Performance of Coated Carbide Tools during CNC Machining- A Review

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Abstract: Better quality with high productivity is the prime concern of manufacturing firms to remain in business in today's competitive manufacturing market. CNC machines provide this opportunity. However, the performance of a cutting tool in high-speed CNC machining plays a key role in achieving high productivity and better quality. Various hard coatings have been developed to increase the performance of the cutting tools. In this study performance of various coated carbide tools in term of wear rate & surface roughness obtained during the CNC machining have been included.

Key Words: Coated Carbide Tools, Coating materials, Performance of coatings, Flank Wear

I. INTRODUCTION

Cemented carbide tools are most desirable in high production in the competitive market of manufacturing industries. A demand for enhanced productivity is the key factor for the improvement of cutting tools with respect to the achievement of a superior tribological attainment and wear-resistance. The tool wear of cutting tools has a very strong impact on the product quality as well as on the efficiency of the machining processes. Despite the ongoing automation high level in the machining industry, a few key issues prevent complete automation of the entire turning and milling process. One of these issues is tool wear, which is usually measured at the large of the machine tool. Therefore, its characterization in a row is essential [1].

This resulted in developing hard coating for cutting tools; these hard coatings are thin films of one layer to hundreds of layers. These hard coatings have been proven to increase the tool life by as much as 10 folds through slowing down the wear phenomenon of the cutting tools. This increase in tool life allows for less frequent tool changes, therefore increasing the batch sizes that could be manufactured and in turn, not only reducing manufacturing cost, but also reducing the setup time as well as the setup cost. In addition to increasing the tool life, hard coating deposited on cutting tools allows for improved and more consistent surface roughness of the machined workpiece [2].

PVD & CVD techniques are widely used to employ hard coating to cutting tools. Physical vapor deposition (PVD) covers a broad family of vacuum coating processes in which the employed material is physically removed from a source by evaporation or sputtering. Then, it is transported by the energy of the vapor particles, and condensed as a film on the surfaces of appropriately placed parts under vacuum. Chemical vapor deposition (CVD), unlike to PVD vacuum processes, is a heat-activated process based on the reaction of gaseous chemical compounds with suitably heated and prepared substrates. Typical deposition temperatures range from 800°C to 1200°C. Fewer CVD reactions are available for use at temperatures below 800°C than above (moderate temperatures, MT-CVD). However, the temperature required for a given reaction can be lowered by exposing the substrate to electrical plasma in the gas phase during deposition, referred to as plasma-assisted (PA-CVD) [3].

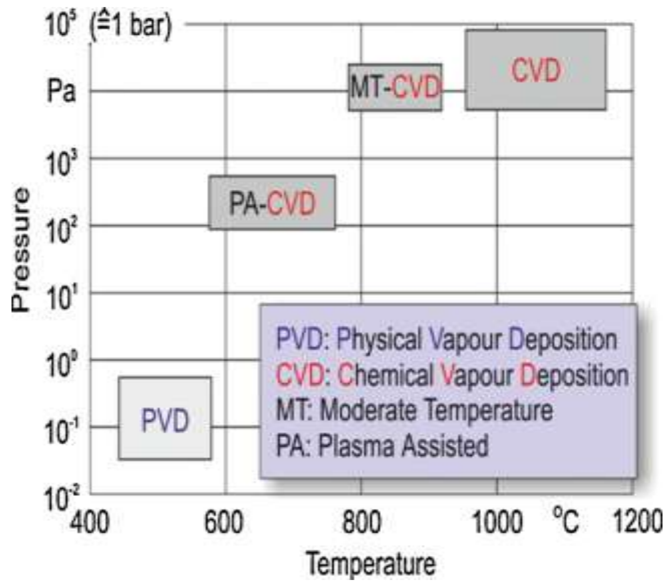

Figure 1 Coating deposition technologies for cutting tools [7].

