ANALYSIS OF GG25 GRAY IRON REAMING WITH CEMENTED CARBIDE TOOLS

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Abstract. *An analysis of reaming gray cast iron is made in this work, observing forces and surface roughness for different commercial tools. Uncoated and coated with TiNAl hard metal reamers were submitted to different cutting conditions. The surface roughness parameter R_a values for the tools were not satisfactory, therefore the reamer geometry was changed. The increase of the width of the guides revealed effective, reducing the values of the parameter R_a in almost 50%. In relation to the coated commercial tools, small reduction of surface roughness in relation to the reamers without coating was observed, however, holes with excessive errors of cilindricity had been observed. This characteristic elapses probably of the higher levels of machining forces generated by the biggest cutting edges radius, due to deposition of the coating layer.*

Keywords: *reaming, reamer geometry, coated and uncoated reamers, gray cast iron.*

1. Introduction

Reaming is a machining finishing operation, which aims to improve geometric quality, dimensional and surface texture of holes generated for a previous process (Ferraresi, 1977; König, 1997; Schroeter and Weingaertner, 2001; SME, 1983). As a finishing operation, it is generally carried out in the latest stages of the component production, in way that refutes cause the loss of all the previous processes. The work precision and the surface quality depend upon the initial conditions of the hole, the machine rigidity, the tool and workpiece fixture, the correct cutting conditions, the convenient fluid, appropriate cutting edge material and geometry, among others (Stemmer, 1995a).

Reamers are the cutting tools used in the reaming process and can be produced with a diversity of materials and forms. They consist of two basic elements: cutting elements and guiding elements. They can have straight or helical teeth. The straight tooth reamer present minor cost and easier sharpening and are usually employed in finish cuts (König, 1997; Schroeter, 1989). The helical tooth reamers shall be used in holes with interruptions in the wall. Reamers tend to follow the existing centerline of the hole being reamed, and in limited instances, it may be necessary to bore the holes prior to reaming to maintain required tolerances (Ferraresi, 1977; Stemmer, 1995a). A schematic reamer can be seen in the Figure 1 (SKF,1987).

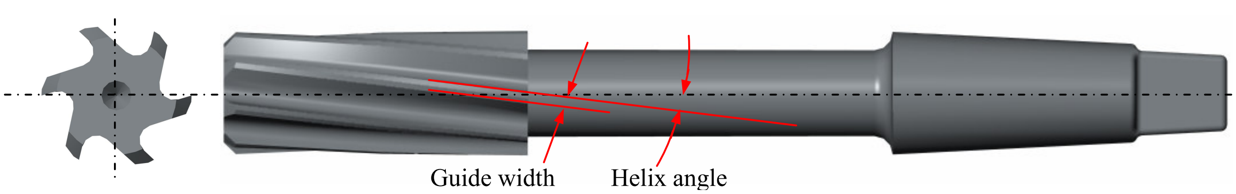


Figure 1. Schematic reamer (SKF,1987)

Reamers can also be coated. The coating has many functions as reduction of attrition and thermal isolation. Due to the reduction of attrition coefficient a better temperature distribution in the contact region between chip and tool face will occur. Moreover, the small thermal conductivity of the coating layer prevents the excessive tool edge heating while the chips remove heat from the cutting zone. The reduction of the amount of heat on the cutting edge allows a better exploration of the tool thermal characteristics for the increase of the cutting speed, feed or both (Bork, 1995).

Lugscheider *et al.* 1997 and 1999 showed that gray cast iron could be reamed with TiNAl coated reamers even without cutting fluid.

Machining forces represent the resistance imposed from the workpiece material against the penetration of the tool edge. The process forces determination are important in order to understand the phenomena that occur in the region of chip formation, for explanation of wear mechanisms and as material machinability criterion determination (König, 1997). Tool geometry, coating type, tool stand, workpiece material, cutting parameters as well as the type and pressure of the cutting fluid are important factors that influence the machining forces (König, 1997; DIN 6580,1963; Tönshoff, 1994). The machining force can be decomposed in three components: the feed force (F_f), the passive force (F_p) and the cutting force (F_c). In reamer process they are schematized according to Figure 2.

