



# Influence of Wiper and Conventional Inserts at Profile Geometry During Turning of D2 Tool Steel



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## Abstract

Latest inventions in the field of manufacturing drive the new technologies and different sources of production and to design the various sources to enhance the productivity as well as to reduce the cost, while maintaining the required specifications and high standards of the products. For achieving the production with high quality, tool manufacturers are continuously improving cutting edge, coating, geometry and the material of the tool. The tool geometry affects different aspects of tool like cutting temperature, tool wear and tool life, surface roughness, dimensional accuracy and surface integrity in the machining. The existing study is an attempt to explore the effect of wiper and conventional insets at profile turning. In this research inserts (wiper and conventional) having three different tool of nose radius (0.4, 0.8 and 1.2mm respectively) were evaluated at cutting speed (150m/min), feed rate levels (0.05, 0.10, 0.15, 0.20mm/rev), and depth of cut (0.2mm). Workpiece surface roughness (Ra) dimensional accuracy and microhardness of the machined surface were assessed. It was found that in profile turning in case of conventional inserts with larger nose radius of 1.2mm performed better than the other two inserts in term of surface roughness and dimensional accuracy. While in case of wiper inserts surface roughness and dimensional accuracy results were not better as comparing to conventional inserts. Microhardness under the machined surface was increased in both the cases of wiper and conventional.

**Keywords:** Profile turning; D2 tool steel; Inserts (Wiper and Conventional); Dimensional Accuracy; Surface roughness; Microhardness

## Introduction

Hard part turning which is also known as hard turning (HT) is the machining of material having hardness more than 60 HRC, these types of materials are cut with CBN and Ceramics tools [1]. In the hard turning process, not only operating parameters and geometry of tool are important but also the material composition and tool type are the elements that influence the surface finish of the product. Previous literature indicates that, in order to increase efficiency in terms of tool life, surface roughness, tool geometry and surface integrity are the parameters that are to be considered [2]. The wiper technology for turning is made up of series of radii that form the cutting edge. In wiper insert adjacent to nose radius, 3 to 9 smaller radii were introduced [3]. To ensure a better surface finish, operating parameters are important and selected very carefully [4], tool geometry and material [5], and

surface reliability is very essential for the machined components having elevated thermal and mechanical stresses [6]. Authors conducted an experimental study while machining D2 tool steel with wiper inserts and found that feed rate is the major factor that affects the surface roughness. Further in depth analysis of surface integrity microhardness was extended up to 150 $\mu$ m beneath the machined surface, and no white layer formation was found after machining [7]. Denni Kurniawan et al. used wiper inserts for the metal removal process of martensitic stainless steel at different material removal speeds and feed rate, and found that combination of truncated feed rate and speed generated the higher tool life with better surface finish [8]. D.M. D'Addona & Sunil J. Raykar carried an experimental research to find out the effect of wiper and conventional inserts during turning of oil hardening non shrinkage steel. From the analysis,

it can be seen that wiper inserts performance in term of surface finish was better than conventional insert in the simple turning process. It was also concluded that feed was the most dominant factor than the other operating parameters that affects the surface finish [9]. In another study, PCBN tools were employed to machine AISI D2 steel and noticed that the most reasonable speeds and feeds were in the assortment of 70-120m/min, 0.08-0.20mm/rev respectively. Higher tool lifespan and metal removal rate obtained at lower speed and uppermost feed rate shows that lower speed is more feasible for the machining at the certain range of parameters combinations; however, highest feed decreases the tool life [10]. An experimental research was carried out on the machinability characteristics of specific cutting force, power, machining force, tool wear and surface roughness (Ra) while machining of AISI D2 tool with inserts (conventional and wiper ceramic). The analysis indicated that the tool wear decreased by increasing depth of cut up to 0.4mm, when GC6050WH and CC650 inserts were used it suddenly increased. It was also noticed that tool wear increased gradually with the depth of cut while using CC650WG. CC650WG type wiper insert performance was enhanced in term of exterior roughness and tool wear [11]. HA Kishawy and MA Elbestawi inspected the surface integrity and tool wear while machining D2 tool steel. Effect of different cutting factors on edge preparation, surface and subsurface damage and tool wear was examined. From the scanning electron microscope (SEM) analysis it was noticed that surface integrity conditions changed significantly with various operating conditions. In addition to that a fine surface finish was obtained at high cutting speed from worm tool and white layers were observed on the subsurface [12]. In another experimental study, during the finishing operation of turning of D2 tool steel using ceramic wiper (multi-radii) tools, the tool lifespan, flank wear and exterior roughness were inspected. From the analysis it was concluded that exterior roughness was in the series of 0.18-0.20 $\mu$ m using wiper tools and tool life was obtained 15min at high cutting speed [13]. Kopac et al. suggested that surface finish obtained by wiper inserts is similar in comparison to machining with conventional tools at low feed rate. Whereas at

