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Influence of Natural Frequency on Stability During Milling of Inconel and Udimet 500

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Abstract

Chatter in the machine tools represents one of the biggest problems due to the instability in the machining process, breakage of the tool and accelerated wear of the tool and spindle or machine components in the metal cutting processes, such as turning, milling, boring, drilling, etc. Which translates into a poor-quality surface finish, this phenomenon consists of self-excited vibrations that are produced and maintained due to shear forces, the purpose of this article is to predict the optimal points of operation in the milling process for Ni-based Inconel and make a comparison with Ni-based Udimet 500 through observation supported by a graphical and analytical tool to generate stability lobe diagrams, a code was developed in the MATLAB® software capable of generating stability lobe diagrams for the milling operation that provides optimal operating points to avoid tool vibration, thus improving chip removal rates and increasing productivity.

Keywords: Chatter, Lobe Diagram, Milling

1. Introduction

The success of machining operations depends on the dynamic relationship between the cutting tool and the workpiece [1]. Under certain circumstances, the movement of the tool against the workpiece can produce self-excited vibrations of great amplitude known as chattering. These vibrations negatively affect tool life, cutting quality and the speed at which operations can be performed. For this reason, understanding and controlling the dynamic interaction between tool and part in order to control the assembly process can lead to cost reduction and an increase in overall machining productivity. This requires the ability to predict the behavior of chattering, which allows guidelines to be established to simplify the process of selecting the appropriate machining parameters.

Regenerative vibration represents the most common self-excited mode of vibration. It occurs because most metal cutting operations involve overlapping cuts that can be a source of vibration amplification. The chip thickness and therefore the force on the cutting tool fluctuates due to the phase difference between the finish left by the anterior teeth (when turning is the surface left after the previous revolution) and the finish achieved by the current teeth [1] [2] [3].

Chatter during milling is also a major obstacle to high surface quality, as it will reduce the service life of the tool and spindle. If chatter is identified and controlled as soon as possible, damage to the workpiece can be prevented in time [4]. In production processes, this phenomenon is prevented by the selection of cutting parameters, which greatly reduces production efficiency; although analytical methods can predict the chatter and identify the most suitable parameters, the predictions are inaccurate due to complex environmental interferences and simplification errors in the cutting system model [5] [1].

For this reason, several authors have been commissioned to study this phenomenon in order to improve the milling process. Kai Yang et al. developed a new method for online chatter detection in which a simulated annealing algorithm (SA) was used to optimize the decomposition parameters of the variational mode (OVMD) and obtain subcomponents containing meaningful chatter information. They conducted a series of machining experiments to monitor the change from stable cut to chatter by machining parts with stepped and angled profiles [6]. On the other hand, Maluimov et al. analyzed the effect of directional chatter relationships on vibration experienced in the peripheral milling process. Based on the directional relationships, they proposed a geometry-based chatter stability index (CSI) to improve the chatter stability of the process [7]. Oleaga et al. proposed a strategy to side-step dataset limitations from the point of view of artificial intelligence by measuring certain parameters such as frequency function responses and analytical calculation of chatter frequency and critical depth in order to test different automatic learning techniques and identify the most accurate and economical in terms of their adjustment requirements [8].

In this work, it is sought to predict the optimal points of operation in the milling process for the alloys Inconel X, whose base is Ni-Cr and Udimet 500, whose base is Cr-Ni-Co, in order to make a comparison between these superalloys through the observation made in a graphical and analytical tool that allows the generation of stability lobe diagrams. This was done using MATLAB® software code capable of generating stability lobe diagrams for the milling operation that provides optimal operating points to prevent tool vibration, thus improving chip removal rates and increasing productivity.

2. Methodology

Plastic surface deformation (DPS) is a method of surface treatment of parts to increase their physical-mechanical qualities, specifically hardness, surface finish and compressive residual stresses taking advantage of the plasticity of metals, which increases resistance to wear, fatigue and corrosion.

