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Evaluation of the machinability of CW614N brass alloy

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Abstract

Brass alloys are widely used materials for general and industrial applications. However, the lead content in them forces manufacturers to develop new ecological types, the properties of which must be gradually specified in order for the product to be produced and processed more efficiently. The article deals with the evaluation of the machinability of CW614 brass by investigating the influence of technological parameters on the surface roughness of the machined surface and the intensity of vibrations during machining. The measured data were statistically processed; with the help of regression analysis, mathematical formulations of the influence of input parameters on monitored variables were defined and based on them, functional dependencies were plotted in the MATLAB software application. The results showed that at the CW614N brass alloy machining, the feed rate has the greatest influence on the surface roughness Ra, but the depth of cut has the greatest influence on the vibration intensity.

Keywords: Brass alloy; machinability; surface roughness; vibration intensity

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1. Introduction

Machinability is a term that cannot be easily specified. It is possible to look at machinability from several points of view, not only depending on the material being machined, but also in terms of the rate of tool wear, total energy consumption, achievable surface treatment, or other criteria. Machinability can be simply explained as the ability of a

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material to withstand easy machining with low power. Machinability is a consideration in the materials selection process. The effortlessness with which a metal can be machined is one of the principal factors affecting a product's utility, quality, and cost. (Mils, 1983; García, 2010; Ivanov, 2021; Braut, 2021; Vukadinovic, 2021)

A critical role in machinability plays the microstructure of metallic alloys. In general, hard structures and fine grains result in lower tool life. (Felho, 2022) Machinability, in terms of tool lifetime and durability, is generally improved for softer and more homogeneous microstructures. (Vukelic, 2022; Sovilj-Nikić, 2018) Fine size and hard intermetallic phases, inclusions or second-phase particles in the matrix increase the wear of the cutting tool. (Varga, 2019; Vukelic, 2021; Stahl, 2014) The chemical composition of the metal is essential and has a complex effect on machinability. (Vaxevanidis, 2018; ISO 3685; Mlikota, 2021) The primary manufacturing process of a material or component will also affect its machinability. (Stephenson, 2016; Toulfatzis, 2016)

Considering that the machinability of the material can be assessed in a comparative way, not only at the machining of several types of materials under the same conditions but also by machining the same material under different parameters, then better or worse machinability of the material is reflected in the quality of the machined surface (surface roughness) or in vibration intensity during machining. (ISO 513) In this study, the machinability of the CW614N brass alloy was investigated under different machining parameters according to the experimental plan, when the surface roughness of the machined surface and relative vibration intensity were evaluated.

2. Materials and methods

Brass, a type of alloy made of copper and zinc, is one of the easiest materials to machine, especially compared to aluminium. (Stavroulakis, 2022) Quantification of the standard properties of individual materials often shows considerable variance according to Table 1. This requires a thorough analysis of the characteristics of the materials affecting the machining process. For the investigation within the research, the workpiece CW614N brass alloy sizes ϕ 40 x 400 mm were selected.

Table 1. Basic characteristics of CW614N (*Depending on the method of production)

Characteristic	Value*
Maximum Lead content (%)	3.50 (EN 12164)
Tensile strength R_m (MPa)	456 (Nobel, 2014) or 360 - 500 (Company Sarbak materials data sheets)
Yield strength $R_{p0.2}$ (MPa)	324 (Nobel, 2014)
Hardness HB	154 (Nobel, 2014) or 90 - 160 (Company Sarbak materials data sheets)
Elongation A to break (%)	26 (Nobel, 2014) or 5 – 20 (Company Sarbak materials data sheets)
Thermal conductivity λ (W/m.K)	123 (Nobel, 2014) or 113 (Company Sarbak materials data sheets)

From the point of view of the availability of workpieces (only in the form of bars), turning was chosen as the most suitable technological method for testing the machinability properties of the brass alloy during machining. The working length (200 mm) of the workpiece was half of the full length of the bar (400 mm) to ensure sufficient rigidity. The second half of the bar was clamped into a three-jaw chuck. The working part of the workpiece for machining was divided by grooves into ten parts (Fig. 1). Each of the 17 mm sections was used to perform the test with one combination of experimental factors.

