ASSESSMENT OF SURFACE ROUGHNESS IN DRY FINISH TURNING OPERATIONS OF AISI 4140 STEEL USING WIPER CUTTING TOOLS

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Abstract. *Machining performance consists to associate the optimal process and cutting parameters and, maximum material removal rate with the most appropriate tool while controlling the machined surface state. This work verifies the influence of standard and wiper cutting tools on generated surface roughness in dry finish turning operation of AISI 4140 steel in a comparative way. Tests are conducted for different combinations of tool nose geometry, cutting edge nose radius, feed rate and with two tool manufacturers being analyzed in respect to surface roughness parameters* R_a *,* R_t *and* R_a / R_t *. For high feeds and with wiper inserts it is possible to generate machined surface with* $R_a \leq 1.0$ *µm while for the same conditions but with standard inserts the best surface state recorded is* $R_a \approx 3.9$ *µm. In complement, an ANOVA is performed to clarify the influence of cutting parameters on generated surface roughness, which outputs inform that tool nose geometry and cutting edge nose radius are the most influent on surface roughness parameters* R_a *and* R_t*, respectively. It is concluded that analyzed wiper inserts present low performance for low feed rates.*

Keywords*: wiper cutting tool, surface roughness, turning, high feed rate, high material removal rate*

1. INTRODUCTION

In machining processes, dimensional and geometric tolerances and surface roughness have significant influence on the quality of the final product. The material removal rate, the tool life and type of lathe are factors that are related directly or indirectly with the process parameters and quality of final machined surface. Wrongly chosen parameters generate failures as premature wear or breakage of tool, in addition to economic losses in down times, nonconforming parts or reduction in the quality of roughness surface (Thomas, 1982).

The irregularities in the machined surface, especially valleys or ridges, which are stress concentrators favors the emergence and propagation of cracks, can lead to a rupture of the material. Thus, a technical surface with low roughness decreases the risk of crack initiation, and consequently its propagation, increasing the part life or component (Davim, 2008). Moreover, the increasing miniaturization of components has led to an increased ratio of surface area and volume of the machined part, thus the surface and its integrity takes on increasing importance despites of the material used (Byrne *et al*., 2003).

Kopač and Bahor (1993) studied the changes in surface roughness as function of cutting conditions for tempered steels AISI 1060 and AISI 4140 observing the cutting speed as the most dominant factor - whether cutting parameters are selected so random. They also reported that for both steels, the cutting tools with larger corner radius (r_ε) generated lower values of roughness. Similar studies were conducted by Yuan *et al*. (1996) and Eriksen (1999).

Gokkaya *et al.* (2004) *apud* Gokkaya and Nalbant (2006) investigated the effects of the tool coating, the cutting cutting speed and feed rate on surface roughness of a machined surface from AISI 1040 steel. They concluded that the lower roughness values were obtained with a cutting tool coated with TiN. An improvement of 176% in roughness was generated by reduction of 80% of advance and a 13% improvement in roughness was obtained by a 200% increase in cutting speed.

Gokkaya and Nalbant (2006) studied the influence of cutting tools with different corner radius r_ε and coating materials for turning of AISI 1015 steel. They concluded that an improvement of 26% in roughness was achieved by reducing the feed rate in 33%, while an increase of cutting velocity in 310% improved the surface roughness by 69%. They also concluded that the average friction coefficient of the cutting tool's coating material exerts influence on surface roughness.

Among the recent technological advances to maximize productivity and meet the specifications of the product being machined, it can be highlighted the development and application of wiper cutting tools. Compared to a tool with a conventional corner radius (standard), there are many advantages in using a wiper cutting tool: increased productivity, improved machined surface and longer tool life (Fleming, 2004 *apud* He *et al.*, 2006; Smith, 2008).

Grzesik and Wanat (2006) presented a comparative study of finish processes generated in hard turning inserts using conventional (standard) and straighteners (wiper) of same radius corner. The results show that the machined surfaces have similar values of roughness for both geometries when using a feed rate equal to 0.10 mm/rev. for standard tools and 0.20 mm/rev. for wiper tools.

Rech and Claudin (2008) concluded that a wiper nose geometry tends to introduce compressive residual stresses on hard turning machined surface workpiece, which is more favorable when wiper cutting tools with a TiN coating and a low c-BN content are selected.

Recently, Correia and Davim (2011) investigated the performance of conventional and wiper geometry tools of finish turning process of AISI 1045. They found that for a wiper tool of 0.8 mm corner radius of and a feed rate 0.25 mm/rev. it was possible to obtain machined surfaces with values of average roughness (R_a) of less than 0.8 micrometers. They also inform that depending on the situation, the use of wiper tools makes it possible to obtain surface qualities in precision engineering parts without the need for cylindrical grinding operations.

Subsequently, Geier *et al.* (2011) performed a comparison between wiper and standard cutting tools in finish turning of AISI 1020, AISI 1045 and AISI 4140 steels aiming the highest possible material removal rate for the generation of low roughness values. Results show that for the same material removal rate the wiper cutting tool presented a superior performance in 270% of surface roughness R_a values and when generating machined surfaces with similar R_a values it was possible to obtain an increase in material removal rate of 269%.