Coating layer enhances the surface properties of tool such as wear resistance, hot hardness, oxidation resistance and chemical inertness, which augments the tool life [4]. The compounds which make up the coatings used are extremely hard and so they are very abrasion resistant. Typical constituents of coating are Boron Nitride (BN), Titanium Nitride(TiN), Titanium Carbonitride (TiCN), Titanium Carbide (TiC) , Titanium Oxy-Carbonitride (TiOCN), Titanium aluminium nitride (TiAlN), alumina (Al_2O_3).

II. LITERATURE SURVEY

S. No.	Author	Process/ Method	Output Parameter	Benefit / Conclusion
01	M. Narasimha et.al [2]	Uncoated, TiN coated, TiN/Al_2O_3 coated, Al_2O_3 coated and $TiC/Al_2O_3/TiN$ coated tools were used to machines AISI 1080 Steel. The Regression procedure was used through SAS software to analyze the flank wear and surface roughness obtained for different coated tools.	Flank Wear And Surface Roughness are the output parameters	Coated tools showed better performance compared to uncoated. Order of resistance to flank wear of different coatings observed is Uncoated <TiN < TiN/Al_2O_3< Al_2O_3< $TiC/Al_2O_3/TiN$. In case of machined surface, TiN/Al_2O_3 Coated produced highest roughness even than uncoated tools. Al_2O_3 Coated produced the second lowest roughness and $TiC/Al_2O_3/TiN$ produced lowest of all.
02	Yassmin Seid Ahmed et. Al [5]	Super duplex stainless steel –UNS S32750 tubes were rough machined under wet conditions on CNC lathe with uncoated, AlTiN coated and CVDTiN+Al_2O_3 coated tool. After the machining, flank wear was measured using a KEYENCE—VHX 5000 digital microscope (Keyence Corp., Osaka, Japan), equipped with a CCD camera and image analyzer software. Surface roughness was measured with Alicona microscope and surface distortions by SEM.	Tool Life, Tool wear, Machined surface roughness	AlTiN coated tools have double tool life than CVDTiN+Al_2O_3 and triple than uncoated. AlTiN tool produced minimum surface roughness and Uncoated produced highest roughness. AlTiN Coated had less value of tool wear than CVD TiN+Al_2O_3 however PVD AlTiN coated tool performed well compared to others.
03	Halil Caliskan et.al [6]	Inconel 18 Super alloy workpiece having hardness ~48HRC was face milled on CNC with Boron nitride coated tool and uncoated tool in dry condition. Surface roughness and tool wear were measured with relation to cutting length. Astereo zoom microscope and then scanning electron microscopy (SEM) (MAIA3 TESCAN) in combination with energy dispersive spectroscopy (EDS) were used for analysis of wear mechanisms.	Surface Roughness of machined surface and Tool wear	The results showed that BN coated tool has two times longer life than uncoated one. This is due to the lubricant property of BN coating. Although the roughness of the machined surface of Inconel 718 superalloy during milling process was seen to be not significantly affected by tool wear, the surface roughness obtained with the BN coated tools was almost lower than the uncoated.
04	Rajaguru J. et.al [07]	A super duplex stainless steel grade 2507 with Rockwell hardness of 32 HRC and UTS=910 MPA was machined on a VDF lathe under dry conditions with AlTiN, MT-$TiCN/Al_2O_3$, Tin/MT-$TiCN/Al_2O_3$, $TiOCN/Al_2O_3/TiCN$/MT-TiCN/TiN Coated tungsten carbide tools. . The process parameters were kept constant throughout machining with cutting velocity=120 m/min, feed=0.3 mm/rev and depth of cut = 1 mm.	Performance of coatings in term of tool wear, cutting force, cutting temperature and surface integrity was analyzed.	Results showed that [MT-TiCN]-Al_2O_3 coating provided relatively better performance in term of tool wear, cutting force, cutting temperature and surface integrity than other coating followed by TioCN – Al_2O_3 – TiCN-[MT-TiCN]-TiN. Surface roughness obtained with [MT-TiCN]-Al_2O_3 coating has lower value than others.
05	Kaladhar, M., et.al [08]	AISI 304 austenitic stainless steel workpiece was machined on a CNC lathe under dry conditions to evaluate the effects of CVD (TiCN-Al_2O_3-TiN) and PVD (TiAlN-TiN) coating on cemented carbide tool and determine optimal level of process parameters for better roughness. Machining was done at different processing parameters. Taguchi's orthogonal array and Analysis Variance (ANOVA) techniques were employed to analyze the effect of coating materials.	Surface Roughness,	The result showed that the best surface finish is obtained for cutting by insert coated with TiAlN-TiN by PVD technique.
06	Patel, L., et.al [09]	Workpieces of EN-8, EN-31 & EN-36 were machined with CVD & PVD TiN coated tools on CNC turning Centre in dry condition with various cutting parameters. Taguchi's L_{27} Orthogonal Arrays approach was employed to find optimum process parameters to get the lowest tool wear rate and flank wear. ANOVA is used to analyse the influence of process parameters. Process parameters were inserted geometry, workpiece material, spindle speed, feed & depth of cut.	Tool Wear Rate, Flank Wear	Performance of PVD inserts is better than CVD coated inset in term of flank wear and tool wear rate. It can be concluded from the results that for particular material and inserts different parameters make different relations with responses.

