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Study of roundness on cylindrical bars turned of aluminium–copper alloys UNS A92024

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Abstract

Aluminium alloys are broadly employed in aerospace industry for the production of the different elements that conform the airships. Moreover, the appearance of emergent government legislations in environmental matters has forced the replacement of machining methods in the last years, which prevents or minimizes the employment of substances or fluids. In this sense, the turning has been carried out in dry for the performance of the experimental part of this work.

In this work, macrogeometric deviations of UNS A92024 (Al–Cu) cylindrical bars are analyzed (roundness), and turned dry under some conditions of imposed cutting (cutting speed and feed). Also, an exponential relation between roundness and the cutting parameters is established for the dry turning process of UNS A92024 alloy.

The obtained relationship allows us to predict the behaviour of these deviations in the range of cutting speed and feed considered.

Keywords: Turning; UNS A92024; Roundness; Parametric model; Continuous surface

1. Introduction

Light alloys are widely employed in the production of elements or pieces integrating the products of most industrial sectors. In this sense, the aluminium industry has benefited from its extensive use. Nowadays, it ends up affecting some sectors of the market and, particularly, the aerospace industry, which is one of the sectors where this type of alloys has a larger number of applications [1]. Taking this into account, the aluminium–copper alloys are being thoroughly used in the production of structural components of the airships, mainly because of the excellent relationship between their weight and their mechanical properties. This growing use is encouraging the undertaking of studies intended to analyze the different ways of conformance of these alloys [2–4].

One of the most characteristic ways of conforming alloys is chip outburst machining. On the one hand, in this type of processes those denominated cutting fluids with objects are usually applied to the cooling of the tool and the elimination the effects due to high temperatures. On the other hand, the lubricating action of these fluids reduces the friction in the cutting area, facilitating the evacuation of the chip and causing a descent in the rate of tool wear due to friction.

However, in the last few years, regulations concerning the environment have forced the development of cutting fluids of low environmental impact together with the search for machining methods that avoid or minimize their use [5]. In this sense, the processes have been carried out under non-lubricating and non-cooling conditions, leading to what is called in-dry machining [6–8].

Nevertheless, this type of machining causes alterations both in the tool and in the piece, giving place to deviations on the design specifications. In this work, we carried out a study of the macrogeometric deviations in the process of in-

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dry turning of UNS A92024 copper–aluminium alloy and in a range of moderate cutting speeds with constant cutting depth. In short, the deviation of roundness has been analyzed, for which a parametric model has been established in function of the technological parameters, cutting speed and feed.

2. Experimental procedures and materials

In this work, the workpieces used in the turning tests were cylindrical bars of UNS A92024 (Al–Cu) alloy in state of tempers T74511. The diameters were 80 mm and the lengths 190 mm. Table 1 includes the percent mass nominal composition of UNS A92024 alloy. Previously to performing the tests, the surface of the cylindrical workpieces were rough-dressed by a high feed horizontal turning process in order to remove the surface deposits formed in the storing period. After this, a latter surface finishing small-feed turning process was carried out in order to avoid chattering effects on the workpiece surface [9].

Turning tests in absence of cutting fluids were conducted in a CNC horizontal lathe, model EmcoTurn 242 TC, equipped with a numerical control Emcotronic TM 02 (Fig. 1). The turning tests have been carried out without lubrication or cooling on the basis of the recent environmental ISO 14000 standard.

Because of this standard, many companies have been obliged to redesign their manufacturing systems in order to use more environmentally friendly production processes [10].

The above-mentioned tests were performed using a fixed cutting depth, *d*, of 2 mm. Table 2 includes the values of cutting speed, *v*, applied in the tests, while Table 3 contains the values of the feed, *f*, applied in them. The tests were carried out combining all the values included in Tables 2 and 3.

Table 1
Nominal composition of alloy UNS A92024 (% mass)

