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STUDY AND DETERMINATION OF THE VARIABLES MORE INFLUENTS IN THE SURFACE ROUGHNESS OF SLIM PIECES MACHINED ON A LATHE UNDER SELF EXCITATION CHATTER VIBRATION

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ABSTRACT
The machining of slim pieces is affected by the chatter phenomenon. In this paper a study of the factors that influence the surface roughness of slim pieces fabricated on a lathe under self-excitation chatter vibration is presented. The purpose of the study is to determine which are the variables more influents in the process. For this study a novel analytical model for predicting the chatter phenomenon is used. The model functions according to the operating conditions of the turning process and the properties of the material to be machined. The one degree of freedom model has been achieved by incorporating into the model the relative motion between the cutting tool and the workpiece and by considering the problem of the forces involved as well as the tool geometry. The aim of the study is to determine which of the operating variables, or combination of variables, influences surface roughness through the chatter effect. Feed rate, depth of cut and cutting speed were found to have the greatest influence.
Keywords: Surface roughness, chatter vibration.

1. INTRODUCTION
The fabrication of slim pieces, such as slim cylinders, can imply problems including breakage or dimensional errors in the workpiece, and instability of the process. Said instability derives from a phenomenon known as *chatter* which arises during rough machining when a large quantity of material is removed, as well as in finishing of workpieces that have low structural rigidity.
In this paper, a study about the main effects that affect Ra (Average Roughness) and Rt (the Peak to Valley Height) is presented. Ra and Rt are calculated using computational simulation: starting from a chatter-generation model, a computational algorithm was developed which generates the surface topography. The paper is divided into the following sections: first, the one degree of freedom model for predicting the chatter is presented; a model for generating surface roughness is explained; the main effects study; the presentation of the results and their discussion; and, finally, conclusions are drawn.

2. SINGLE DEGREE OF FREEDOM MODEL OF THE CUTTING PROCESS

The developed model [1,2], for a turning process, is an orthogonal cutting model in which the tool-piece interface is treated as a structure with a single degree of freedom: movement only takes place in the horizontal direction (x-axis). Equation (1) dictates a dynamic system with a single degree of freedom:

$$m_{eq}(t)\ddot{x} + c(t)\dot{x} + k(t)x = \Delta F_x(x, \dot{x}, \alpha_0, V_c, h_0, f, S_f, \varepsilon) \quad (1)$$

Whereby: x = the position of the tool in function of the time; $\dot{x}$ = velocity; $\ddot{x}$ = acceleration; m_{eq} = equivalent mass; c = damping coefficient; k = rigidity constant; α_0 = steady state rake angle; V_c = cutting speed; h_0 = steady-state undeformed chip thickness; f = feed rate; S_f = true fracture strength of the work material; ε = ratio of the chip thickness to the undeformed chip thickness; and ΔF_x = the oscillating forcing function. Determination of the function ΔF_x is fundamental to the model, as it is this function which excites the system to produce dynamic behaviour [2].

3. MODEL FOR GENERATING SURFACE ROUGHNESS

Starting from the chatter-generation model (1), a computational algorithm was developed which generates the surface roughness for a workpiece machined on a lathe. The profile is simulated by initially considering the effect of the tool geometry, which derives from the repetition of the cutting tool tip moving along the workpiece at a desired feed rate during the turning process. The profile is affected by the displacements $x_i(t)$, which are generated by vibration of the piece and calculated using equation (1). As such, each imprint formed in the surface varies in function of the value of $x_1(t)$, $x_2(t)$,…, $x_n(t)$. Lastly, the definitive profile is the result of the superimposition of the different imprints left by the tool. These imprints are treated discretely.

The model was experimentally evaluated by comparing theoretical values obtained for the surfaces of thin cylinders with real values obtained for the surfaces of machined thin cylinders under the same cutting conditions, which include chatter. Inspection of the profiles reveals that they are quite similar. There values for the average surface roughness (Ra) and the peak to valley height (Rt) are similar, as are the Fourier Spectrum each surface roughness wave: the wave components are the same in both cases [2].

