International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 05, May-2019

REVIEW OF HARD TURNING AND HARD MILLING

Ravi Kumar[1], P. Sudhakar Rao[2]

[1]*M.E. scholar, Department of Mechanical Engineering, National Institute of Technical Teachers Training and Research, (NITTTR),Chandigarh*
[2]*Assistant professor, Department of Mechanical Engineering, National Institute of Technical Teachers Training and Research, (NITTTR), Chandigarh*

ABSTRACT
Hard turning is a machining process which is used to machine the materials which have Hardness rating of 45 HRC and above. The process is capable of giving the surface finish of a very precise grinding operation but at a much lower coast. In similar way the hard milling operation is there. Both these machining techniques have become very popular these days as a wide range of materials for tools are available. Various experimental studies been conducted by the researchers on the topics like tool wear and tool life, microstructure change, white layer formation, surface integrity and fatigue strength of hard milled surfaces. This review paper compiles the results and conclusion of above experimental studies.

Key Words- Hardness, Hard Turning, Hard Milling, Tool Wear, Fatigue strength.

1. INTRODUCTION

1.1 HARD TURNING

The process came into existence with advancement and discovery of new materials. **[1].** Initially before 19th century the available materials were not very hard to be used as tools for hardest materials. In addition to this the material which were being used to make the machines were not very rigid to withstand the cutting band twisting forces generated by hard turning. So the development in materials made the hard turning process as a good alternative to precise grinding operations which were costly and had a very low material removal rate compared to hard turning.

For some time the natural and synthetic diamonds were being used to machine non-ferrous materials but in case of steel it failed as diamond forms a compound on interaction with the steel and it gets graphitised so a different crystalline structure was the needed.

Cubic Boron Nitride was found to be suitable for this purpose. Its hardness is comparable with diamond. For a good surface finish a CBN tool with CBN content 50% is sufficient and along with this the rest 50% is a ceramic binder material that is to be used. Only a polycrystalline structure exist in CBN. So it is also called PCBN. Generally in turning hardened steel negative cutting angle is used and no any cutting fluid is required. But if we do this operation on conventional lathe machine it produces vibrations and the surface finish is compromised. Turing with high pressure force can be carried out only on machines that have a high stiffness and stability of the structure. Work should also be rigid. If it is not very rigid then the work supports can be used near the cutting tool.

1.2 HARD MILLING

Hard milling is an offshoot of high speed machining techniques. The essence of high speed machining is taking many light cuts at closely spaced step over, thus leaving minimal cusps between passes. The goal is to create an as-machined surface that drastically reduces the need for subsequent processing. For the cutting tool to achieve an effective chip load, feed rates and spindle speeds must be much higher than those normally applied in traditional machining; hence the name high speed machining. The high feed rates also make it possible to complete a much larger number of passes across the work-piece more quickly than with traditional methods.

Hard milling takes the concept of high speed machining one step further. The combination of light cuts at high feed rates and spindle speeds makes it possible to remove steel in the hardened state efficiently when all of the proper conditions are met. Likewise, closely spaced step over with small-diameter, radial tools leave a surface that approaches the fineness of one that has been stoned or polished by hand. Because the steel is already hardened, subsequent heat treating, stress relieving or grinding steps are unnecessary. More importantly, the process also replaces many costly steps with EDM.

The ability to hold extremely tight tolerances (±0.0004 inch or less) is an added benefit of hard milling that is valuable in mold machining. It allows mold contours to be machined without the excess stock normally left for hand spotting. Moreover, by machining to zero stock, mold geometry will perfectly match that of the CAD model. Likewise, this ability allows mating mold surfaces to be machined to a negative stock condition. The concept is to machine shutoff areas along the parting lines, usually on the cavity side, slightly but precisely below the nominal dimension. This leaves a small gap between the surfaces that would normally contact each other when the mold closes. Gap size is too small (0.0008 inch is typical) to allow plastic to flow out during the injection process, so the mold still shuts off effectively. The gap allows air within the mold to escape readily, without additional provisions for venting, as molten plastic is forced inside. Small contact pads in corners maintain the gap otherwise, shutoff surfaces do not touch each other. The interference between these surfaces that must normally be resolved during spotting and fitting is eliminated. In addition, the gap eliminates the impact between these surfaces when the core and cavity sides come together so that the sharp edge at the parting line is fully protected.

