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Recent Advancements Under Varying Cutting Conditions- A Review

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Abstract: This paper presents the information mainly on various cutting conditions applied during machining with different types of cutting tools such as carbides, ceramics and cermets. In various types of machining process, the important parameter which needs to be control or reduce are cutting temperature and cutting force because these parameters directly effects the life of tool thus effected the tool cost. Metal working fluids are essential coolants and lubricants used in material removal and deformation processes to improve manufacturing productivity by increasing process throughout and tool life. Automobile industries uses different types of coated or multilayer coated cutting tools under varying cutting conditions for producing the various types of parts. This paper shows the study of the performance of coated ceramic tools under varying cutting conditions such as dry turning and wet turning. The objective of this study is to analyze the effect of different cutting conditions on various types of tools so as to determine its various parameters such as temperature, spindle speed, feed and depth of cut in machining of hardened steel. This study reviews the literature on the performance of coated Ceramic inserts under varying operating conditions.

Keywords: Coated Cutting tools, Ceramics, Dry Turning, wet turning etc.

I. INTRODUCTION

In the modern civilization, to meet the increasing demand, overall production and productivity the major force on the industry is to developing a new and good quality tool material. The purpose of developing a new cutting tool material has following advantages like lead time reduces, manufacturing cost has been reduced, difficult and hard materials are easily machined, improve surface roughness and Material Removal Rates (MRR) increases. In various types of machining process, the important parameter which needs to be control or reduce are cutting temperature and cutting force because these parameters directly effects the life of tool thus effected the tool cost. Metal working fluids are essential coolants and lubricants used in material removal and deformation processes to improve manufacturing productivity by increasing process throughout and tool life [1]. The process of using cutting fluids during the machining process has influential effect in reduction of temperature and lubrication of both the tool and the work piece, which ultimately tends to enhance the life of tool. Where as in case of machining processes where high production takes place, the high cutting region temperature causes failure of the cutting tools and dimensional deviation and subsequently the surface integrity damages of the product [2]. Conventional cutting fluids flop to transfuse the tool-chip interface and consequently fail to strip the heat generation in the cutting zone [3]. Also, cutting fluids tends to increase the overall machining cost. A no. of researchers also reported the fact that machining costs are quite high due to the use of cutting fluids during the machining processes which have considerably of higher cost than that of the cutting tools used for the machining [4]. An estimate of the total cost has been made by some researchers which suggests that almost 16% of the total manufacturing costs are consist of cutting fluid costs and when it comes to the cut or machine the materials which are very hard to machine and they reach up to 20-30 percent [5,6].

Ceramics were introduced in the 1940s. Ceramic cutting tools in recent years have been sought in many applications due to their enhanced properties such as improved thermal shock resistance, good high-temperature strength.

II. ADVANCEMENTS IN VARYING CUTTING CONDITIONS

Yeckley et al. [7] studied the machining process on Austempered Ductile Iron (ADI), the most broadly used ceramic class is the alumina-based class. There are different classes of ceramic materials for cutting tools, each one along with different properties. The two major classes of ceramic for cutting tools are Aluminum Oxide (Al_2O_3)-based, and silicon nitride-based (Si_3N_4). The Si_3N_4-based ceramics are produced by crystals of Si_3N_4 with an intergranular phase of SiO_2, sintered with alumina.Paiva et al. [8] experimentally investigated that the turning with TiN coated ($A12O3$+TiC) wiper mixed ceramic inserts by using Multivariate Robust Parameter Design on the hardened steel (AISI 52100). The new optimization approach has following characteristics variable of hard turning consists of controllable (x_i) and noise (z_i) to find out the parameter levels that decrease the distance of each response (y_i) from its respective targets (Ti) and each variance due to noise variables as low as possible.Long ying et al. [9] investigated that the effect on cutting performance and the wear mechanism of the silicon nitride ceramic inserts when Ti-Al-N and Al-Cr-O coatings were deposited on it. After experimentation it has been observed that the cutting performance, hardness and wear resistance can improve during the machining process. During uncoated inserts abrasive wear and where as in case of coated inserts abrasive wear has the most dominant factor. Bensouilah et al. [10] studied the effect of speed, feed and depth of cut during the hard turning of AISI D3 steel using ceramic inserts and from the experimentation it has been found that surface quality obtained with the coated ceramic insert is 1.6 times superior than the uncoated ceramic inserts. Whereas the less cutting forces were generated during the uncoated ceramic inserts. Shihab et al. [11] studied the effect of cutting parameters (cutting speed, feed rate and depth of cut) on the cutting temperature during hard turning of AISI 52100 alloy steel using Multilayer Coated Carbide Insert (TiN/TiCN/Al2O3/TiN). Central Composition Design (CCD) was adopted to perform the experiments and analysis was done with the help of ANOVA. To determine the optimal values of cutting parameters Response Surface Methodology (RSM) was employed.