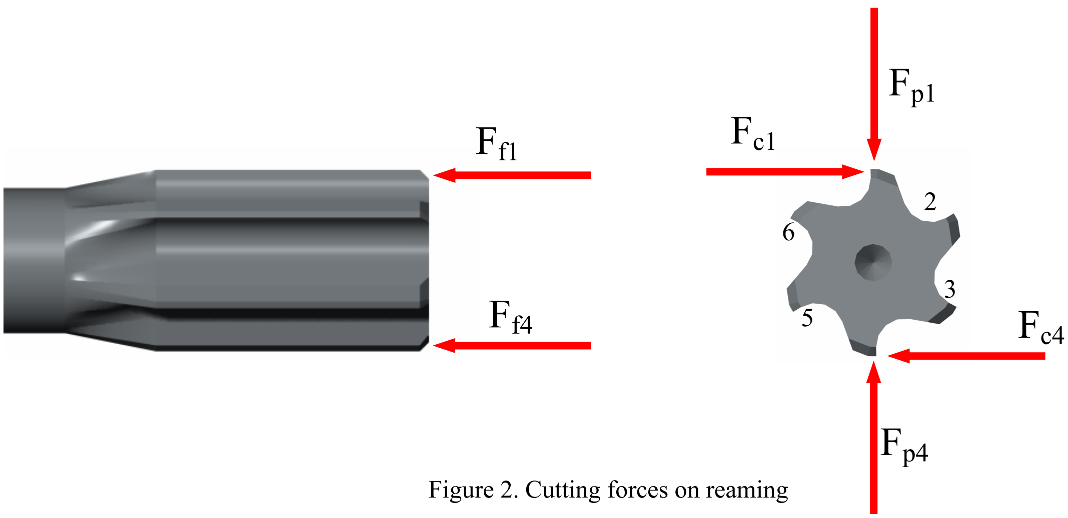


Figure 2. Cutting forces on reaming

Due to reamers tendency of following the previous hole centerline, the passive forces tend to cancel themselves. Because of this, only feed force and torsion moment are usually measured in reaming process. Most of commercial machining forces measuring systems are able to do this.

The machining force of each tooth contributes to feed force and torsion moment. Attrition between tool guides, hole surface and chips also increase the total amount of torsion moment. This contribution depends upon tool sharpening qualify and upon the cutting fluid (Stemmer, 1995b).

Reaming process is usually used in automotive parts, where gray cast iron is largely employed. Finishing processes have some surface requirements, typically R_a parameter. This works aims to identify which tool characteristics are more important in surface quality, in order to reduce R_a parameter. It was predetermined maximum 2 µm as tolerance limit. Machining forces were measured to better phenomena understanding. Hole diameters were measured, and a 20 µm tolerance range was defined.

2. Experimental procedures

In order to determine which tool characteristics depreciate hole quality, 4 types of hard metal reamers were employed: spiral uncoated reamers, spiral coated reamers and 2 types of straight teeth reamers. All of them are six teeth tools.

Four spiral reamers were selected, being two of them coated with TiNAl and the other two without coating. TiNAl was selected because of its high hardness and low friction coefficient (Balzers, 2004). Some papers report good results when using on reaming GG25 gray cast iron (Lugscheider *et al.* 1997 and 1999). This reamers are shown in Figure 3, and the nominal tool diameters was 9 mm. Because of the coating thickness, the coated tools have diameters 0,007 mm bigger. The four reamers have tip diameter reduction in order to establish the entrance of the tool into the workpiece.