2. LITERATURE REVIEW ON HARD TURNING AND HARD MILLING

Haq and Tamizharasan [2] As a means to overcome the limitations of cutting fluids in machining, more and more attention is being paid to the internal cooling of cutting tools. The elevated cutting zone temperature in hard turning causes the instant boiling of coolant in the cutting zone, which pulls down the tool life and surface finish, by making thermal distortions and hence in most of the hard turning operations, the coolant is not used at all. The absence of coolant also reduces the tool life and surface finish to some extent. As an alternative solution to the direct application of coolant in the metal cutting zone to improve tool life and surface finish, the heat pipe cooling system is introduced in this investigation. A parametric study is conducted to analyze the effects of different heat pipe parameters such as diameter of heat pipe, length of heat pipe, magnitude of vacuum in the heat pipe and material of heat pipe. All these parameters are varied to three levels. In this analysis, it is assumed that the single point cutting tool is subjected to static heating in the cutting zone which verifies the analysis and feasibility of using heat pipe cooling in turning operations. The heat pipe parameters are optimized by using Taguchi's Design of Experiments and a confirmation test is conducted by employing the heat pipe fabricated with the best values of parameters. The results of the confirmation test are compared with the previous experimental results. The comparison shows that the use of a heat pipe in hard turning operations reduces the temperature field by about 5%, improves tool life by reducing tool wear and improves surface finish significantly. The result of this analysis is applicable to define controlling parameters of heat pipes for optimal design and set-up for various related studies. The finite element analysis also shows that the temperature drops greatly at the cutting zone and that the heat flow to the tool is effectively removed when a heat pipe is incorporated.

Singh and Rao,[3] An experimental investigation was conducted to determine the effects of cutting conditions and tool geometry on the surface roughness in the finish hard turning of the bearing steel (AISI 52100). Mixed ceramic inserts made up of aluminium oxide and titanium carbonitride (SNGA), having different nose radius and different effective rake angles, were used as the cutting tools. This study shows that the feed is the dominant factor determining the surface finish followed by nose radius and cutting velocity. Though, the effect of the effective rake angle on the surface finish is less, the interaction effects of nose radius and effective rake angle are considerably significant. Mathematical models for the surface roughness were developed by using the response surface methodology.

Li and Guo [4] Studied the surface integrity of AISI H13 tool steel samples which were milled by using PVD (Physical Vapour deposition) coated inserts. A flank wear of three levels was used to study the effects of cutting speed radial depth and feed.ie. VB=0mm, Vb=0.1mm and VB=0.2mm. Analysis of evolution of surface finish obtained by different combinations of milling perimeters was carried out. The evolution of tool flank wear was inspected on a CNC integrated optical inspection tool.

Li et al. [5] Investigation is made on the effect of surface integrity on the endurance limit of AISI H13 tool steel (50 HRC) by hard milling in which PVD coated tool was used. The study was conducted on three levels of flank wear VB=0, 0.1, 0.2 respectively. On each level effects of cutting perimeter were studied. Endurance limit at each reliability was calculated and compared with the experimental result. A good finish of hard milled surface enhance the endurance limit.