Taking into consideration the material removal rate and machined surface, the values adopted for the cutting parameters can be large or small, depending on demand and availability of materials and tools. Thus, the cutting operations in different machining processes are roughing and/or finishing. In roughing operations there isn't much concern with the surface finish, since the goal is a high rate of material removal during a given tool life. Already in finishing operations, the goal is to achieve surface, dimensional and geometric qualities of the part. As a general rule to finishing, the combination of a minimum as possible feed rate value and a small depth of cut with high cutting speed results in generating a fair amount of chips in time unity without the influence of vibration on removal of remaining stock of the part (Diniz *et al.*, 2008).

Due to the lack of information about the performance of tools with wiper geometry, this study aims to evaluate in a comparative way the roughness generated by inserts with this geometry against standard inserts in dry finish turning of SAE 4140. Tools will be used from two manufacturers, with different chip breaker geometry and tool nose, with corner radius of 0.4 and 0.8 mm for feed rates of 0.075 up to 0.30 mm /rev with fixed cutting velocity of 475 m/min and depth of cut of 0.5 mm. Cutting velocity and depth were fixed due its minor influence on surface roughness, as presented in previous works from Correia and Davim (2011), Geier *et al.* (2011), Gokkaya and Nalbant (2006) among others.

2. MACHINED SURFACE ROUGHNESS

Finishing is a colloquial term used to broadly designate the overall quality of a machined surface. The goal of machining is to obtain a technical surface which presents surface (texture) and sub-surface (integrity) factors appropriate to ensure safety, reliability and long life to the manufactured component-especially when human lives are involved (Mesquita, 1992).

The finishing is not specifically linked to texture or pattern characteristic of the technical surface, nor to specific roughness values. However, a "good" finishing implies low roughness values and vice versa (Risbood *et al.*, 2003). Thus, the ability of a machining operation to produce a specific finishing depends on the cutting tool, the characteristics of the part, the machining process, cutting parameters and lubrication and coolant conditions (Brallo, 1986).

The texture is related to irregularities present in the surface of solid materials and with the characteristics of measuring instruments; is defined in terms of roughness, waviness, marks and flaws (Kalpakjian and Schmid, 2010). Figure 1 shows the profile of a surface.

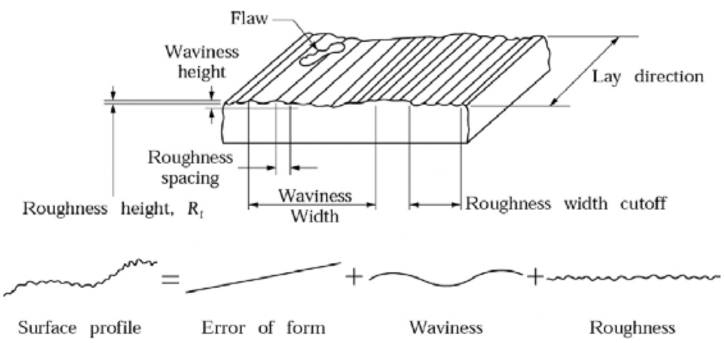


Figure 1. Terminology and symbols to describe the pattern and surface roughness (Kalpakjian and Schmid, 2010)

The roughness is generated only by the manufacturing method, being more influenced by the process than by the machine. As Kalpakjian and Schmid (2010) and Machado *et al.* (2009), factors that may contribute to the generated roughness are in metal cutting processes may be attributed to:

- marks the tool edge or its fragments, which may present in a periodic nature for some processes and random to others;
- generation of burr during machining operation;
- build up edge debris of a cutting tool on the machined surface;
- chip breaker geometry on tool edge;
- The waviness can be attributed to characteristics of a specific machine (unbalanced spindle, irregularities of the feed mechanism, low rigidity, among others). Further information on form deviations in technical surfaces can be obtained from DIN 4760 (1982). Errors of form are generally caused by:
- chip breaker geometry on the tool tip;
- insufficient rigidity in the positioning and clamping system (workpiece deformation due to cutting forces);
- irregularities on the slideways used to guide the workpiece or in the carriage;
- relief of remaining residual stresses in the workpiece material derived from previous technological processes (heat treatment, forming, casting, welding).

Thus for metal cutting operations it is necessary to determine appropriate values of the control variables (process parameters) that will ensure the achievement of the desired machined surface characteristics.

The profile of a surface is composed of roughness, waviness and form, as showed in Fig. 1.

In this study, the parameters for evaluating the texture of the machined surface are the average roughness R_a and the total roughness R_t, in accordance with ISO 4287 (1997), both are the internationally parameters of roughness and are universally recognized, Fig. 2. R_a is the area between the roughness profile and its mean line or the integral of the absolute value of the roughness profile over the evaluation length (L) (Eq. 1) and R_t is an amplitude parameter, which is the total height of the profile, i.e. the sum of the maximum height of peak and deepest valley in the assessment of the profile (Machado *et al.*, 2009).

