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COMPARISON BETWEEN ALUMINUM ALLOYS 7075 MACHINED BY TOOL WITH POLISHED CARBIDE INSERT AND CARBIDE INSERT COATED WITH TIB_2

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Abstract. *Physical, chemical and mechanical characteristics of the materials used in cutting tools, as well as the geometries of these result in different behaviors and results in machining of materials. The behavior of each tool can vary also depending on the material to be machined and the machining process variables. Different technologies are being applied to improve the characteristics of the cutting tools such as application these materials coating tools with specific chemical and physical characteristics, coupled with a greater or lesser degree of surface finishing of these tools. The present study aimed to analyze the influence of different materials of cutting tools in the process of turning aluminum alloy 7075 used mainly in the field of metalworking, automotive, aeronautical and marine, as well as check and compare the influence of feed rate and depth of cut on the surface finish and power required during the process. We compared the tools with coated carbide insert with titanium diboride (TiB_2) and polished carbide insert in three forward speeds and three depths of cut in machining operation by external cylindrical turning with the aluminum alloy 7075. We collected data instantly power consumed during rehearsals of machining, as well as collections of average roughness values (R_a) and total (R_t) of specimens. For the study of the variables was used a completely randomized complete factorial planning. Statistically significant differences were observed, at a significance level of 5 %, between the two cutting tools and the three forward speed to the surface finish. For the power consumed, also considering a significance level of 5%, significant differences were observed between levels of all factors examined, in addition to a degree of correlation between the power consumed and analyzed variables.*

Keywords: *Surface quality, Material machining, Methods of measuring, Improvement of materials*

1. INTRODUCTION

According to Diniz, Marcondes and Coppini (2013), carbide tools can machine any type of material, since that this material does not exceed the hardness of 45 HRc. In machining operations such as turning, carbide tools can work with higher cutting speeds than speed-steel tools. However, the use of this tool requires a machine more rigid and with higher speeds, to prevent vibrations. To improve the mechanical properties of carbide tools, coatings were developed. The main purpose of these coatings is to increase the wear resistance of the top layer, which comes into contact with the chip and the workpiece.

About 90% of industries using coated carbide tools, according to Machado (2011). This number is a result of a larger mastery of coatings techniques, with more accessible product cost and high number of products supplied by toolmakers. Coatings are applied to substrates of any of carbide classes. The coatings are fine-grained layers that combine the properties of hardness and wear resistance.

One of the compounds indicated for the carbide insert coating is TiB_2 (Titanium diboride). According to Cabral (2012), the TiB_2 is a ceramic compound of hexagonal structure, where the boron atoms are covalently bonded in titanium matrix. This compound is one of the most stable titanium-boron based, and is synthesized from the thermal treatment of TiO_2 and B_2O_3. Due to the high electron mobility in its structure, the TiB_2 is a good electrical and thermal conductor. It has considerable mechanical strength and good wear resistance.

Considering the excellent properties of TiB_2, it can be a great alternative for machining of aluminum alloy 7075. According to Aonuma and Nakata (2011), 7000 series alloys such as 7075 are often used in transportation applications, including the marine, automotive and aviation because of their high ratio resistance-density. However, Diniz, Marcondes and Coppini (2013) reported that the mechanical and thermal properties of pure aluminum are decisive factors in machining alloys characteristics. The elasticity modulus of aluminum has approximately ⅓ of the steel, meaning that under the same cutting force, the aluminum is deformed three times. This characteristic has negative consequences in obtaining machined surfaces of good quality and can generate undesirable deformations.

For Suarez (2008), the cutting tools having micro grain carbide coated by chemical or physical vapor deposition (CVD / PVD) are proving promising in the application of aluminum machining.

Thus, the aim of this study was to analyze if the coating of cutting tools with TiB_2 can improve the machining of aluminum alloy 7075. The influence of feed rate and depth of cut, on the surface roughness and power required during the machining, also it was evaluated.

