Communication Science & technology vol 19. July 2017 COST

MATERIALS TOOLS CUTTING PARAMETERS STUDY

Ahmed Sahli[1], Said Kebdani[2] and Sara Sahli[3]

[1]Université Ibn Khaldoun de Tiaret
Département de Génie Mécanique
[2]Université des Sciences et de la Technologie d'Oran (USTO MB)
E-Mail : sahli_ah@yahoo.com
[3]Université d'Oran 1

Reçu le : 15/05/2017 *Accepté le : 24/09/2017*

Abstract

In this research paper, the effects of the machining parameters over the tools wear mechanism and the residual stress induced into machined material have been examined in turning using carbide with coated (TiN/Al2O3/TiCN, TiAlN and Al2O3/TiCN) tool. Wear on the flank of a cutting tool is caused by friction between newly machined surface and the contact area on the tool, which plays predominant role in determining tool life. Detailed study wear mechanism at the cutting edge of carbide tools were carried out at cutting speed of vc = 80 -110 m/min and f = 0.25 - 0,4 mm/rev. These machining parameters are adopted to analyze their influence, significance and contributions on the wear on the flank of a cutting tool and residual stress. The tool wear analysis showed a predominance of the adherence/attrition mechanism with the appearance of grooves caused by the hammering of the burr generated in the chip during the turning. This, in its turn, contributed even more with the adhesion, making it difficult to remove the material which increased the effort in cutting, generating superficial compressive residual stress.

Keywords: turning, cutting parameters, super duplex stainless steel, residual stress, wear, coatings.

Résumé

Dans ce document de recherche, les effets des paramètres d'usinage sur le mécanisme d'usure des outils et la contrainte résiduelle induite dans le matériau usiné ont été examinés en tournage en utilisant du carbure avec un outil revêtu (TiN / Al2O3 / TiCN, TiAlN et Al2O3 / TiCN). L'usure sur le flanc *d'un outil de coupe est causée par le frottement entre la surface nouvellement usinée et la zone de contact de l'outil, ce qui joue un rôle prédominant dans la détermination de la durée de vie de l'outil. L'étude détaillée du mécanisme d'usure à la fine pointe des outils en carbure a été effectuée à la vitesse de coupe de vc = 80 -110 m / min et f = 0,25 - 0,4 mm / tour. Ces paramètres d'usinage sont adoptés pour analyser leur influence, leur importance et leurs contributions sur l'usure du flanc d'un outil de coupe et la contrainte résiduelle. L'analyse de l'usure des outils a montré une prédominance du mécanisme d'adhérence / usure avec l'apparence des rainures causées par le martelage de la bavure générée dans la copeau pendant le tournage. Ceci, à son tour, a contribué encore plus à l'adhésion, ce qui rend difficile l'élimination du matériau qui a augmenté l'effort de coupe, générant une contrainte résiduelle compressive superficielle.*

1. INTRODUCTION

Improved tool materials based on traditional methods of production has reached a certain limit, and further progress in this direction is possible only in the design of composite materials integrating properties of the components within them.

In 70-80 years of the XX century, it developed the methodology, equipment, processes and technology of synthesis of coatings of different composition and function, allowing to master the production of composite tool materials, including as a substrate tool material and surface wear-resistant coating. Instruments made of composite materials were widely used in the production of metal and allow to solve the range of technological problems to improve the processing performance, durability and reliability of the instrument, obtaining high-quality precision machined parts specifications, expanding areas of technological application of tools with limited strength of the substrate.

Despite this progress, the cutting tools are the weakest link in the technological cutting systems. In this regard, further exploration on improving composite tool materials through the development of ultrafine substrates best adapted to the conditions of coating and maintenance of composites, the search for new compounds, the structure, architecture and properties of the coatings, the improvement of methods, processes and equipment to produce them, is an important part created highly cutting systems [1-7].

