PRODUCTION ENGINEERING ARCHIVES 2020, 26(3), 92-98

PRODUCTION ENGINEERING ARCHIVES

ISSN 2353-5156 (print)
ISSN 2353-7779 (online)

Exist since 4th quarter 2013
Available online at https://pea-journal.eu

Relationship between surface roughness and chip morphology when turning hardened steel

Youcef Abidi[1]

[1]*LRTAPM, Badji Mokhtar University, Annaba, P.O Box 12, 23000 Annaba, Algeria,*
Corresponding author e-mail: abidiyoucef73@gmail.com

Article history
Received 28.06.2020
Accepted 03.08.2020
Available online 30.09.2020

Keywords
Hard machining
AISI 1045 steel
Ceramic tool
Chip
Surface roughness

Abstract
Hard machining is a process which has become highly recommended in manufacturing industry to replace grinding and perform production. The important technological parameters that determine this process are tool wear, machined surface roughness, cutting force and morphology of the removed chip. In this work, an attempt has been made to analyse the morphology and form of chip removed during turning of hardened steel AISI 1045 (40HRC) with mixed ceramic tool type CC650. Using a Taguchi plan L_9, whose factors are cutting speed and feed rate with three levels for each. Macroscopic and microscopic results of chip morphology were correlated with these two cutting parameters additional to surface roughness. Sufficient experimental results were obtained using the mixed ceramic tool when turning of hardened steel AISI 1045 (40HRC) at high cutting speeds. Roughness of machined surface confirmed that it is influenced by feed rate. Chips show a sawtooth shape for all combinations of the experimental plan used. The chip form changed with cutting parameters variation and given an important indicator of suraface quality for industriel. Having the indicators on the surface quality from simple control of chip without stopping machining give an important advantage in order to maximize production and reduce costs.

DOI: 10.30657/pea.2020.26.19 JEL: L69, M11

1. Introduction

AISI 1045 is a highly recommended steel in the industry due to its excellent mechanical properties, machinability and favorable thermal hardening.

The machining of hardened materials has become a highly demanded manufacturing process due to its appreciated technological and ecological contribution. The development of this process suggest for continuous investigations to improve the quality and control of production costs. Improvement of the quality requires an optimization of the compromise between properties (of tool, the piece machined and the machine) and parameters (thermal, dynamic and cutting). Much research has invested in mastering and improving the surface quality machined for hardened materials. They found that the control of cutting forces and machining vibrations leads to a clear improvement of the surface quality (Khorasani et al., 2012). The feed is found as the most influential parameter on the surface roughness (D'addona et al., 2016; Rajeev et al., 2016; Keblouti et al., 2019; Azizi et al., 2020), others added to cutting feed, the tool nose geometry and workpiece hardness (Ozel et al., 2005; Bouziane et al., 2018). Therefore, weak feed and large nose radius lead to weak surface roughness, the opposite is true (Meddour et al., 2015). The effect of the depth of pass on surface roughness is negligible (Bouacha et al., 2010).

During machining, different chip form can be generated. The study of chip formation and its morphology, and pamameters they influence it will help to understand the phenomenon of material removal and surface integrity (Ben salem et al., 2012), as well as the performance of the tool cutting (Kumar et al., 2017).

In hard machining, an important quantity of heat produced during cutting is evacuated mainly by the chip avoiding thermal expansion of the workpiece (Khamen et al., 2007). There are different types of chips that are produced in machining: continuous, segmented, scalloped and discontinuous (Vyas et al., 1999). In hard machining of AISI 52100 steel, saw tooth chips are envisioned (Watmon et al., 2010).

It has been established that Cutting forces condition chip formation and its evaluation (Ben salem et al., 2012; Anthony, 2015). Cutting tool performance is considerably affected by a scrambled chip type (Motorcu, 2011).

Ekinović *et al.* (2014) found that the using of dry technology in hard machining of 30CrNiMo8 steel (48HRC) is possible to affect chip morphology. A degradation on surface quality when generated the fragmented chip segments during hard machining (Khorasani et al., 2012).