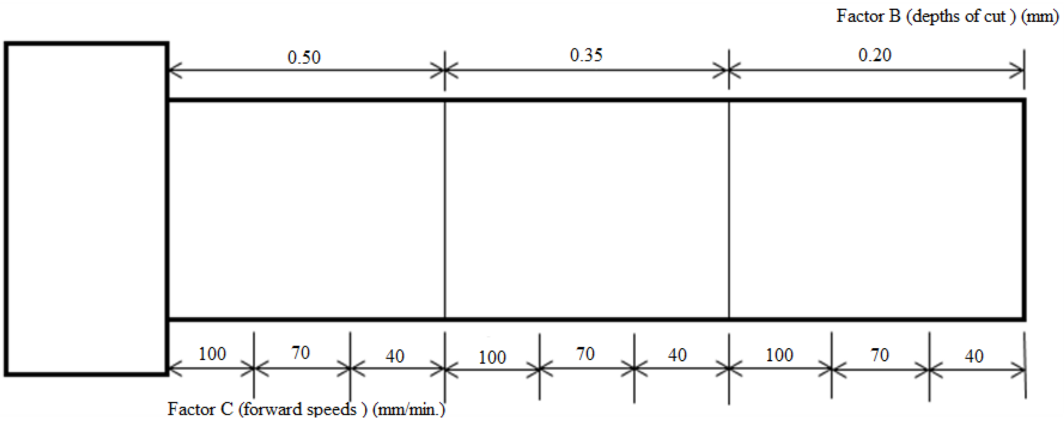
2. METODOLOGY

Aluminum alloy 7075 specimens were subjected to machining external cylindrical turning.

The test pieces with 26 mm diameter and 230 mm in length, were machined using two types of cutting tools (Factor A). One of the cutting tools (carbide insert) was coated with TiB2. The other consisted of a polished carbide insert.

Three feed rates (Factor B) and three depths of cutting (Factor C) were used for each cutting tool, according to Fig. 1. Each experimental condition was repeated three times, and the rotation was set at 1000 rpm.

A complete factorial design (eighteen experimental conditions) was used for the study of input variables.



Source: Adapted from Miyahara, N. M. B. (2015). Comparative analysis of the performance of tools in the turning of aluminum 2024

Figure 1. Scheme for demonstration of the parameters used in machining

The organization of the input variables, the complete factorial design can be seen in Tab. 1.

Table 1. Process input variables and their respective levels to full factorial design.

Factors:	Levels		
	1	2	3
A (materials used in cutting tools)	**Polished carbide insert**	Titanium diboride (TiB_2)	-
B (forward speeds) (mm/min.)	40	70	100
C (depths of cut) (mm)	0.20	0.35	0.50

The machine tool used in the tests was the CNC Emco belonging to the Machining Laboratory of the Department of Materials and Technology of the Colegee of Engineering- UNESP Guaratingueta (Fig. 2a).

The tools used were as polished carbide inserts (Fig. 2b), and the coated carbide insert with TiB_2, (Fig 2. c).