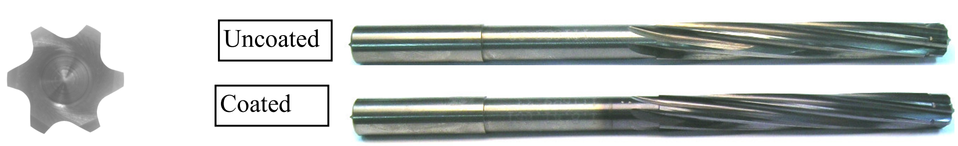


Figure 3. Spiral teeth reamers – tool number 1 and 2 uncoated, 3 and 4 coated

The first type of straight teeth reamer is shown in Figure 4. It’s a six teeth reamer also with tip diameter reduction.

Figure 4. Straight teeth reamer, type 1, number 5

The second and last type of straight teeth reamer is shown in Figure 5. Three units of them were used (numbers 6, 7 and 8) and, in standard sharpening, they had no tip reduction. Some geometry modifications were carried out in order to reduce hole surface roughness.

Figure 5. Straight teeth reamers, type 2, numbers 6, 7 and 8 (standard sharpening)

Through holes were performed in a CNC 3 axes milling machine at the LMP (Precison Mechanics Laboratory) plant. The machine has a maximum of 6,000 rpm spindle and 30,000 mm/min feed speed. Mineral oil was used as cutting fluid with (4,0 ± 0,5) l/min flow rate.

Surface roughness were evaluated by a Mitutuyo tester (SJ301). Machining forces were measured with a piezeletric dynamometer Kistler Instrumente AG model 9273conected to two power amplifiers and a PC. The acquisition frequency was 0.5 kHz.

The workpiece were GG25 gray cast iron cylinders with hardness between 240 and 280 HB and 72 mm leght. The depth of cut of 0.3 mm follows from the overmeasure of the hole from 0.6 mm. A chuck and clamping collet system was used to guarantee workpiece fixture and alignment. In all cases a fluted chuck was used to fixture the tools.

Surface roughness was measured on the start and on the end of the hole, at 5 mm from each extremity, with two repetitions. The maximum accepted value for R_a parameter was 2 μm. The confidence intervals were calculated as described in standard ISO 8688-1/2 (1999) and ISO 3685 (1977).

3. Results and discussion

3.1. Spiral reamers

The spiral reamers, coated and uncoated, were employed under different cutting conditions. These two types presented good repeatibility, where the tools of each group showed the same tendency for all tests. However, between the two groups a significant difference can be observed on Figure 6, where the machining force are represented as function of cutting speed an feed.