high feed rate, conventional tools provide higher value of surface roughness as compared to wiper inserts [14].

Researchers carried out numerous experiments to examine the effect of operating limitations on Ra in turning operation [15] as it is a major parameter used in the performance of machined components. Rzewski & Wan at, used inserts (conventional and wiper) in rigid turning process at constant parameters, which are depth of cut, nose radius, cutting speed, and variable feed rates. It was concluded that both types of inserts provide similar values of Ra at lower feed rates [16]. Cakir et al. discovered that, feed rate had substantial influence on Ra followed by cutting speed. A greater value of feed rate generates higher exterior roughness, however cutting speed had an opposing result and depth of cut had no major influence [17]. Prasad et al. investigated that Ra values rise with escalation in speed, varying nonlinearly with augmentation variation of feed conversely; depth of cut was not affecting much on roughness values. Most of the researchers concluded in their research that feed rate considerably affect the surface roughness along with depth of cut and cutting speed [18]. Neslusan et al. found the effect of feed rate (0.10-0.65mm/rev) while turning bearing steel 100Cr6 at unchanged cutting speed (150m/min) and depth of cut (0.15mm) and made a comparison with conventional inserts. Approximately 60% higher surface compressive residual stresses and ~33% reduced white layer thickness has been reported. The surface integrity attributes were recorded when feed rate was low (0.225mm/rev) [19]. Amini & Paktinat [20] used mixed alumina multi radii inserts while turning Monel K500 at feed rates ranging from 0.12mm/rev to 0.24mm/rev. Though they report 57% and 60% reduction in cutting force and Ra respectively as compare to conventional insert, however, no data related to tool wear has been reported. Recently, Ferreira et al. [21] evaluated hard turning of AISI H13 steel using multi radii and conventional inserts at four levels of feed rate (0.05, 0.10, 0.25 and 0.40mm/rev) and at a perpetual depth of cut (0.20mm). Roughness values (Ra) obtained for multi radii inserts were approximately 5 times less in comparison to their conventional counterparts.

### Experimental Detail

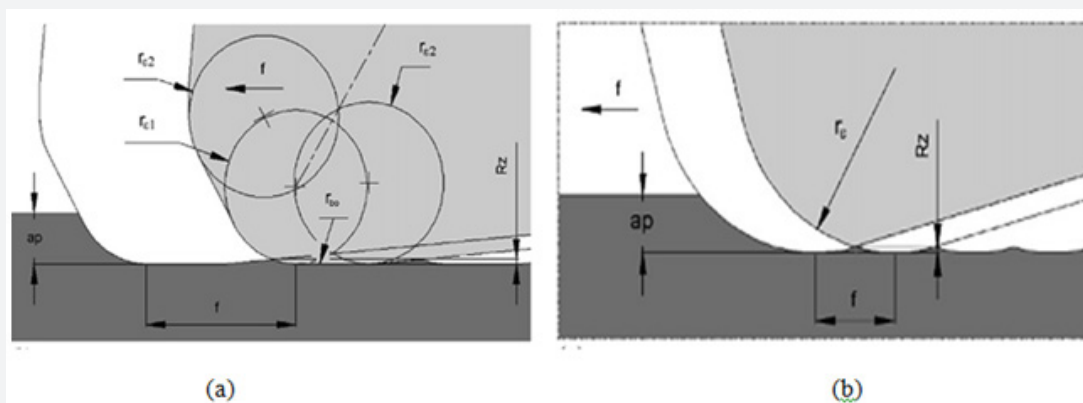


Figure 1: Assessment of inserts with (a) wiper and (b) conventional geometry.

