DIMENSIONAL CONTROL IN ALUMINUM WORKPIECE MACHINED WITH COATED CERAMIC CUTTING TOOLS

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Abstract. *Ternary coatings TiN and Ti(C,N) processed by PAPVD (Plasma-assisted physical vapour deposition) either as mono or multilayer have become extremely important to several and strategic industrial applications such as automotive and aeronautic industries. These coatings are thermodynamically metastable and posses high micro hardness value, high oxidation stability, low thermal conductive and relatively low coefficient of friction against different materials. Considering these properties of coatings and aluminum alloys this work is focused on the investigation of the possibility of the best dimensional control when machined aluminum with TiN and Ti(C, N) coated carbide tools. For this purpose was considered cylindrical and conical geometries in turning. Was used an uncoated tool (substrate – WC-Co 6%) for comparative analysis. Machining tests were carried in real cutting conditions (cutting speeds, feed rates and depth of cut). Even so either an initial study results showed the best results for dimensional control when used coated cemented carbide tools if compared with an uncoated cutting tool (substrate).*

***Keywords**: coatings, dimensional control, aluminum alloys, tribological systems*

1. INTRODUCTION

Binary and most recently ternary coatings Ti-N and Ti-C-N processed by PAPVD either as mono or multilayer have become extremely important to several and strategic industrial applications such as automotive and aeronautic industries. These coatings are thermodynamically metastable and posses high microhardness value, high oxidation stability, low thermal conductive and relatively low coefficient of friction against steel and several materials for different applications in the metal-mechanical industries. Because of these remarkable advantages, these coatings are currently used mainly for metal cutting operations (turning, milling and drilling) since the 90´s providing high metal removal rates (Paldey et al, 2003; Hultman, 2000 and Karlsson et al, 2000).

Based in these properties and conditions in process could affect the dimensional control in the workpieces for different applications. Main intercambiability is required for assemblies.

Nowadays topographical parameters have been studied for characterization a surface the most realistic possible. For this purpose are considered and/or classified the following categories: amplitude parameters, spatial parameters, hybrid parameters and functional parameters (area/volume and properties). A key problem in surface related research is choosing parameters that characterize surface properties in such way that they correlate with surface formation mechanisms, geometry and functional behaviour in a fundamental way. There are limited information about these parameters and theirs correlation with performance (Stout, 1993).

Recently, the ceramic coatings has involved in two promising directions: three-dimensional measurement precision measurement and dimensional control, mainly when machining workpieces that has got a high thermal conductive, for example carbon steel with aluminum alloys (value aproximadely 15 each more). The industries that will benefit from the introduction of an integrated approach to three-dimensional data collection included: aerospace, automobile, machining tool manufacture, electronics, communication, metal working, materials and medical engineering. Nowadays, , the development in nanotechnology will make increasing use of such a standard both in terms of surface produced and in terms of the use of high precision manufacturing machine for use in this important industry (Stout, 1993).

2. EXPERIMENTAL PROCEDURE

The experimental work was carried out at the Machining Laboratory (University of Juiz de Fora / CTU). The experimental work was divided into following steps: production/characterization of coatings, machining tests, cleaning of workpieces after that elaboration of a specific methodology for comparative: qualitative and quantitative analysis.

2.1. Coatings production and adhesion characterization

First of all, ternary coatings (Ti-N and Ti-C-N) were produced on cemented carbide tools (WC-Co (6%)) by Plasma-assisted physical vapour deposition (TECVAC IP35L equipment produced by electron beam evaporation) with approximately 3, 0μm thickness. The coating deposition temperature was within the range from 669 to 715K.

The Rockwell-C hardness test was employed to evaluate the adhesion of the coatings. The principal advantage of this method is that it is easy to use, even in an industrial enviroment. A conventional Rockwell hardness test was performed using loads of 588N and 980N for each coating. The damage pattern around the imprint was evaluated at the optical microscope (magnification of 200 times). Standard damage pictures were used to classify the adhesion into six classes, as presented in Figure 1.

