MACHINABILITY OF EN24 ALLOY STEEL WITH DIFFERENT TEXTURED TOOLS UNDER MQL ENVIRONMENT

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Abstract
While machining difficult-to-cut materials, rise in temperature near the machining area is one of the major phenomena affecting tool wear and potentiality of the process. Use of cutting fluid while machining in the industry has grown to be more hazardous that typically results in tool economy and makes it simpler to maintain tight tolerances and the quality of work piece surface without causing any damage. Owing to these, some alternatives have been looked for, to cut back on or perhaps do away with the cutting fluid for a satisfactory process. Also, manufacturers and researchers are consequently facing the open problem of using green machining techniques to meet the growing demands of sustainability. To overcome all these, Minimum Quantity Lubrication (MQL) with textured tools were employed and to enhance machining performance. Hence, this work presents comparison of circular pit hole texture (T1) and parallel grooved textured tool (T2) under MQL environment. Experiments are continuously conducted to evaluate parameters like cutting force measurement. On the whole, the experimental results indicate that under certain selected cutting conditions, MQL technique seems to be a better option using T2 tool over T1tool.T2 tool significantly reduced the cutting force (Cf) to 8.39% over T1.

Keywords: Minimum Quantity Lubrication, T1 tool, T2 tool, EN24 steel, cutting force.