The specific character of chip formation significantly affect such aspects as shear and chip speed, friction processes in the cutting zone related heat generation and high temperatures in this zone with the consecutive impact on surface quality represented by residual stresses, surface hardness, structural changes (Neslušan et al., 2012; Yadav, 2016). Increasing the hard machining feedrate will increase chip thickness *hc*, which translates into an increase in chip ratio, $K = hc/f$ (Neslušan et al., 2012). While increasing the cutting speed, chip hardness will decrease, as well as its thickness and height (Anthony, 2015). Das et al. (2015) found out that depth of cut and cutting speed are the most affecting parameters of the chip reduction coefficient. The color of the chip provides indicators on the evolution of the thermal field during cutting (Sahoo et al., 2012). Elshwain *et al*. (2020) confirmed that chip morphology characteristics change when the combination of cutting speed and feed rates are changed while hard turning stainless steel (48HRC), increasing speed from 100 to 170m/min changes chip type of twisted long ribbon to snarled tubular. Zhang et al. (2016) discovered that,with proper selection of feed rates and cutting depths (0.15mm/rev and 0.2 to 0.3 mm respectively), high-speed machining of hardened steel AISI 1045 (45HRC) with CBN tool can produce desirable surface roughness.

For this experimental study, taguchi plan L_9 compound by the factors cutting speed and feed rate with three levels for each parameter, depth of cut maintained constant, was used for the finishing and dry turning process of steel AISI 1045 hardened to 40HRC by the mixed ceramic tool 70% Al_2O_3 + 30% TiC in order to have chip morphology and surface roughness, as responses. ANOVA analysis was performed to determine the influence of cutting parameters on surface quality. An analysis of relationship between chip morphology and machined surface quality was done.

2. Experimental procedure

2.1. Experimental materials and equipment

Machining tests has been performed in dry conditions on a SN40 parallel Lathe with a spindle power of 6.6kW and a maximum rotational speed of 2000rev/min. The heat treatment has been carried out using an electric oven type WOT 9703- 457 404 with maximum heating temperature of 1600°C. Hardness values after tempering, measured with a Hardness Testing HLM-100 Plus. A CCD camera equipped by optical microscope type HUND (W-AD) has been used for to show chip morphology and form. An acquisition system has been used (Motic 2000 software). A Surftest 301 Mitutoyo roughness meter has been employed to measure roughness on the machined surface (Fig. 1). Eight square working edges removable cutting inserts of the designation SNGN 120408 have been used, they are made of mixed ceramics (CC650) made of (70% Al_2O_3 + 30% TiC). They are mounted on a tool holder PSBNR2525M12 of the following geometry: $\chi_r = 75°$; $\alpha = 6°$; $\gamma = -6°$; $\lambda = -6°$.

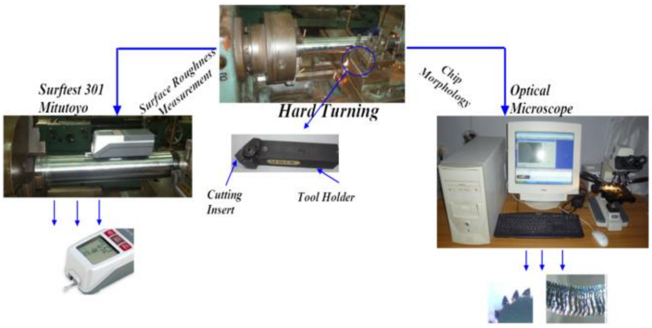

Fig. 1. Materials of the experiment

2.2. Workpiece preparation

The AISI 1045 steel (C45 according to DIN) characterized by an important quenching ability has been used. It is classified as non-alloy tool steel with good resistance to wear. It is commonly used in mechanical engineering for various uses (molds for plastic material, several pieces for automotive sector, axes, gears...). The chemical composition identified by an optical emission spectrometer (Thermo Scientific ARL 4460) is illustrated (Table 1). Hardening of the material has been achieved on a round bar blank of 60mm diameter and 400mm length by quenching from 850°C in water bath and then tempering at 200°C. Hardness values after tempering have reached 40HRC. Machining has been performed in dry conditions. The blank has been mounted in between chuck and center.

Table 1. Chemical composition of grade AISI 1045 steel in weight %

Designation	C	Mn	Si	Ni	Cr
Steel of ex-perience	0.452	0.723	0.238	0.055	0.092

2.3. Experimental design

Experimentation tests have been carried out using a L_9 full factorial design (Table 2) in order to investigate the effect of cutting parameters (cutting speed and feed rate) on the chip morphology and machined surface roughness and then to analyse a corresponding correlation. Factor levels were chosen corresponding to the literature (Abidi et al., 2017). As the effect of depth on surface roughness is negligible in hard machining according to the literature (Abidi *et al.* 2018), it is kept constant and equal to 0.5mm for this investigation. The process was shown in Fig. 2.