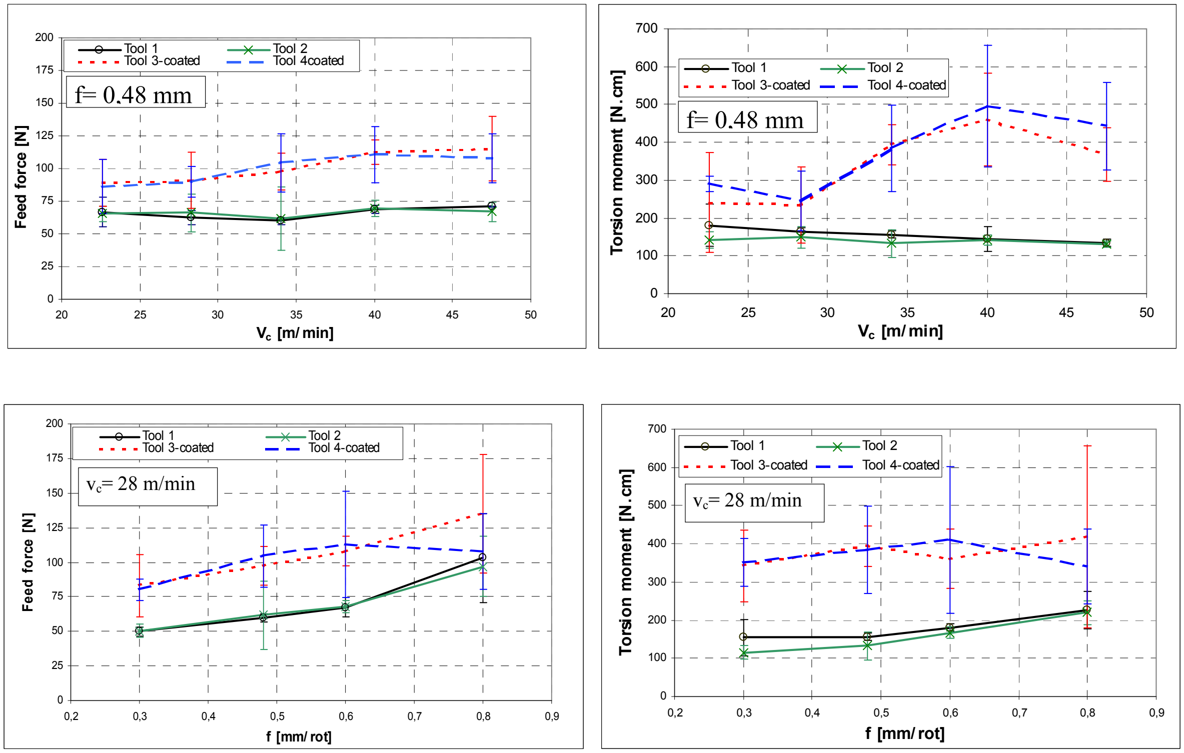


Figure 6. Cutting forces for uncoated and coated reamers

It can be seen that torsion moment for coated tools has almost twice the values for uncoated tools. The feed force is about 50% higher. Due to the coating thickness the cutting edge corner radius increases significantly. Consequently, more deformation on workpiece material occurs, resulting in higher machining force. These higher values caused excessive errors on hole linearity, observed with a go and no-go pin. This effect could be observed on the not established torsion moment along the hole during measurements.

In relation to surface roughness, it can be seen that coated reamers maintain below the 2 µm line while uncoated tools increases greatly (Figure 7).

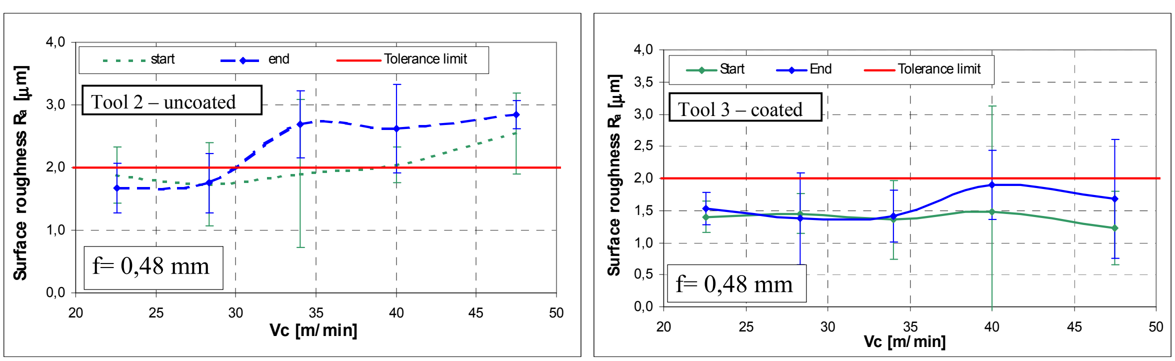


Figure 7. Surfacer rouhgness for uncoated and coated reamers

This can be explained due to lower attrition coefficient between TiNAl and cast iron. The absence of the coating increases the abrasive stress resulting a reduction of cutting oil lubrication efficiency leading to higher values of R_a. Some tests carried out without cutting fluid showed that the surface roughness, and also the hole diameter, increases greatly. These results reaffirm that explanation.

3.2. Straight teeth reamers

The first straight teeth reamer type was submitted only to two cutting conditions. In both cases, the R_a values were above the set limit of 2 µm. No more tests were performed with this tool.

Two of the second straight teeth reamers type were analyzed on standard sharpening, at the same cutting conditions. Both presented the same results for roughness, as shown in Figure 8, but above 2 µm.