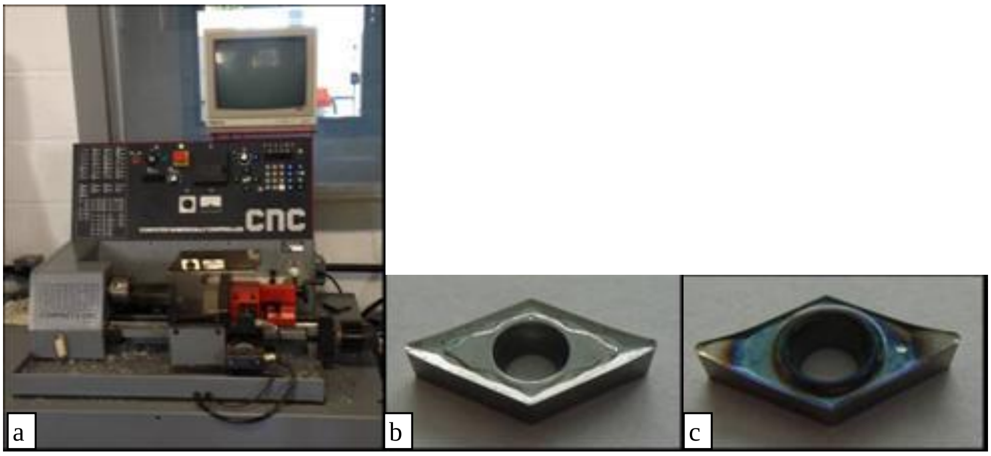


Figure 2. (a) CNC Emco lathe, Compact 5- Factor A; (b) Polished carbide insert; (c) Coated carbide insert with TiB_2

Values of power consumed during the machining tests were collected instantly using LabVIEW software (Fig. 3).

Figure 3. Software LabVIEW

The average values of average (R_a) and total (R_t) roughness were obtained after each experimental condition. Roughness measurements were obtained using a Mahr profilometer, M300 model (Fig. 4 a) and a RD 18 model (Fig. 4 b).

Three measurements, lagged 120 º, were performed for each test piece (Fig. 4c), with the help of support (Fig. 4 d) and of the feeler of profilometer (RD 18 model) (Fig. 4 e). The cut-off parameter was set to 0.8 mm, in all measures and all passes.

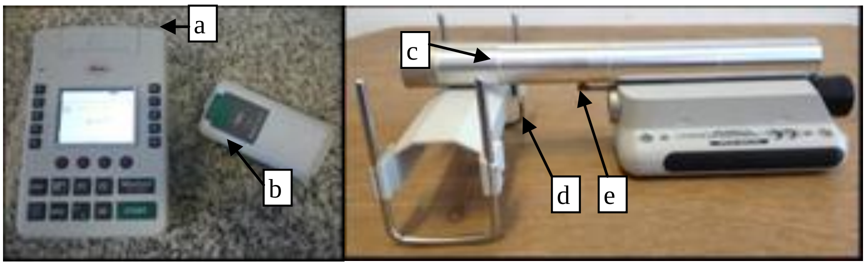


Figure 4. (a) Profilometer display (MarSurf M300) and (MarSurf RD 18); (b) Support and feeler of profilometer (MarSurf RD 18).

3. RESULTS AND DISCUSSION

The roughness values (R_a e R_t) and consumed power, obtained during machining, were presented and analyzed in two parts. In the first part, the results were described with aid of graphical analysis. In this part, the effect of the input factors on average, when their levels are altered, was described. In the second part, the data were statistically analyzed with the help of variance analysis table (ANOVA). The significance level was of 5%.

3.1 Analysis of results of surface roughness (R_a) and total roughness (R_t)

Figures 5 and 6 deal with main effects of factors on average, when levels of input factors (A, B and C) are altered, to the surface roughness (Ra) and total roughness (Rt), respectively.

For the factor A (materials used for cutting tool) (level = 1 Polished carbide insert; level = 2 Titanium diboride (TiB_2)) was observed that the results were similar. However, with a greater reduction in the total roughness (R_t), leaving a roughness situation above the overall average roughness (center line of the graph) for a condition below it.

Using the same type of analysis for the factor B (feed rate) (level 1 = 40 mm/min; level 2= 70 mm/min; level 3 = 100 mm/min), at level 1 and level 2, the roughness obtained were lower than the overall average roughness (center line of the graph). The same behavior was observed for surface roughness parameter R_t. However, for level 3, the roughness value increased considerably for the two roughness parameters obtained. Level 2 showed the lowest roughness values.

In the factor C (depth of cut) (level 1= 0.20 mm; level 2 = 0.35 mm; level 3 = 0.50 mm), values of roughness, R_a and R_t, may be seen in Fig. 5 and Fig. 6, respectively. R_a and R_t were very close to the overall average of roughness, however, for roughness R_t, a slight downward trend in roughness, caused by changing levels, was observed.