1. Introduction

Machining of EN24 steel material lacks productivity due to the poor surface quality and formation of more built-up-edge (BUE) on the cutting edge. This results in the requirement of more cutting tools in the production operation of the machining process which leads to increasing manufacturing cost. However, BUE may sometimes have a positive effect on cutting forces. Metal cutting industries are looking for a higher production rate while machining EN24 steel due to the attractive applications in many industries. Especially, the aerospace industry pays much attention to the usage of this material in different aerospace components. In the present scenario, machining industries started the shift from the usage of conventional coolants to surface textured tools due to the advantages results. In the recent past, researchers carried out experimental work using different surface texture design tools on tool rake face while turning of various materials.Elias et al.[1] developed square pyramid-shaped micro indentations on the flank face of the cutting tool and experiments were performed on Ti-6Al-4V alloy under novel textured tool and untextured tool in presents of MQL and dry condition. In this connection, MQL technique, textured tools were store the cooling mist more time and flows on flank face effectively. It was found that, significant results of machinability indices were noticed when compared to untextured tools.Orra and Choudhury[2]Performance of various texture shapes designs having MoS2 and untextured tools on machining of AISI 4340.In view of author ,optimum results were noticed under textured tools ,accordingly. Further, due to good thermal conductivity of MoS2, vertical textured geometry exhibits outperformed results over untextured tool respectively. Senthilkumar et al. [3] various machinabity indice performance were noticed under optimizing of TGRA ,experiments designed using Taguchi.Authour revealed that, substantial improvement of MRR and flank wear have been noticed under turning of different materials. Jerold and Kumar [4] diminished machined output results were noticed with PVD-coated carbide inserts under cryogenic machining over dry and wet cooling methods when turning of Ti–6Al–4 V alloy.Goel et al. [5]machined indices significantly increase under TGRA when cutting of Mono-Crystalline Germanium at optimum process parameters in turning respectively. As per literature survey, no attempts were done on EN24 alloy steel with with newly developed textured geometry using MQL cooling environment. Jianfeng Ma [6] described all the factors related to a type of texture that affects the cutting forces, by preferring micro-grooved texture in dry machining of AISI 1045 steel. A descending trend in feed force and main cutting forces by 9.39-17.62%, 8.64-16% than wet machining.Shanmugasundaram et al.[7] Have investigated the effect of micro-texture during orthogonal cutting and determine a suitable parameter through experimentation on Al 6061 alloy. The most influential parameter is the diameter of the texture unit cell. It was observed that cutting force and thrust force are greatly reduced at the diameter of 150μm, depth of 50μm, the pitch of100μm as compared with that of untextured tools. Jesudass et al. [8] Has carried an experiment to study the performance of micro textured high-speed steel cutting implement within the machining of steel and aluminum samples. It was observed that the machining characteristics such as surface roughness (23.21 to 15.86%) and cutting force (24.09 to 41.2%) are improved with micro-Textured (T2, T3, T4) as compared with that of untextured(T1) high-speed steel inserts. Xing et al.[9] recorded more cutting performance with textured tools over untextured tools in dry machining of 6061 aluminum alloy. Orra and Choudhury[10] cutting of AISI 4340 using fabricated tools such as horizontal, vertical, and elliptical shape micro textures along with and without MoS2 and untextured tools, respectively. The pavement results were gained with textured tools over untextured tools, respectively. Moreover, it was found that vertically textured tools have outperformed results over the other textured tools. Thomas and Kalaichelvan[11] did a series of experiments and noticed low Tt, Ra, cutting force (Fc) with dimple tools over nondimple tools during turning of EN3B and AA 6351. Furthermore, observed favorable chip formation with tools having dimples. A few comparative studies were made with different surface texture design tools and found beneficial results with all designs of textured tools over the untextured tools during the turning of various materials. They also carried out simulation studies with different-textured tools and simulation results were compared with experimental results, respectively. Dhananchezian et al.[12]recorded low machined indices with a new cryogenic cooling approach over wet cooling due to ‘Tt’ while turning of AISI 304 SS. Bertolete et al.[13] developed linear grooves parallel to the tool cutting edge at different distances from the cutting edge and investigated these tools performance for the duration of dry turning of VSM13 martensitic SS and the untextured tool was used to compare the results. Results indicated that all textured tools significantly changed the tribological properties in favor of machining processes over untextured tools. Furthermore, it was found that the texture groove dimensions and distance initially from the cutting edge considerably affect the turning process performance.Durairaj et al.[14] found lower cutting force, larger shear angle during dry turning of aluminum alloy in textured tools having circular dimple patterns when compared to untextured tools. It was stated that the control of adhesion of workpiece to tool contributes favorable results in textured tools. Further, carried out the analysis of variance and found that the circular dimple diameter is identified as the most noteworthy variable. Moreover, optimum turning process parameters were determined included textured tool design using Taguchi analysis. Hao et al.[15] excuited experiments on titanium alloy using single textured tools having linear grooves, hybrid textured tools and untextured tools in dry and MQL cutting conditions, respectively. In textured tools, it was found low cutting force and low tool wear due to low friction coefficient in both cutting environments, respectively. Furthermore, hybrid textured tool tools significantly reduced the tool-chip contact length (L) as well as it provides a facility for coolant storage results in improved turning performance after comparing with single textured tools with respect to MQL cutting conditions. In literature, no experiments were performed with so developed tools in turning of EN24 steel under MQL environment.

1.1 Materials and methods

Circular pit hole texture (T1) as diameter of hole is 100µm and parallel grooved textured tool with width 100µm (T2) was developed by laser textured machine .The consider textures has enhance the lubrication capacity of coolant mist in both circular holes and parallel grooves .It was the reason for fabricate the texture on cutting inserts. The performance of textured tools were showed under Minimum Quantity Lubrication cooling environment by using SINUMERIK 828D BASIC made by LMW SMARTURN CNC machine. Figure 1. Shows (a) CNC machine setup with MQL (b) circular pit hole texture (T1) and (c) parallel grooved textured tool (T2) with CNC machine set up. Efficient MQL setup was developed with nozzle diameter 1mm to deliver the coolant at machined zone incessantly. For the experimentation, cutting velocity (Cv) are 110 and 137m/min ,feed rates (F) are 0.1and 0.12mm/rev, depth of cuts (Dp) are 1.0 and 0.2mm as cutting parameters .A 300mm length of EN24 alloy steel work piece with dimensions of (Φ 35 mm x 150 mm) was taken the experimentation.Table.1 shows chemical compositions of EN24 steel material. Each experiment was repeat three times and changes the tool edge at every single pass. With help of lathe tool dynamometer Cutting force was measured effectively.