There are several procedures for the use of plastic deformation as an alternative for the surface finishing of mechanical parts, being burnishing a simple, simple and easy to apply process and it is possible to apply it to different types of parts and metals.

2.1. Review of the concepts: Burnishing

Burnishing is a cold forming surface finishing process as shown in Figure 1, that involves the application of controlled pressure to a surface by means of an indenter, either a ball or roller indenter [7]. Both procedures have the same purpose, the difference being that ball burnishing is used more for flat or complex surfaces on a milling machine and roller burnishing is used to treat cylindrical surfaces on a lathe. The roller and the ball must be made of a material with a high hardness between 58 and 65 HRC [8], the pressure exerted by the indenter plastically deforms the irregularities of the treated piece, achieving a leveling of the ridges and valleys without the need to remove the material [9].

2.2. Burnishing characteristic

Burnishing stands out among the different surface finishing processes as it not only improves the roughness of the treated part considerably, between 0.05 to 0.0 but also improves its roughness to 5 µm [10], also shows some improvements in the mechanical properties of the work piece, it has been found that it increases the useful life of the pieces due to the compressive stresses applied to the surface, due to the increase in the resistance to fatigue [7], [11], resistance to corrosion [12], resistance to wear [13], surface hardness, among others, achieving these improvements depending on the process variables.

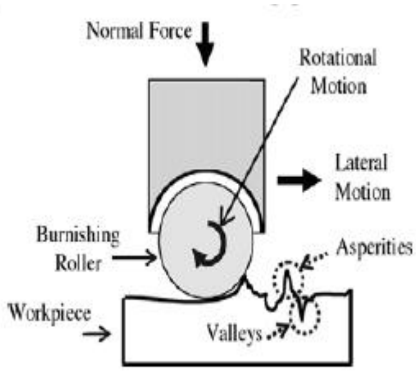

Figure 1. Burnishing process description [14]

2.3. Burnishing advantages

Burnishing stands out from other machining techniques due to its ability to increase wear resistance due to the leveling of heights and depth of the valleys on the surface to be worked. On the other hand, it also helps to remove imperfections such as porosity, fingerprints, or cracks left by the machine during the process. The burnished piece, usually has tight tolerances, surface hardening, prevents the propagation of cracks, among others.

2.4. Tool functionality test

The tests were carried out with AISI 1045 specimens, due to their wide use and utility, to form various elements in the industry. The specimen as shown in Figure 2 is 10 cm long, 7 cm wide and 1.6 cm thick.

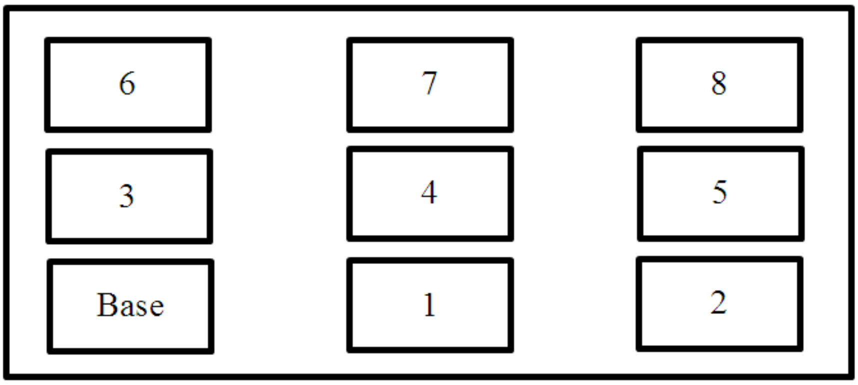

Figure 2. Distribution of zones on the surface of the specimen [15]

The dimensions of the specimen was intended to burnish 9 equal areas, ranging from the virgin area to zone 8, as shown in Figure 3.