At a first moment, through the graphical roughness analysis, it was possible to define the best combinations of input factors, which contribute to improving the quality of machining. The conditions showed minor roughness, i.e. better machining quality, were:

- Factor A (materials used in the cutting tool): level 2 (Titanium diboride (TiB_2));
- Factor B (feed rate): level 2 (70 mm/min.);
- Factor C (depth of cut): level 3 (0.50mm).

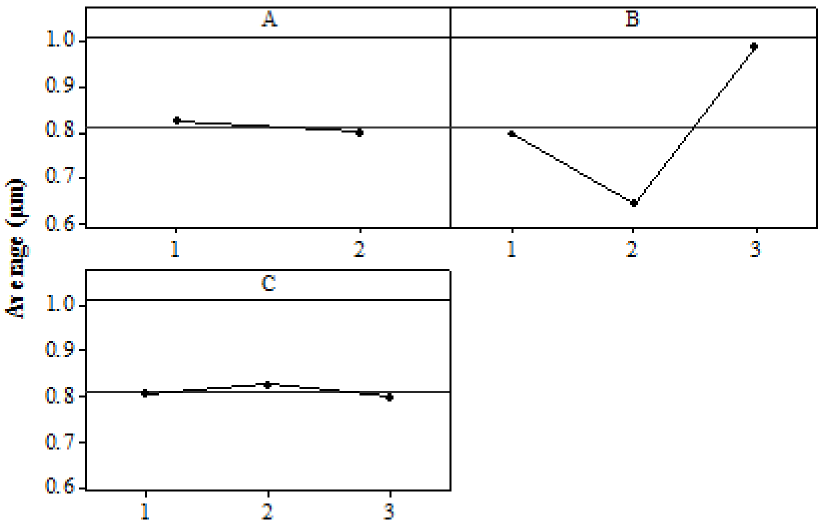


Figure 5. Main effects on the averages for R_a when levels of the input factors are varied

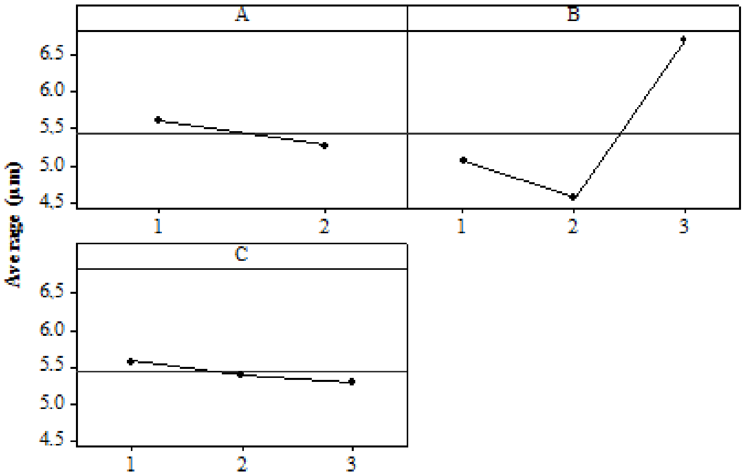


Figure 6. Main effects on the averages for R_t when levels of the input factors are varied

Verification of existence of significant differences between factor levels was done using analysis of variance (ANOVA), according to Tab.2 and Tab. 3, respectively for R_a and R_t.

Variance analysis for surface roughness (R_a) resulted in a p-values (p) less than 5%, for factor B (p = 0.000). The same result was true for the analysis of the interaction between the factors (A * B: p = 0.034). Thus, statistically significant differences among the three levels of factor B and interaction (A and B) were observed.

A good value for adjusted R^2 (R-Sq = 58.98 %) was obtained. Therefore, the linear statistical model can explain the variable response from the input factors.

Table 2. Variance analysis (ANOVA) for surface roughness (R_a).