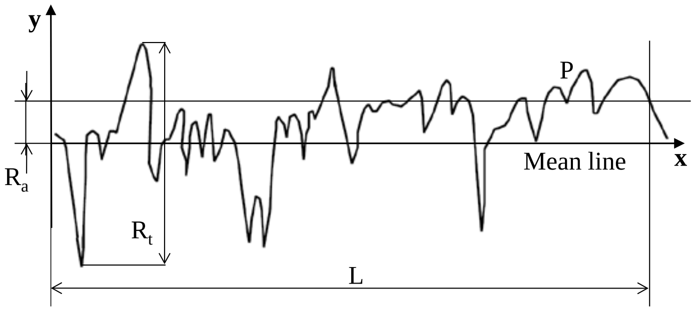


Figure 2. Total roughness R_t and average roughness R_a of a surface profile P in one sampe length L

$$R_a = \frac{1}{L}\int_0^L |P(x)|dx \tag{1}$$

When evaluated form digital data, Bewoor and Kulkarni, 2009, explains that the integral is normally approximated by a trapezoidal rule:

$$R_a = \frac{1}{n}\sum_{i=1}^{n} |P(x)| \tag{2}$$

where R_a is the arithmetic average deviation from the midline, L is the length of the sample and x is the ordinate of the profile curve.

The R_a parameter can be used in surfaces where the finishing presents well oriented machined grooves (turning, milling etc), situations that require continuous control of the roughness in production lines and for low responsibility surfaces, as finishing with only aesthetic purposes (Rebrac, 2011).

The surface texture of the machined surface is fortunately the same within a proportionally large region since the cutting conditions are met, which should be constant for each specific operation (step), as far as possible. Thus, if the roughness profile is measured in two parallel sites of the examined surface then only small differences are observed between these sites which differ in small details (Kalpakjian and Schmid, 2010). This allows the control and optimization of machining processes aiming the achievement of a specificied surface texture through the measurement of particular characteristics of the machined surface (Kolpac and Bahor, 1999).

In general, Orberg *et al.*, 2008, explains that the surfaces will contain irregularities with a wide band width. The surface texture measurement instruments are designed to gather the irregularities spacing bellow a certain level, called the cutoff. In some cases, such as surfaces on which the actual contact area with a second surface is important, the higher cutoff point should be used. In other cases, such as surfaces subjected fatigue failure, only the irregularities of a small extent are important, and most significant values are obtained when a short cutoff point is used. In other cases, such as identification of marks on the machined surfaces, the information is needed only in the far way spaced irregularities and in this measurements the cutoff point should be large as well as the radius of probe (stylus tip) used.

2.1. The role of tool geometry on surface finish

The surface generated form a turning operation is affected by lathe conditions, tool fixture and especially by the feed rate f and by the tool nose radius r_ε of the insert. In case of standard inserts, Machado *et al.* (2009), inform that the surface roughness R_a and R_t is directly related with the feed rate f [mm/rev] and tool edge radius r_ε [mm], shown in Eq. (3) and Eq. (4), respectively:

$$R_a = \frac{1000\, f^2}{18\sqrt{3}\; r_\varepsilon} = 32.075\frac{f^2}{r_\varepsilon} \tag{3}$$

$$R_t = \frac{1000\, f^2}{8\; r_\varepsilon} = 125\frac{f^2}{r_\varepsilon} \tag{4}$$

The largest amplitude between peak and valley recorded by R_t parameter is dependent of the insert corner radius $r_\varepsilon = r_s$, the tool minor (end) cutting edge angle of χ'_r and tool feed rate f (Diniz *et al.* 2008), Fig. 3. However, for the wiper insert, besides to the process factors aforementioned, the largest amplitude between peak and valley appointed by R_t is also dependent to the modified corner radius r_w; these remain in contact with the workpiece wiping or smoothing the peaks to leave an improved surface finish (Smith, 2008).

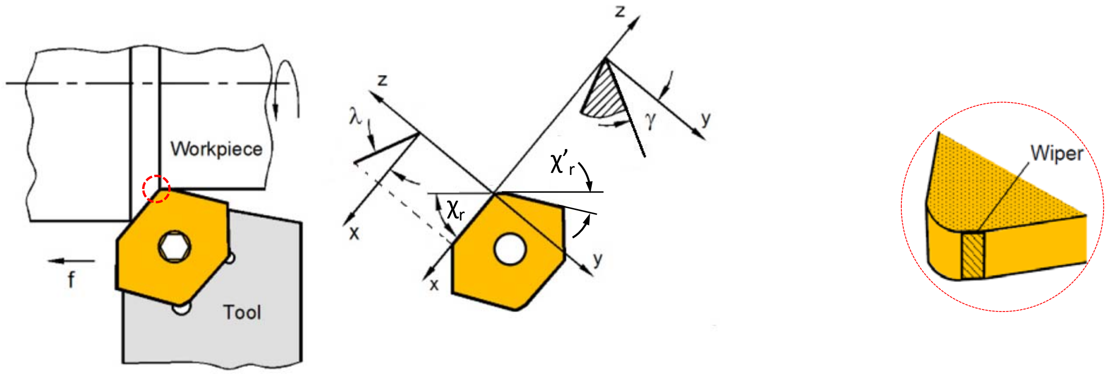


Figure 3. Wiper cutting insert geometry and its part of the modified tool nose radius (adapted from Astakhov, 2010)

According to most popular manufacturers, wiper geometry allows to halve the roughness for the same feed rate or to double the feed rate and obtain the same surface roughness when compared with standard inserts for each mentioned situation, Fig. 4.