After performing no. of experiments and analysis the results revealed that the cutting speed, feed rate and depth of cut had significant effect on the cutting temperature. Results also showed that the optimal cutting temperature lies within the range (566.593 Cº - 592.028 Cº) at cutting speed ranging from (100.12 m/min-250.00 m/min), feed rate within the range (0.13 mm/rev – 0.22 mm/rev) and the cutting speed ranging from (0.20 mm-0.85 mm) and the desirability was 100% for this optimized condition.Deiab et al. [12] investigated and studied the effect of turning of Titanium-6Al-4V alloy using Uncoated Carbide Tool at certain speed and feed. Rapeseed vegetable oil was used as cutting lubricant and Minimum Quantity Lubrication (MQL) technique was adopted. The main area of focus was on flank tool wear, surface roughness and energy consumed during turning. After experimentation and analysis the data was recorded. It was fond that vegetable oil was more sustainable alternative as compared to synthetic oil in term of tool flank wear, surface quality and energy consumed during cutting, Especially at feed rate close to 0.1 mm/min and cutting speed 90 m/min for turning of Titanium.Priarone C. P. et al. [13] evaluated the effect of different lubricating conditions (dry, wet and minimum quantity lubrication) on Turning and Milling of (Ti-48Al-2Cr-2Nb) Titanium Aluminides using Coated Carbide tools. Vacuum Arc Remalting and EBM processes were used to obtain the work pieces. No. of experiments were performed under dry, wet and MQL conditions to check the tool wear and surface quality and compared for best results. After experimentation the results revealed that dry machining is stable when there was sensible reduction in process parameters. MQL was advantageous in milling under choosen cutting condition, reduced the friction and increased the tool life. In turning, wet cutting was best suitable by reducing tool wear and improved surface quality. Because higher process temperatures requires higher cooling effect of emulsion which cannot be obtained by small mixture of oil and air in MQL having low thermal capacity.Srikaya et al. [14] investigated the CNC turning of AISI 1050 and analyzed the machining parameters by using Taguchi design and response surface methodology.