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	1	0.00816	0.00816	0.00816	0.54	0.466
B	2	1.07774	1.07774	0.53887	35.79	0.000
C	2	0.00723	0.00723	0.00361	0.24	0.788
A*B	2	0.11177	0.11177	0.05589	3.71	0.034
A*C	2	0.01575	0.01575	0.00787	0.52	0.597
B*C	4	0.11153	0.11153	0.02788	1.85	0.140
A*B*C	4	0.07105	0.07105	0.01776	1.18	0.336
Error	36	0.54196	0.54196	0.01505		
Total	53	1.94519				

S = 0.122696; R-Sq = 72.14 %; R-Sq (adj) = 58.98%

Legend: DF = Degrees of freedom, Seq SS = Sequential sums of squares; Adj SS = Adjusted sums of squares; Adj MS = Adjusted Mean Square; F = F-statistic; p = p-value; S = standard errors of the coefficients R-Sq = R square or coefficient of determination; R-Sq (adj) = Adjusted R square or Adjusted coefficient of determination.

A Análise de variância (ANOVA) para rugosidade média (R_t), identificou diferenças estatisticamente significativas entre os 3 níveis dos fatores A (p = 0.047) e B (p = 0.000). Diferenças para a análise das interações entre os fatores (B*C: p = 0.017) também foram observadas. Um bom valor de R^2 ajustado (R-Sq = 71.93%), aproximadamente 13% maior em comparação com o R^2 ajustado para o parâmetro de rugosidade R_a, foi encontrado.

By variance analysis of the total roughness (R_t) were identified statistically significant differences between the three levels of the factors A (p = 0.047) and B (p = 0.000). Differences for the analysis of interactions between factors (B * C: p = 0.017) were also observed. A good value for R^2 adjusted (R-Sq = 71.93%), approximately 13% higher in comparison with R^2 set to R_a parameter was found.

Table 3. Variance analysis (ANOVA) for total roughness (R_t).

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	1	1.6227	1.6227	1.6227	4.22	0.047
B	2	45.2427	45.2427	22.6213	58.83	0.000
C	2	0.7242	0.7242	0.3621	0.94	0.399
A*B	2	1.5768	1.5768	0.7884	2.05	0.143
A*C	2	1.0779	1.0779	0.5389	1.40	0.259
B*C	4	5.3046	5.3046	1.3262	3.45	0.017
A*B*C	4	3.2249	3.2249	0.8062	2.10	0.101
Error	36	13.8431	13.8431	0.3845		
Total	53	72.6169				

S = 0.620104; R-Sq = 80.94 %; R-Sq (adj) = 71.93%

Legend: DF = Degrees of freedom, Seq SS = Sequential sums of squares; Adj SS = Adjusted sums of squares; Adj MS = Adjusted Mean Square; F = F-statistic; p = p-value; S = standard errors of the coefficients R-Sq = R square or coefficient of determination; R-Sq (adj) = Adjusted R square or Adjusted coefficient of determination .

3.2 Results analysis for power consumed by machining

In Fig. 7, the main effects, for the average power consumed during machining, are observed. With the variation of factor A (materials used in the cutting tool) (level 1 = Polished carbide insert; Level 2 = Titanium diboride (TiB2)) occurred a significant increase in consumed power. The power ranging from 220 W (level 1) to 250 W (level 2).

An increase, visually significant, was seen in the power consumed, when the factor B (feed rate) (level 1= 40 mm/min; level 2= 70 mm/min; level 3= 100 mm/min) was varied. The power consumed increased from 210 W to 235 W and then to 260 W.

The variation of the factor C levels (depth of cut) (level 1= 0.20 mm; level 2= 0.35 mm; level 3 =0.50 mm), resulted in decreased power consumption from 265 W to 235 W and then 200 W, respectively, for levels 1, 2 and 3.