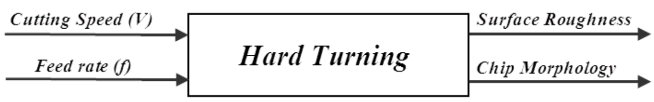

Fig. 2. Methodology of the Experimental

Table 2. Machining parameters and levels (depth of cut D= 0.5mm)

Cutting parameters	Unit	Levels		
Cutting speed (*V*)	m/min	140	200	280
Feed rate (*f*)	mm/rev	0.08	0.16	0.22

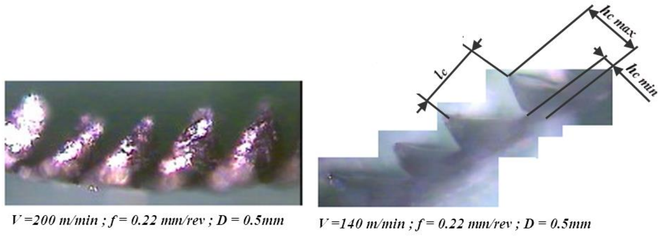

Fig. 4. Chip morphology (sawtooth)

3. Results and discussion

3.1. Chip morphology analysis

Chips were collected for the experiments conducted while turning of hardened steel AISI 1045 with mixed ceramic tool (CC650). Fig. 3 shows the matrix (f_i , V_i) of 9 different types of chips collected from the machining experiments conducted with 9 different cutting combinations of input parameters. The chip morphology which is presented in the matrix form was studied under an optical microscope to show the secondary deformation zone at the tool-chip interface.

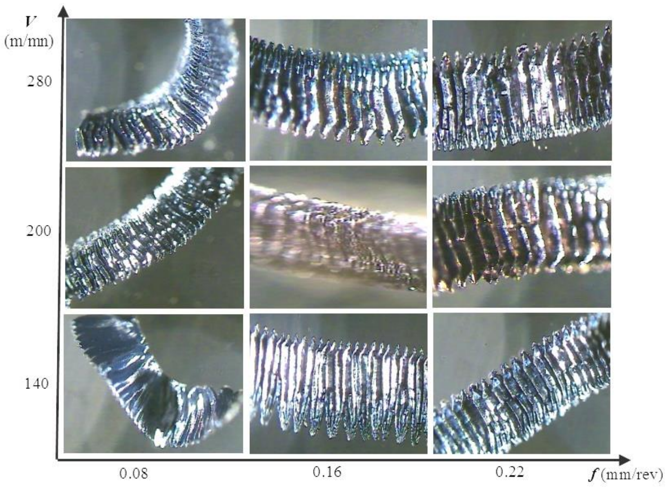

Fig. 3. Microscopical chip morphology for different cutting combinaisons

The microscopic views of the chips show localized material deformation with fractures in the three directions (cutting, feed and thrust) for the different cutting combinations selected, but without complete chip fracture. The chips show a sawtooth shape, which can be well illustrated through a microscopic representation in the axial plan corresponds to the feed force (free surface) (Fig. 4).

This shape is characterized by a maximum chip thickness (*hc* max) and a minimum chip thickness (*hc* min) and a slip distance (*lc*). The *hc* is a function of the cutting parameters (speed and feedrate) (Daymi et al., 2009) while *lc* is usually represented as a function of the cutting speed, feedrate and depth of cut (Sadik et al., 1995). The sawtooth shape is due to cyclic cracking which creating very intensive shear bands and which is favored by the high hardness of the material, cutting speed, the negative cutting angle and the feedrate (Barry et al., 2002).

The plastically deformed chips are segmented ; this phenomenon is related to a fluctuation of cutting force and stress distribution in the cutting zone, and it influences the temperature distribution (Neslušan et al., 2012), origin of the strong compression stresses generated in the material is the penetration of the cutting tool which is very hard compared to workpiece.. For this purpose, we refer to literature (Dogra et al., 2010), we can note that the use of a ceramic cutting tool whose hardness is more than 5 times the hardness of the machined workpiece (tool hardness = 2100HV, workpiece hardness = 390HV), with a negative angle that is equal to (-6°) leads to produce more high compressive stresses.

From Fig. 3, we note that the morphology of the chip vs the cutting conditions looks similar configuration. The increase in the feedrate leads to the increase in the distance between two successive segments, hence an increase in the distance lc and the chip is increasingly scalloped. With the increase of cutting speed, tears in the saw teeth of the chip deepened (become more pointed) and it became very remarkable for the speed *V*= 280m/min, then, the considerable reduction in the width of contact between the segments hc_{min}. This is due to important deformation in the shear zone advantaged by the increase in the temperature.