Zhang et al. [6] To explore the effects of cutting speed, feed rate and rake angle on chip morphology transition, a thermomechanical coupled orthogonal (2-D) finite element (FE) model is developed, and to determine the effects of tool nose radius and lead angle on hard turning process, an oblique (3-D) FE model is further proposed. Three one-factor simulations are conducted to determine the evolution of chip morphology with feed rate, rake angle, and cutting speed, respectively. The chip morphology evolution from continuous to saw-tooth chip is described by means of the variations of chip dimensional values, saw-tooth chip segmental degree and frequency. The results suggest that chip morphology transits from continuous to saw-tooth chip with increasing feed rate and cutting speed, and changing a tool's positive rake angle to negative rake angle. There exists a critical cutting speed at which the chip morphology transfers from continuous to saw-tooth chip. The saw-tooth chip segmental frequency decreases as the feed rate and the tool negative rake angle value increases; however, it increases almost linearly with the cutting speed. The larger negative rake angle, the larger feed rate and higher cutting speed dominate saw-tooth chip morphology while positive rake angle, small feed rate and low cutting speed combine to determine continuous chip morphology. The 3-D FE model considers tool nose radii of 0.4 mm and 0.8 mm, respectively, with tool lead angels of 0 deg and 7 deg. The model successfully simulates 3-D saw-tooth chip morphology generated by periodic adiabatic shear and demonstrates the continuous and saw-tooth chip morphology, chip characteristic line and the material flow direction between chip-tool interfaces. The predicted chip morphology, cutting temperature, plastic strain distribution, and cutting forces agree well with the experimental data. The oblique cutting process simulation reveals that a bigger lead angle results in a severer chip deformation, the maximum temperature on the chip-tool interface reaches 1289 deg, close to the measured average temperature of 1100 deg; the predicted average tangential force is 150N, with 7% difference from the experimental data. When the cutting tool nose radius increases to 0.8 mm, the chip's temperature and strain becomes relatively higher, and average tangential force increases 10N. This paper also discusses reasons for discrepancies between the experimental measured cutting force and that predicted by finite element simulation.

Chaudhari [7] In this study, three levels of each parameters viz. Hardness (HRC), Speed(mm/min), Feed(mm/rev) and three different tool materials are evaluated for process quality characteristics such as tool wear. The three different tool materials used are High CBN, Low CBN, Mixed ceramic. AISI H 11 was taken as work piece material. The experiment is designed using Taguchi Method. The results obtained from the experiments are transformed into signal to noise (S/N) ratio and used to optimize the value of tool wear. The analysis of variance (ANOVA) is performed to indentify the statistical significance of parameters. The conclusion is that for tool wear optimum condition can be achieved with work piece of 45HRC while using High CBN tool bit at speed of 230 mm/min and feed of 0.12 mm/rev. And the most affecting parameter on tool wear is hardness which has impact of about 43.30%.

Panda et al. [8] The objective of the present work has been set to have a study on hard turning of EN 31 steel (55HRC) using TiN/TiCN/Al2O3 multilayer coated carbide inserts through Taguchi L16 orthogonal array design and investigates surface roughness under dry environment. The mathematical model has been developed for better prediction of responses using response surface methodology and correlated for its significance. The mathematical model presented high correlation coefficients (higher R2 value) and fitted well. Feed is found to be most dominant parameter for affecting the surface roughness. A Taguchi technique has been utilized for parametric optimization of surface roughness. From the study, the potential and effectiveness of multilayer coated carbide insert has been noticed while turning hardened steels under dry environment. Following conclusions can be drawn. Better surface quality generated using coated carbide insert even 0.2 microns at run 9 justify its application during hard machining. The improved surface roughness obtained from coated carbide may be attributed to the retained cutting edge geometry with better hardness, wear resistance and low friction properties. An increase of feed deteriorates the surface finish with feed noted as a detrimental factor and highly significant noticed from ANOVA study. The RSM model presented high determination coefficient (R2 = 0.97 and 0.95 close to unity) explaining 97% and 95% of the variability in the Ra and Rz which indicates the goodness of fit for the model and high significance of the model. The experimental and predicted values are very close to each other .From main effect plot of S/N of Ra and Rz, the optimal parametric combination for Ra has been found to be d4 (0.4 mm)-f1 (0.04 mm/rev)-v2 (110 m/min) and for Rz, it has been found to be d3 (0.3 mm)-f1 (0.04 mm/rev)-v2 (110 m/min).The improvements of S/N ratio from initial parameter level to optimal parameter level are found to be 1.5145dB and 1.8551 dB respectively for Ra and Rz respectively. From the experimental investigation and observations on surface roughness in hard turning with multilayer coated carbide tools, it has been concluded that the coated carbide tool out performs over the range of parameters chosen.