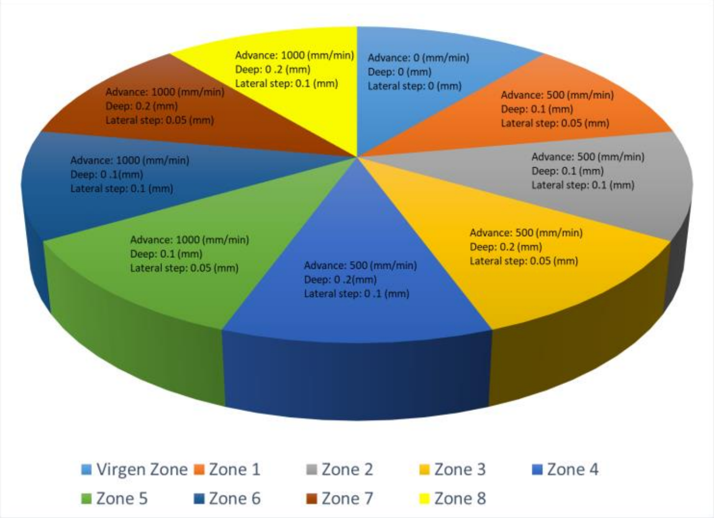

Figure 3. Buffing parameters per zone

3. Results and Discussion

In each of the areas studied, a total of 3 measurements were made to see how the *R*a, *Rq Rpk* and *Rvk* parameters influence as the 12 mm diameter indenter zones were changed. In Figure 4, it is observed that of the 3 measurements taken for the roughness parameter Ra, the highest average value is given for zone 8 with a value of 3.132, in addition to finding the highest value in zone 5 and 8 3.484.

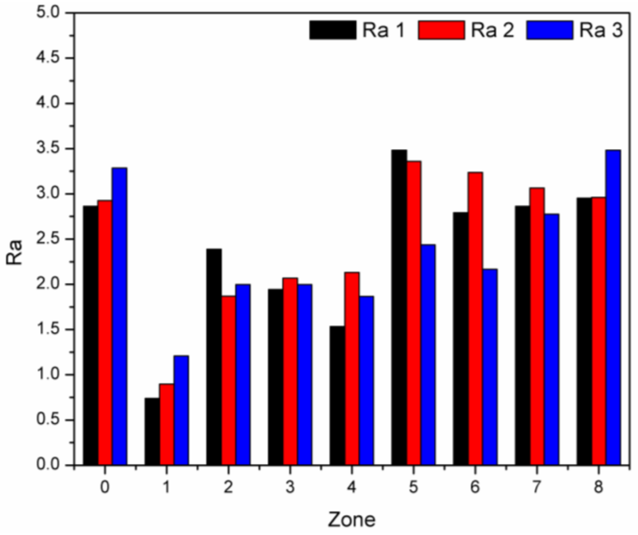

Figure 4. *Ra* values obtained for the different measurements of the different zones

The highest average value of the 3 measurements was found in zone 5 with a value of 3.904, followed by zone 8 with a value of 3.743 and ending the top with the virgin zone with 3.725, the above is shown graphically as shown in Figure 5.

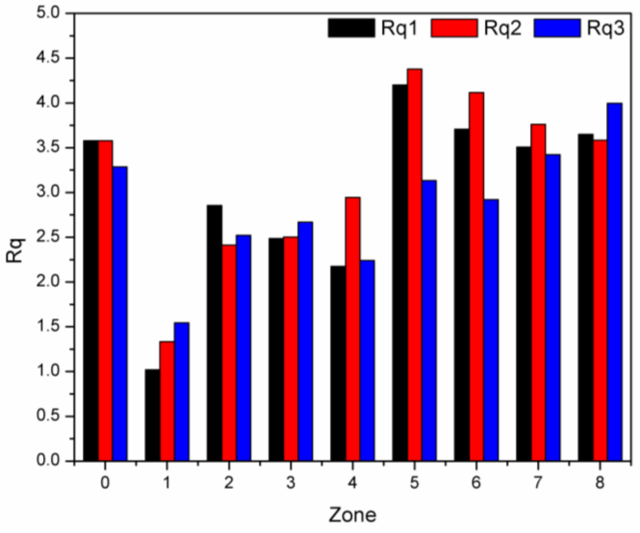

Figure 5. Values obtained from *Rq* for the different zones

Figure 6 shows that the Rpk parameter undoubtedly had a greater effect on the virgin zone than any other zone, meanwhile its next zone, 1, had the lowest average value of 1,308.