3.2. Chip morphology analysis

Fig. 5 shows different chip form obtained during the 9 combinations of the cutting parameters. It is observed that variation of cutting speed has no significant effect on the chip form this is probably due to the constant depth maintenance (D = 0.5mm), hence a small variation of the cutting force, this shape is helicoidal.

For small feed rate, and with the increase of the cutting speed the form of chip produced during the machining will change from continuous long to continuous fragmented, which is explained by the reduction of the contact width between the chip segments due to accumulation of cutting bands which become more and more intense. Localized deformation in the primary cutting zone becomes important due to the thermal stress generated during increase of the temperature. The mechanical properties on the workpiece surface change by creating a plastic instability that causes abrupt chip shear.

For moderate feed (average feed level), increasing cutting speed during hard turning will change the form of chip produced from a continuous ribbon chip to a segmented ribbon chip.

For high feed rate, with the increase of cutting speed, the chip form changes from a thin long ribbon to a continuous non-fractured ribbon.

The colour for chip varies from blue to gray when cutting speed increased.

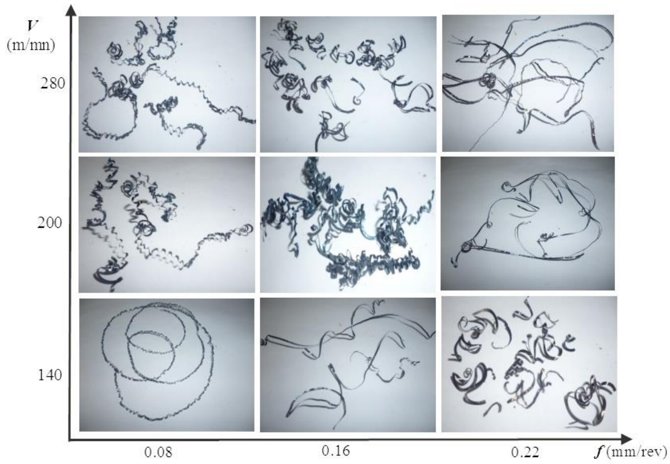

Fig. 5. Chip form for the different cutting combinaisons

3.3. Surface roughness

Surface roughness is an important technological characteristic in the machining process of hardened materials that replaces grinding. Table 3 presents the results of the surface roughness in three criteria *Ra*, *Rz* and *Rt* in relationship to cutting speed and feed rate parameters during the turning of the hardened steel AISI 1045 (40HRC). Tests were carried out according to an orthogonal plan Taguchi L_9.

Table 3. Orthogonal array L_9 of Taguchi experiment design and experimental results for surface roughness (D = 0.5)

V (m/min)	*f* (mm/rev)	Ra (µm)	Rz (µm)	Rt (µm)
140	0.08	1.345	6.76	8.3
140	0.16	1.575	8.12	9.39
140	0.22	2.515	10.43	10.87
200	0.08	0.72	4.02	4.51
200	0.16	1.66	7.94	8.87
200	0.22	2.55	11.07	11.31
280	0.08	0.59	3.17	3.54
280	0.16	1.4	6.8	7.32
280	0.22	2.22	10.71	11.42

Ra : Arithmetic mean roughness ; Rz : Average maximum height of the profile ; Rt : maximum height of the profile.

The best surface roughness is recorded for the cutting combination, low feed with high speed, while surface roughness is high for combination, low speed with high feed.

Fig. 6 shows the main effect of the cutting parameters (speed and feed) on the surface roughness, it is clear that the effect of the feed is more important than the speed. feed increase leads to an increase in the surface roughness resulting in a degradation of the surface quality, while increasing the cutting speed improves the surface quality slightly. This is in agreement with the literature (Abidi et al., 2017; Azizi et al., 2020). It can be noted that trends of main effect of cutting parameters on the three surface roughness criteria are similar. Therefore, only interested to Arithmetic mean roughness remains in the scope of the further analysis.