Touazine et al. [9] This study investigated the effects of semi finish, finish and critical finish machining parameters on the microstructural evolution of subsurface layers in Inconel 718. In order to assess the microstructural evolution in the subsurface layer following machining, advanced characterization methods including opto-digital microscopy, X-ray diffraction and nanoindentation were used. Results showed that friction between the tool and the workpiece during machining lead to microstructural changes such as hardness enhancement on the surface, and softening on the subsurface. It was also observed that damage in the machined surface is related to the presence of defects such as cracks, cavities and carbide detachment from the surface. Finally, residual stress measurements revealed that, within the investigated parameters, the cutting speed has the most significant effect on surface integrity.

Zhang [10] This paper investigates white layer formation and morphology in hard turning process using various process parameters, taking into account the effects of heat treatment which results in microstructure and hardness differences on bulk materials. Samples undergone three typical heat treatment processes are prepared and then machined using different cutting speeds and radial feed rates. Optical microscope, scanning electron microscope (SEM), and X-ray diffraction (XRD) are employed to analyze the microstructures of white layer and bulk materials after varies heat treatments and cutting processes. Through the studies, we find the existence of a cutting speed threshold, below which no white layer forms for both the low and medium-temperature tempering. The threshold value increases; however, the white layer thickness decreases under the same cutting conditions, for the low and medium- temperature tempering, respectively. Also, we find that the white layer thickness and the scattering of it along the cutting direction on the surface increases with cutting speed and radial feed rate. White layer with wavy morphology can be found in samples after quenching at high cutting speed. We first discover that the pitch of the white layer with wavy morphology is similar to the displacement of tool at the time a segment of the serrated chips forms. Also, the surface residual stresses of the samples are measured. Relationship between white layer and residual stresses is presented. Based on the relationship we reveal that high temperature is more dominant than volume expansion for white layer formation.

Duc and Long [11] This paper presents a comprehensively experimental study on investigation of MQL performance in hard milling of S60C steel for multiple responses, including surface quality, cutting forces and tool wear. Compared to dry milling, even-enhanced surfaces finish quality, 20% less cutting force (Ft) and almost 112% prolonged tool lifetime are achieved by using MQL with 5% Emulsion in hard milling. In addition, this study compared the performances of MQL milling by using 5% Emulsion to the peanut oil completely harmless to the environment. This encouraging result, therefore, reveals that the MQL-employed hard milling can enable significant improvement in productivity, product quality, and overall machining economy even after covering the additional cost of designing and implementing MQL system. Moreover, this study also shows the limitation of peanut oils employed in MQL and proposes the further research in novel additives to enhance the performance of cooling lubricant for vegetable oils. It concludes that This research has successfully applied MQL to hard milling with cemented carbide cutting inserts, wherein both surface quality and tool wear can be improved compared with the case of dry milling. Moreover, it can be seen that the selection of cutting fluid is very important for most of the machining processes. The results have demonstrated that using MQL with Emulsion 5% in hard mill can much increase the cutting performance, in comparison of dry milling and peanut oil-based MQL milling. The degree of wear on tools can be varied by using different cutting fluid and cooling methods; however extreme wear mainly occurs at the areas near the major cutting edge during surface hard milling. This is the distinguished property of hard milling over other cutting processes. This understanding significantly guides further research on the decrease of tool wear, increase of surface quality, tool life and cutting performance and explores the new appropriate additives for vegetable oils in order to enhance the performance of cooling lubricant in MQL-employed hard machining while remaining their characteristics of friendly environment .