The current study was conducted to explore the effect of inserts (wiper and conventional) geometry on the profile turning of D2 tool steel. Two-axes CNC lathe machine was used for experiments. Experiments were performed at high chromium heat treated AISI D2 tool steel with chemical configuration of C=1.51%, Si= 0.42%, Mn= 0.37%, Cr=15%, Mo=1.3%, V=0.80%. A bar of dimensions 70 mm diameter and 22mm length with a hardness value of 59±1HRC was used for experimentation. Mixed alumina TiN coated ceramic inserts having 71%Al<sub>2</sub>O<sub>3</sub>, 28%TiC&1% other were used having conventional and wiper geometry. Rhombic shaped Wiper tool geometry having 0.4mm, 0.8mm and 1.2mm nose radius corresponding to ISO code CNGA 120404 S01525 WH (0.4mm), CNGA 120408 S01525WH (0.8mm) and CNGA 120412 S01525WH (1.2mm) [Ref. CC6050WG]. The conventional inserts had chamfered plus honed edge and also TiN coating having nose radius of 0.4mm, 0.8mm and 1.2mm with ISO code CNGA 120404 S01525 (0.4mm), CNGA 120408 S01525 (0.8mm) and CNGA 120412 S01525 (1.2mm) [Ref. CC6050] (Figure 1).

The inserts had an 80° rhombic shape with cutting edge length of 12mm. The insert thickness was 4.76mm. A single

insert had four cutting edges. The geometry of the inserts provided 6° clearance angle with a negative rake of 6°, cutting edge inclination angle of -6° and cutting edge angle of 95°.

Tool holder with ISO code of MCLNR 2020K12 was used to mount these inserts throughout the experiments. The tool holder gave rake angles of 5° to tool's end and back. Similarly, end cutting edge angle was also 5° while -5° was side cutting edge angle. The end and back rake angles were -5° as negative rakes are common in hard machining but the effective rake was positive.

In the current study two factors involving feed rate at 4 levels and nose radius at 3 levels were investigated using full factorial design. Each tool nose radius was evaluated against different values of feed rate (0.05, 0.10, 0.15 and 0.20mm/rev) at continuous cutting speed (150m/min) and depth of cut (0.2 mm), in order to find out the exterior roughness and dimensional precision using complete factorial design. All inserts of (0.4, 0.8, 1.2mm) were evaluated at different feed rate value. The experiments were performed separately for both the wiper and conventional inserts. Experiments were performed without using any coolant (Figure 2).



Figure 2: (a) Two axis CNC lathe machine (b) Experimental setup for profile turning.

## Results and Discussion

### Surface roughness

Exterior roughness is the key factor that is used to measure the performance of the machined part, less value of surface roughness is necessary to manufacturing work piece, it reduces the coefficient of friction and wear rate besides improves the corrosion resistance properties [22].

In the current study, workpiece surface roughness values were taken at corresponding feed rate with the three types of inserts while machining at the given conditions of constant cutting speed, depth of cut and varying feed rate. The values were also taken at the start and end of tests so as to learn the range of surface roughness variation for a particular test. An evaluation length of 4mm was selected to measure Ra value at the profile. From the analysis it was observed that surface

roughness (Ra) values decreased while increasing the nose radius of the tool, but instead specific cutting energy to some extent increased with increasing the nose radius because of large contact area of the tool. The minimum value of surface roughness 0.44µm was achieved with the conventional tool at large nose radius of 1.2mm. So conventional tools provided better results in comparison to the wiper tools in the profile turning. Following Figure 3 represent the workpiece surface roughness with respect to each tool nose radius.

Similarly, each nose radius was evaluated to investigate the feed rate against surface roughness. From the graphs it was perceived that, surface roughness increased while increasing the feed rate due to large uncut chip thickness. While in comparing both the tools, conventional tools provided better results in term of surface roughness than wiper tools in each tool nose radius. Following graphs represent the workpiece surface roughness

with respect to feed rate for each tool nose radius. A similar kind of trend was observed in the foremost influence plot for surface roughness. The graph also indicated that workpiece surface roughness increased with the rise in feed rate. Maximum surface roughness was observed at maximum feed rate, while lower

value of surface roughness was noticed at smaller value of feed rate for both the wiper and conventional tools. The main effect plot in Figure 4, 5 showed that, in the process of profile turning, better results were achieved by conventional tools as compared to the wiper tools.