The super duplex stainless steels are materials of biphasic structure containing ferrite and austenite, which guarantee a good pitting corrosion resistance, mechanical resistance and other characteristics that make the material attractive to industries: petroleum, oil/gas, paper/cellulose and chemical. The same characteristics that make the super duplex stainless steel more resistant make its machining more difficult. Therefore, the definition of machining parameters should comply with the commitment on the one hand of guaranteeing high productivity and on the other of not compromising the characteristics of the material in its application.

According to Charles and Faria [8], the replacement of stainless steels martensitic and austenitic by stainless steel Super duplex was due to the increase in the price of nickel alloys and molybdenum shown in the survey during 2004-2007 period.

For the reasons explained it is necessary a comparative study of this material raising the best cutting parameters in accordance with the materials of the tools to be studied. In order to see which the best performance among the tested tools a comparison was made: wear rate of the tool in the turning process, residual stress and the degree of finish of the piece.

Currently the concern of researchers in the machining industry goes beyond production costs, part finish and dimensional control. It is important to machine the workpiece without incurring losses in material properties due to variations of mechanical and thermal stresses. Therefore, it was decided to check the residual stress after the machining process because residual tensile stresses induce less resistance to fatigue. What it is not appropriate for the application of the material under study.

In the early twentieth century, metallurgists noticed that oxygen had a greater chemical affinity for chromium than the iron and decided to add the element chromium to steel. Studies have shown that when adding at least 10% chromium to steel, this element is joined to oxygen to form a thin, continuous, transparent layer on the steel surface, which prevents the oxidation, it prevents further oxidation.

This transparent layer when the surface is recomposed suffers damage such as scratches, wear or kneading [9]. This high resistance to chemical attack, all common stainless steels, is a property that is also called passivation consisting of the formation of a continuous, thin, impermeable layer of chromium oxide which protects the underlying material against corrosive attack [10].

The contribution of this study is to investigate the causes of excessive wear between the classes of tested tools, the behavior of residual stresses in the material machined and establish a correlation between tool life and residual stress.

2. MATERIALS AND METHODS

The super duplex Stainless steel was turned with different advances and cutting speeds using the same cutting geometry tools coated with TiN / Al2O3 / TiCN, Al2O3 / TiCN and TiAlN in order to evaluate the best performance among them through wear study tool, residual stress induced in the material machined and roughness of the piece.

Two different test bodies A and B were prepared but its input data were similar to correlate the output measurements taken after turning. However, the test body B, in addition to common factors with the test specimen A that are cutting speed, tool feed and tool class, the tool relationships in early life have been studied (VBB = average tool flank wear = 0) and tool at the end of life (VBB ≥ 0,3) in the generation of residual stress and the roughness of the piece. The cutting fluid, the workpiece material, the tool geometry and the depth of cut were constant values for the samples A and B. All tests were performed with cutting fluid because of the need its application, ensuring greater life tool and decreasing vibrations that could cause premature breakage in the tool. The depth of cut (ap) was maintained at 1 mm because it is the least important variable in the variation of residual stress and the roughness [11, 12].

The specimen A shown in Figure 1 was turned with different class tool, and under the conditions defined by Table 1. At this stage it was monitored the average flank wear (VBB) at every pass on the length of 110 mm and depth of cut (ap) 1 mm; at each machine stop it was done the check of wear. By repeating this process successively until the average flank wear (VBB ≥ 0,3 mm) or the piece reaches a diameter of 31 mm, diameter limit for which ensures a good stiffness and avoid vibrations in the test. After reaching flank wear of 0,3 mm the edge used was considered at the end of life. After this occurrence the edge was analyzed in a scanning electron microscope.

At this stage there were two replicates of each test and evaluated the results. In cases where tool life difference between the replicas was greater than 20%, a third replica was performed. The specimen B shown in Figure 2 shows excerpts divided by channels. Each portion was turned in a different condition according to the table 2 for each tool class generating a total of four specimens B.