The principle parameters considered were cooling condition, cutting speed, depth of cut and feed rate. Experimentation was performed under Dry Cutting (DC), Conventional Wet Cooling (CC) and Minimum Quantity Lubrication (MQL) method. The design of the tests were done according to Taguchi approach and ANOVA was used for the analysis. After experimentation the results revealed that surface roughness was significantly affected by feed rate. For cutting operation machined surface quality can be increased by MQL technique as compared to dry cutting and conventional wet cutting. Elmunafi. et al. [15] investigated the effect on tool life of Wiper Coated Carbide cutting tool during turning of Hardened AISI 420 Stainless Steel. Castor oil was used as cutting fluid and Minimum Quantity Lubrication (MQL) was adopted to supply the fluid to the cutting zone. No. of experiments were performed by varying the cutting speed at the rate of 100, 135 and 170m/min and feed rate at 0.16, 0.2 and 0.24mm/rev). The cutting oil was supplied at a flow rate of 50ml/h. After experimentation the results revealed the tool life is inversely proportional to the cutting speed and feed rate both, but cutting speed had more significant effect on tool life than the feed. And during the investigation the optimal cutting parameters for coated carbide cutting tool was found to be 170m/min cutting speed and feed rate of 0.24 mm/rev.Shyha et al. [16] experimented the turning of Ti-6AL-4V using vegetable oil based cutting fluid. No. of experiments were performed and analysis was done with the help of ANOVA. The results showed that the surface roughness ranges from 0.56 to 0.81 µm and the main contributing factor for Ra was feed rate having PCR of 94.4% and the cutting tool material having PCR of 44.5 %. The use of PVD TiAlN coated carbide tools resulted lower surface roughness while mixed ceramic cutting tools experienced premature failure at a level of depth of cut 1mm. It has also been found that with increase in cutting speed tool tip flank wear also tends to increase.Priarone et al. [17] investigated the machinability of Ti-48Al-2Cr-2Nb alloy using Minimum Quantity Lubrication (MQL) method. Various emulsifiers and pure water were nebulized by using compressed air and varying the flow rate 6.5 to 115 ml/min to the cutting area in the form of mist. The results showed that the emulsion mist was more advantageous than pure water mist and dry cutting. As the flow rate increases the tool life was improved due to higher cooling effect. Elmunafi et al. [18] evaluated the performance of MQL using castor oil as cutting fluid on hardened AISI 420 Stainless Steel with wiper coated carbide cutting tool at different cutting speed and feed rate. After performing no. of experiments the results were compared with dry cutting also. It was found that the tool life was increased by using small amount of lubricant at a flow rate of 50 ml/h. Results also showed that MQL was good for machining hardened stainless steel using coated carbide tool for cutting speed upto 170m/min and feed rate of 0.24 mm/rev. Beyond that oil mist became evaporated and surface roughness and cutting forces were enhanced.Qehaja N. et al. [19] investigated the effect of various cutting parameters on surface roughness in dry turning using Tungsten Carbide inserts. It has been found that feed rate, nose radius and cutting time were the main influencing factors for surface roughness. Three level factorial experiment was designed and carried out and regression equation was generated. The results showed that feed rate influenced the surface roughness (0.513) more significantly than nose radius (0.394) and cutting time (0.258). The obtained results were more significant than the previous results in the research field.Ekinovic S. et al. [20] investigated the influence of MQL machining parameters on cutting forces during turning of Carbon Steel St52-3. The principle factors quantity of oil (10-50ml/h), water (0.3 to 1.7 l/h) and position of nozzle were explored in the experiment. The results revealed that for turning of CS St52-3 the optimum values of MQL parameters were 10 ml/h of oil and 1.7 l/h of water. Cutting forces were also reduced by 17% as compared to dry turning, while the position of nozzle does not affect much the cutting forces.Talib N. et al. [21] evaluated the performance of chemically modified Crude Jatropha Oil (CJO) for machining process as a bio-based metalworking fluid. Transesterification process was adopted to develop Modified Jatropha Oil (MJO) with different molar ratios of Jatropha Methyl Ester (JME) to Trimethylolpropane (TMP). Viscosity and density tests were conducted on MJOs and the samples were compared with CJO and synthetic ester (SE).