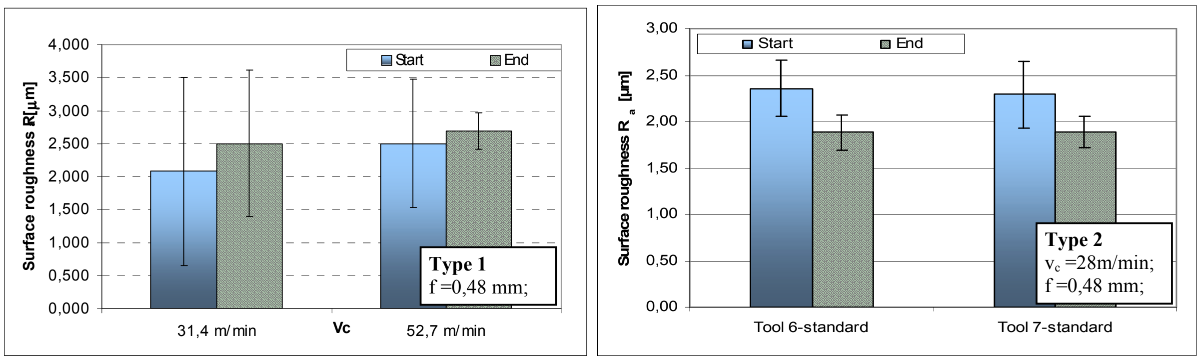


Figure 8. Surface roughness for straigth teeth reamers

In this cases, a well established torsion moment along the hole during measurements were observed. However, the standard sharpening is not properly for using with fluted chuck tool fixture. This leads to an unstable entrance of the tool into the workpiece, prejudicing surface quality.

3.3. Surface roughness analysis

In order to get more details about the different machined holes, the surface profile were plotted for each tool. The results are shown in Figure 9.

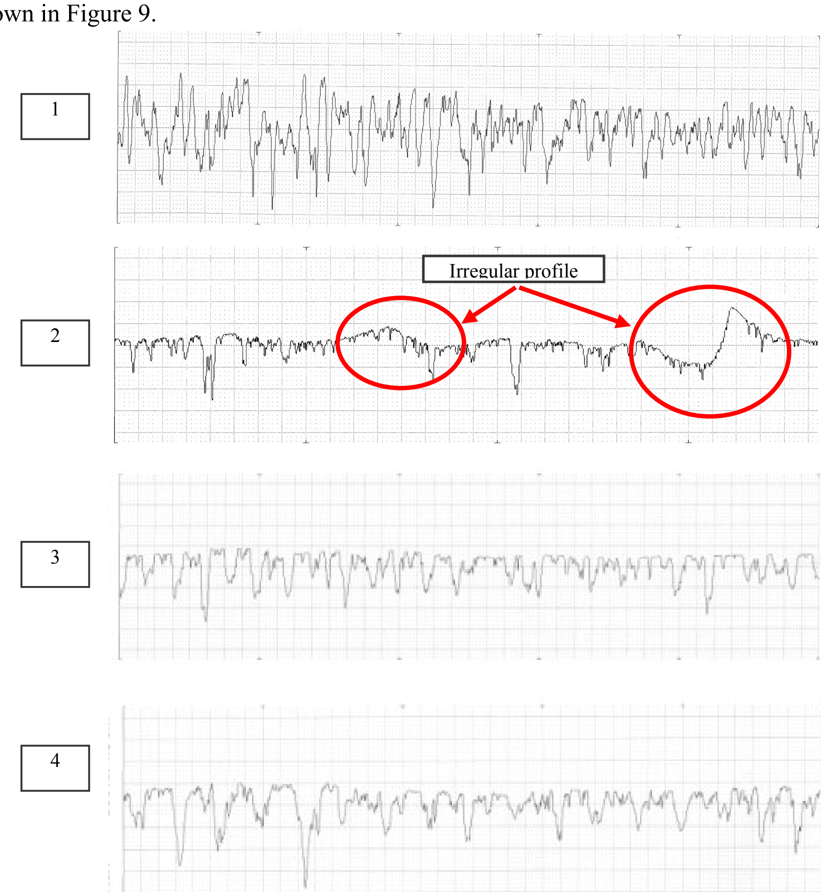


Figure 9. Surface roughness profiles: a) tool 1-helical uncoated, b) tool 3-helical coated, c) tool 5-straight teeth and d) tool 6-straight teeth type 2