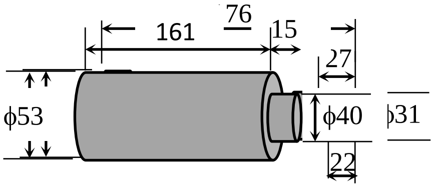


Figure 1: Test piece for tool wear measurement.

Figure 2: Test piece for measurement of residual stresses.

Table 1 Machining conditions for the specimen A.

Control factors	Levels	Machining conditions		Answer
Vc (m/min)	2	80	110	Tool wear
F (mm/rev)	2	0,25	0,4	

Table 2 Machining conditions for the specimen B.

Control factors	Levels	Machining conditions		Answer
Vc (m/min)	2	80	110	Surface residual stress;
F	2	0,25	0,4	

(mm/rev)				residual stress in subsurface layers.
VB_B (mm)	2	0	0,3	

1. RESULTS AND DISCUSSIONS

3.1. Tool life

In this work the main effect of tool wear was not the temperature, but the mechanical shock caused by the formation of burrs on the workpiece surface causing wear formation by slot during machining.

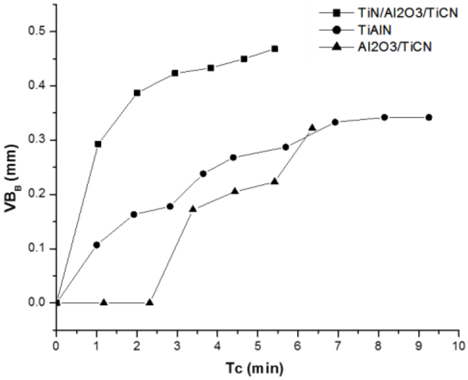
Biermann and Heilmann [14] showed in the study of the turning duplex stainless steel burr formation influences the wear notch on the depth of cut.

The advance also influences the size of the burr. According to Olvera and Barrow [15] small steps cause increase in size burr due to higher rates of plastic deformation of the material. Inasmuch as the advancement increases, become clear the increasing thickness of the chip sheared, providing the reduction of plastic deformation and consequently the height of the burr.

The figures 3, 4, 5 and 6 show the progression of the average flank wear presented by the tools within the tested conditions.

The Figures 3 – 6 showed typical wear patterns curves carbide tools, except in Figure 3 and 5 showing progressive wear over time for tools coated with Al2O3 / TiCN in advance of 0,25 mm / rev. the greater or lesser life of the tool is given in terms of the rate at which wear occurs. These figures note also that the initial wear is not an identifiable pattern, sometimes wear coated tool with TiAlN starts high in other conditions the same tool is worn close to zero, even if giving with the other classes tested.

3.2 Residual stress



In figure 7 we observe a trend in the turning process is the generation of residual stresses on the positive traction, because the thermal effect predominated over mechanical effect.

In vc = 80 m / min and f = 0,25 mm / rev there was no significant change in residual stresses obtained with different machining tools. However observing other parameters tested, it is seen that the material machined by TiAlN coated tool with had higher tensile stresses followed by machining using tools coated with TiN / Al2O3 / TiCN and Al2O3 / TiCN.

The friction coefficient associated with low thermal conductivity may be associated with higher

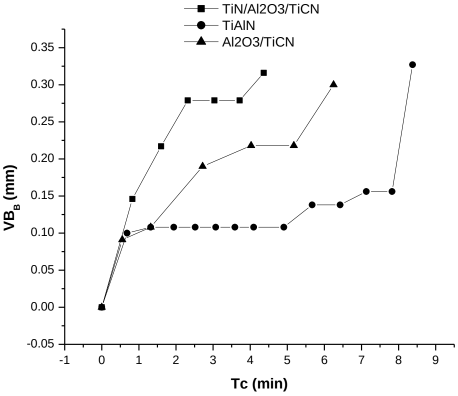
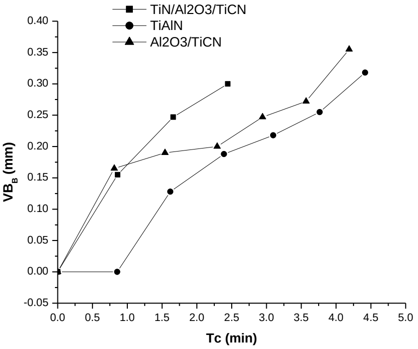


Figure 3: Average Flank wear versus time Figure 4: Average Flank Wear versus time

used: vc = 80 m / min and f = 0,5 mm / rev used: vc = 80 m / min f = 0,4 mm / rev for the

for the three types of tools used classes three types of tools used classes.