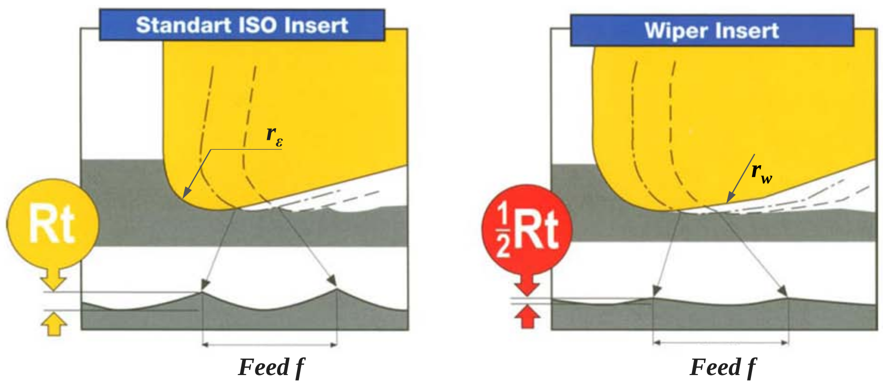


Figure 4. Comparison of R_t for standard and wiper inserts for same f (adapted from Smith, 2008)

However the wiper geometry has some limitations. This geometry is not suitable for every application, among which to light finishing operations, because they require more stock and slightly heavier depths of cut to work correctly. Also, they must be used at higher feeds to take full advantage of the wiper geometry which associated with larger negative rake angle and tool corner radius which in turn influences the increase of passive force *Fp*, demands a sufficient stable and rigid process to prevent vibration associated with this geometry (Smith, 2008; Askathov, 2010). Moreover, considering the lathe, tool presetting should be very accurate, preferably using a digital cutting tool pre-setter to achieve the tool minor (end) cutting edge angle $\chi'_r = 0$. This is because if $\chi'_r > 0$, the efficiency of the wiper geometry reduces and if $\chi'_r < 0$, the cutting force rises significantly and may result in the cutting insert breakage (Astakhov, 2010). And finally, the wiper geometry is not suitable in machining of some difficult-to-machine work materials having significant yield strength, due to elastic recovery (springback) of the machined surface which may demand another cutting operation (Astakhov, 2004).

3. EXPERIMENTAL PROCEDURES

The surface finish performance evaluation of standard and wiper cutting tools was carried in terms of average roughness R_a and total roughness R_t in turning operations in respect to different tool manufactures, tool radius and feed rates. Steel SAE 4140 was selected as workpiece material due its large application on metalworking industry, mainly on the manufacturing of pins, shafts, gears, and other parts. Workpiece geometry is presented in Fig. 5 and its chemical composition in Tab. 1.

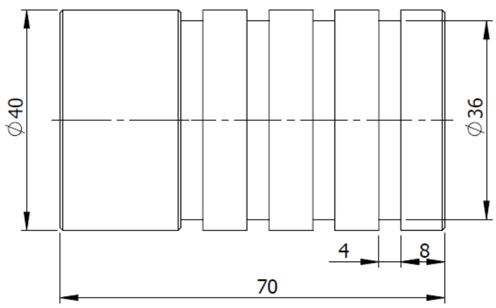
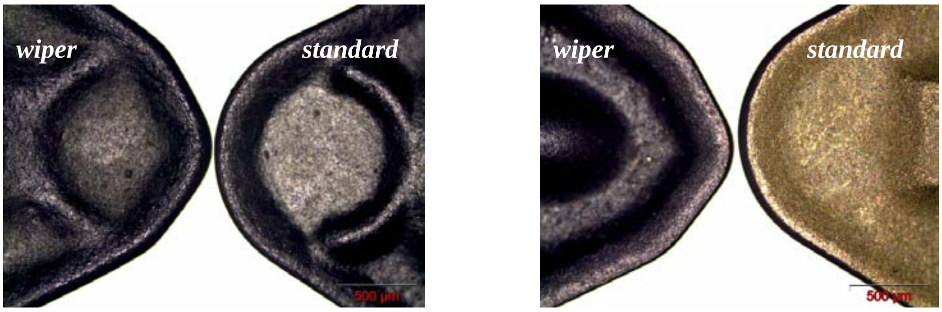


Figure 5. Workpiece geometry (dimensions in mm)

Table 1. Chemical composition (SAE-J404) of SAE 4140 steel

% C	% Mn	% P (max.)	% S (max.)	% Cr	% Mo	% Si
0.38 – 0.43	0.75 – 1.00	0.030	0.040	0.80 – 1.10	0.15 – 0.25	0.15 – 0.35

Wiper and standard inserts used in this investigation (Fig. 6) presents triangular geometry with basic negative format and chipbreaker for finish turning operations. Tool inserts have in common the same TiCN-Al2O3-TiN coating layer, slightly differing only on its deposition process: MTCVD for manufacturer *A* and CVD for manufacturer *B*. Also, for both inserts the considered corner radius r_ε were 0.4 and 0.8 mm. The insert's fixture system in the tool holder is the wedge-clamp kind which minimizes vibrations. The cutting tool presents a position angle χ_r=93º.



(a) (b)

Figure 6. Comparison of tool nose geometry used for the experiments: (a) manufacturer *A* and (b) manufacturer *B*

Selected tools have similar ranges of cutting parameters, Tab. 2. However, they slightly differ in the recommended ranges of operation in order to maintain the pre-established lifetime, usually estimated by the manufacturers as 15 minutes. For carrying the tests, all inserts were set on a tool holder MTJNL 2020K 16M1.