Experiments were performed by supplying all the fluids one by one to the machining area. The results revealed that the lubricant viscosity had a significant effect on machining performance, as the viscosity of lubricat decreases the cutting temperature and cutting forces were also increased. The results also showed that MJO recorded better performance in terms of machining performance and lubricating properties and was able to substitute SE. Due to lack of thermal stability and oxidation CJO was not recommended to be used as metalworking fluid. Busch K. et al. [22] investigated various strategies of cooling and lubrication for machining high temperature alloys. Titanium Ti6Al4V and Inconel 718 was taken as working material for investigation. The objectives behind the research was to increase the tool life, surface quality, reduction in machining cost, processing time and energy consumption. The three methods of cooling and lubrication adopted were High Pressure Cooling (HPC), Aerosol dry lubrication with CO2 and cryogenic cooling by CO2. Experiments were performed and the results showed that HPC was beneficial in roughing operations as high material removal rates reduces the specific energy consumption and a reasonable tool life was recorded. ADL with CO2 when supplied to cutting zone in very fine spray form reduces the friction thermal load on cutting edge and the process was almost dry, prevents the cleaning of workpieces and chips. CO2 cooling was completely residue free due to the sublimation of the cryogenic media at higher temperature. Also due to missing lubrication effect leads to adhesion on the work piece surface, additional lubrication has to be implemented with CO2.Putz M. et al. [23] investigated the machining of Elastomers after cooling them with liquid Nitrogen. No. of tests were carried out and compared with dry turning. The friction coefficient between tool and chip was evaluated by temperature dependent friction law. Results showed that there was increase in tangential cutting force by approx. 30% as compared to dry turning. Surface integrity and chip formation was also improved under cryogenic conditions.Paturi et al. [24] had done the analysis and measurement of surface roughness during turning of Inconel 718 using Tungsten disulfide (WS2) solid lubricant assisted Minimum Quantity Lubrication (MQL).

For the research work micron sized WS2 solid lubricant powder particles were dispersed (0.5%) in emulsifier oil based cutting fluid (20:1). The effect of cutting parameters on surface roughness was evaluated using Taguchi design approach and ANOVA. Multiple linear regression equation was used to find correlation between cutting parameters and surface roughness. Two lubrication strategies were used, one was WS2 dispersed in emulsifier and other was oil based emulsifier alone supplied to the cutting zone by MQL method. No. of experiments were carried out by varying the cutting parameters the results demonstrate that for both the machining environments the optimal cutting parameters for surface roughness of machined material were cutting speed at level 3 (100m/min), feed rate at level 1 (0.1mm/rev) and depth of cut at level 1 (0.05mm). Surface quality of machined work was also improved about on average of 35% when WS2 solid lubricant was used rather than emulsifier oil based cutting fluid alone.Rahim et al. [25] investigated the performance of Supercritical Carbondioxide (SSCO2) as a sustainable cooling technique for machining operation. The efficiency of SSCO2 cooling technique was compared with MQL technique and the principle factors under consideration were cutting temperature, chip thickness, cutting force and tool chip contact length.

The experiments were carried out using orthogonal cutting process and the results showed that with SSCO2 cooling temperature reduced by 15% to 30% which improved the tool life, cutting force was reduced by 5% to 14% which reduced the specific energy consumption as compared to MQL. SSCO2 was also found to be environment friendly and safer for the health of the worker so it was sustainable and can substitute the other mineral oil based metal working fluids.Ginting et al. [26] had done the investigation and reviewed the feasibility of three methods of cold air generation for cutting processes. The reason behind this research was to eliminate the traditional flood cooling and to find the best sustainable alternate. The three methods reviewed and investigated for generation of cold air were Vortex Tube (VT) cooling, Thermoelectric Cooling (TEC) and cooling the compressed air by Liquid Nitrogen (LN2). The results revealed that Coefficient of Performance (COP) of VT and TEC were very low as compared to LN2 produced cold air. From the previous research it was also found that VT was quite inefficient, TEC used very less energy than VT and LN2 method but its COP was very low only to be 0.011. After research it was concluded that more future work has to be done on TEC system which would increase its COP and comes out to be best sustainable alternate.

III. CONCLUSION

Heat generation between tool and work piece during cutting is continuous and cannot be neglected but can be reduced by the application of cutting oils, lubricants and cryogenic coolants In the present study performance of cutting tools such as ceramics under varying cutting conditions has been reviewed. The machining of hard materials at higher speeds is improved by using coated tools. From the investigation it is observed that the performance of coated inserts during Wet Turning was better than that of the inserts during Dry Turning for surface roughness and wear rate of tool under the same given experimental conditions. Whereas material removal rate was found better with the Multilayer Coated Carbide inserts during Dry Turning.

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