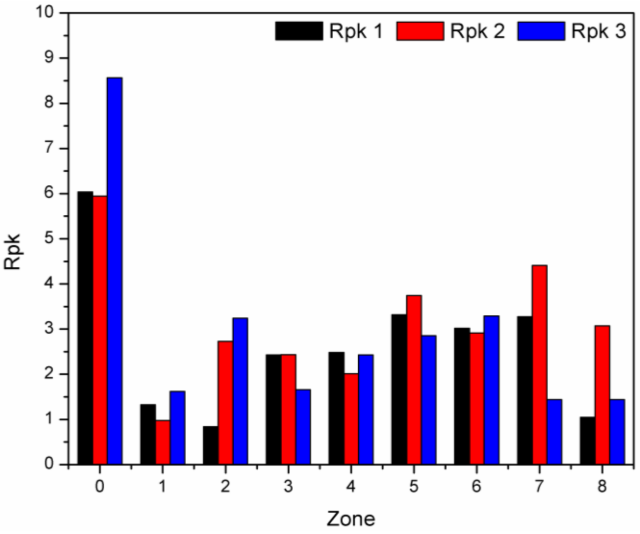

Figure 6. Values obtained from the *Rpk* study parameter for all zones

From the roughness parameters studied, the one that stood out most in terms of improvement was the Rvk factor, showing excellent measurements in the last areas studied, as shown in Figure 7. Specifically, zone 6 with an average of 8,851, however, the highest value can be seen in the first measurement of zone 4 with a value of 10,684.

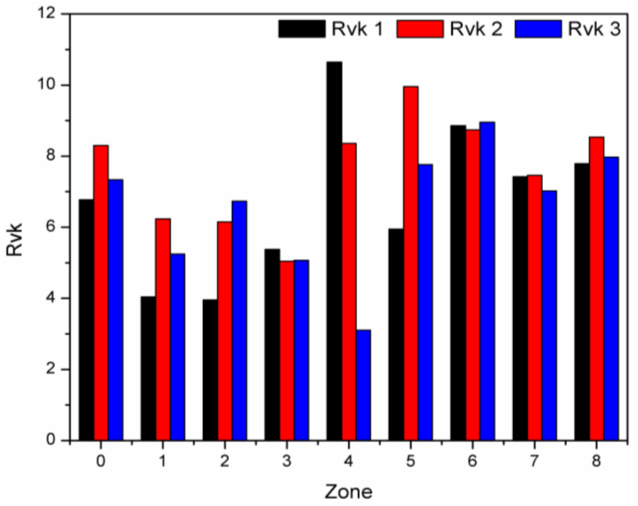

Figure 7. Values obtained from the roughness parameter *Rvk* for the different zones

4. Conclusions

Based on the conclusions obtained by the different authors, the starting point was the development of an optimal conceptual design, with which the existing characteristics were improved, offering versatility in addition to the wide field of use. To verify the properties obtained, the cutting tool was used on AISI 1045 steel specimens to improve the ratio between the reductions of the values of the surface roughness parameters. The best results were obtained in terms of reducing surface roughness when the process was executed with the 12 mm diameter spheres, 500 mm/min feed rate, 0.1 mm depth radius and 0.05 mm lateral pitch, which correspond to zone 1. Of the specimen, where an improvement of 64% and 69% was observed in the *Rpk* and *Ra* parameters respectively, in relation to the initial roughness of the specimen surface.

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