4. MAIN EFFECTS

Using techniques of Design of Experiments (DOE) with the results obtained from an analytical model (equation 1), the machining parameters or combinations of parameters that have the greatest influence on surface roughness were determined. Six factors were considered in the study: f, V_c, h_0, α, m_{eq} and E (Young's module). These were varied from 90% to 110%. The following data were used:

For steel: Turning off of a solid bar, diameter 9.5 mm, projecting length 100 mm; f = 0.1 mm/rev; V_c = 1 m/s; h_0 = 0.00025 m; α = 5º; and E = 210 GPa

For brass: Turning off of a solid bar, diameter 8 mm, projecting length 100 mm; f = 0.05 mm/rev; V_c = 1 m/s; h_0 = 0.00050 m; α = 5º; and E = 120 Gpa

5. RESULTS AND DISCUSSION

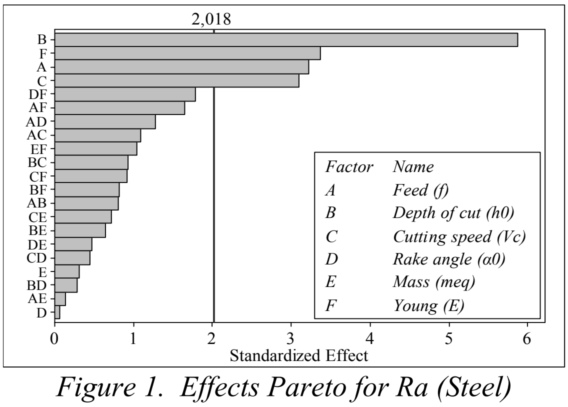

Figure 1. Effects Pareto for Ra (Steel)

For the steel, the most important factor that affects Ra is depth of cut, followed by Young´s module, feed rate and finally cutting speed (Fig. 1). Ra increases when depth of cut increases. That behaviour is similar for feed rate. For Young's module, the effect is inverse: Ra decreases when Young's module increases. For cutting speed, Ra decreases when cutting speed increases (Fig. 2). These results are in accordance with those obtained by Suresh *et al.* [3], who found that surface roughness diminishes with decreasing feed rate or with increasing cutting speed.