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07	Sahoo, A. K. et.al [10]	The high carbon high chromium (AISI D2) workpiece material was machined on CNC lathe with uncoated (TTS) and MTCVD (TiN/TiCN/Al_2O_3/TiN) coated multi-layered tool. The aim is to explore the role of chosen parameter on the machinability characteristics mainly in terms of progression of flank wear and surface roughness and assess the tool life of both inserts in dry machining conditions. Regression models have been developed and economical comparisons between both inserts have also been made.	Surface roughness, Flank wear	The performance of multilayer coated and uncoated carbide inserts have been assessed with respect to flank wear and surface roughness. The tool life of TiN coated insert is approximately 30 times higher than the uncoated carbide insert under similar cutting conditions. It is seen that the progression of flank wear for multilayer TiN coated carbide insert was steady without any premature failure by chipping and fracturing.

III. CONCLUSION

Due to the advancement in the development of superior materials which are strong & difficult to cut there is need of superior tools as well that could exhibit excellent performance during their machining. The performance of available carbide tools can be improved by the hard coatings. These coatings are deposited on the substrate of carbide by CVD and PVD methods. This includes mono layer and multi layered coating of Boron Nitride(BN), Titanium Nitride(TiN), Titanium Carbonitride (TiCN), Titanium Carbide (TiC) , Titanium Oxy-Carbonitride (TiOCN), Titanium aluminum nitride (TiAlN), alumina (Al_2O_3). The different coating materials have different properties. The benefit of different coating materials depending upon the application can be used by applying multi-layer coating of desired coating materials. The comparison of performances in terms of flank wear and surface roughness obtained of uncoated and different coated tools revealed the following:

1. Coated tools have shown superior performance than uncoated carbide tool
2. Multi-layered coated tools proved to be better than mono layered
3. Coated tool showed higher erosion wear resistance than uncoated one
4. Surface roughness produced by the coated tools has lower value that uncoated tools
5. The tool life of coated tools is significantly higher than the uncoated carbide under similar cutting conditions
6. Performance of PVD inserts is better than CVD coated inset in term of flank wear and tool wear rate during machining of EN-8, EN-31 & EN-36

IV. FUTURE SCOPE

The present study is about the performance of various coated carbide tools like Boron Nitride(BN), TiN, TiCN-Al_2O_3-TiN, Al_2O_3 in term of wear rate & surface roughness, tool life obtained during the CNC machining. The performance of these as well as other coatings commercially available can be studied in term of other parameters useful for high production.

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