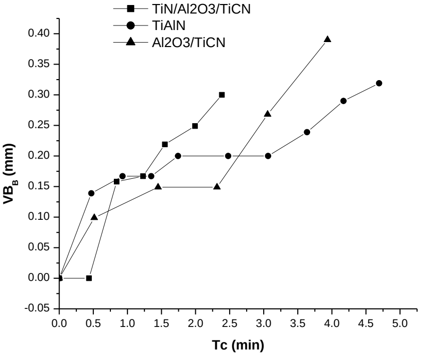


Figure 5: Average Flank Wear versus time used: vc Figure 6: Average Flank Wear versus time used: vc

= 110 m / min f = 0,25 mm / rev for the three types = 110 m / min f = 0,4 mm / rev for the three types of tools used classes. of tools used classes.

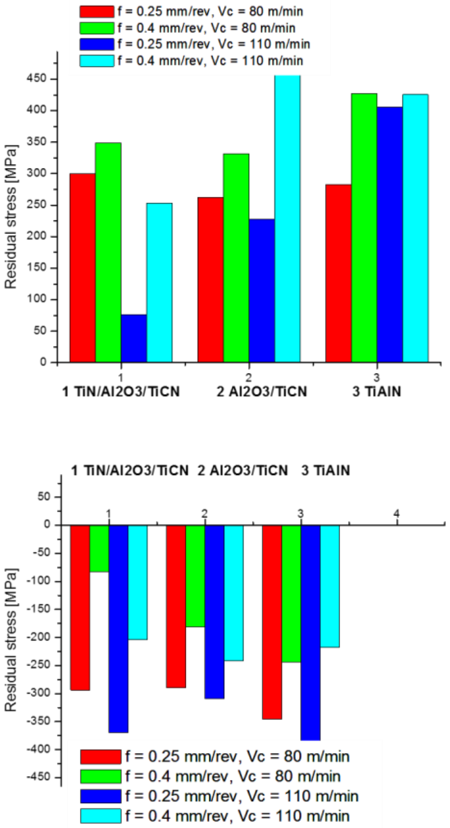


Figure 7 - 8: Comparison of surface residual stresses induced in the workpiece with tools in early life and at the end of life, respectively, between the cutting parameters and classes of tablets used.

tensile stresses in the material machined by the tool coated with TiAlN. Principally in the condition of vc = 110 m / min f = 0,4 mm / rev which has a larger volume of material removed in a short time with a high coefficient of friction preventing slip on the chip output surface, contributing a temperature increase in the tool-workpiece contact.

In Figure 8 we see that the worn tools tested induced compressive stresses in the part. According to Tang et. al. [16] compressive residual stress in this case is promoted by the effect of mechanical stress on the tool part, caused by flank wear.

In the conditions used to machine the workpiece in vc = 80 m / min with f = 0,25 mm / rev and vc = 110 m / min with f = 0,4 mm / rev shown in Figure 9, there was no variation significant residual stresses induced by the classes of the tested tool as in figure 8.

3.3 Residual stress in sub layers

The figures 9 and 10 show the residual stresses induced in the sublayers in part by the tools at the beginning of life (VBB = 0). In figure 9 we observe that the material machined by the three tools tested had higher residual stress values traction depths between 60 to 80 micrometers.