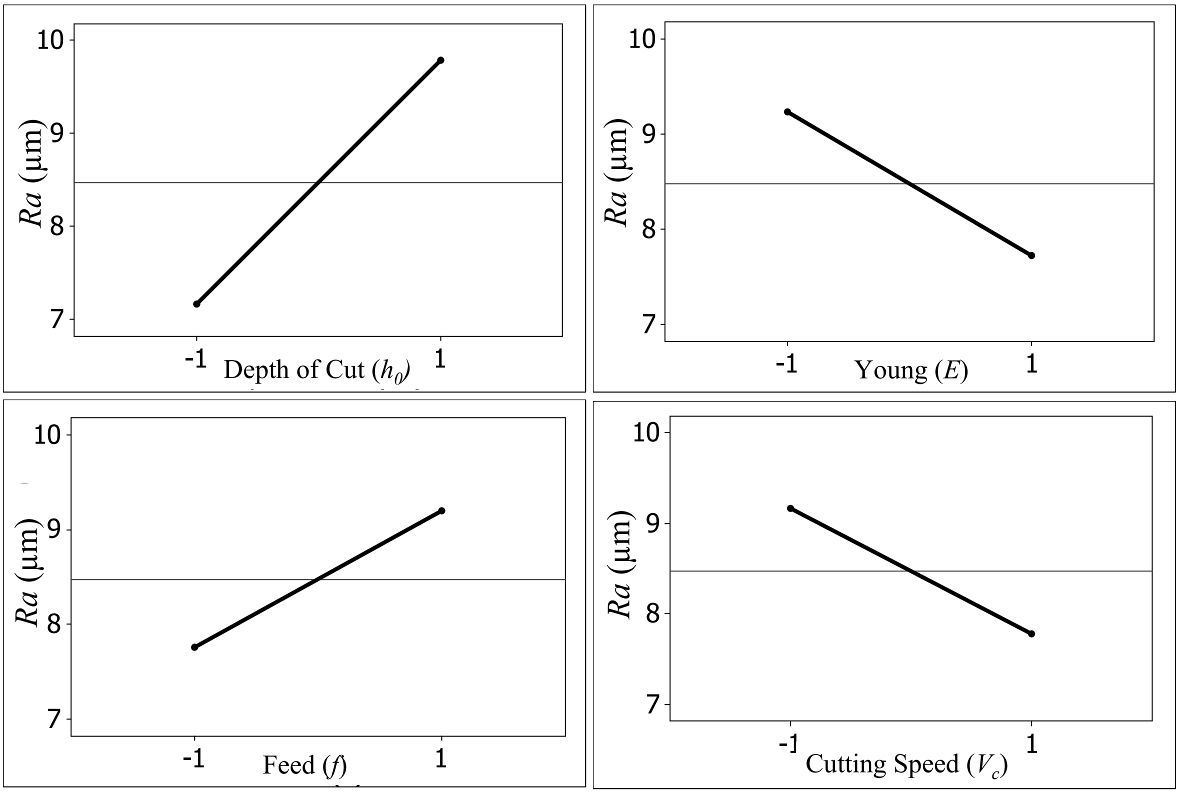

Figure 2. Main Effects Plots for Ra

The main parameters for Rt are the same as for the Ra: depth of cut, Young´s module, cutting speed and feed rate (Fig. 3). The effect of these factors on Rt has the same behaviour as the effect on Ra. There is an interaction effect between feed rate and Young´s module: if the feed rate is small, Rt decreases when Young´s module increases. The interaction effect is less significant when the feed rate has a greater value (Fig. 3).

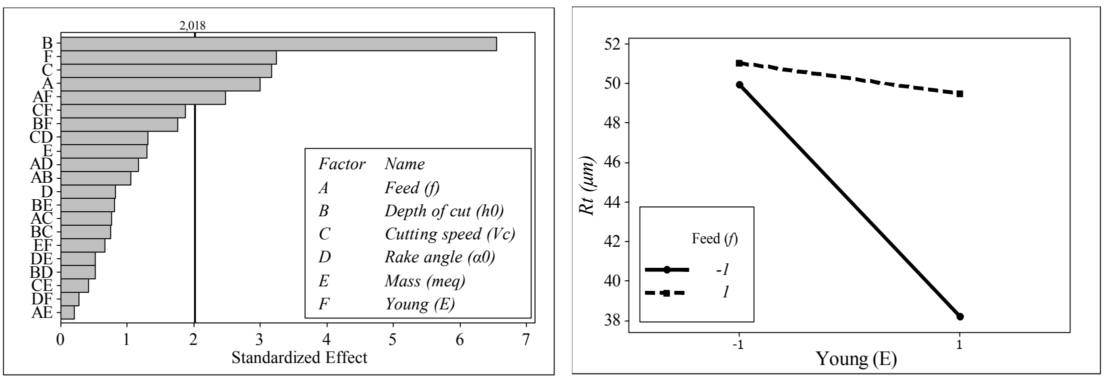

Figure 3. Pareto Chart and Interaction Plot for Rt (Steel)

For brass, the most important factor on Ra is the feed rate, followed by depth of cut, cutting speed and Young´s module (Fig. 4). The results coincide with those of Lin *et al.* [4], who determined that the most important factors for the cutting force are feed rate and depth of cut—the former having greatest affect on surface roughness. The effect of these factors on Ra has the same behaviour as for steel. There is an interaction effect between the rake angle and m_{eq} (Fig. 4): if the rake angle is small, Ra increases slowly when m_{eq} increases and if the rake angle is greater, the effect of m_{eq} is more important and Ra decreases.