Table 2. Specifications of tools

ISO specification	Nose geometry	Tool Manufacturer	Recommend Parameters		
			v_c [m/min]	f [mm/rev]	a_p[mm]
TNM 16 04 04	*Standard*	A	515 (415 – 575)	0.15 (0.07 – 0.30)	0.40 (0.25 – 1.50)
		B	360 (280 – 480)	0.15 (0.05 – 0.35)	1.00 (0.30 – 2.50)
	Wiper	A	475 (415 – 570)	0.20 (0.08 – 0.30)	1.00 (0.20 – 3.00)
		B	330 (280 – 480)	0.20 (0.05 – 0.35)	1.00 (0.30 – 2.50)
TNM 16 04 08	*Standard*	A	475 (555 – 370)	0.20 (0.10 – 0.40)	0.40 (0.30 – 1.50)
		B	360 (280 – 480)	0.25 (0.05 – 0.3)	1.00 (0.20 – 2.00)
	Wiper	A	415 (370 – 555)	0.30 (0.10 – 0.40)	1.50 (0.20 – 3.00)
		B	400 (300 – 500)	0.30 (0.10 – 0.40)	2.00 (1.00 – 4.00)

According of the above information, a cutting velocity of 475 m/min, a cutting depth of 0.50 mm and four feed rates (0.075, 0.150, 0.225 and 0.300 mm/rev) were selected, thus totalizing 16 combinations. Figure 7 shows a picture of the CNC lathe Mazak QTN 100-II and workpiece used in the experiments.

(a) (b)

Figure 7. CNC lathe used for the experiments: (a) Mazak QTN 100-II; (b) workpiece to perform the operation

The cutting operation consisted of subsequent external longitudinal turning, each of 10 mm length matching the four selected feed rates (see Fig. 5). For each tool insert evaluated, in respect to the four combinations of feed rate, only one of the six cutting edges was used. After each pass, the specimen was carefully removed from the lathe for subsequent surface measurement with a portable roughness tester Mitutoyo model SJ-201 with a resolution of 0.01 µm (Fig. 8). The device was calibrated to correct the systematic error.

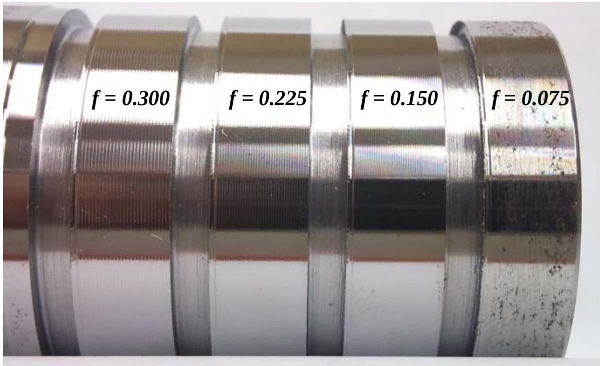
(a) (b)

Figure 8. Roughness measurement system: (a) Mitutoyo roughness tester SJ-201; (b) Detail of probe in operation (13×)

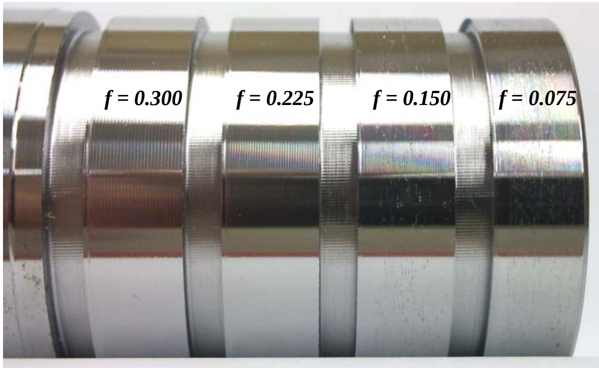
For roughness verification, Fig. 8(b), a cutoff of 0.8 mm was established and three readings were taken on random positions for each segment (matching the feed rate combinations) of the workpiece. In complement to the experiments, an ANOVA from roughness average (R_a), total roughness (R_t) and R_a / R_t (K) ratio was made with the objective of analyze the influence of cutting parameters feed, tool nose radius, tool nose geometry and tool manufacturer on the total variance of results, for a 95% confidence level.

4. RESULTS AND DISCUSSION

Figure 9 shows a photo of two of the machined workpieces, pointing out the generated roughness profiles. It is clearly evident the effect of feed rate and tool cutting edge geometry on the surface of the machined segments. For some analyzed cutting conditions, the presence of burr at the end of some machined segments is noted. Thus special care should be taken with the stylus while probing the surface roughness in order to avoid incorrect readings or its damage.