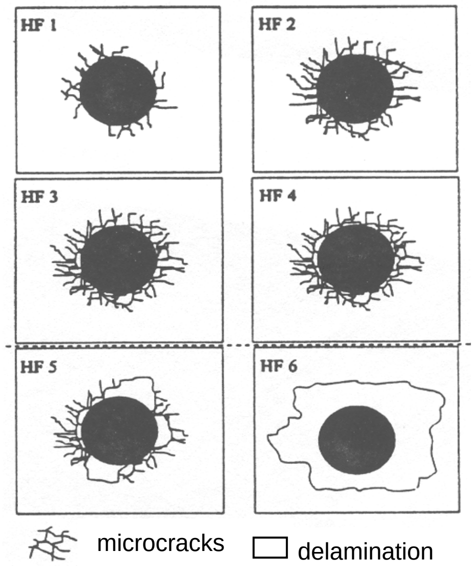

Figure 1. Standard damage picture in Rockwell-C adhesion test (Heinke et al, 1995)

2.2. Machining tests

Bars of Alluminum Alloy AA 6262 T6 with 76,2mm diameter and 200mm long were used as work materials. ISO grade K10 cemented carbide inserts with geometry ISO SNMA 120408 (without chip breaker) was used as substrate. The inserts were mounted on a tool holder code PSDNN2525-M12. Thus, the following angles were obtained: cutting edge angle χ_r = 45°, included angle ε_r = 95°, cutting edge inclination angle λ_s = -5°, rake angle γ_o=-6° and clearance angle α_o = 6°. The criteria for this geometry was to continue others investigations before. Continuous turning tests were performed on a C.N.C. lathe (4000rpm and 7,5kW) in real finish conditions Table 1 shows the cutting conditions chosen after preliminary machining tests.

Table 1: Optimized cutting conditions for machining tests

Tribological systems	cutting speed (m/min)	feed rate (mm/rev)	depth of cut (mm)
WC-Co/aluminum	600	0,04	0,5
WC-Co/Ti-N/aluminum			
WC-Co/Ti-C-N/aluminum		0,12	

2.3. Methology of measurements and analysis

Measurements were realized in the coordinate measuring machine Crysta-Plus (M700 model): measuring range 700 x 1000 x 600 mm, resolution of 0,0005mm, respectively X, Y and Z axis. For quantitative and comparative analysis, was used the Software Geopak-win. in both geometries (cylindrical and conical) after established an criterious procedure. Figure 2 shows the optimized fluxogram for this purpose and Figure 3 and 4 some details these steps.

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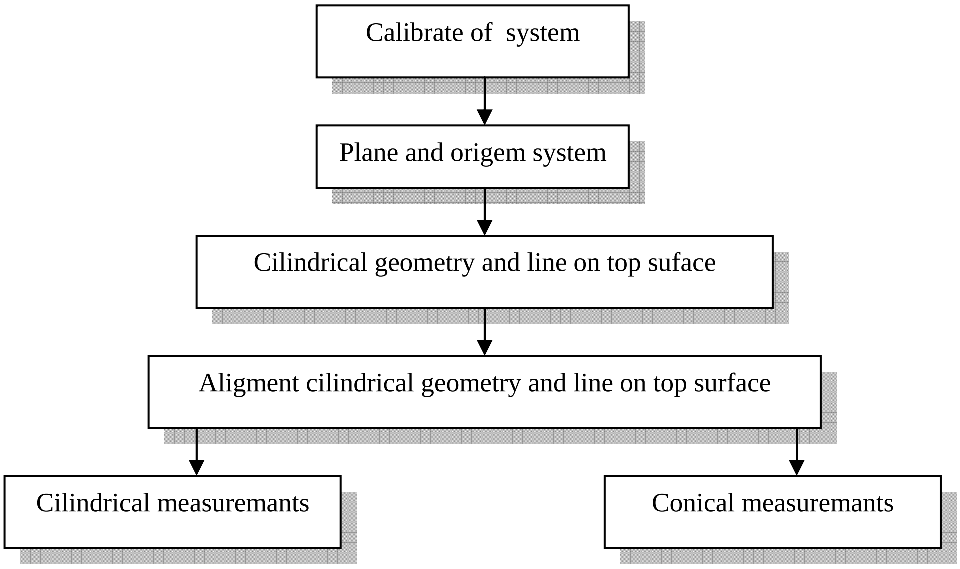
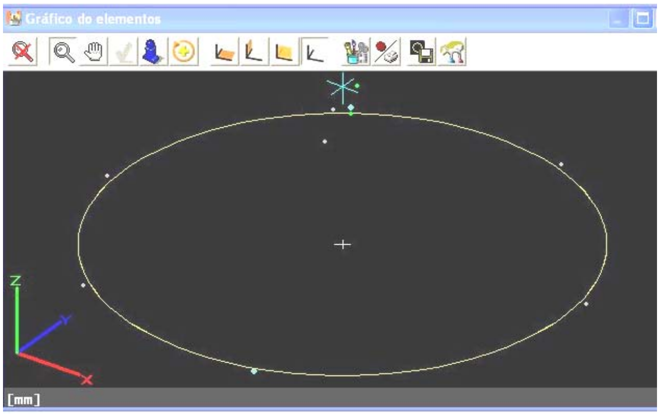
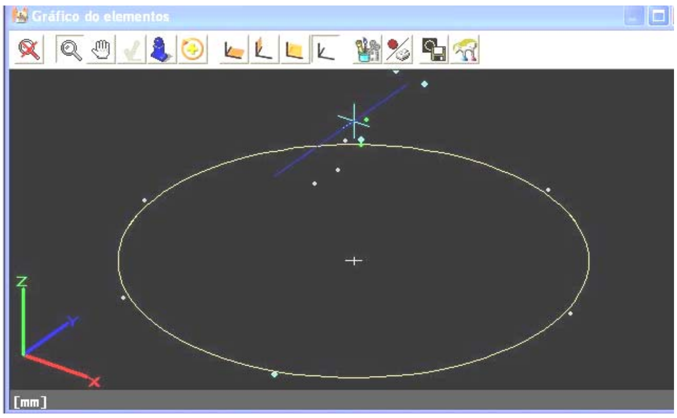


