A Review on Different Technique Used to Optimized Hard Turning Operation

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Abstract— Hard turning is a machining process used to machine materials with hardness of 45 HRC and more. The process is able to provide a very precise surface finish for grinding operations, with small cost. Hard milling operations are performed in a similar fashion. Both machining techniques are very popular these days because of the wide variety of tool materials that can be used. A number of researchers have worked on by considering parameters like tool wear, lifetime of tool, change in their structure, formation of white layer, fatigue strength etc of hard milled surfaces. This paper presents the techniques used, with their outcomes in terms of above defined parameters along with conclusion.

Keywords: Hard Turning, Cubic Boron Nitride, Scanning Electron Microscopy

I. Introduction

The process of turning of hard materials above 45 HRC is called as hard Turning Usually the metals are turned in the range of 58-62 HRC. Hard doesn't mean that the material is difficult to cut but it refers to the hardness of the materials [1]. The tools used for cutting the hard material are usually made of Cubic Boron Nitride (CBN), Ceramic and Cement. The type of tool used for cutting and finishing of materials depends on the production quantity and type of surface finish required [2]. The tools made of ceramic are used for small production and CBN tools are used when the quantity of production is large or for mass production. Proper tools must be selected for hard turning depending upon the application of tool and type of metal used as low content CBN tool cannot be used for intermittent cutting [3].

From the existing work, it has been observed that by using proper combination of nose radius, and feed rate, better results can be attained using hard turning compared to surface finishing [4]. Instead of multiple grinding setups, multiple hard turning operations can be performed in a single setup (see Fig. 1). This also helps to achieve high precision through hard turning process [5].

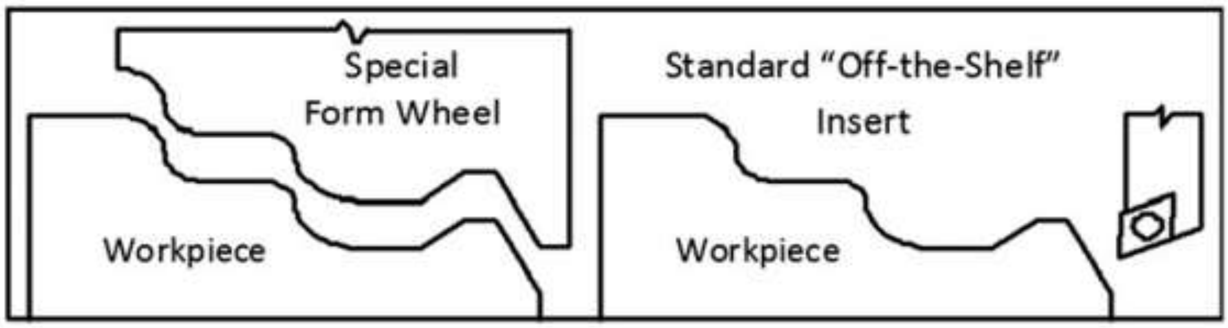

Fig. 1: Grinding versus hard turning [5]

Originally prior to the 19th century, the materials available were not difficult to use as tools for the hardest materials. In addition to this, the material used for machine making was not very hard to withstand the twisting force of the cutting belt that hard turning creates [6]. Therefore, to get rid from this problem, hard turning process came into existence. Natural and synthetic diamonds have been used to process non-ferrous materials for some time, but in the case of steel, a different crystal structure is required as the diamond interacts with the steel to form compounds and be graphitized [7]. Cubic Boron Nitride (CBN) was found to be suitable for this purpose. Its hardness is more comparable to that of diamonds. To obtained better metal surface finishing rate, CBN tool wool with 50 % of CBN is enough. Due to its polycrystalline structure, it is also known as PCBN. Negative cutting angles are generally used when turning hardened steels without any cutting fluid [8]. However, if we do this on a conventional lathe, there will be vibrations and the surface finish will suffer. High pressure Turing can only be performed on machines with high stiffness and structural stability. The work should also be rigid. If it's not very sturdy, then a work stand can be used near the knife. Based on the volume percentage, CBN can be categorized into following tools as listed in Table 1.