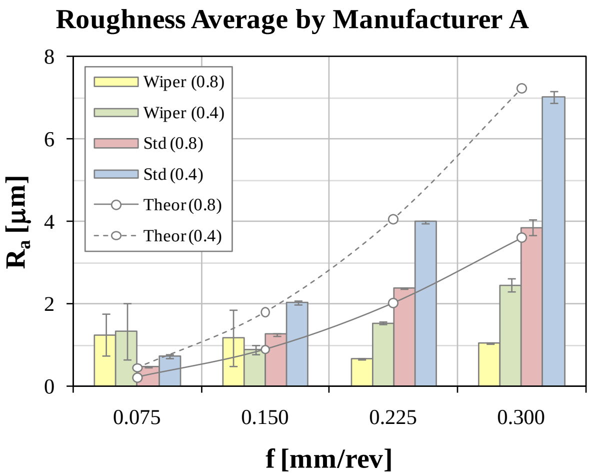
(a)



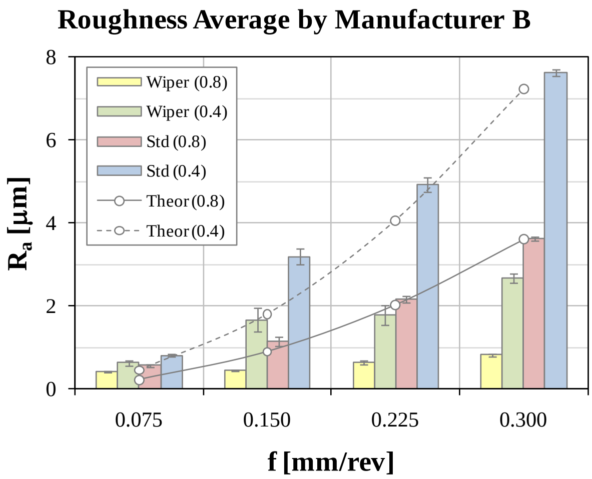
(b)

Figure 9. Roughness profiles for different analyzed feed rates, in mm/rev, with (a) wiper cutting tool (manufacturer *A*) of r_ε=*0.8 mm* and (b) standard cutting tool (manufacturer *B*) of r_ε=*0.4 mm*. Turning direction was from right to left on each specimen with feed increasing from right to left on each specimen's segment

Following Fig. 10 and Fig. 11 presents the evolution of established roughness parameters R_a and R_t as function of feed rate (0.075, 0.15, 0.225 and 0.300 mm/rev) for different cutting tool manufactures (*A* or *B*), tool radii (r_ε = 0.4; 0.8 mm) and insert type (*Std* or *Wiper*). In order to ease the analysis, theoretical trend curves for respective roughness parameters (*Theor*, r_ε = 0.4; 0.8 mm), according to Eq. (3) and (4) are plotted along with experimental results.



(a)



(b)

Figure 10. R_a as function of feed for different tool cutting radius (0.4 and 0.8 mm) and insert type (standard and wiper) for: (a) manufacturer *A* and (b) manufacturer *B*

It is clearly visible in the Fig. 10 that for standard inserts (*Std*) the experimental values for R_a agrees with theoretical values (Eq. (3)). In general, turning surfaces with standard inserts presents higher values of R_a in comparison with wiper inserts for high feed rates. The exception is for the manufacturer *A* with its wiper cutting tools for the lowest feed rate (0.075 mm/rev), in which the generated values of roughness and its expanded uncertainty are higher than the ones obtained with standard tools (Std); referring to Fig. 9(b), it is possible to note the dark spots on the first machined segment (lowest feed). Reasons for that unexpected behavior may be related to wiper geometry, cutting parameters f and a_p (Astakhov, 2010), workpiece material and chip breaker geometry. Also, Diniz *et al.* (2008) informs that when the ratio a_p/r_ε is small, the chip will bend laterally with a wide-angle flow, forming a chip that is not easily broken and may collide to the exposed machined surface, thus, damaging the surface finish. When this ratio is large, as well as lateral curvature, vertical curvature will also occur bending the chip toward the tool's rake surface and there to break. Achieved results by Geier *et al.* (2011) are in agreement, where in high-performance turning of AISI 4140 steel with wiper cutting tools of 0.4 mm radius, a_p =1.00 mm and feeds of 0.150 and 0.300 mm/rev, ie higher f , a_p and a_p/ r_ε ratio, slightly minor values for R_a where achieved. This, plus information from Tab. 3, supports the hypothesis that the chip, and consequently the tool geometry (radius and chip breaker), plays an important role in the machined surface finish obtained by wiper tools of 0.8 mm radius from manufacturer *A*. Also, it is evident the lower results of R_a for standard tool of 0.4 mm radius (*Std. (0.4)*) from manufacturer B when compared to wiper tool from manufacturer *A*.