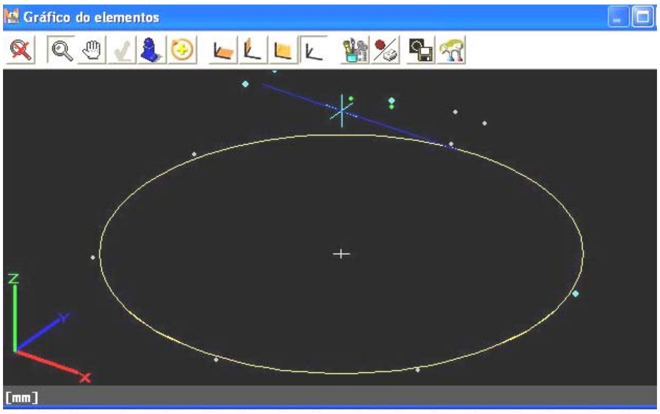
Figure 2. Fluxogram for quantitative and comparative analysis



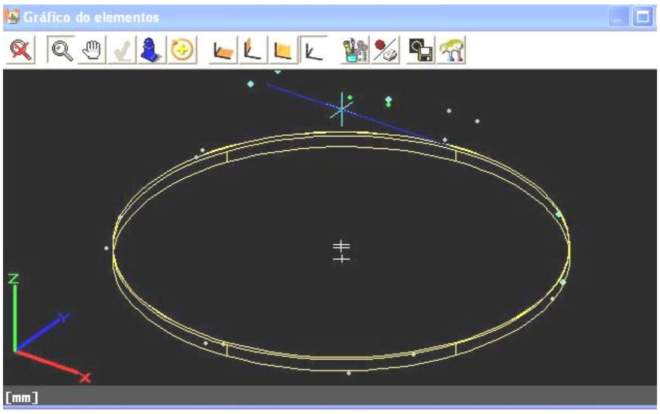
(a)



(c)



(b)



