

**24th COBEM - 2017**



24th ABCM International Congress of Mechanical Engineering  
December 3-8, 2017, Curitiba, PR, Brazil

**COBEM-2017-0648**

## **THE INFLUENCE OF CUTTING EDGE PREPARATION ON THRUST FORCE AND TORQUE IN DRILLING OF SAE 4144M**

**Moises Izaias de Santana**

**Milton Luiz Polli**

Federal University of Technology - Paraná, PPGEM, Department of Mechanics, Rua Deputado Heitor Alencar Furtado, 5000 – Ecoville, CEP 81280-340, Curitiba - PR, Brazil  
moises.san@outlook.com, polli@utfpr.edu.br

**Abstract.** *The cutting edge preparation is a process which has drawn attention from the tool's manufacturing and refurbishing industry due to specialization to its benefits specially to tool life. This process results in a major competitive advantage to those who have the knowledge of its application. As far as the twist drills are concerned, the lack of information is even greater, due to the high complexity of the tool and process itself. This paper presents the influence of twist drills cutting edge preparation on thrust force and torque in drilling process of SAE 4144M quenched and tempered steel. Experiments were also performed on SAE 4144M without heat treatment, SAE 4140 and SAE 8620 steel in order to compare the resulting torque and thrust force for the honed geometry. The manual brushing process was used to prepare tools with rounded edges and manual filing process was used to prepare tools with chamfered edges. The results showed that there was no significant difference in torque between the analyzed geometries, however the thrust force was lower for the sharpened tool without any edge preparation.*

**Keywords:** *drilling, twist drill, honing*

### **1. INTRODUCTION**

The cutting edge preparation is a process which has drawn attention from the tool's manufacturing and refurbishing industry due to specialization to its benefits specially to tool useful life. This process results in a major competitive advantage to those who have the knowledge of its application. As far as the twist drills are concerned, the lack of information is even greater, due to the high complexity of the tool and process itself.

Edge preparation has been made to avoid common defects from the sharpening process such as chipping, cracks and breakage in order mainly to improve the tool life by changing the micro-topography of cutting edge and also to adapt the surface of the cutting edge for a subsequent coating process of the tools (Cheung, 2008; Rech, 2006). The geometry of the edge preparation influences the thermomechanical aspects of the cutting process, such as shape of the deformation zone, temperature distribution in the cutting process, machining forces, chip formation and flow, superficial integrity of the work piece and the tool's resistance to wear (Denkena *et al.*, 2011; Hosseini, 2012; Woon *et al.*, 2008; Heo, 2011).

The key motivation towards the development of a process for the preparation of the cutting edge by rounding (honing), chamfering or the combination of both, is to improve its microtopography. Thus adapting the surface of the cutting edge as well as the cutting surface for a subsequent coating process of the tool or improving the contact zone for machining (Rodrigues, 2009). There are many kinds of cutting edge preparation processes applied in the industry as magnetic abrasive, polishing, abrasive flow machining, abrasive filled nylon filament brushing, abrasive blasting, electro-discharge machining, water jet machining, micro grinding and others (Gillespie, 1999; Rodrigues, 2009).

Studies from several researchers (Bierman *et al.*, 2008; Biermann *et al.*, 2012; Bouzakis *et al.*, 2000) presented some benefits related to the protection of the cutting edge achieved in different machining processes. Some authors investigated the influence of edge preparation on the machining surface quality, tool wear, cutting forces and temperatures (Fang, 2005; Bouzakis *et al.*, 2003; Özel, 2005; Ranganath *et al.*, 2007).

SAE 4144M is a low alloy steel widely used in the manufacture of injection holders which carry fuel from the high-pressure pump to the combustion chamber. Due to the high injection pressure, it is necessary to use a material with good high-pressure and wear resistance. In general, material used to manufacture injection holders are low alloy steels from the 41XX family. These steels are alloyed with Chrome (~1%) and Molybdenum (~0,2%) and achieve high resistance through heat treatment. They are widely used in the diesel fuel system component industry, especially for the

generations of more modern systems that work with injection pressures up to 2,300 bar. The main steels from the family are AISI/SAE 4140, 4144 and 4150, the last two being the most used in the manufacture of injection holders (Wosniak et al., 2010). SAE 4144M was specially developed for use in the automotive industry. Its chemical composition is similar to AISI/SAE 4140 (DIN 42CrMo4), however it contains nickel and lower permissible percentage of sulphur and phosphorus making more difficult its machinability.

This paper presents the influence of twist drills cutting edge preparation (sharpened, chamfered and honed geometry) on thrust force and torque in drilling process of SAE 4144M quenched and tempered steel. Experiments were also performed on SAE 4144M without heat treatment, SAE 4140 and SAE 8620 steel in order to compare the resulting torque and thrust force for the honed geometry.