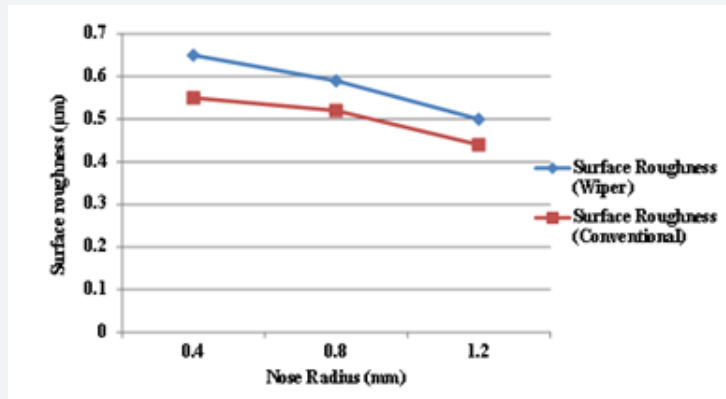


Figure 3: Workpiece tool nose radius against surface roughness.

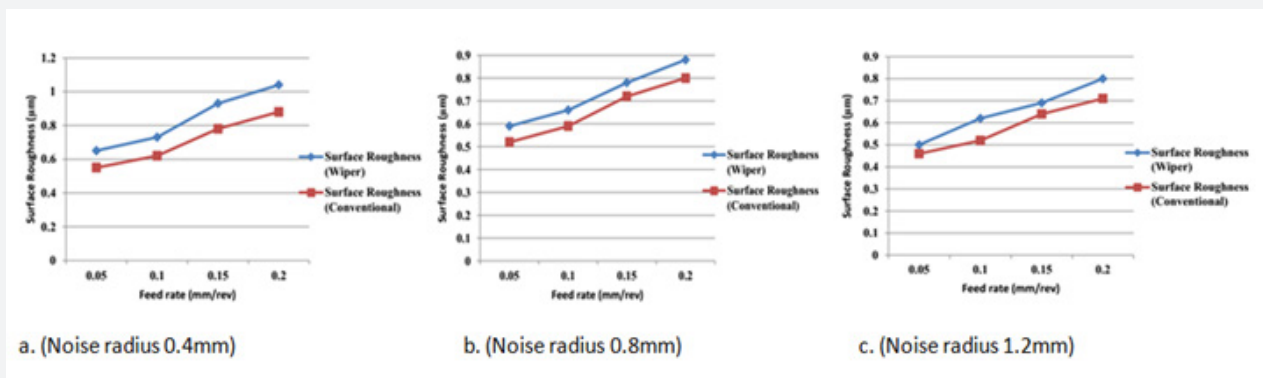


Figure 4: Feed rate against surface roughness for each tool nose radius.

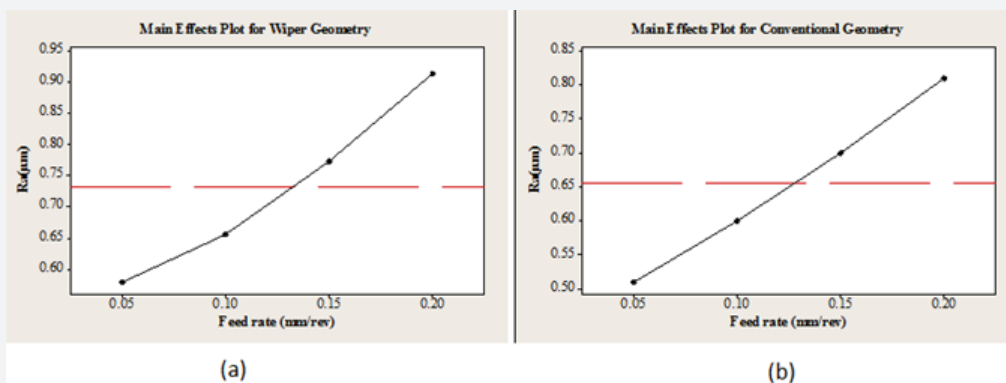


Figure 5: Main effect plot for (a) wiper (b) Conventional tools in term of surface roughness.