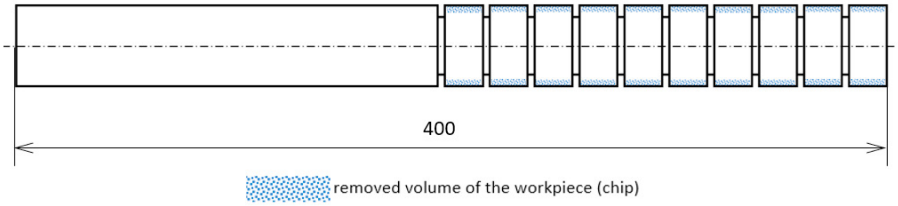

Fig. 1. Design of the workpiece ready for machining.

The experiments were carried out employing the machine DMG MORI ecoTurn 450. The used cutting tool consists of a tool holder SSBCR 2525 M 12-M-A and a cutting insert type SCGW 12T304 K10 that was selected in cooperation with an experienced tool supplier. The sizes of the insert were 12.7 x 12.7 x 3.18 mm, while its basic geometrical characteristics were: rake angle $\gamma = 0°$, clearance angle $\alpha = 7°$, cutting edge inclination angle $\lambda_s = 0°$ and corner radius $r_\varepsilon = 0.4$ mm. A new corner of the cutting insert was used to machine every sector of the bar. (Monka, 2022)

The cutting tip with its indexing and the experimental set used in the presented research are shown in Fig. 2.

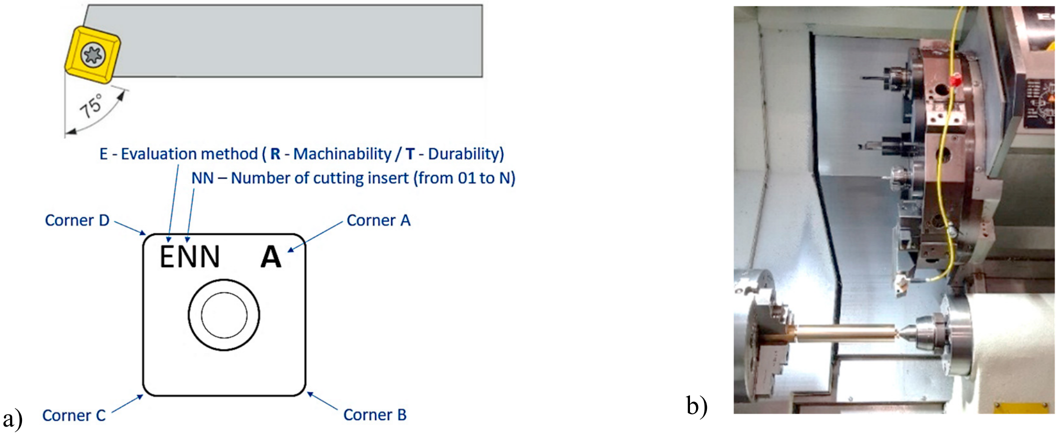

Fig. 2. (a) Cutting tool with a cutting insert; (b) Machining set.

The input machining parameters summarized in Table 2 were used at the experiments.

Table 2. Input machining parameters for machinability investigation of CW614N brass alloy

Input machining parameters	**Values**
feed f (mm)	0.06; 0.12; 0.18
cutting speed v_c, (mmin^{-1})	100; 200; 300
cutting depths a_p (mm)	0.5; 1; 1.5

The surface roughness of every machined sector of the workpiece was measured in the surface roughness laboratory by means of equipment MITUTOYO SJ-410 after completing the whole plan of the experiment.

During machining, the response of the material to excitation was measured, taking into account the frequency range up to 25 kHz (based on the characteristics of the accelerometer). The highest amplitude of the vibration characteristics was considered for the evaluation (after excluding peaks related to resonance frequencies of other parts of the machining set). The accelerometer Wilcoxon Research WR-712F-M4 was positioned on the bottom of tool holder, against the clamped cutting insert and as close as possible to the cutting edge.

3. Results and discussion

The experiments were carried out on the basis of a non-rotating composition plan. The measured data were statistically processed, subsequently the coefficients of functional dependencies were determined by regression analysis, and these dependencies on the input parameters were plotted in the MATLAB software.