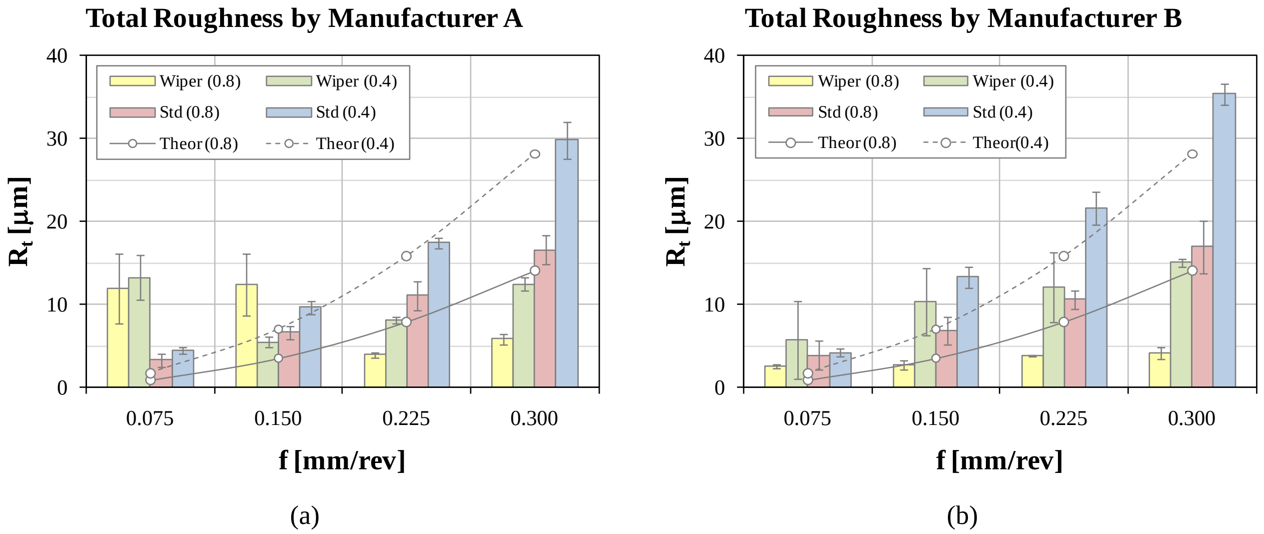


Figure 11. R_t as function of feed for different tool cutting radius (0.4 and 0.8 mm) and insert type (standard or wiper) for: (a) manufacturer *A* and (b) manufacturer *B*

The evolution of R_t is presented in Fig. 11. For this roughness parameter it is also observed in general that turning surfaces with standard inserts generated higher R_t values in comparison with wiper inserts for high feed rates. Here, the exception is again for manufacturer *A* with higher R_t wiper inserts at lower feeds rates of 0.075 mm/rev (*Wiper 0.4* and *0.8* mm) and 0.15 mm/rev (*Wiper 0.4*) in which the generated values of total roughness and its expanded uncertainty are higher than the ones obtained with standard tools. In general, as occurred for $R_{a,}$ R_t experimental values from standard tools are the ones which best agrees with theoretical values. Possible reason for that relies on previously presented arguments (wiper geometry, cutting parameters f and a_p, ratio a_p/r_ε) and by respective references (Askathov, 2010; Diniz *et al.*, 2008, Geier *et al.*, 2011; Smith, 2008).

In order to ease the analysis between wiper and standard cutting tools, Correia and Davim (2011) introduced a non-dimensional parameter K (the ratio of theoretical values of average and total roughness), obtained from Eq. (3) and (4):

$$K = \frac{R_{at}}{R_{tt}} = \frac{\dfrac{1000 \cdot f^2}{18 \cdot \sqrt{3} \cdot r_\varepsilon}}{\dfrac{1000 \cdot f^2}{8 \cdot r_\varepsilon}} = \frac{32.075}{125} = 0.2566 \tag{5}$$

Figure 12 shows the evaluation ratio of experimental R_a and R_t values as function of feed rate and cutting tools (standard and wiper). It is noted that for the standard tools, its ratio R_a/R_t is very close to the theoretical ratio (non-dimensional parameter K, Eq. (4)). Also, the influence of wiper inserts on surface finish is highlighted. The relative variation of R_a is greater for wiper cutting tools, ie R_a and R_t for wiper cutting tools decreased, in general, approximately 100% and 50%, respectively. Thus, it is possible to estimate qualitatively the ratio of experimental roughness parameters generated by standard and wiper tools as approximately K_{Std}=0.20 (considering all feeds) and K_{wiper}=0.17

(disregarding roughness parameters for *f*=0.075mm/rev due to the wide dispersion of results, which was previously discussed). Reasons for experimental ratio R_a/R_t values being bellow the theoretical one (*K=0.2566*) may be due the fact that theoretical equations for R_a and R_t doesn't consider the influence of other cutting parameters such as cutting velocity, depth of cut and material's machinability, as presented in literature (Davim, 2001; Diniz *et al.*, 2008; Correia and Davim 2011; Geier *et al.*, 2011; Gokkaya and Nalbant (2006) amoung others).