## 2. MATERIALS AND METHODS

The main workpiece material used was SAE 4144M forged, quenched and tempered steel (39 HRC), with a 100% martensitic structure. Its chemical composition measured by a spectrophotometer Spectrolab Analytical Instrument is shown in Tab. 1. Experiments were also performed on SAE 4144M without heat treatment (34 HRC), SAE 4140 and SAE 8620 steel in order to compare the resulting torque and thrust force for the honed tool.

Table 1. Chemical composition (%) of SAE 4144M.

Steel	C	Si	Mn	Mo	Cu	Ni	Cr	P	S
AISI 4144M	0.44	0.24	0.95	0.25	0.22	0.17	1.26	0.02	0.02

The machine used for conducting the machining tests was a Daewoo DVC-320 machining center. For machining, tungsten cemented carbide twist drills with  $\varnothing 11\text{mm}$  were used, coated with a  $3\mu\text{m}$  layer AlCrN Based (Helica® from Oerlikon Balzers), with three different cutting edge geometries, sharpened, chamfered and honed one. The tools' macro geometries (chip angle, clearance angle and drill point angle) were prepared on a CNC grinding machine manufactured by Walter, model Power Production. In order to perform the micro geometry (chamfer and hone) some especial devices were used to make the tool's positioning aided by one optic microscopy. A file was used to produce the chamfer and the diamond brushes assembled in a Kennametal equipment to perform the honing. The process parameters used for drilling blind bores without tool retraction at a depth of 48 mm were kept the same during all tests, whereas the rotation was at 2,350 rpm, feed rate of 0.3 mm/rev (700 mm/min), cutting speed of 81 m/min, and internal cooling by emulsion with 40 bar of pressure were used. Thrust force and torque were measured by using a Kistler dynamometer type 9272 and a data acquisition system (Fig. 1).



Figure 1. Experimental setup. (1 - Machine, 2 - Notebook, 3 - Amplifier, 4 - Data acquisition board, 5 - SAE 4144M, 6 - Dynamometer, 7 - SAE 4140 and SAE 8620)

## 3. RESULTS AND DISCUSSIONS

### 3.1 Thrust force

Figure 2 shows the thrust force behavior during drilling of SAE 4144M quenched and tempered steel with sharpened, chamfered and honed tools. The sharpened tool obtained the least penetration effort into the material, around 400 N below the measured value for the other tools. The thrust force values were similar for the chamfered and honed

tool. There was a slight increase in thrust force after the half hole depth for the chamfered tool, while a slight decrease can be observed for the honed tool. These small variations are probably related to chip evacuation.

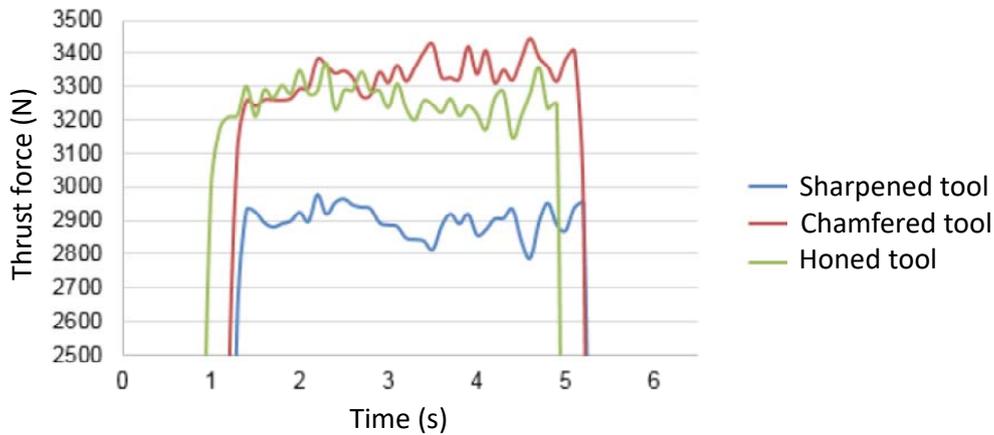


Figure 2. Thrust force for different tool geometries

Figure 3 presents the thrust force behavior during drilling with honed tool for different workpiece materials. The results show that SAE 4144M steel is the most difficult material to machine among the evaluated ones. The highest thrust force values were achieved for the quenched and tempered steel. The thrust force was also high for the SAE 4144M without heat treatment, the difference was nearly 1000 N compared to drilling of SAE 4140. The thrust force values were close to SAE 8620 and SAE 4140 steels.