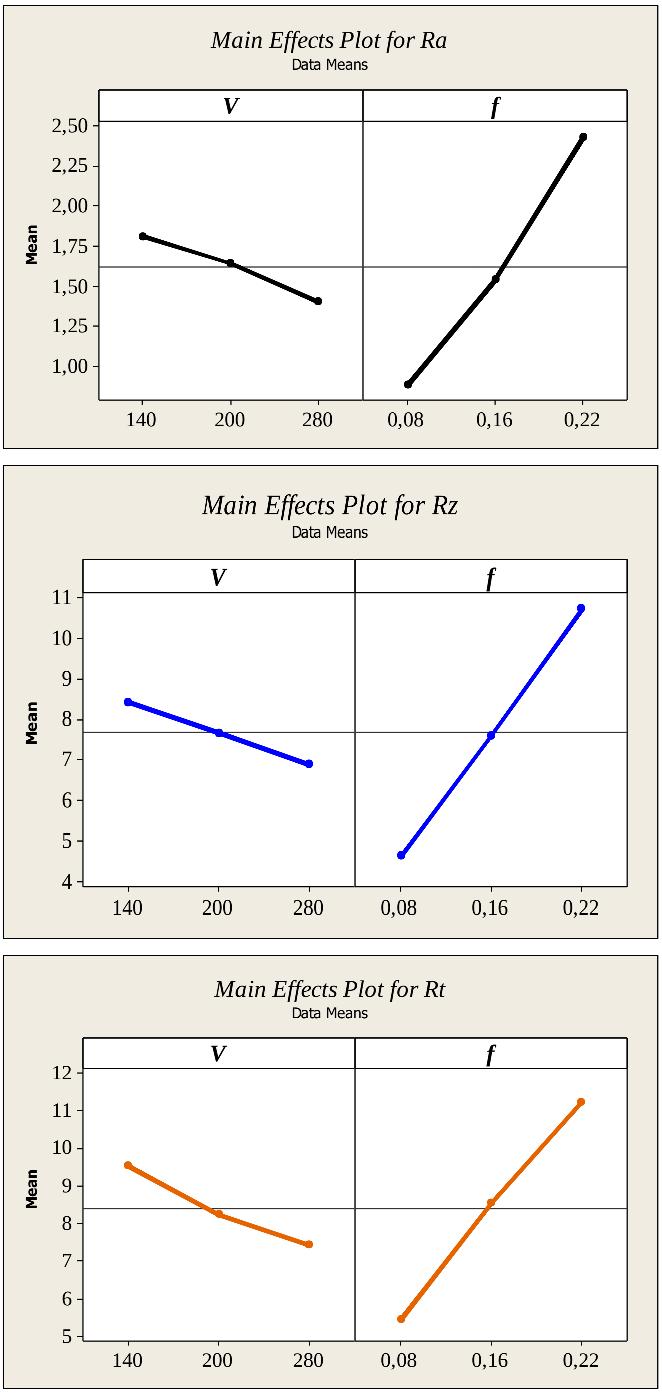

Fig. 6. Main effect on the surface roughness

The contour plot of surface roughness according to cutting speed and feed rate shown in Fig.7. The best roughness is recorded at cutting speeds greater than 160m/min with feed less than 0.12mm/rev. The increase of the feed leads to increasing roughness, resulting degradation of the surface quality. It can also be observed that the concave of the contour lines always corresponds to the speed 200m/min which implies that this speed is the most suitable for this machining environment in order to reach a best roughness.

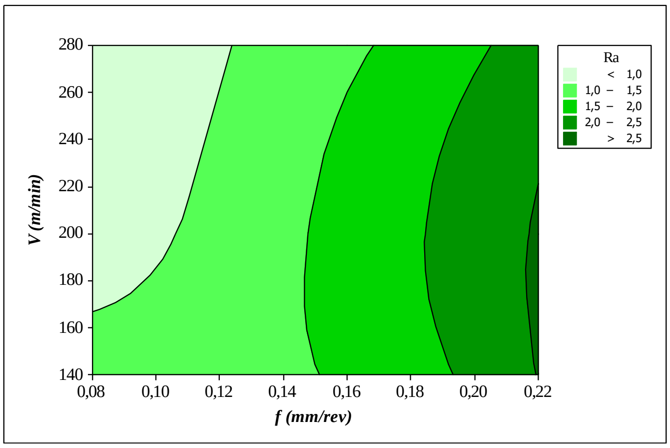

Fig. 7. Contour plot of Ra Vs cutting speed and feed rate

Multiple first order regression model has been implemented at 95% confidencelevel to obtain the relationship between the machining parameters (cutting speed and feed rate) and surface roughness (Ra). The obtained equationwas as follows:

$$Ra = 1.27 - 0.0064V + 6.19f + 0.0227V \cdot f \qquad (1)$$

With $R^2 = 94.5\%$.