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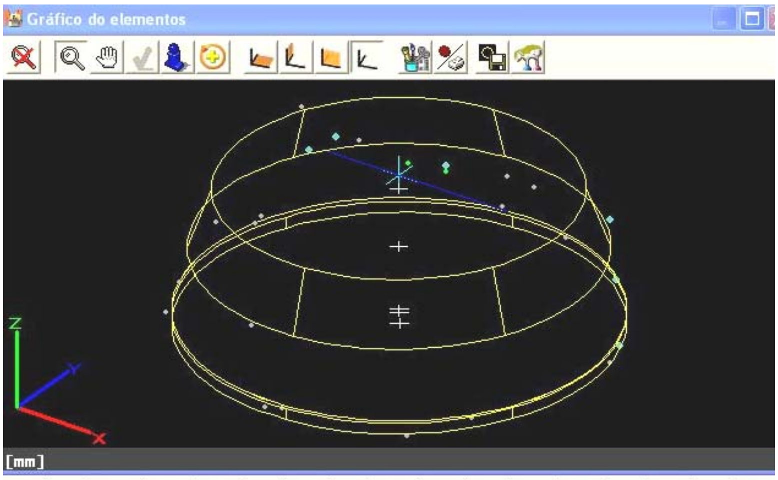


(e)

Figure 3. Details of steps of procedure: a) Plane and origin system, b) cylindrical geometry and line on top surface, c) alignment cylindrical geometry and line on top surface, d) cylindrical measurements and e) conical measurements.

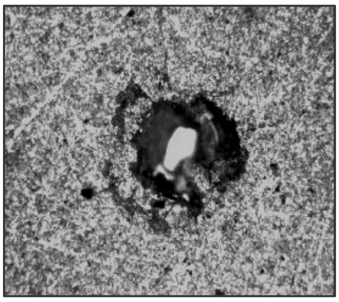
(a) (b) (c)

Figure 4. Some details of main steps of experimental procedure: a) calibrate of system, b) Cylindrical measurements and c) Conical measurements.

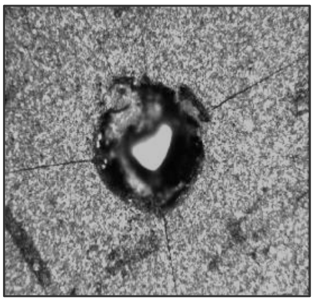
This methodology created constitute a preliminary studies of the influence of ceramic coatings on dimensional control of workpieces after machining process, cylindrical and conical geometries, in particular.

3. RESULTS AND DISCUSSION

The experimental work was divided into three phases: firstly, a procedure for coating characterization was carried out covering the following aspects: Rockwell-C adhesion test, machining tests were performed and surface analisys. Figure 5 shows the results obtained for Ti-N and Ti-C-N coatings in the Rockwell-C adhesion test using two loads (588 and 980 N).



(a)



(b)

Figure 5. Rockwell C adhesion test: a) WC-Co/Ti-N and b) WC-Co/Ti-C-N

According to the standard damage pictures shown in Figure 5, both coatings under study showed good qualitative results for the adhesion tests classified as standard damage HF1 – HF4. In such away, firstly a problem with possibly occurrence of delamination during machinig test was discarded.

Figure 6 show the main results: variance versus feed rate, obtained after machining process for different conditions established on preliminary tests (table 1) for cylindrical geometries. Table 2 shows of the comparative form the medium diameter and conical angle.