Dong et al. [12] The hard turning process is widely used in automobile and heavy machinery industries. Extreme cutting conditions like high temperature and tool wear rate, are associated with the hard turning process. Cubic boron nitride (CBN) cutting tool is generally preferred for hard machining operations. However, higher tool cost, and tool failure due to thermal shock limits its widespread usage. In machining performance analysis, tool wear is an important parameter which is directly related to the cost of the machining process. Previous studies have reported the improvement in tool life by using cryogenic coolant as a cutting fluid. Objective of this paper is to investigate the effect of cryogenic cooling on the tool wear of CBN and Ti-coated alumina ceramic cutting tools used in the hard turning Of AISI 52100 hardened steel. High pressure cryogenic jet (HPCJ) module was optimized and configured to use it for hard turning case. Computational fluid dynamics (CFD) based simulation was used to test and optimize the nozzle design for the flow of cryogenic coolant. It was validated by fundamental heat removal test. Ceramic and CBN cutting tools were then used for hard turning of parts using HPCJ module. Flank wear lengths for various cooling conditions were measured and analyzed. It was observed that the higher tool life of a Ti-coated alumina ceramic can be achieved under cryogenic cooling technique, as compared to the CBN insert under dry conditions. Cost analysis of these hard turning cases was also conducted to check the feasibility of its usage under realistic shop floor conditions. It was observed that the machining using Ti-coated ceramic under cryogenic jet may reduce the total tooling cost compared to CBN cutting tool conducted under dry conditions

Grezesik and Zak [13] In this paper the state of surface integrity developed on hardened high strength steel 41CV steel after hard machining and finish ball burnishing. The surfaces obtained by machining were classified as 2D and 3D surfaces based on roughness parameters. Among the characteristics of surface layer the microstructure, microhardness and residual stresses were calculated. The investigation confirms that the surface produced after ball burnishing has lower roughness and better service properties than those generated by CBN finished hard turning operation.

Wang et al. [14] In this work, data-dependent systems (DDS), a stochastic modeling and analysis technique, was applied to study the power of spindle motor during a hard milling operation. The objective was to correlate the spindle power to tool wear conditions using DDS analysis. The spindle power was monitored, and the time series trends were decomposed to study the frequency variation with different severities of tool wear conditions and processing parameters. Analysis of variance (ANOVA) was also used to determine factors significant to the power by a spindle motor. Experiments indicate that low-level frequency of spindle power is correlated with the amount of tool wear, cutting speed, and feed per tooth. The results suggest that effective tool wear monitoring may be achieved by focusing on low-level frequencies highlighted by DDS methodology.0

3. CONCLUSIONS

After going through literature survey we it can be concluded that hard turning is better substitute of grinding. Hard turning offers a number of benefits over grinding including lower setup times, low machine cost, flexibility in operations and accuracy and elimination of high usage of cutting fluid. Surface roughness and MRR are performance parameters and are significantly affected by cutting parameters, work hardness, cutting tool materials and tool vibrations. From this study, it is found that feed rate is most important factor followed by depth of cut in case of surface roughness and cutting speed is most significant factor for tool wear. Feed and depth of cut are significant for increasing MRR. By carefully selecting the feed rate, depth of cut and cutting speed hard turning can significantly enhance the profitability of a low tolerance products. Taguchi method, Response surface methodology and analysis of variance are efficient tools for designing, controlling and optimization of parameters.

4. FUTURE WORK AND SCOPE

Hard Machining operations have been observed as a better and low cost substitute for costly grinding operations. As the new inventions and research is taking place in materials we are getting better materials for tooling which have extremely low tool wear rate and poses a high hardness and strength which have the potential to improves the surface integrity further hard machining operations have a bright future.