Despite superficial residual stresses induced by the tested tools do not have different behavior between them in vc = 80 m / min at f = 0,25 mm / rev Note that in Figure 12 in machining with the tools coated with Al2O3 / TiCN and TiAlN showed higher compressive residual stresses in the depths from 20 to 40 micrometres unlike what happened in the material machined by the tool coated with TiN / Al2O3 / TiCN that showed no residual stresses compressive to depths of 100 micrometers. This behavior can be linked to the efficiency of direct contact of the thermal barrier coating in Figure Al2O3 tools with Al2O3 / TiCN and TiAlN, which reduced the amount of heat transmitted to the workpiece. The residual voltage curves versus depth in the machining tools coated with Al2O3 / TiCN and TiAlN exhibit similar behavior.

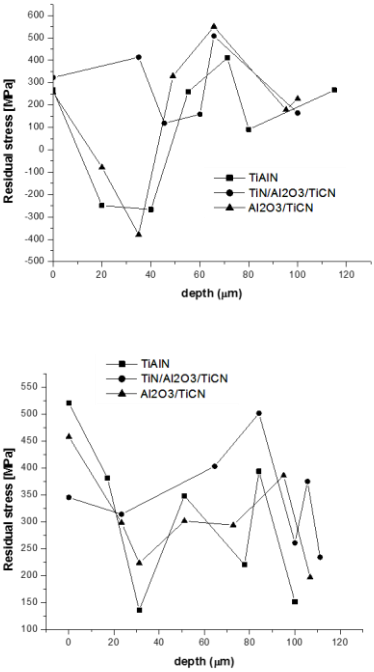


Figure 9-10: Stress x depth for Vc = 80 m/min and f = 0.25 mm/rev, f = 0.4 mm/rev respectively induced in the workpiece by the tools in early life.

Figure 13 shows that the machining tool using the coated Al2O3 / TiCN there was little residual stress variation between the depth from 20 to 80 micrometers.

When machining with the three tested tools see that induced in part higher residual stress values of traction between the depths of 80 to 100 micrometres at this depth the coated tool with TiN / Al2O3 / TiCN induced higher value of residual stress between the other tools. In figure 13 we note that although the surface residual stress induced in the workpiece by the coated tool TiN / Al2O3 / TiCN be smaller in comparison with the tools coated with TiAlN, and Al2O3 / TiCN between the depths of 20 to 40 uM coated tool with TiAlN and Al2O3 / TiCN were more compressive. Figure 11 shows that the material machined by the tools coated with TiN / Al2O3 / TiCN and

Al2O3 / TiCN had higher residual stress of compression between the depths of 60 to 80 m and the material machined by the coated tool with a TiAlN showed greater residual stress compression depth between 80 to 100 micrometers.

Despite the surface residual stresses induced by the tested tools do not have different behavior between them in vc = 80 m / min f = 0,25 in note that in figure 14 machining with tools with TiAlN coated induced reduced residual stress in compression depths from 20 to 40 µm followed by coated tools with Al2O3 / TiN and TiCN / Al2O3 / TiCN.

As the residual stresses are auto equilibrants, measurements of residual stresses in sublayers showed peaks tensile residual stresses, near or far showed that the surface compressive residual stresses depending on the machining conditions. Although the residual stresses are more critical on the surface but in the case where surface residual stresses are similar as shown in Figures 9 and 11 in the residual tensile stresses near the surface sublayers may involve the fatigue of the

material.

Figure 12 shows that the depths between 20 to 40 µm the material machined by the tools coated with TiN / Al2O3 / TiCN and TiAlN showed lower compressive residual stresses.

Between depths of 20 to 60 µm shown in Figure 25.4 showed no significant changes in residual stress in machining using the tools coated with TiAlN and Al2O3 / TiCN.