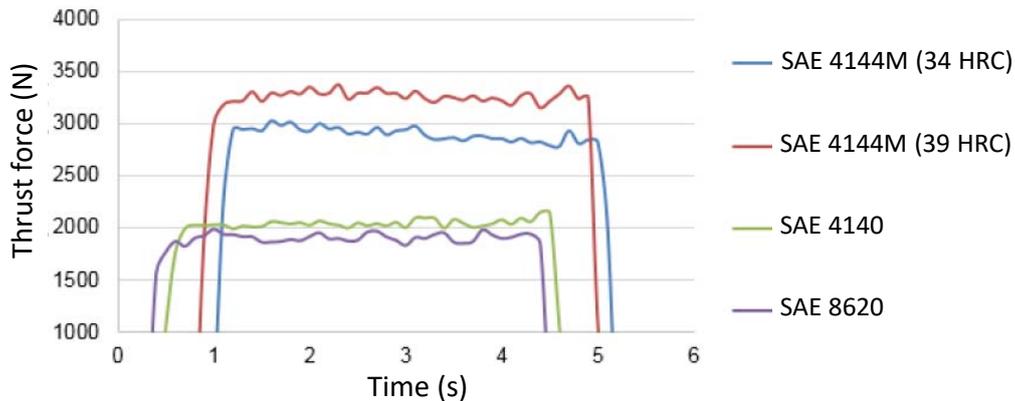


Figure 3. Thrust force for different workpiece materials

### 3.2 Torque

The torque behavior during drilling of SAE 4144M quenched and tempered steel with sharpened, chamfered and honed tools is shown in Fig. 4. There was no significant difference in torque measured during the process for the three analyzed geometries. This result is in accordance with Cheung *et al.* (2008), which reported that the torque does not vary in function of the geometry of the cutting edge in drilling with HSS drills.

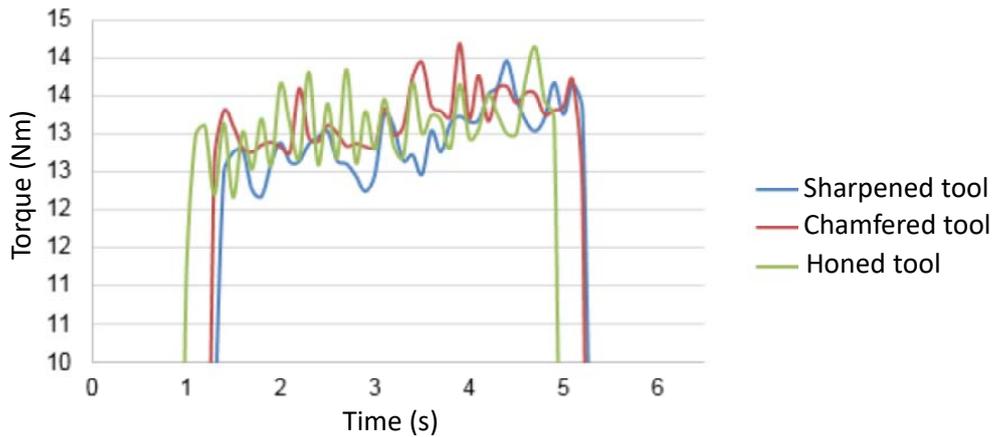


Figure 4. Torque for different tool geometries

Figure 5 presents the torque behavior during drilling with honed tool for different workpiece materials. The result showed that the lowest torque was obtained for SAE 8620 and the highest for SAE 4144M steel. The torque values were similar for SAE 4144M quenched and tempered steel and SAE 4144M without heat treatment. SAE 4140 presented intermediate torque values when compared to SAE 8620 and SAE 4144M steel.