CBN Types	Volume (%)	Grain size (micrometer)	Thermal conductivity (W/mK)	Binder type
Low Content CBN	50 to 60	0.5 to 1	-	Ceramic
High Content CBN	85 to 90	3 to 6	100 to 40	metallic
Binder less CBN	More than 99	Less than 0.5	350 to 400	Completer hBN

Table I: CBN tool with their Properties

The comparison between hard turning and conventional machine is shown in Fig. 2. It is very clear from the Fig. that hard turning needs small steps compared to traditional machine. In addition to this, hard turning also saves energy, minimize machines operating time etc [9].

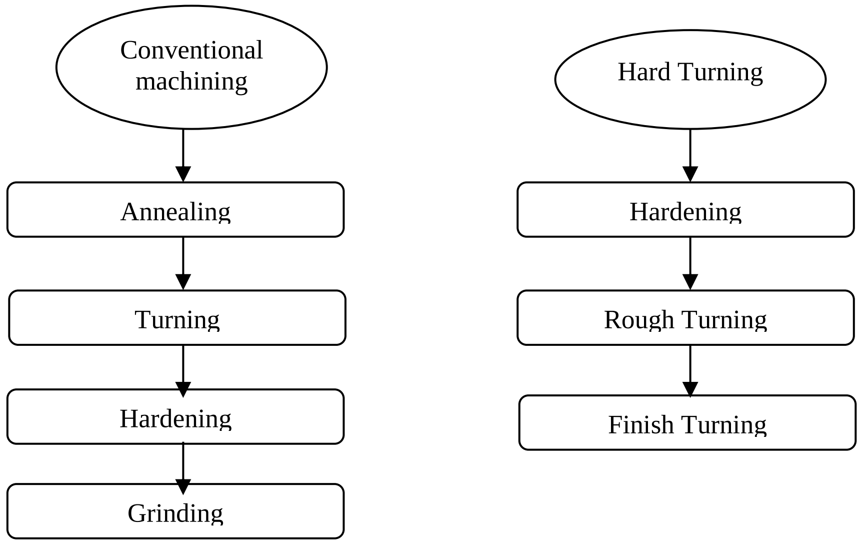

Fig. 2: Comparison between Conventional machine and hard turning [10]

Compared to grinding, hard turning offers greater flexibility and also has the ability to fabricate complex geometries in one setup [10]. The material removal rate in hard turning is high in less time than machining. Some geometries and surface finishes comparable to grinding can be achieved by hard turning. The most significant difference between hard turning and grinding is that hard turning can result in relatively deep surface, compressive residual stresses compared to grinding. Although it is generally accepted that the deep-pressure residual stress induced by hard turning is beneficial to the rolling contact fatigue life [11]. In order to make hard turning a viable alternative to grinding, it is important to choose process parameters suitable for machining operation. Hard turning has a narrower range of acceptable values for process parameters than conventional turning, and failure to optimize properly can result in poor tool life, poor surface finish, and unacceptable dimensional accuracy or chatter [12].

II. RELATED WORK

Ozel and Karpat (2005) studied the impact of various factors on surface roughness in hard turning of AISI H13 hot work tool steel which was hardened to 50 and 55 HRC. The various factors include cutting speed, cutting edge geometry, and work piece hardness. The CBN cutting inserts used had different type of edge geometries like honed, chamfer, and chamfer and honed combined and sharp. The results showed that a good finishing surface was obtained with the use of honed edge geometry and low work piece harness. There was a decrease in the tangential force when lower cutting speed and less feed rate was used. The force component was affected by these factors like cutting speed and cutting edge geometry[13].

Chavoshi and Tajdari (2010)have determined the surface hardness model by the reverse Artificial Neural Network (ANN) model. Hard turning was done on AISI 4140 using CBN cutting tool. Two parameters named as spindle speed and hardness was considered. Experiments conducted showed that the reverse ANN model was more accurate than the regression model. Spindle speed had less effect on surface roughness. Hardness and surface roughness shows a parabolic relationship. First decreased and then increased. The results indicated that hardness of the metal surface has been predicted with better accuracy but with poor spindle speed detection accuracy for both training as well as testing data [14].

Benlahmidi et al. (2017) has optimized cutting parameters using CBN7020 tool during the process of turning hardened AISI H11 steel (50 HRC). The results show that by increasing the cutting speed as well as hardness of work piece, surface roughness of the machine part has been increased. But reverse effect has been shown on surface roughness with feed rate. Better surface smoothness has been obtained with higher cutting rate and lower speed. But in the case of feed rate, it has a negative effect on surface roughness. Higher surface finish was observed at the combination of higher cutting speed and lower feed rate. The reason behind this is the higher temperatures created during turning that diminishes the workpiece's hardness and thus get better performance of machine [15].