The layer of the determination coefficient R^2 is extremely desirable. This confirms that the model is appropriate. The analysis of variance for the regression presents in Table 4. The P-value (probability of significance) is inferior to 0.05 which indicates that model is statistically significant. It is revealed that terms mentioned in the regression model have significant effects on the responses.

Table 4. Analysis of variance for surface roughness (Ra) 1st order model

Source	*DOF*	Seq SS	MS	F	P	Remarks
Regression	3	3.8026	1.2675	28.56	0.001	Significant
Residual Error	5	0.2219	0.0444			
Total	8	4.0254				

The validation of data obtained from the model are given by the average percentage error for the first order model of surface roughness (*Ra*) which was 10.26%. The percentage error was presented in Table 5.

The percentage error (%δ) was calculated by the following relation in Eq :

$$\%\delta = \frac{\sum absolu \dfrac{\exp erimental\_value - predicted\_value}{\exp erimental\_value} abso}{test\_number} \times 100 \qquad (2)$$

Table 5. Predicted values and their percentage error for Ra

Test N°	*Experimental value Ra*	Predicted 1st model value	% Error in value predicted
1	1.345	1.1234	16.47
2	1.575	1.8729	-18.9
3	2.515	2.435	3.18
4	0.72	0.8484	-17.8
5	1.66	1.7068	-2.8
6	2.55	2.3506	7.82
7	0.59	0.4817	18.36
8	1.4	1.4854	-6.1
9	2.22	2.2381	-0.8

Average percentage error δ = 10.26%.

3.4. Correlation between surface roughness and chip form

A very strong relationship between chip segmentation and technological characteristics (surface roughness, cutting forces,..). Chip segmentation generates the oscillation of the cutting forces and causes geometrical defects on the machined surface and a non-uniform distribution of residual stresses (Mabrouki et al., 2015; Zhang et al., 2013). This allows us to analyze the correlation between surface roughness machined and chip produced.

The industrialist is always interested in maximizing the profits of the production by reducing the machining time. One way is to get some information about machined surface quality without stopping production. In this context, the chip form analysis will give indicators on the surface roughness. therefore, an analysis of the correlation between chip form and machined surface roughness during the turning of hardened steel AISI 1045 (40HRC) using mixed ceramic (70% Al_2O_3 + 30% TiC) is very advantageous.

Fig. 8 shows the 3D Scatterplot of surface roughness Ra vs cutting parameters (feed rate and cutting speed) correlated with variation in chip forms produced during turning.

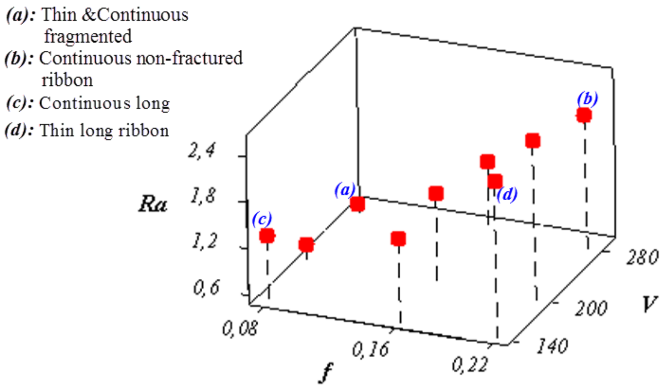

Fig. 8. Correlation between chip forms and Roughness

For low feeds, increasing the cutting speed leads to a decrease in surface roughness that reflects a form chip production varies from a long continuous helical to a thin and continuous fragmented helical. Which means that best surface quality obtained with a generation of a fragmented helical chip.

As the feed rate increases, and the cutting speed decreases, the surface roughness increases and translate by production of chip form varied from long ribbon-shaped to a fragmented thick ribbon shape, the latter correspond to the largest roughness.

4. Summary and conclusion

In order to reduce production costs while maintaining quality in manufacturing, the present work is a contribution to determining the effect of cutting parameters (speed and feed) on the chip morphology and form, as well as machined surface roughness when turning of hardened AISI 1045 steel (40 ±1HRC) using the mixed ceramic (70% Al_2O_3 + 30% TiC). The correlation between chip form and roughness has been investigated in order to give to industrialist a practical advantage of online control of machined surface quality. The main conclusions are :

- In this investigation, saw-tooth morphology for serrated chips are formed in all the experiments.
- The hardness of the material and the high cutting speeds favored a ductile break in the primary cutting zone and produced a saw-tooth segmented chip.
- Increasing the cutting speed reduces the width of the chip segment and refines it from the rounded to pointed.
- The best surface quality is recorded for the cutting speed V = 280m/min, f = 0.08mm/rev and D = 0.5mm.
- The morphology of the chip vs the cutting conditions remains the same. Increasing the feed leads to increasing the distance between two successive segments.
- The variation in cutting speed has no significant effect on chip form under the cutting conditions of this study.
- The fragmented helical chip indicate a best machined surface roughness at level Ra = 0.59µm.
- Fragmented thick ribbon chip indicate a poor machined surface roughness at level Ra = 2.5µm.