Cu	4.00
Mg	1.50
Mn	0.60
Si	0.50
Fe	0.50
Zn	0.25
Ti	0.15
Cr	0.10
Al	Rest

Table 2
Cutting speed values applied in the turning tests

v (m/min)	43	64	85	127	170

Table 3
Feed values applied in the turning tests

f (mmpr)	0.05	0.1	0.2	0.3

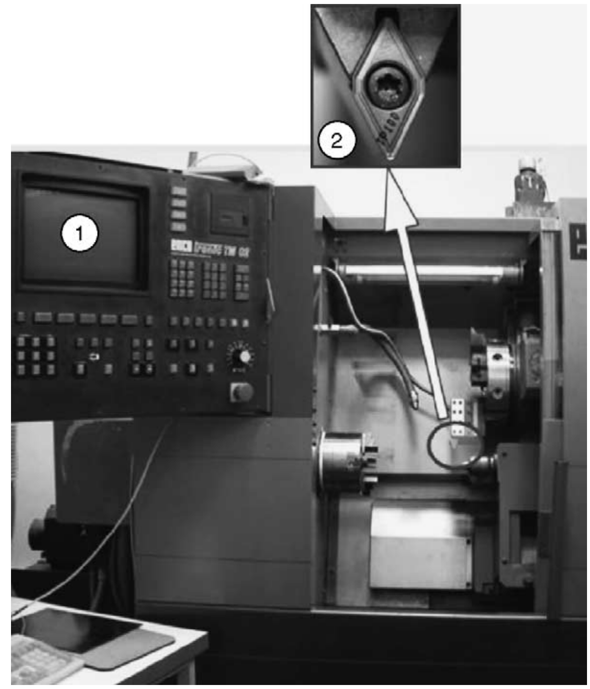

Fig. 1. Experimental devices for the turning tests: (1) horizontal lathe equipped with numerical control, (2) tools used.

A digital-clock comparator with scale division 1 μm and an adapter connected to the RS-232 were the elements used in the measurements of roundness. These elements allowed the automatic acquisition of the data, as shown in Fig. 2.

The experimental devices that are shown in Fig. 2, allow us to obtain the roundness by means of the least square circle assessing approach.

The differences of the values obtained for the devices shown in Fig. 2 and those obtained for the Formtester MMQ 44 Mahr, as in Fig. 3, are shown in Table 4 (partial reproduction).

In Table 4, the values obtained by both devices can be observed (see also Figs. 2 and 3).

Titanium nitride (TiN) DCMT 11 T 308 F2 TP100 turning inserts were used as cutting tools. The tool beared employed was a 9153A20 for external turning. In order to guarantee the initial conditions of each test, a new tool was used in each experiment.

The representative roundness value in each machined sample was obtained from the mean value taken from 10 circles drawn on the lathed surface.

Table 4
Differences of roundness (μm) both experimental devices (partial reproduction)

Clock-comparator (μm)	MMQ 44 (μm)	Differences (μm)
10.2	10.5	0.3
8.8	9.8	1.0
7.8	8.7	0.9
8.8	8.3	−0.5
3.9	4.8	0.9

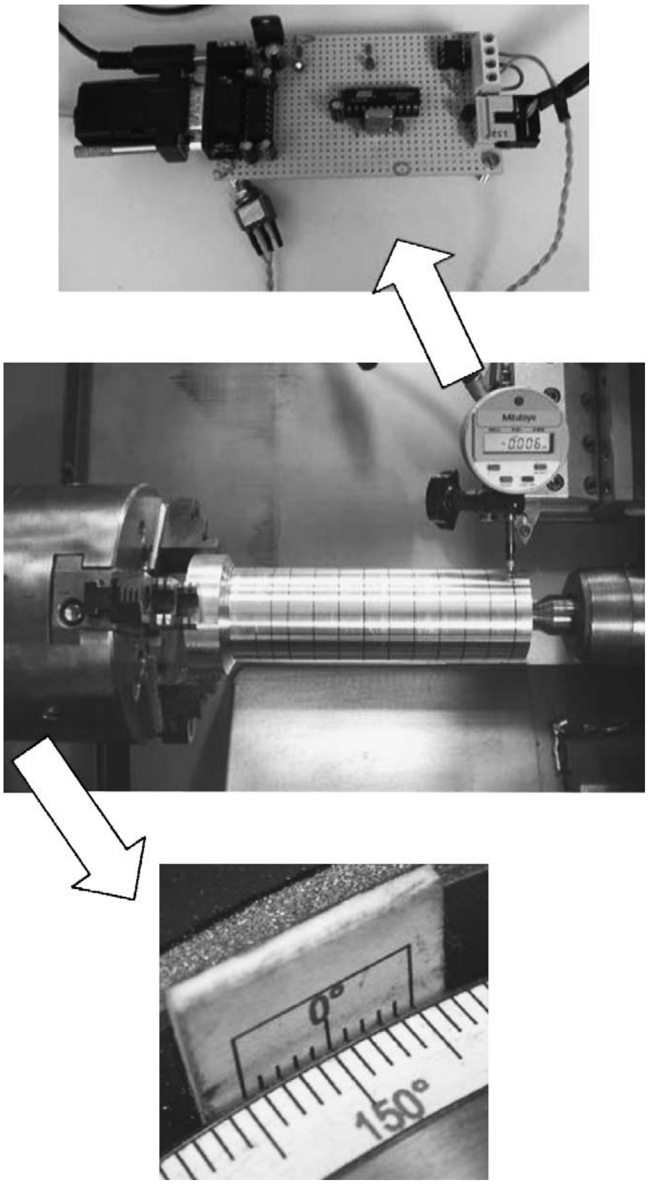

Fig. 2. Experimental devices for the measurements of roundness.

