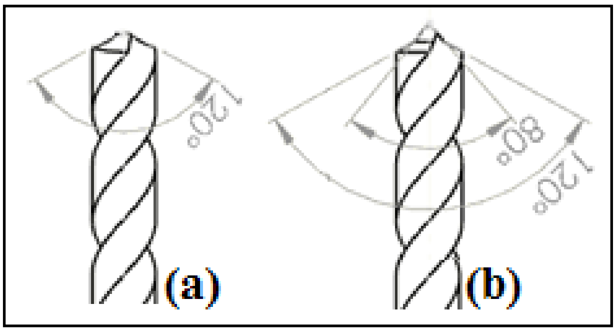

Figure 2. Point angles of selected HSS twist drill tools a) 120°, b) 80°-120° (double-angled).

Drill tool flank wears were viewed by SOIF XJP-6A model trinocular microscope and 9 MP MD90 camera as seen Figure 3. The flank wear values were measured via MShot software after drilling 50 holes and 100 holes. In addition, drill tool SEM (Scanning Electron Microscopy) images were taken by FEI Philips XL30 ESEM-FEG device.

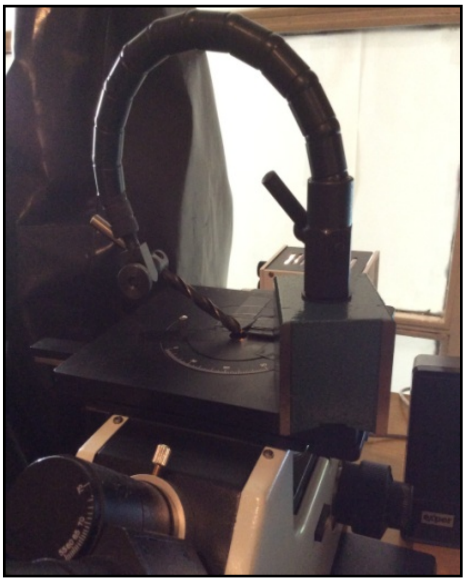
Figure 3. Viewing and measuring of drill tool flank wears by trinocular microscope.

Experimental Results and Discussion

As is known, friction between drill tool and poymer material increases at higher cutting speeds. Therefore, drill tool flank wear increased with increase of cutting speed for both pure HDPE and CBR-HDPE as seen in Figure 4.

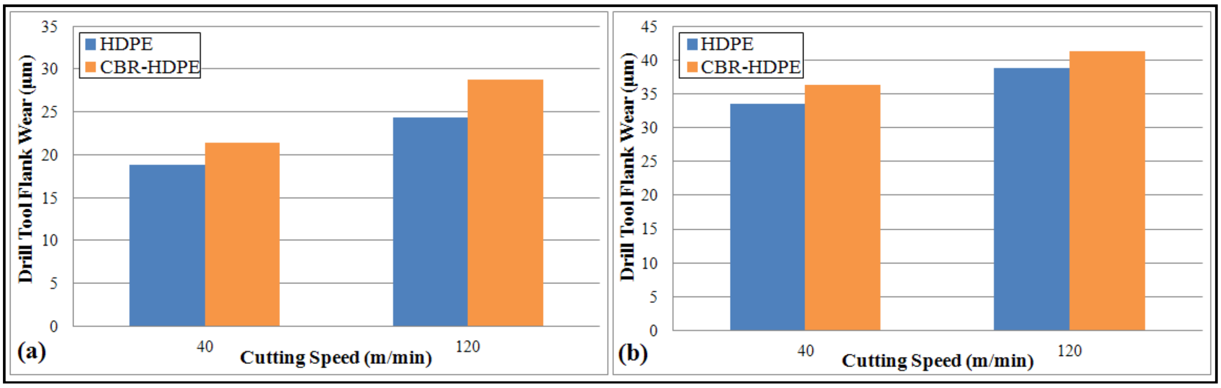

Figure 4. Drill tool flank wear according to the cutting speed (α=120°, f=0,1 mm/rev), after drilling of a) 50 holes and b) 100 holes.