Reference

Abidi, Y., Boulanouar, L., 2017. *Analyse de la correlation entre la rugosite et la vibration de coupe en usinage des aciers durcis*.U.P.B. Sci. Bull., Series D, 79, 4, 157-170.

Abidi, Y., Boulanouar, L., Amirat, A., 2018. *Experimental study on wear of mixed ceramic tool and correlation analysis between surface roughness and cutting tool radial vibrations during hard turning of AISI 52100 steel*, Journal of Engineering Science and Technology, 13, 4, 943-963.

Anthony, X.M., 2015.*Analysis of cutting force and chip morphology during hard turning of AISI D2 steel*, Journal of Engineering Science and Technology, 10, 3, 282-290.

Azizi, M.W., Keblouti, O., Boulanouar, l., Yallese, M.A., 2020. *Design optimization in hard turning of E19 alloy steel by analysing surface roughness, tool vibration and productivity*, Structural Engineering and Mechanics, 73,5, 501-513.

Barry, J., Byrne, G., 2002, *The Mechanisms of Chip Formation in Machining Hardened Steels,*Transactions of the ASME, 124, 528-535.

Ben Salem, S., Bayraktar, E., Boujelbene, M.,Katundi, D., 2012. *Effect of cutting parameters on chip formation in orthogonal cutting*, Journal of Acheivementsin Materials and Manufacturing Engineering, 50, 1, 7-17.

Bouacha, K., Yallesse, M.A., Mabrouki, T., Rigal, J.F., 2010. *Statistical analysis of surface roughness and cutting forces using response surface methodology in hard turning of AISI 52100 bearing steel with CBN tool*, Int. Journal of Refractory Metals & Hard Materials, 28, 349-361.

Bouziane, A., Boulanouar, l., Azizi, M.W., Keblouti, O., Belhadi, S. 2018. *Analysis of cutting forces and roughness during hard turning of bearing steel*, Structural Engineering and Mechanics, 66, 3, 285-294.

Das, A., Khan, A., Mohanty, S., 2015. *Optimization of machining parameters using taguchi approach during hard turning of alloy steel with uncoated carbide under dry cutting environment*, International Journal of lean Thinking, 6, 2, 1-15.

Daymi, A., Boujelbene, M., Ben Salem, S., Hadj Sassi, B., Torbaty, S., 2009, *Effect of the cutting speed on the chip morphology and the cutting forces*, Archives of Computational Materials Science and Surface Engineering, 1**,** 2, 77-83.

D'Addona, D.M.,Raykar, S.J., 2016, *Analysis of surface roughness in hard turning using wiper insert geometry*, Procedia CIRP,41, 841-846.

Dogra, M., Sharma, V.S., Sachdeva, A., Suri, N.M., Dureja, J.S., 2010. *Tool wear, chip formation and workpiece surface issues in CBN hard turning: a review*, International Journal of Precision Engineering and Manufacturing, 11, 2, 341-358.

Ekinović, S., Begović, E., Fakić, B., Burić, A., Čeliković, A., 2014. *Cold air dry machining Part 2: SEM and metallographic analysis of the chip*, 18th Trends in the Development of Machinery and Associated Technology · TMT 2014, Budapest, Hungary,21-24.

Elshwain, A., 2020. *Comprehensive Study of Chip Morphology in Turning Hardened Tool Steel under Nitrogen Gas and Oil Mist Conditions*, International Conference on Technical Sciences (ICST2019), March 2019, 1176-1182.

Keblouti, O., Boulanouar, L., Azizi, M.W., Bouziane, A., 2019. *Multi response optimization of surface roughness in hard turning with coated carbide tool based on cutting parameters and tool vibration*, Structural Engineering and Mechanics, 70, 4, 395-405.

Khorasani, A.M., Yazdi, M.R.S.,Safizadeh, M.S., 2012. *Analysis of machining parameters effects on surface roughness: a review*, Int. J. Computational Materials Science and Surface Engineering, 5, 1, 69-84.