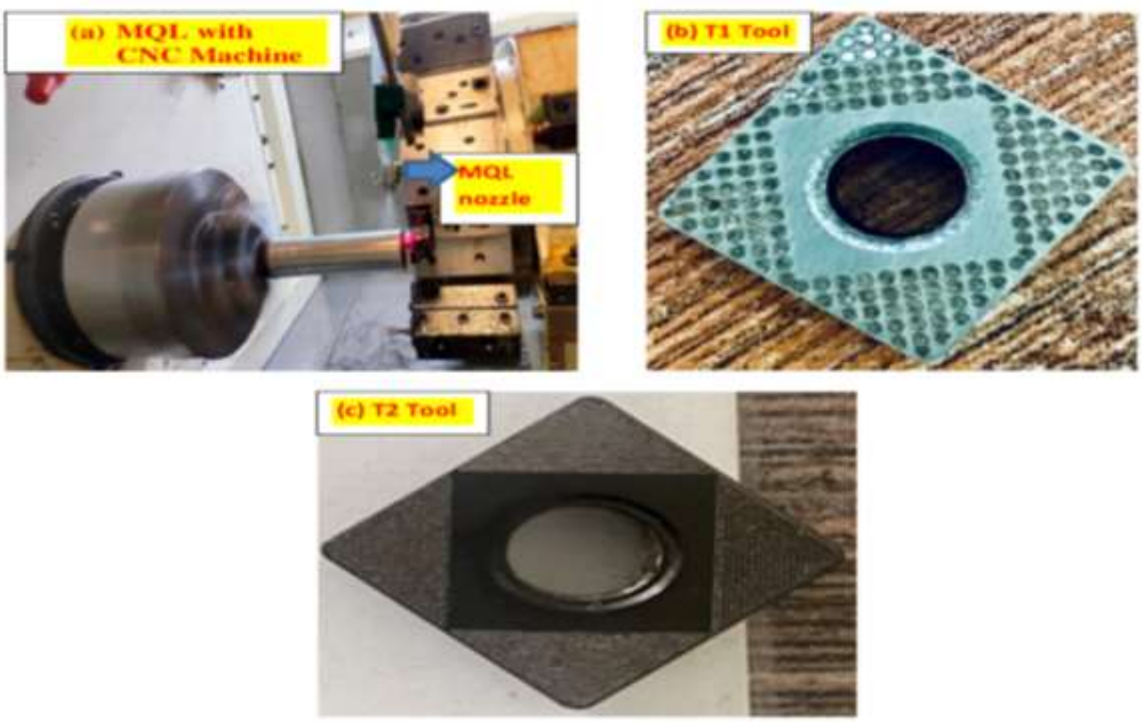

Figure.1 schematic view of (a) CNC Machine with MQL (b)T1,depth 100µm and (c) T2 Tool

Table 1. Chemical composition of EN 24 alloy steel (%)