REFERENCES

[1] Amritpal singh, Harjeet Singh, Rakesh kumar “Review on Effects of Process Parameters in Hard Turning of Steel”, JIRST –International Journal for Innovative Research in Science & Technology, Vol. 3, pp. 30-35, 2016.

[2] A. Noorul Haq and T. Tamizharasan “ Investigation of Effects of Cooling in Hard Turning Operations”. International Journal of Advanced Manufacturing technology October 2006, Vol. 30, pp. 808-816, 2006.

[3] Dilbag Singh, P. Venkateswara Rao, “A surface roughness prediction model for hard turning pocess”, The International Journal of Advanced Manufacturing Technology, Vol. 32, pp. 1115-1124, 2006.

[4] W.Li and Y.B.Guo “The Effects of PVD Coated Tool Flank Wear and Process Parameters on Surface Integrity in Hard Milling AISI H13 steel” ,STLE/ ASME International Joint Tribology Confrence. Paper No.- IJCT2010-41216, pp. 239-241, 2010.

[5] W. Li, Y.B. Guo, M.E. Barkey, C. Guo and Z.Q. Liu “ Surface Integrity And fatigue Strength of Hard Milled surfaces”, ASME International manufacturing Science and Engineering conference, Paperno.- MSEC2011-50282,pp. 199-206, 2011.

[6] Xueping Zhang Shenfeng Wu, Heping Wang and C. Richard Liu, “Predicting the Effects of Cutting Parameters and Tool Geometry on Hard Turning Process Using Finite Element Method”, Journal of Manufacturing Science and Engineering, vol.133, pp. 041010-1 to 041010-13, 2011.

[7] Chaudhari Y D “Investigation Of Tool Wear In Hard Turning Using Taguchi Method”, International Journal Of Engineering Research and Applications, Vol. 3, pp. 317-321, 2013.

[8] Panda, A, Dutta, S.K, Sahoo, A.K, Rout, A.K4, Routra, B.C5 “Experimental investigation on surface roughness characteristics in hard turning of EN31 steel using coated carbide insert: Taguchi and mathematical modeling approach”, 5th International & 26th All India Manufacturing Technology, Design and Research Conference, pp.177-1 to 177-6, 2014.

[9] H. Touazine, M. Jahazi and P. Bocher, “Influence of Hard Turning on Microstructure Evolution in the Subsurface Layers of Inconel 718”, International Mechanical Engineering Congress and Exposition, IMECE2014-37348, pp. V02AT02A018; 5 pages, 2014.

[10] Xiao-Ming Zhang, Li Chen and Hang din, “ Effects of process parameters on white layer formation and morphology in Hard Turning of AISI52100 steel”, Journal of manufacturing science and engineering, Volume 138, pp. 074502-1 to 074502-9, 2016.

[11] Tran Minh Duc and Tran The Long “Investigation of MQL-Employed Hard-Milling Process of S60C Steel Using Coated-Cemented Carbide Tools”, Journal of Mechanics Engineering and Automation, pp. 128-132, 2016.

[12] Dong Min Kim, Do Young Kim, In Su Jo, Tae Jin Song, Kyung Soo Paik and Hyung Wook Park ”Experimental Tool Wear of Assisted High Pressure Cryogenic jet in Hard Turning process”, ASME International manufacturing Science and Engineering conference, Paper no.- MSEC2017-2935, pp. V001T02A018; 9 pages, 2017.

[13] Wit Grezesik and Krzystof Zak " Characterization of Surface Integrity Produced by sequential Dry hard turning and ball burnishing operation" , Journal of manufacturing science and engineering, Vol. 136, pp. 031017-1 to 031017-9. 2017.

[14] Xingtao Wang, Robert E Williams, Micheal P Sealy,Prahalad K Rao and Yuebin Guo " Stochastoic Modeling and Analysis of Spindle Energy Consumption During Hard Milling With a Focus on tool Wear ", International manufacturing Science and Engineering Conference, paper no. MSEC2018-6511, pp. pp. V003T02A002-VT003T02A010, 2018.