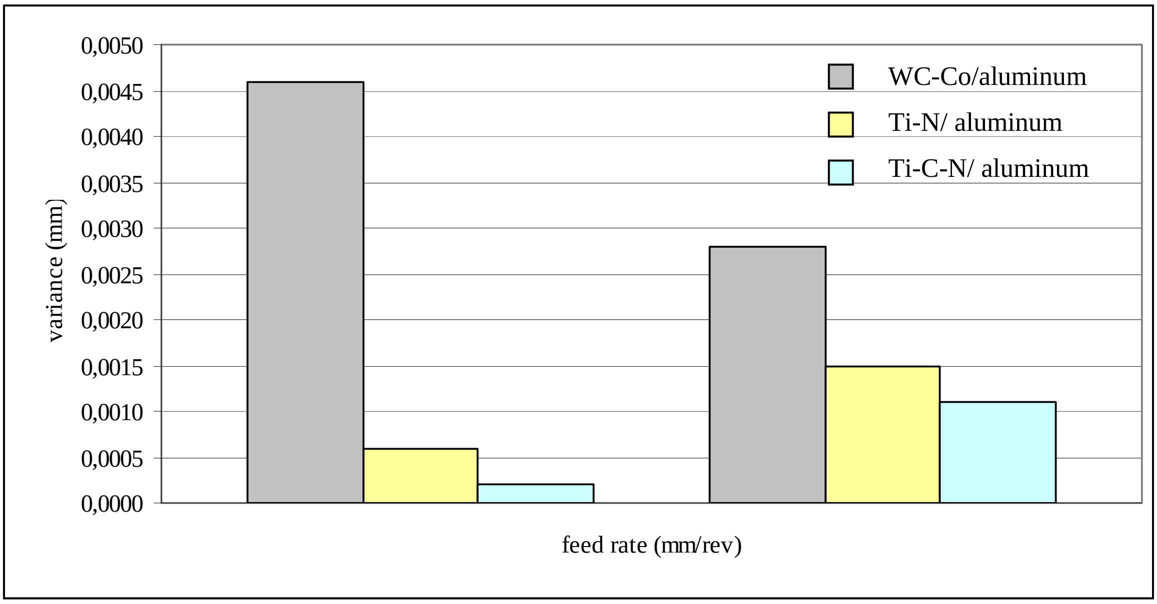


Figure 6. Variance versus feed rate for tribological systems studied

Table 2: conical angle obtained for bi dimensional analysis: conical geometry

	cutting speed = 600m/min, feed rate = 0,04mm/rev depth cut = 0,5mm			**cutting speed = 600m/min, feed rate = 0,04mm/rev depth cut = 0,5mm**		
Statistical results	**WC-Co**	**Ti-N**	**Ti-C-N**	**WC-Co**	**Ti-N**	**Ti-C-N**
mean diameter (mm)	72.902	72.743	72.785	72.935	72.755	72.776
variance	0.0046	0.0006	0.0002	0.0028	0.0015	0.0011
Conical angle (°)	39:57:05	39:55:51	39:54:56	39:53:08	39:57:08	39:55:18

Preliminary analysis indicated that different dimensional control based on variance are obtained when used uncoated and coatings cuttings tools. In general, the lowest values of variance were observed in the tribological systems constituted by Ti-C-N/ aluminum and Ti-N/ aluminum in this order if compared with WC-Co/aluminum for different cutting conditions (table 1).

This fact suggests that the best results for dimensional control in cylindrical geometries were obtained when used ternary ceramic coatings. In general ceramic coatings have got the lowest thermal conductive if compared with hard metal (WC-Co): 85W/mK, 30W/mK and 43W/mK for substrate (WC-Co), Ti-N and Ti-C-N coatings respectively (Sandvik, 2000, Stappen et al, 1995, Holmenberg et al, 1994). Like this form the most part of cutting temperature has dissipate although the chip removed when used coatings tools. Best mechanical properties, such as higher hardness and lowest coefficient of friction of these protective layers (Paldey et al, 2003; Bull et al, 2003; Batista et al, 2002; Hultman, 2000 and Karlsson et al, 2000). These properties are critical to machining processes because they increase the resistance to thermal and mechanical shocks, reduce the cutting forces and facilitate the chip removal from the work zone. These advantages have got a direct influence on dimensional control, in this study cylindrical and conical geometry.

This fact suggests that the selection of the coating has got an influence for strategic applications in engineering, for example when is required a maintenance of a thin layer of oil on surfaces, assembly aspects (high dimensional precision), each others.

Considering the workpiece material (aluminum), this material has got a conductive thermal approximately fifteen each bigger than the steel, in general. This fact suggests modification on geometric surface: dimensional control (cylindrical and conical geometries) when used uncoated and coated ceramic cutting tools in machining process.

4. CONCLUSIONS

Results of this study constitute a first investigation. Others parameters and the methodology have been improved in future steps for the same tribological analysis. At present moment, this experimental procedure was the best optimized for minimal error conditions. The main conclusions for this first step were:

- Ceramic coatings have a relation with different performance (dimensional control) when both are submitted in high mechanical and thermal solicitation (typical in machining process);
- Results of variance for cylindrical geometries suggest that the most part of cutting temperature has dissipate although the chip removed when used coatings tools.
- Ti-C-N, in general, showed the best performance (lowest variances for cylindrical geometries) for both cutting conditions tested.

5. ACKNOWLEDGEMENTS

The authors would like to thank FAPEMIG (Brazil) for financial support.

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