When the double-angled (80°-120°) drill tools were preferred, less drill tool wear occurred as seen in Figure 5. Polymer material can be crashed when high drill point angle (120°) is used and this increases friction and also drill tool wear while sharp pointed tip makes easier the cutting operation.

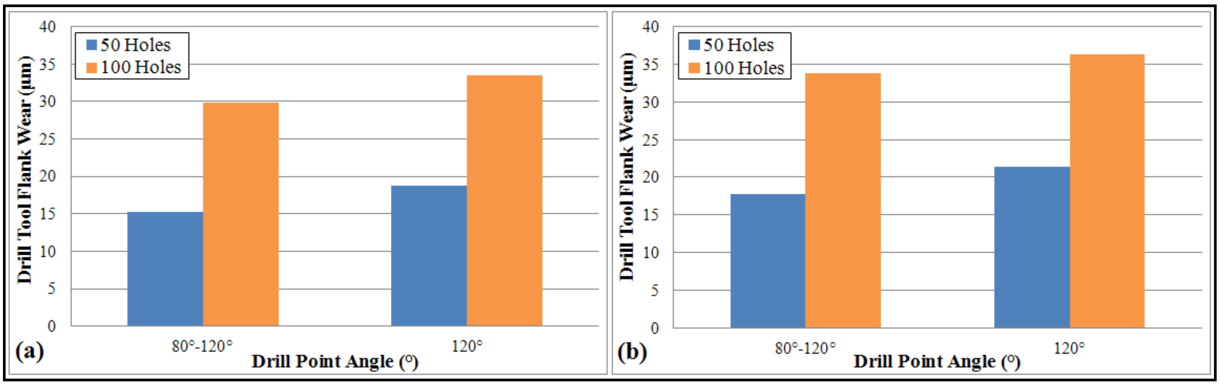

Figure 5. Drill tool flank wear according to the drill point angle (V=40 m/min, f=0,1 mm/rev), a) HDPE and b) CBR-HDPE.

The changing of drill tool flank wear with the feed was given in Figure 6. As increasing the feed, the drilling operation can be performed faster and so it is resulted that the heat based friction decreases. For this reason, less drill tool flank wear values were measured when the feed increased.

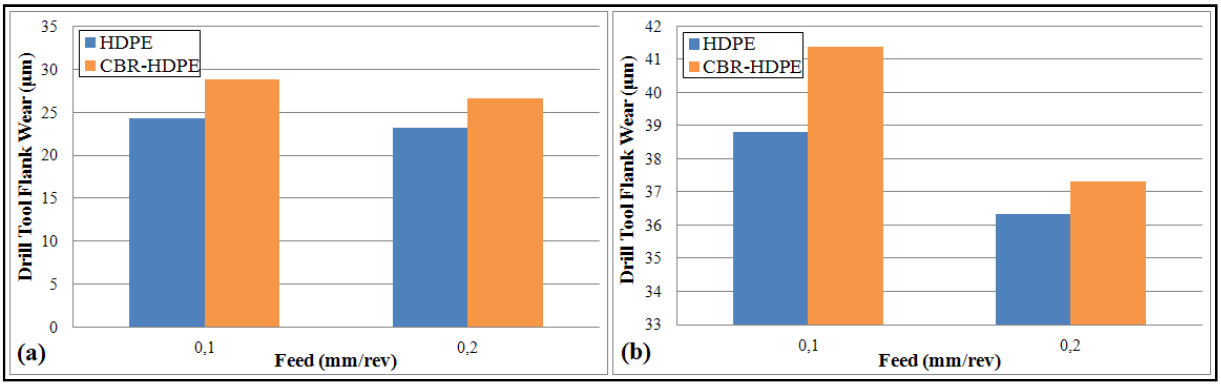

Figure 6. Drill tool flank wear according to the feed (α=120°, V=120 m/min), after drilling of a) 50 holes and b) 100 holes.

Polymer materials have low thermal conductivity and in the machining process, the generated heat is collected at the upper surface of polymer material due to not conducting. However, the carbon black reinforcement increases the thermal conductivity and also it is known that the carbon black particles improve the strength and hardness values of the polymer materials. Therefore, higher drill tool flank wears were measured in the drilling of CBR-HDPE when compared to the drilling of pure HDPE.