Kumar, C.S,Patel, S.K.,2017. *Experimental and numerical investigations on the effect of varying AlTiN coating thickness on hard machining performance of Al_2O_3-TiCN mixed ceramic inserts*, Surface & Coatings Technology, 309, 266-281.

Mabrouki, T., Courbon, C., Zhang, Y., Rech, J. Nélias, D., Asad, M. Hamdi, H., Belhadi, S.,Salvatore, F., 2016. *Some insights on the modelling of chip formation anditsmorphology during metal cutting operations*, Comptes Rendus Mécanique, 344, 4, 335-354.

Meddour, I., Yallese, M.A., Khattabi, R., Elbah, M., Boulanouar, L., 2015. *Investigation and modeling of cutting forces and surface roughness when hard turning of AISI 52100 steel with mixed ceramic tool: cutting conditions optimization*, Int J Adv Manuf Technol, 77, 1387-1399.

Motorcu, A.R., 2011. *Tool life performances, wear mechanisms and surface roughness characteristics when turning austenised and quenched AISI 52100 bearing steel with ceramics and CBN/TiC cutting tools*, Indian Journal of Engineering & Materials Sciences, 18, 137-146.

Neslušan, M., Šípek, M., Mrázik, J.,2012. *Analysis of chip formation during hard turning through acoustic emission*, Materials Engineering - Materiálové inžinierstvo, 19, 1-11.

Ozel, U., Hsu, T.K.,Zeren, E., 2005. *Effects of cutting edge geometry, workpiece hardness, feed rate and cutting speed on surface roughness and forces in finish turning of hardened AISI H13 steel*, Int J Adv Manuf Technol,25, 262-269.

Rajeev, D., Dinakaran, D., Kanthavelkumaran, N., Austin, N.,2016. *Experimental study of surface roughness in hard turning of AISI4140 steel with coated carbide tool*, World Applied Sciences Journal, 34, 10, 1310-1317.

Sadik, M.I., Lindström, B., 1995. *The effect of restricted contact length on tool performance*, Journal of Materials Processing Technology, 48, 275-282.

Sahoo, A.K.,Sahoon, B., 2012. *Experimental investigations on machinability aspects in finish hard turning of AISI 4340 steel using uncoated and multilayer coated carbide inserts*, Measurement, 45, 2153-2165.

Vyas, A., Shaw, M.C., 1999. *Mechanics of saw-tooth chip formation in metal cutting", Journal of Manufacturing science and Engeneering*, 121(2), 163-172.

Watmon, T.B., Ijeh, A.C., 2010. *Coating cutting tools with hard substance lowers friction coefficient and improves tool life - a review*, Proceedings of the International Multiconference of Engineer and Computer Scientists, 3, Hong Kong, March 17-19.

Yadav, L., 2016. *Analysis of chip formation during hard turning through acoustic emission*. International Journal of Mechanical Engineering, 4, 11, 34-38.
Zhang, S., Li, J., Zhu, X., Lv, H., 2013. *Saw-tooth chip formation and its effect on cutting force fluctuation in turning of inconel 718*, International Journal of Precision Engineering and Manufacturing, 14, 957-963.
Zhang, X.P., Wu, S.B., 2016. *Chip control in the dry machining of hardened AISI 1045 steel*, Int J Adv Manuf Technol, 88, 3319-3327.

淬火钢表面粗糙度与切屑形态的关系

關鍵詞
硬加工
AISI 1045钢
陶瓷工具
芯片
表面粗糙度

摘要
硬加工是制造业中强烈推荐的一种替代磨削和生产的工艺。决定该过程的重要技术参数是刀具磨损，机加工表面粗糙度，切削力和切屑的形貌。在这项工作中，已尝试分析在使用CC650型混合陶瓷刀具对淬硬钢AISI 1045（40HRC）进行车削时去除的切屑的形态和形式。使用田口计划L9，其因素是切削速度和进给速度，每个都有三个级别。芯片形态的宏观和微观结果与除表面粗糙度外的这两个切削参数相关。当以高切削速度对淬硬钢AISI 1045（40HRC）进行车削时，使用混合陶瓷工具可以获得足够的实验结果。加工表面的粗糙度证实了它受进给速度的影响。对于所用实验计划的所有组合，切屑均显示锯齿形状。切屑形状随切削参数的变化而变化，并为工业表面质量提供了重要指标。通过简单地控制切屑而无需停止加工即可获得表面质量指标，这对提高产量和降低成本具有重要的优势。