All the tests and measurements were repeated at least three times in order to guarantee reproducibility.

In the realization of this work, the evaluation of the expanded typical uncertainty of the adopted measurement system has been studied, yielding a value of 3 μm. This allows us to claim up to a 95% certainty for the true value of the measurement to be in the interval defined by the mean value and its associated uncertainty ($\overline{\mathrm{RD}} \pm 3\,\mu\mathrm{m}$) [11–13].

3. Results and discussion

In Fig. 4, the evolution of the mean values is represented for the deviations of roundness in function of the cutting speed for each feed used. From a first observation carried out on this

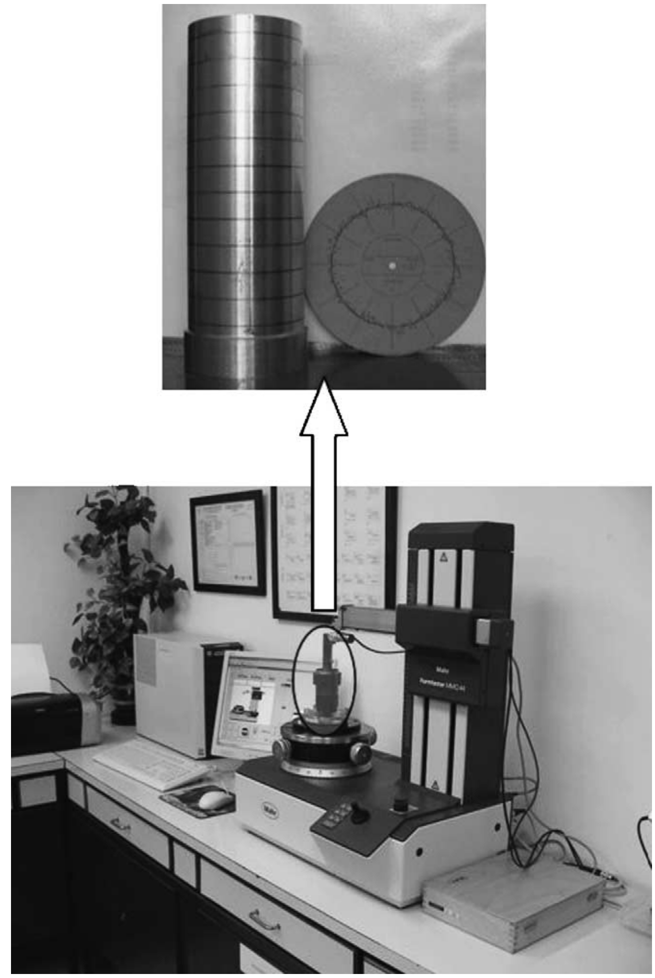

Fig. 3. Formtester MMQ 44 – Mahr.

figure, it can be deduced that, in general, when the cutting speed is increased, there is a decrease of these deviations. This fact seems to indicate that the geometric precision, at least in relation to this parameter, increases with cutting speed. In this way, the biggest deviations are obtained for speeds of 43 m/min.

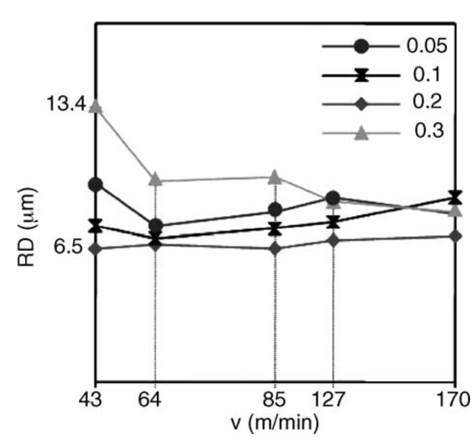

Fig. 4. Evolution of RD with v for f considered.

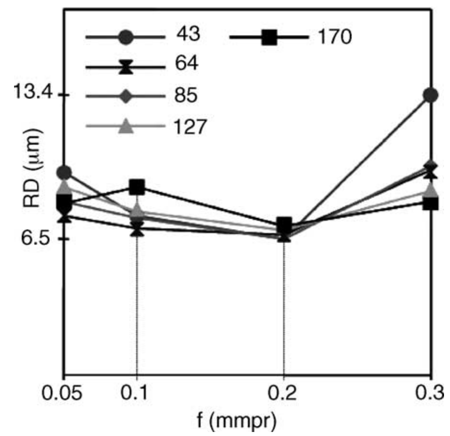

Fig. 5. Evolution of RD with f for v considered.