It can be observed in the machined surface with the coated tool, which had quite low R_a values that the profile peaks are cut, like a plateau surface. However, some irregularities were found, probably due to the high machining force.

It can be verified that uncoated tool had a completely irregular profile due to lack of lubrication. Both straight teeth reamers present surfaces very similarly, with peaks partially cut, but not enough for significant low values of R_a.

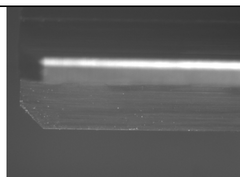
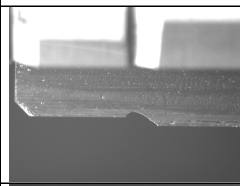
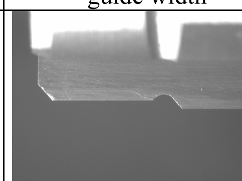
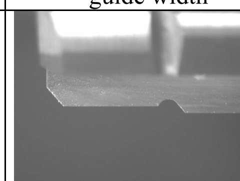
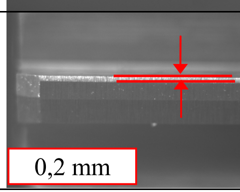
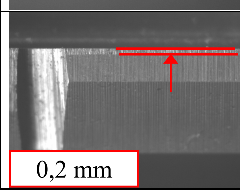
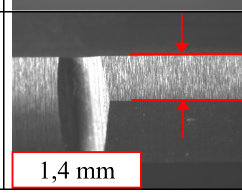
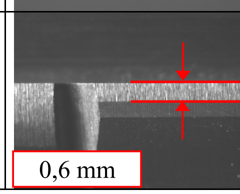
Based on these pictures showed in Figure 9, it can be supposed that tools capable to cut the profile peaks maintaining enough lubrication can produce surfaces with lower R_a values. A way to validates it is to produce tools with larger guide widths. Tools with modification on geometry are presented in the next section.

3.4. Modification on tool geometry

Based on the results above, some tools had their geometry modified in order to improve better contact between tool guides and machined surface. The aim is verify if larger tools guides lead to lower R_a.

The type 2 straight teeth tools were sharpened. A tip diameter reduction was improved in all the tools for better machining begin. One tool had only tip reduction, one reamer had its guide width increased to 1.4 mm and the last one to 0.6 mm, as shown in Table 1.

Table 1. Modifications on tools geometry

	Tools 6, 7 and 8 (Standard)	**Tool 6 (modified)** Only tip reduction	**Tool 7 (modified)** Tip reduction and 1,4 mm guide width	**Tool 8 (modified)** Tip reduction and 0,6 mm guide width
Face				
Guide				

The primarily results showed that only the tip reduction was not significant in surface roughness reduction. However, machining force was increased. The tip diameter reduction improve large contact area between tool and surface on the tool tip. This large area lead to a higher friction and consequently higher machining force, specially torsion moment. These results are shown in Figure 10.