Equation (1) was determined for the dependence of the surface roughness of the machined surface Ra (μm) on the feed f and cutting speed v_c, while the dependencies generated for individual cutting depths a_p are shown in Fig. 3.

$$Ra = 2.0832\, v_c^{-0.0940}\, f^{1.7929}\, a_p^{-0.0198} \tag{1}$$

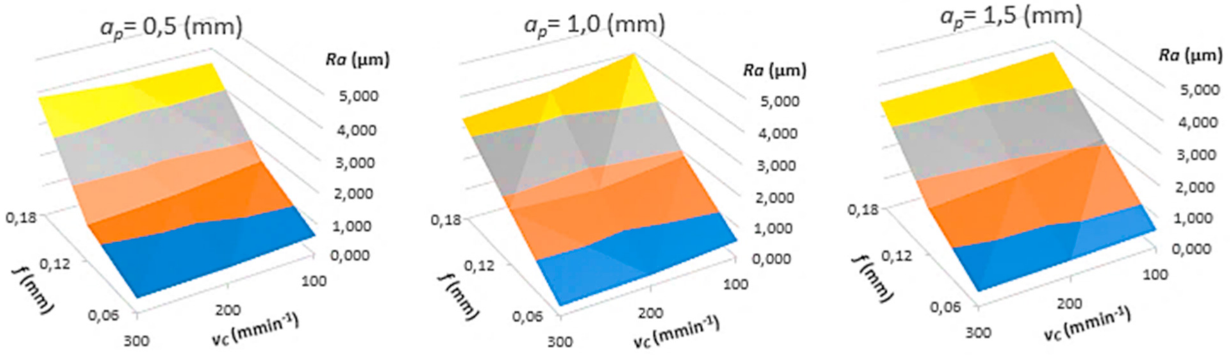

Fig. 3. Results for CW614N brass alloy machined - surface roughness *Ra* evaluation.

It can be seen from the dependencies in Fig. 3 that the most significant influence on surface roughness Ra has feed, while influence of cutting speed and cutting depth within the monitored range is almost insignificant.

It is different when monitoring the influence of input parameters on the vibration amplitude A (ms^{-2}), which is expressed by equation (2) and visually displayed by the graphs in Fig. 4.

$$A = 4.7728\, v_c^{-0.4188}\, f^{2.6869}\, a_p^{0.3294} \tag{2}$$

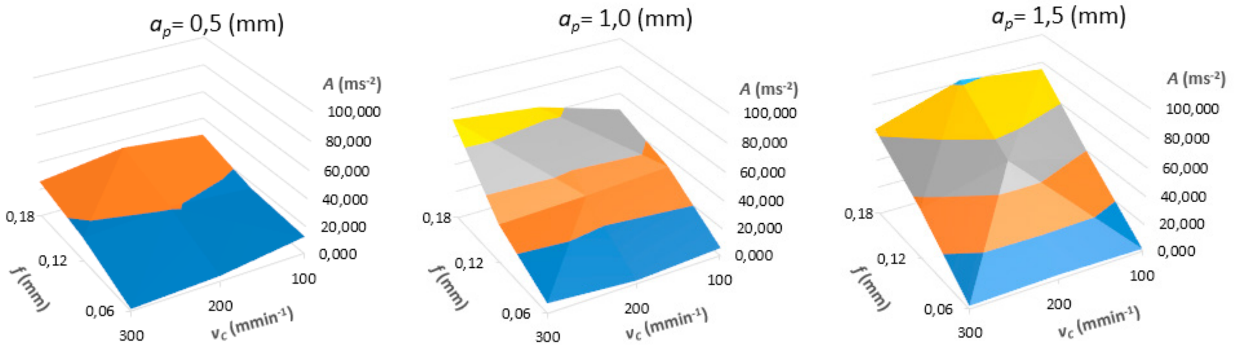

Fig. 4. Results for CW614N brass alloy machined - relative vibration intensity evaluation.

From Fig. 4, it is clear that the intensity of vibrations increases with the increasing depth of cut. The most dominant factor together with the depth of cut is feed rate, although at the depth of cut a_p = 0.5 mm, the influence of feed on vibrations is only moderate. At the cutting depths a_p = 0.5 and 1.5 mm, the highest values of vibration intensities were recorded at a cutting speed of v_c = 200 mmin^{-1}, in contrast to the cutting depth a_p = 1 mm, where the maximum values were measured at the cutting speed v_c = 300 mmin^{-1}.

4. Conclusions

As part of the presented research, the influence of technological parameters on the machinability of the CW614N brass alloy was studied by monitoring the values of surface roughness and vibration intensity.

It is possible to state that the feed rate has the greatest influence on the surface roughness Ra and the depth of cut on vibration intensity when machining a brass alloy.

In the future, the obtained values will be compared with other types of brass alloys when machining under the same conditions and based on the results, the machinability of individual alloys with each other will be possible to compare.

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