**Dimensional accuracy**

The dimensional accuracy is the important key to ensure the achievement of correct functioning of parts machining. Nowadays many manufacturers try to produce good machining parts or components with good dimensional tolerance in order to fulfil

customer requirements. Normally, dimensional accuracy of the machining parts depends on the machining process that involves in the selection of cutting parameters. In the current research dimensional accuracy of the machined surface against feed rate for each tool nose radius was investigated. The analysis reveals

that, with the dimensional accuracy increased by increasing the feed rate for both the cases. It was also observed from the graphs that percentage error for the conventional tools was less than the wiper tools. The conventional inserts provided better dimensional tolerance in comparison to the wiper inserts in the profile turning process, the main effect plot in Figure 6 showed that surface finish decreased by increasing feed. In the process

of profile turning, better results were achieved by conventional tools as compared to the wiper tools. The main effect plot in the Figure 7 indicated that higher value of radius of curvature was achieved by wiper tools in comparison to the conventional tools, So a significant deviation was notice in term of radius of curvature in the wiper tools.

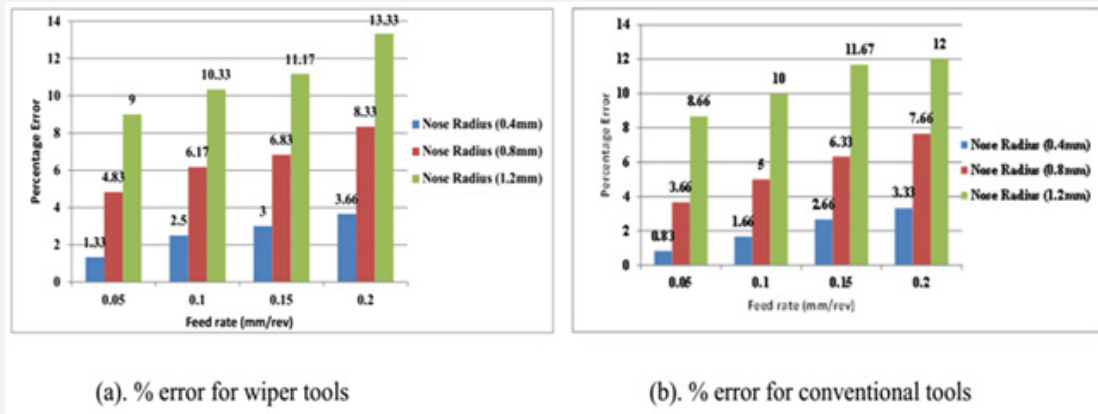


Figure 6: Percentage error for (a) wiper tools and (b) Conventional tools.