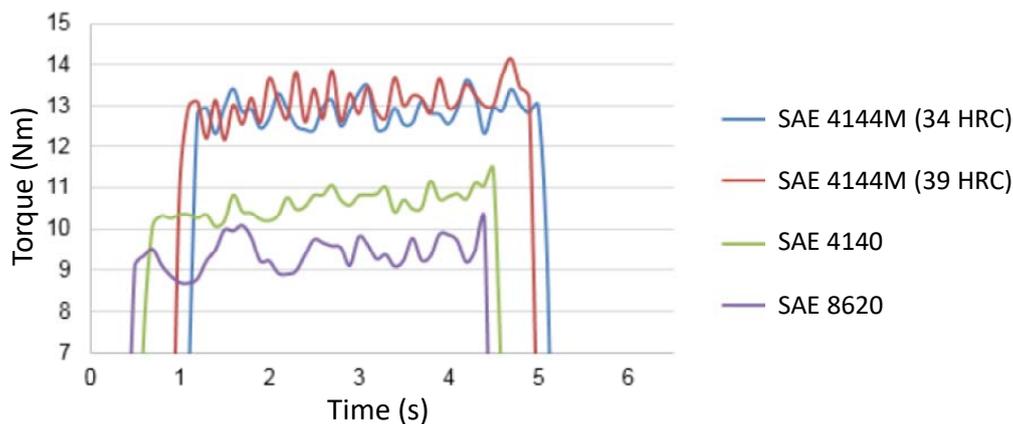


Figure 5. Torque for different workpiece materials

#### 4. CONCLUSIONS

The results showed that the lowest thrust force was obtained with the sharpened drill without any edge preparation. The thrust force values were similar for the chamfered and honed tool. The highest thrust force values were achieved for the quenched and tempered steel. The thrust force values were close to SAE 8620 and SAE 4140 steels. There was no significant difference in torque measured during the process for the three analyzed geometries. The lowest torque was obtained for SAE 8620 and the highest for SAE 4144M steel. SAE 4140 presented intermediate torque values when compared to SAE 8620 and SAE 4144M steel.

#### 5. REFERENCES

- Biermann, D., Terwey I., 2008. "Cutting edge preparation to improve tools for HPC process". *CIRP Journal of Manufacturing Science and Technology*, Vol. 1, p. 76-80.
- Biermann, D., Wolf, M., Asmut, R., 2012. "Cutting edge preparation to enhance the performance of single lip deep hole drills". *5<sup>th</sup> CIRP Conference on High Performance Cutting*, Vol. 1, p. 172-177.
- Bouzakis, K. D. et al., 2000. "Optimization of the cutting edge radius of PVD coated inserts in milling considering filmfatigue failure mechanisms". *Surface and Coating Technology*, Vol. 133, p. 501-507.
- Bouzakis, K.D., et al., 2003. "Optimization of the cutting edge roundness and its manufacturing procedures of cementedcarbide inserts, to improve their milling performance after a PVD coating deposition". *Surface and CoatingTechnology*, Vol. 163-164, p. 625-630.

- Cheung, F.Y., Zhou, Z. F., Geddam, A., Li, K. Y., 2008. "Cutting edge preparation using magnetic polishing and its influence on the performance of high-speed steel drills". *Journal of Materials Processing Technology*, Vol. 208, p. 196-204.
- Denkena, B., et al., 2011. "Effects of the cutting edge microgeometry on tool wear and its thermo-mechanical load". *CIRP Annals - Manufacturing Technology*, Vol. 60, p. 73-76.
- Fang, N., Wu, Q., 2005. "The effects of chamfered and honed tool edge geometry in machining of three aluminum alloys". *International Journal of Machine Tools & Manufacture*, Vol. 45, p. 1178-1187
- Gillespie, L.K., 1999. *Deburring and edge finishing handbook*. Society of Manufacturing Engineers / American Society of Mechanical Engineers, New York, 1<sup>st</sup> edition.
- Heo, J.Y., 2011. "Effects on honing treatment on AlP-TiN and TiAlN coated end-mill for high speed machining". *Trans. Nonferrous Met. Soc. China*, Vol. 21, p. 83-87.
- Hosseini, S.V., 2012. "Vahdati M., Modeling the effect of tool edge radius on contact zone in nanomachining". *Computational Materials Science*, Vol. 65, p. 29-36.
- Özel, T., 2005. "Effects of cutting edge geometry, workpiece hardness, feed rate and cutting speed on surface roughness and forces in finish turning of hardened AISI H13 steel". *International Journal of Machine Tools & Manufacture*, Vol. 47, p. 820-840.
- Ranganath, S., et al., 2007. "A model to calibrate and predict forces in machining with honed cutting tools in inserts". *International Journal of Machine Tools & Manufacture*, Vol. 47, p. 820-840.
- Rech, J., 2006. "Influence of cutting edge preparation on the wear resistance in high speed dry gear hobbing". *Wear*, Vol. 261, p. 505-512.
- Rodriguez, C.J.C., 2009. "Cutting edge preparation of precision cutting tools by applying micro-abrasive jet machining and brushing". Ph.D. thesis, Kassel University, Kassel.
- Woon, K.S., et al., 2008. "Investigations of tool edge radius effect in micromachining: A FEM simulation approach". *Journal of Materials Processing Technology*, Vol. 195, p. 204-211.
- Wosniak, F.A., Polli, M.L., Beltrão, P.A.C., 2010. "Influence of cutting parameters on deep hole drilling of AISI 4144 Steel". *Journal of Manufacturing Technology Research*, Vol. 2, p. 232-244.

## 6. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.