After drilling of 100 holes, SEM images of drill tool flank wear were given in Figure 7 and Figure 8. Drill tool were adversely worn in the drilling of CBR-HDPE at the point angle of 120°, the cutting speed of 120 m/min and the feed of 0,1 mm/rev (Figure 7). Less drill tool flank wear was occurred when drilling with the double-angled (80°-120°) drill tool at the cutting speed of 40 m/min and the feed of 0,2 mm/rev (Figure 8). Besides, it was specified that the carbon black reinforcement increased the drill tool flank wear.

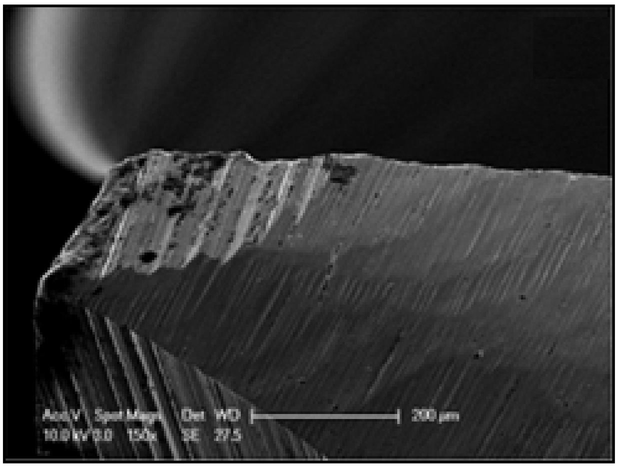

Figure 7.SEM image of drill tool flank wear after drilling of 100 holes on the CBR-HDPE (α=120°, V=120 m/min, f=0,1 mm/rev).

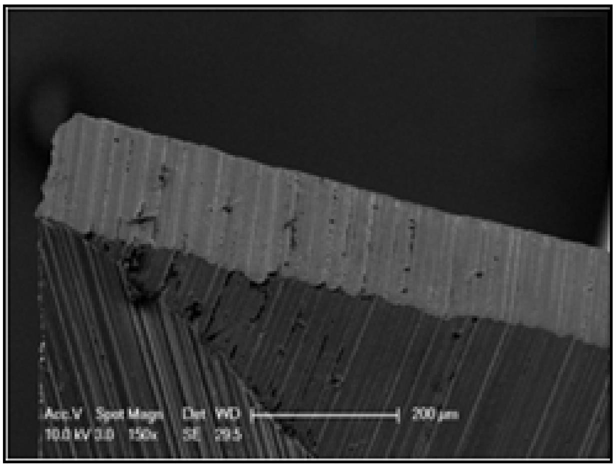

Figure 8.SEM image of drill tool flank wear after drilling of 100 holes on the pure HDPE (α=80°-120°, V=40 m/min, f=0,2 mm/rev).

Conclusion

In this study, pure and carbon black reinforced HDPE materials were drilled with drill tools having different drill point angles at two different cutting speeds and feeds and drill tool flank wear was investigated. The experimental results were given below.

- At higher drill point angles, polymer materials are subjected to plastic deformation with cutting, high drill forces occur to drill a hole and also friction and cutting temperature increase. Therefore, maximum drill tool flank wears were observed in the drilling of pure and carbon black reinforced HDPE with drill tools having drill point angle of 120°.
- The friction between drill tool and polymer material increased with increase of cutting speed and more drill tool flank wear was occurred in drilling both pure and carbon black reinforced HDPE polymer materials.
- Drill tool flank wear values decreased when increasing the feed due to the fact that drilling process was perfomed faster and less heat based on friction was occurred at high feed.
- It has been observed that the heat around the drilling zone is transmitted through the polymer material and the heat does not accumulate in a zone due to the fact that the carbon black reinforcement increases the thermal conductivity of polymer materials. In addition, less softening is observed when compared to pure polymer materials. For these reasons, drill tool flank wear values measured in the drilling of CBR-HDPE were higher than

that observed in the drilling of pure HDPE.

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