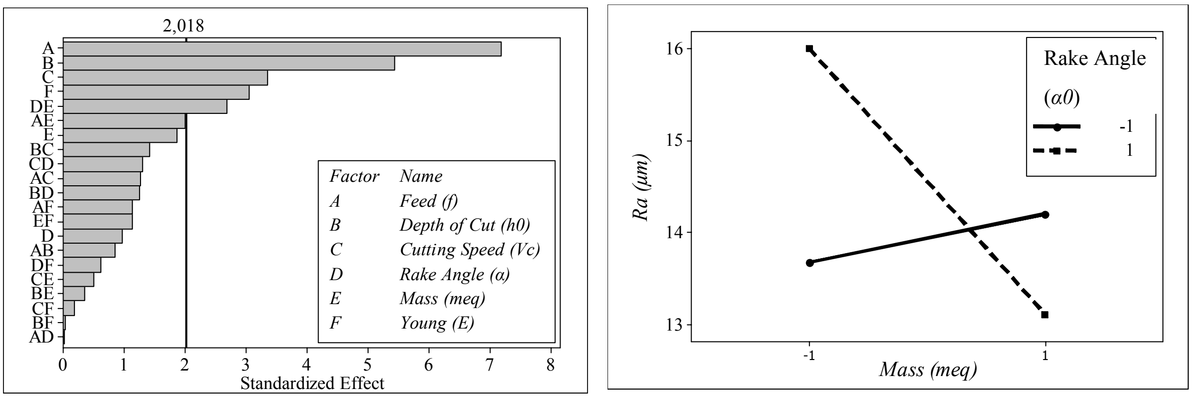

Figure 4. Pareto Chart and Interaction Plot for Ra (Brass)

Just like it happens with Ra for brass, the main factor for Rt is the feed rate (Fig. 5). Other factors that influence on Rt are Young´s module and depth of cut. There is an interaction effect between the rake angle and the m_{eq} (Fig. 5): when the rake angle has a smaller value, Rt increases when m_{eq} increases, and when the value of the rake angle is greater, Rt diminishes when m_{eq} increases.

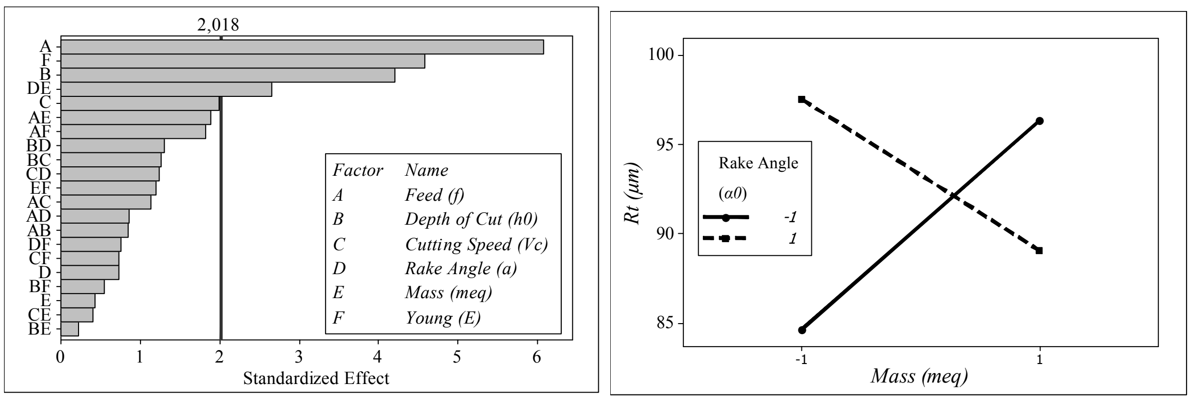

Figure 5. Pareto Chart and Interaction Plot for Rt (Brass)

6. CONCLUSIONS

From the study of the main factors it was determined that the operating conditions which have the greatest influence on surface roughness are depth of cut and feed rate, and to a far lesser extent, cutting speed.

7. REFERENCES

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