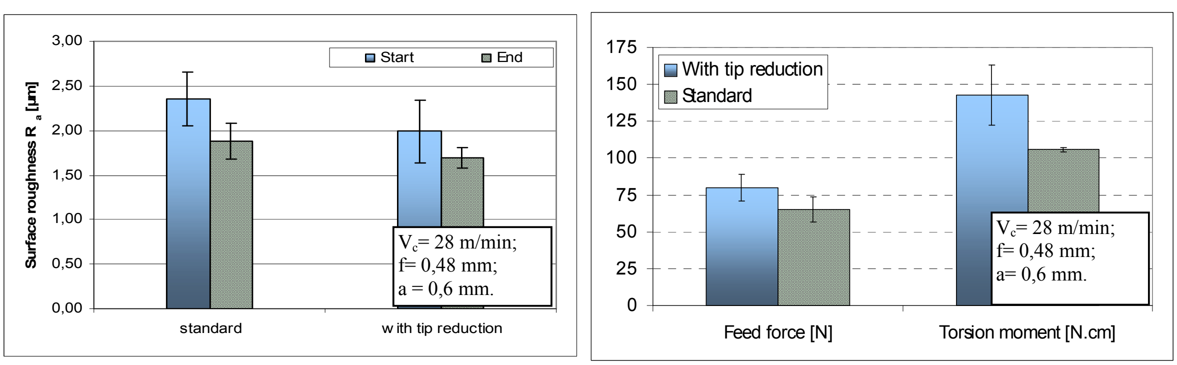


Figure 10. Surface roughness and machining force from tools with and without tip diameter reduction

In relation to the others two tools with wider guides, a significant reduction of surface roughness was observed. These tools had been submitted the three cutting conditions, as shown in Figure 11.

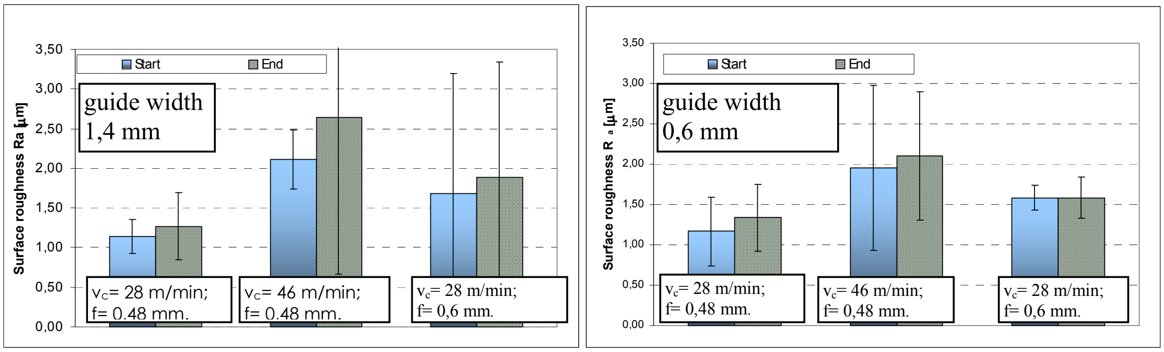


Figure 11. Surface roughness for tools with different guide widths

The first condition was v_c= 28 m/min and f= 0.48 mm per revolution. The second and third combinations are with increase of the cutting speed and increase of the feed respectively. It was observed that, in both tools, the surface roughness values for the first condition had been similar. These values are about to the half of that ones for standart tool, i. e., a reduction of up to 45%, thus under the definite requirements of quality. It can also be observed that the tool with width of guides 0.6 mm presented minors values of surface roughness for the other conditions, and also a less variation between them. This probably occurs because wider guides can have an excessively friction between machined surface and tool guides, harming the workpiece/tool lubrication. This effect of attrition rise was comproved by result of torsion moment measurement of standart tool and atool only with a tip diameter reduction. A commitment relation is perceived then, where an increase of the guides width improves the kneading of the surface peaks until the unstable instant where the excessive attrition compromises its quality, due to lack of lubrication. Weinert and Hagedorn (2002) obtained similar results with larger tool guides.

5. Conclusions

In this work, some conclusions were found. The coating thickness in reamers increases machining force due to higher tool edge radius. These higher stress propiciate linearity hole erros. Although this unsatisfactory results, coated tool showed lower surface roughness, due to low coating attrition coeficient.

The lubrication condition between tool guides and the machined surface can be modified with different tools geometries. This lubrication was found to have a significant effect on surface roughness. Narrow guides were not able to cut surface peaks while excessive large guides compromises lubrication efficiency.

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