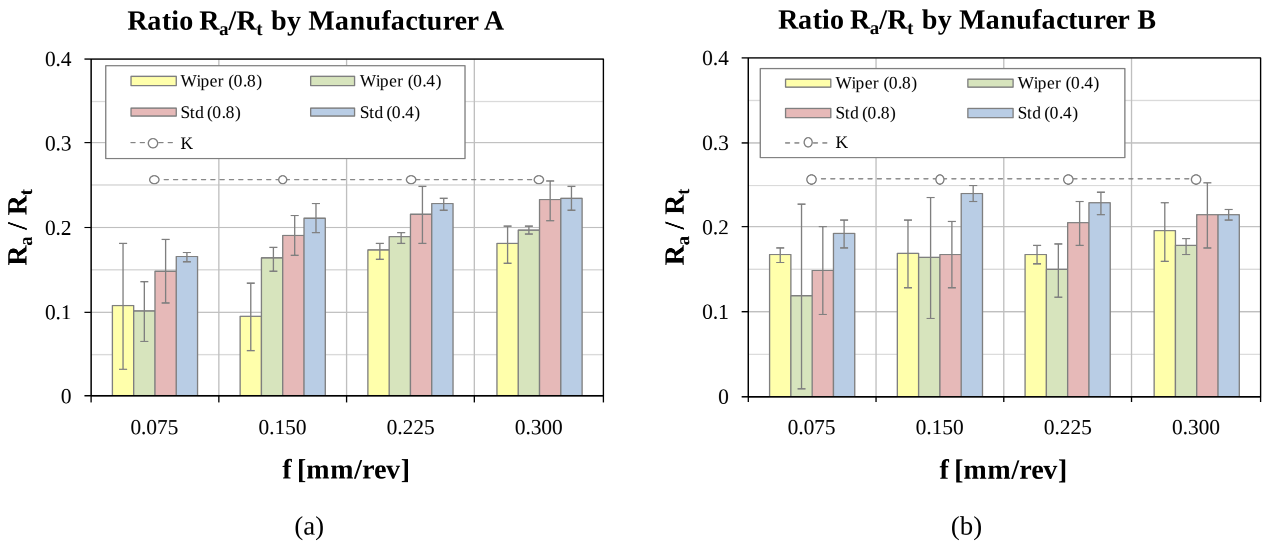


Figure 12. Ratio $K = R_a/R_t$ as function of feed for different tool cutting radius (0.4 and 0.8 mm) and insert type (standard or wiper) for: (a) manufacturer *A* and (b) manufacturer *B*

The ANOVA with R_a, R_t and ratio R_a/R_t outputs are presented in Fig. 13. In general, feed rate influence is reported as approximately 25% for both surface roughness parameters. For R_a, the most influent cutting parameter was nose geometry (standard or wiper) with 45.3% followed by cutting edge radius with 29.6%. When considering R_t, the most influent cutting parameter was cutting edge radius with 42.3% (0.4 or 0.8 mm). Concluding, with relation to *K* ratio (R_a/R_t) the most influent cutting parameter is nose geometry (standard or wiper) being follow by cutting edge radius with 5% and, recorded for the first time, by manufacturer (*A*or *B*) with 1%. In other words, R_a parameter is more influenced by wiper nose geometry as these roughness parameter isn't able to distinguish peaks and valleys. The R_t parameter is rather influenced by tool nose radius than the benefits from nose geometry (*Wiper*).

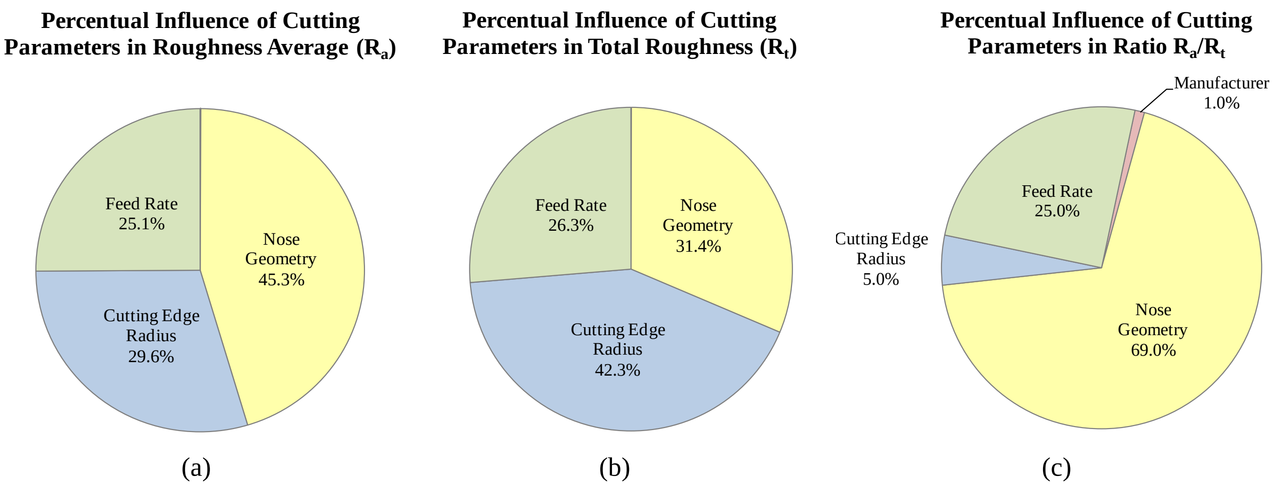


Figure 13. ANOVA outputs for percentual influence of cutting parameters in (a) R_a, (b) R_t and (c) *K* ratio (R_a/R_t)

5. CONCLUSIONS

This study presented an assessment of wiper cutting tools in generated surface roughness from dry turning of AISI 4140 in terms of R_a and R_t parameters. For this, wiper performance were compared to standard tools from similar specifications (same class) for different cutting edge radius and feed rates. In general, achieved results are in agreement with well know cutting parameters as feed rate, tool cutting edge radius and tool nose geometry, as presented in literature, with wiper cutting tools presenting the best surface finishing. However, some wiper cutting tools didn't perform well for the lowest feed rate when compared with standard cutting tools. In addition to these findings, the following conclusion can be summarized:

- R_a parameter is more influenced by wiper nose geometry since the wiper blade smoothes the surface, minimizing roughness peaks;
- R_t parameter is more influenced by cutting edge radius;
- for R_a, R_t ratio R_a/R_t the feed rate presented a constant influence of approximately 25%;
- theoretical equations for predicted R_a and R_t values are well suitable for standard tools, but not for wiper tools;
- with wiper cutting tools and high feed rate (f=0.300 mm/rev) a surface finish with R_a =0,83 µm was achieved;
- ANOVA outputs informed that tool manufacturer didn't show significant influence on R_a and R_t.

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