C	Si	Mn	P	S	Mo	Cr	Ni	Fe
0.398	0.258	0.527	0.016	0.009	0.240	1.151	1.522	95.622

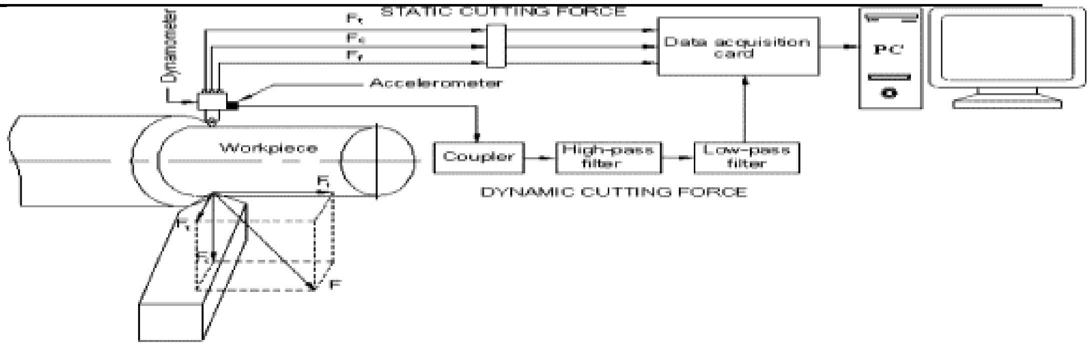

Figure 2. Measurement of cutting force using lathe tool dynamometer

Results and discussion

1.2 Influence of MQL - assisted cooling condition on cutting force with T1 and T2 Tools:

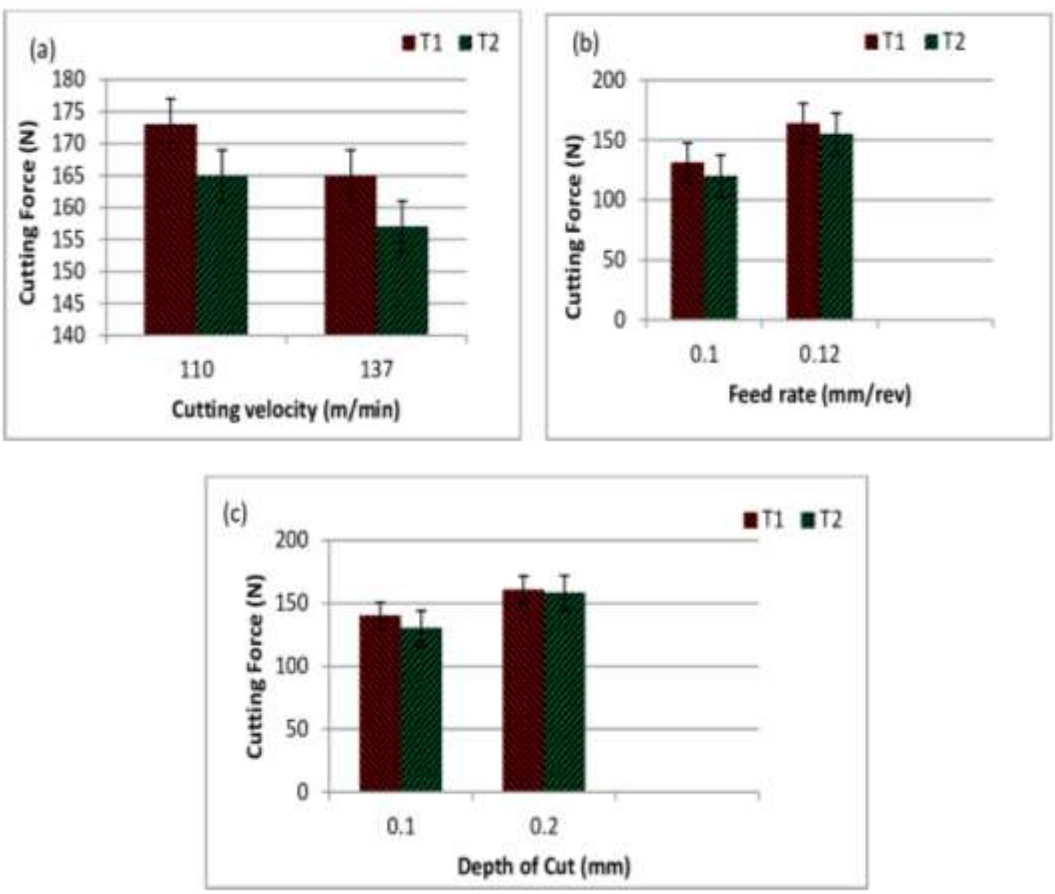

Figure.3 Effect of cutting force, at cutting velocity 137m/min, feed 0.12mm/rev and depth of cut 0.2mm T1 and T2 tools under MQL cooling.