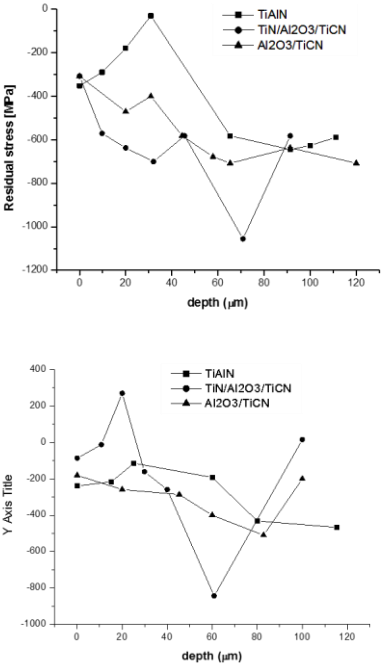
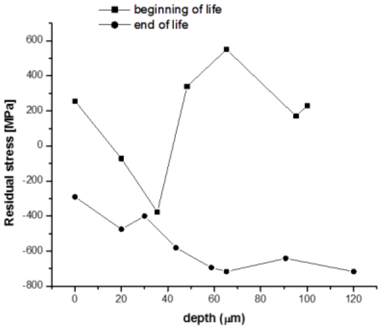


Figure 11-12: Stress x depth for vc = 80 m/min and f = 0.25 mm/rev, f = 0.4 mm/rev respectively induced in the workpiece by the tools at the end of life.



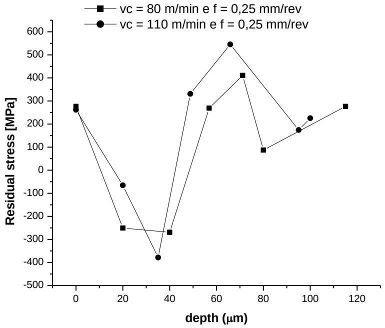


Figure 13: Ratio of residual stresses induced in Figure 14: Comparison of residual stresses induced
sub-layers in the workpiece by the coated tool with in sub-layers in the workpiece by the tool coated
Al2O3 / TiCN at vc = 80 m/min f = 0,25 mm/rev. with TiAlN between cutting speeds.

Figure 12 also shows that the material machined by the tool coated with TiAlN, and Al2O3 / TiCN had higher residual stress of compression between the depths of 80 to 100 m and the material machined by the coated tool with TiN / Al2O3 / TiCN showed greater residual stress compression depths between 60 to 80 micrometers. Figure 13 shows the residual stresses in sub layers to a depth of approximately 100 micrometers. As previously mentioned, in machining tools at the beginning of life of the tool induced tensile stresses in the part and end of life of the tool induced compressive stresses in the part. Compared with the residual stresses induced by the tools at the beginning of life and end of life, Figure 13 shows that the residual stress peaks although the intensity difference occurred at the same depth. As shown in figure 14 the surface residual stresses in the machined material are the same for different cutting speeds. But when analyzing the sub layers note that occur higher residual stresses in the compressive and admin- peaks for the cutting speed of 110 m / min. A similar result was published by [19], which analyzed the residual stresses induced in the machining of Inconel 718TM.

CONCLUSIONS

Finalized all laboratory tests and analysis of results, some aspects of the evaluation experiments of related parameters with cutting tool wear and residual stress in the Super duplex stainless steel turning process can be observed:

- Of the parameters analyzed, the condition of vc = 80 m / min and f = 0,4 mm / rev was the one that stood out among all the classes tested in terms of productivity (better life in time and greater volume of material removed);
- Of the conditions tested the coated tool with TiN / Al2O3 / TiCN (IC9250) showed better results in terms of tool life compared to the tools coated with TiAlN (IC907) and Al2O3 / TiCN (IC8250);
- The predominant wear mechanism was the notch caused by burr hammering depth of cut that led to the extrusion material adhered causing adhesion / attrition.
- The formation of burr generated during machining mechanical shocks on the tool that caused the wear notch causing the advancement exerts a greater influence on the wear of the cutting tool;
- The tool wear exerted influence on the variation of the residual stresses in the part. During testing with tools in early life (VBB = 0) measurements of residual stresses were tensile while the tools at the end of life (VBB ≥ 0,3) measures the tensions were compression due to the mechanical stress of the part on the tool caused by flank wear and or adhesion of the material;