Yousefi and Zohoor (2019)have experimentally studied the effect of cutting parameters on the accuracy and surface roughness of hardness steel. To do this comparison between cutting force, tool wear were studied and investigated. From result, it was observed that feed rate was an important factor that affects the surface roughness of work piece while spindle speed and cutting depth has no effect on surface roughness. But, spindle speed and cutting depth have significant effect on its dimensional accuracy [16].

Mohruni et al. (2018)have studied the effect of feed rate along with cutting speed to check the surface roughness of AISI D2 while operated through hard turning process. The steel work piece was operated with Cubic Boron Nitride (CBN) under dry condition. Empirical method was used to determine the machining parameters. From result, inverse relation between surface roughness and cutting speed has been observed. On the other hand, surface roughness has direct relation with spindle speed. Optimized value of feed and cutting speed for 0.267 micro meter surface roughness was analyzed as 105 m/min and 0.10 mm/revolution respectively [17].

Gutnichenko et al. (2021) have addressed the improvement in tools lifetime while applying various schemes to monitor tool wear. The data was collected by implanting three sensors that are force sensor, accelerometers, and microphone. The training of the collected data was performed using Support Vector Machine (SVM) as a machine learning approach. The developed model has shown better accuracy around 98 % [18].

Şahinogluet al. (2021)have emphasized the work to analyze parameters like power consumption, sound generation, and surface roughness of AISI 4340 steel. The examination was done using CBN tool. The model was designed based on two techniques that are ANN and Response surface methodology (RSM). The sound level observed in the input parameters was maximum, which is due to the machine and tool variations. More is the sound means less will be the power consumption but it will increase the surface roughness along with the sound level. Comparison between both the above defined techniques has also been executed. From the result it has been shown that both the techniques have better correlation relation but ANN technique performed well with high accuracy [19].

Nayak et al. (2021)have examined the characteristics of AISI D6 steel using CBN tool. The analysis has been performed based on the steel's machinability behavior, revealing CBN tool wear, Scanning Electron Microscopy (SEM), microstructure analysis, and Energy Dispersive X-ray (EDAX) basis. The designed model has outputs like cutting force, cutting temperature, thrust force, and surface roughness that were examined with respect to the variation in cutting speed as well as feed rate. From the results it has been observed that forces and surface finish are increases with the increase in feed. The aim of the researchers was to use low cost CBN tool kit that includes the brazed content in tooltip, but with low productivity [20].

Nikam et al. (2021) have analyzed the mechanical properties of AISI 4140 steel using CBN tool kit. Cutting speed (150-175-200m/min) and feed (0.1-0.15-0.2 mm/revolution) were considered as input variables. L9 factorial orthogonal array has been considered to perform turning experiments at constant depth of 0.25 mm. Using Grey relation criterion life of tool, and tool wear have been measured at optimum condition. The results show that machine force incline with the increase in input variables. Feed of machine also has direct relation with surface roughness. The applied method shows lowest cutting force and lowest surface roughness at speed of 200 m/min, with a feed of 0.1 mm/ revolution [21].

III. CONCLUSION

After studying literature, it was concluded that hard turning is a better alternative to grinding. Hard turning has many advantages over grinding, including short set-up times, low machine cost, flexibility in operation and precision, and the elimination of heavy use of cutting fluids. Surface roughness and force are performance parameters that are greatly influenced by cutting parameters, workpiece hardness, and cutting tool material and tool vibration. From the above study, it was observed that in the case of surface roughness, feed rate was the essential parameter, which was followed by depth of cut, while cutting speed was the most important factor in tool wear. Feed and depth of cut are important to improve roughness. With careful selection of feed rates, depths of cut and cutting speeds, hard turning can significantly improve the productivity of low-tolerance products. Taguchi approach, response surface technique and examination of variance are effective tools for designing, controlling and optimizing parameters. Hard machining operations have been considered a better and low-cost alternative to expensive grinding operations. With new inventions and research in materials, we are getting better tool materials with extremely low tool wear rates and high hardness and strength with the potential to improve surface integrity, further hard machining operations have bright prospect.

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