Cutting forces are the forces that occur during the machining process and are influenced by various factors, including the tool geometry, work piece material, cutting conditions and machine tool characteristics.Figure.2 depicts recorded cutting force with respect to contact of tool and work piece at a distance of 20mm.From the experimental data, Figure.3(a) cutting force increased when increasing of feed and depth of cut values at interaction time of tool and workpiece.obseverd that, Due to high friction at machined junction, rapidly increases the 'Cf' at high feed and depth of cut values from increase zero to 175N in T1 tool over T2 tool under MQL environment.When'Cv' values increased from 110-137m/min significant reduction of cutting force was noticed in T2 tool. Here, thin lubrication film was developed between contact area of tool-tip interface. Consequently, reduce the cutting temperature in T2 tool at consider cutting setting condition . Apart from, T2 tool stores the coolant mist long time and accelerate the machined indices. At a 'Cv' 110m/min, noticeable 'Cf' values are 173N and 165N in T1 and T2 tool respectivily.Where, T2 tool, reduce the tool chip contact length. So that, up to 4.67%reduction of 'Cf' observed in T2 tool when compared to T1 tool under MQL.More over ,at cutting velocity 137m/min,MQL mist effectively supplies at machined junctions.Consequently,reduce the vibrations , fluctuations and friction at machined zone was observed .Where recorded 'Cf' values T1 and T2 tools are 165N and 157N .On the way , mitigation up to 4.84% 'Cf' was seen in T2 under MQL .From figure.3(b) depicts that increasing of feed rates from 0.1-0.12mm/rev, 'Cf' values significantly increased from 131N -164N under T1 tool. At a 'F' 0.1mm/rev ,T1 and T2 tools 'Cf' are 131N and 120N,better reduction of 'Cf' was observed in case of T2 tool under MQL process. Up to 8.39% reduction was noticed in T2 over T1 under MQL circumstance respectivily.On the way, MQL mist effectively ingresses cutting junction region .So, less contact length of tool-chip was seen .Moreover, at a 'F' 0.12mm/rev, T2 tool was reduce 'Cf' over T1 tool .Here, T1 and T2 tool values of 'Cf' are 164N and 155N. A 5.84% of decrement of cutting force was noticeable in T2 tool. Finally, feed rates 0.1-0.12mm/rev, maximum reduction of 'Cf' up to 5.78%-8.39% under MQL with T2 tool respectivily.Figure.3(c) noticeable 'Cf' values at 'Dp' 0.1mm are 140N and 130N under T1 and T2 tools .Slight reduction of cutting force up to 7.142 was noticed in T2 .At a 'Dp'0.2mm almost nearer value of 'Cf' were noticed in both developed tools. Here, observed T1 and T2 tools of 'Cf' are 161N and 158N.Here, up to 1.86% reduction of cutting force was seen in T2 tool over T1 .An increasing of 'Dp' from 0.1-0.2mm, significant reduction of 'Cf' varies from 1.86%-7.142%.From whole, less vibrations, fluctuations of machine and work piece .Further reduce the power consumption under MQL process in T2 tool over T1 tool respectively.

1.3 Conclusions

1. T2 tool developed fewer vibrations while cutting under MQL circumstance.
2. T1 tool found maximum cutting force values over T2 tools under MQL environment.
3. Parallel grooves in textured tools under MQL method acted as a coolant reservoir and assist in improving the lubrication effect at the cutting zone.
4. T2 tool developed less cutting force value maximum as 120N over T1 tool .This meant, grooves were effectively worked under MQL circumstance.
5. T2 tool significantly reduced cutting force up to 8.39% over T1 tool under MQL medium.

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