- The advance was the most influential parameter on the residual stresses in the part. The smaller the smallest advance the residual voltage value induced in the piece;
- Factor analysis of residual stresses in the top tool shows that the machining using tools coated by the CVD process (TiN / Al2O3 / TiCN and Al2O3 / TiCN) induced stress less tensile compared to tool coated by PVD (TiAlN) which can It is related to the rounding of the edge of the deposition process;
- Among the tested tools, tool coated with TiN / Al2O3 / TiCN stood out with longer life and lower harmful effects surface integrity of the piece. As suggestions for future work, the following points may be addressed:
- Extending the study to other machining processes such as: grinding, milling and drilling.
- Redo the study using the same parameters, but changing the process lubrication.
- Study using different tool geometries to achieve greater tool path.
- Monitor the evolution of residual stresses, with wear and roughness to better understand the correlation between them.
- study the effects of residual stress on the surface and sublayers in fatigue machined material.

REFERENCES

[1] J. Vetter, W. Burgmer, H. Dederichs, A. Perry, Material Science Forum Vols. 163 - 165 (1994) pp.527 - 532.

[2] G. Byrne, CIRP Annals. Vol 52/2/2003.

[3] A. S. Vereshchaka, Hardening and coating technology. 2005, number 9. S.9-19.

[4] A. S. Vereshchaka, The efficiency of the cutting tool with wear-resistant coatings - M .Engineering, 1993. 336

[5] A. S. Vereshchaka, Some methodological principles of functional coatings for cutting tools. Proc. Modern technologies in mechanical engineering. Kharkov: NTU "KPI", 2007, pp 210-32.

[6] E. Moll, Surface and Coating Technology, 37 (1989) 483- 509.

[7] H. Holleck, Surface and coatings Technology, 43/44 (1990), 245 - 258.

[8] J. Charles, R. A. Faria, duplex stainless steels and applications in oil and gas: A review including the new offer of Arcelor Mittal. In: IX SEMINAR

BRAZILIAN STEEL STAINLESS, 8, 2008, Sao Paulo. Annals of the Brazilian stainless seminar 2008. St. Paul: ABINOX, 2008.

[9] AK Steel Corporation, Product Data Bulletin – Stainless steel, 2011.

[10] AB Sandvik Coromant, The World of Machining, v. 1, p. 19-26, 2001.

[11] E. Capello, P. Davoli, G. Bassanini, G. Bisi, A. Transactions of the ASME, v. 121, p. 346-351, 1999.

[12] F. Gunnberg, M. Escursell, M. Jacobson, Journal of Materials Processing Technology, v. 174, p. 82-90. 2006

[13] A. E. Diniz, F. C. Marcondes, N. L. Coppini,. Technology machining of materials. Sao Paulo: Artliber, 5 ed., 2006.

[14] D. Biermann, M. Heilmann, Minimization Strategies in Machining Operations. In: AURICH, J. C.; DORNFELD, D. Burr – Analysis, control and removal. 2. ed. Germany: Springer, p. 13-20, 2010.

[15] O. Olvera, G. Barrow, Int. J. Mach. Tools Manufact., v. 36, p. 1005-1020, 1996.

[16] Z. T.Tang, Z. Q. Liu, Y. Z. Pan, The influence of tool flank wear on residual stresses induced by milling aluminum alloy. *Journal of Materials Processing Technology*, 2009, vol. 209, no 9, p. 4502-4508.

[17] A. R. Machado, A. M. Abram, R. T. Coelho, M. B. Silva, Theory of machining of materials. Ed. Edgard Blücher, São Paulo, (2009), 384.

[18] J. Hua, D. Umbrello, R. Shivpuri, Journal of Materials Processing Technology, v. 171, p. 180-187, 2006.

[19] A. R. C. Sharman, J. I. Hughes, K. Ridgway, K.. *Journal of Materials Processing Technology*, 2006, vol. 173, no 3, p. 359-367.