The experimental condition which resulted in lower power values was:

- Factor A (materials used in the cutting tool): level 1 (Polished carbide insert);
- Factor B (feed rate): level 1 (40mm/min.);
- Factor C (depth of cut): level 3 (0.50mm).

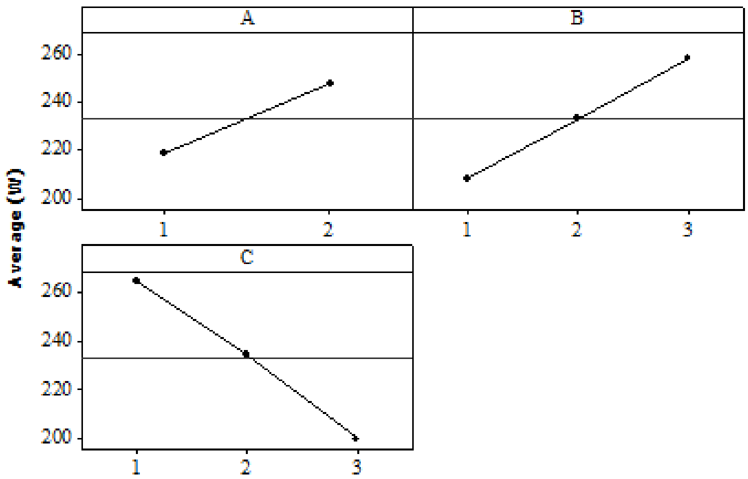


Figure 7. Main effects on the averages for power consumed during machining when levels of the input factors are varied

Through variance analysis between the levels of the factors, for the power consumed, was possible to identify statistically significant differences in the three factors and in interactions, according to Tab. 4.

The value of adjusted R² (R-Sq = 99.93%) was high, this mean that there is an excellent fit linear statistical model. The adjusted R² value and low p-value indicates good sensitivity of the data acquisition system of power. The data acquisition system was able measuring the differences between the levels of the analyzed factors.

Table 4. Variance analysis (ANOVA) for power consumed during machining.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	1	11186.5	11186.5	11186.5	10714.94	0.000
B	2	22133.5	22133.5	11066.8	10600.25	0.000
C	2	38480.4	38480.4	19240.2	18429.17	0.000
A*B	2	138.5	138.5	69.2	66.32	0.000
A*C	2	131.8	131.8	65.9	63.12	0.000
B*C	4	2495.4	2495.4	623.9	597.56	0.000
A*B*C	4	13.7	13.7	3.4	3.29	0.021
Error	36	37.6	37.6	1.0		
Total	53	74617.5				

Note: S = 1.02177; R-Sq = 99.95 %; R-Sq (adj) = 99.93%
Legend: DF = Degrees of freedom, Seq SS = Sequential sums of squares; Adj SS = Adjusted sums of squares; Adj MS = Adjusted Mean Square; F = F-statistic; p = p-value; S = standard errors of the coefficients R-Sq = R square or coefficient of determination; R-Sq (adj) = Adjusted R square or Adjusted coefficient of determination .

4. CONCLUSION

The following conclusions were obtained in this study:

Surface roughness:
- Statistically significant differences were observed between the levels of factor B;
- Statistically significant differences were observed for the interaction between the factors A and B (A*B);
- Values lower R_a were achieved in the following experimental conditions: A2B2C3.

Toral roughness:
- Statistically significant differences were observed between the levels of factor A and B;
- Statistically significant differences were observed for the interaction between the factors B and C (B*C);
- Values lower R_t were achieved in the following experimental conditions: A2B2C3.

Power consumption:
- Statistically significant differences were observed among the levels of all factors;
- Statistically significant differences were observed for interaction among all factors;
- Lower values of power consumed are achieved in the following experimental conditions: A1B1C3.

The factor, cutting tool, significantly influenced the roughness (R_t) and the power cut. The use of coated carbide insert with TiB_2 improve the machining of aluminum alloys 7075, this compared to polished carbide insert.

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