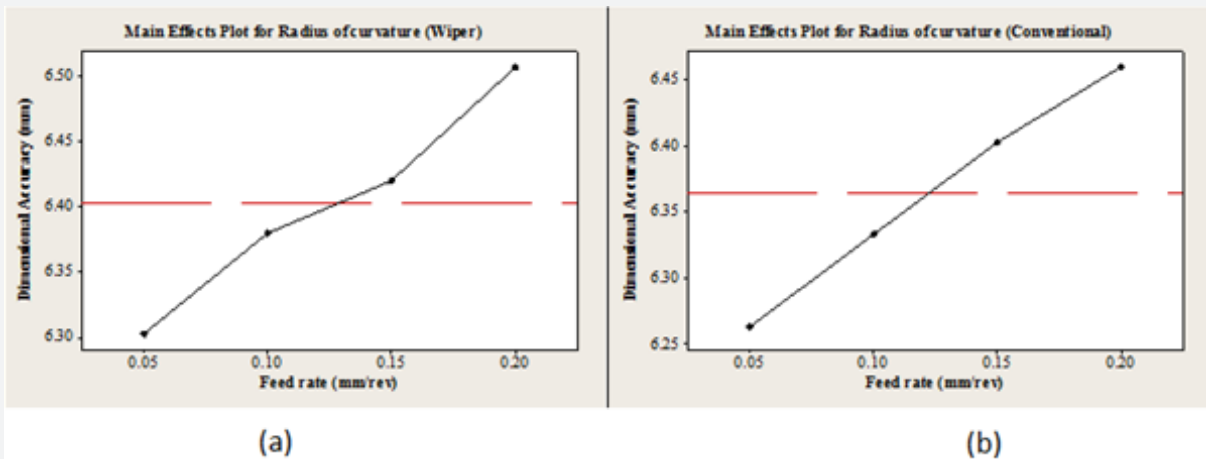


Figure 7: Main effect plot for (a) wiper (b) Conventional tools in term of dimensional accuracy.

### Micro hardness

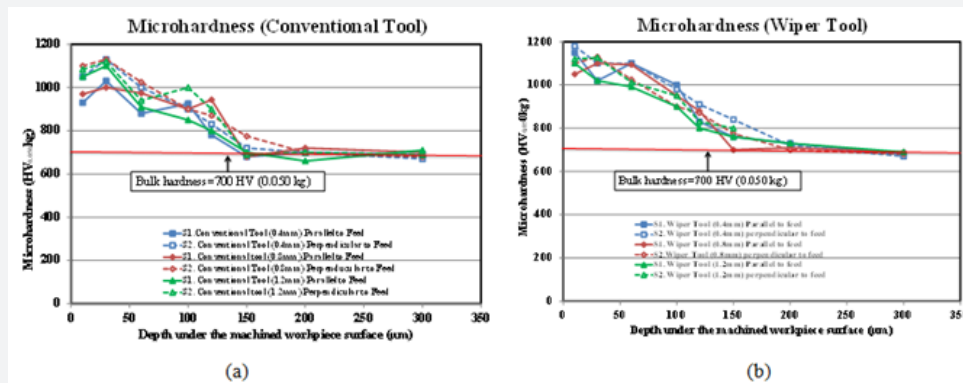


Figure 8: Microhardness of (a) conventional and (b) Wiper Tools.

Microhardness under the machined surface was measured at a distance of (10, 30, 60, 100,120, 150,200 and 300 $\mu$ m). Indenter was placed at the workpiece surface at different location in the zigzag form to measure the diagonals of the indenter. Microhardness was measured for the samples that were machined for both the new and worn tools. Following observations were noticed from the graphs. It was observed from the graph that microhardness was increased under the machined surface, and uniformly decreases as the depth under the machined surface increased. It was also observed from the graph that microhardness under the machined surface for both new and worn tools at the distance of 10 $\mu$ m was increased 1.4 to 1.6 times more than the bulk hardness of the material. In comparison to the new and worn tools similar results were obtained that microhardness was increased near the machined surface. Although larger values of microhardness were observed under the machined surface at 10 $\mu$ m for worn tools because of mechanical stresses and vibration tendencies increased. It was also noticed that micro hardness become stable under the machine surface after 150 $\mu$ m (Figure 8).

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## Conclusion

The statistical analysis revealed that tool geometry and cutting parameters have noteworthy influence on the work piece surface finish. It was found that, in profile turning process while using conventional inserts with larger nose radius of 1.2mm produced better surface finish than the other two nose radii i.e 0.8mm and 0.4mm. The surface roughness at 1.2mm nose radius is 15% less than that at 0.8mm and 20% less than that at 0.4mm nose radius. Almost same trend appeared while using wiper inserts of respective nose radii. As comparison between wiper and conventional inserts, at 1.2mm nose radius, conventional inserts resulted 20% lower surface roughness than as with wiper inserts and it remained lower at other nose radii also. It was also established that increase in the feed rate value resulted the decrease in surface finish but surface finish for conventional inserts was 5% better than that with wiper inserts. While in case of dimensional accuracy, conventional inserts with larger nose radius performed better than wiper tools. At lowest nose radius, dimensional accuracy in term of profile turning from wiper inserts was almost 32% less than that with conventional inserts and at higher nose radius this difference of dimensional accuracy reduced to 4% between wiper and conventional inserts. Microhardness shows a mix behavior for wiper and conventional inserts and same trend is appeared for both inserts.

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