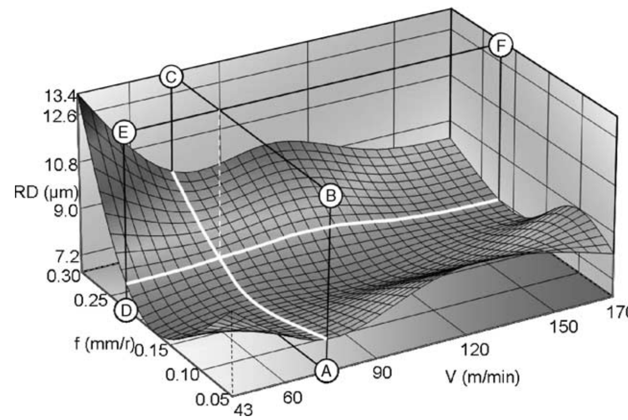

Fig. 6. Surface continuous for prediction RD with v and f established.

An inverse tendency seems to be deduced from the study of the deviation of roundness with the feed, as in Fig. 5. Indeed, deviations of the roundness become larger as the imposed feed increases, as shown in Fig. 5. From the above-mentioned data, it can be inferred that geometric precision, at least in what refers to this parameter, diminishes with feed increment. In this way, the largest deviations are obtained for 0.3 mmpr feed.

Taking all this into account, we may conclude that lathed high-speed and lower feed allow a better approach to geometric specifications.

These results allow us to suggest the possibility of looking for a parametric model in which roundness (RD) would depend on the technological parameters employed as variables. In general, the parametric models have a potential form regarding taylor-made models. In this case, the adjustment to models of these characteristics presents a very low coefficient of determination, which indicates that the adjustment carried out was not good enough. For this reason, we decided to change the model, using an exponential type, which is closely related to the values obtained. Therefore, a model was proven as follows:

$$\mathrm{RD} = C\,\mathrm{e}^{\sum_{i=1}^{2}\sum_{j=1}^{2} K_{ij}\, f^{i} v^{yj}} \qquad (1)$$

The expression (1), can be expressed:

$$\mathrm{Ln[RD]} = \mathrm{Ln}[C] + fv^{y}[1 \quad f]\begin{bmatrix} k_{11} & k_{12} \\ k_{21} & k_{22} \end{bmatrix}\begin{bmatrix} 1 \\ v^{y} \end{bmatrix} \qquad (2)$$

When applying non-linear regression, the coefficients and exponents of the pattern are determined, being:

$$C = 11.2, \qquad k_{11} = -102.4, \qquad k_{12} = 330.4,$$
$$k_{21} = 226.6, \qquad k_{22} = 0, \qquad y = -0.57$$

Therefore, the proposed model can be expressed as:

$$\mathrm{RD} = 11.2\,\mathrm{e}^{(-102.4 f v^{-0.57} + 330.4 f v^{-1.14} + 226.6 f^{2} v^{-0.57})} \qquad (3)$$

The adjustment made allows a superior adjustment to 80% of the obtained values and those proposed by the expression (3).

On the other hand, the mean values of the obtained deviations of roundness and the parameters of cutting in the machining of each sample, allow us to represent a continuous surface as suitable in Fig. 6, which allows us to predict the behaviour of these deviations for the range of speed and feed established. This surface is represented in Fig. 6. As it has been remarked, it is possible to predict the roundness behaviour in function of the feed, for a given cutting speed, tracing parallel planes to the one defined for RD and f (Plane A–B–C). Similarly, tracing parallel planes to the one defined for RD and v (Plane D–E–F), it is possible to define the evolution of the roundness with the cutting speed for a certain feed [14].

4. Conclusions

In the machining of aluminium alloys, the specified geometric and dimensional deviations due to the interactions the tool-workpiece systems are obtained. These interactions are magnified when the machining process is carried out in absence of cutting fluids.

Roundness deviation has been analyzed in the turning of aluminium–copper alloys with constant cutting depth. This study has revealed that as speed increase and feed decreases, loss of precision in roundness tends to increase. The data obtained have allowed us to establish a parametric model for the deviation of roundness that shows that the largest variations in this variable are caused by the feed. Fig. 6 allows us to predict the values of these deviations for the range of cutting speed and feed considered.

Finally, the methodology used in this work allows the evaluations of the deviations of roundness of the turned samples mounted in CNC horizontal lathe.

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