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Optimization of machining parameters to improve the surface quality

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Abstract

The preparation of quality surfaces is very important process in the surface engineering. The surface roughness will influence the quality and effectiveness of the subsequent coatings for protection against corrosion, wear resistance and finishes quality of decorative layers. For these reasons, the authors of the present work have focused in manufacturing parameters that influence the surface quality of hardness metallic materials. In this work, the effects of varying four parameters in the milling process, namely cutting speed, feed rate, radial depth and axial depth. The influence of these parameters on the surface roughness are analyzed individually and also the interaction between some of them for the milling machining of hardened Steel (steel 1.2738), being used the Taguchi optimization method. For this purposed was built a L16 orthogonal array and for each parameter were defined two different levels, corresponding to sixteen experimental tests. From these tests were retrieved sixteen surface roughness measurements The influence of each parameter in surface roughness were then obtained by applying the analysis of variance (ANOVA) to experimental data. It is noted that the minimum roughness measured was 1.05µm. This study also serve to determined the contribution of each machining parameters and their interaction for surface roughness. The results show that the radial cutting depth and the interaction between the radial and axial depth of cut are the most revelevant parameters, being their contributions for the minimization surface roughness about 30% and 24%, respectively.

Keywords: surface engineering; surface roughness; machining parameters; optimization; Taguchi method

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1. Introduction

The roughness level on surface finishing has a crucial role in the efficiency and quality of subsequent surface coatings, Thomas (2014). From many processes used to prepare the surfaces, the machining is the most used and allow low levels of surface roughness, Benardos and Vosniakos (2003), which can reach values down-to 50 nm for optical applications, Guenther *et al.* (1984). The economic factors have a strong impact in today's machining processes demanding a higher productivity, flexibility of the production systems, reduction of costs and obtaining manufactured parts with better surface and dimensional quality, Besseris (2008).

Most of the industries use different machining techniques, namely drilling, turning, milling, among others, as well as, the combination of these techniques. However, the efficiency is not the same for all machining techniques, i. e. to obtain the same part there is a more suitable machining technique that allows a better quality for the machining time and a lower power consumption. The best technique depends on the goal to be achieved. Today, the most widely used machining process in the industry is milling due to its high flexibility, especially if it is associated with the numerical control. Several studies focus have on the milling process to optimized the quality of the finishing surface and time production time Shivade (2014), Ghani (2004) and Zhang (2007). However, one issue that arises often is how these new technologies evolved in the industry. In this context, adequate planning of experiences is presented as one of the ways to achieve the competitiveness characteristics or critical factors. The use of the scientific method in the implementation of experimental projects is associated with the foundations of modern statistical, theoretical and experimental, which began in the 20th century and is largely due to Ronald Fisher (1925) and (1935). The first practical application of Design of Experiments (DOE) was in British Textile in 1930, Box (1978). From the relevant contributions of Fisher, many experimental designs were developed for the most varied situations, including in machining processes, Yih-Fong (2006) and Chang and Kuo (2007).

According to the machining goal and the choice of a cutting tool, there are different combinations of parameters, mainly cutting speed, feed rate, axial or radial cut depth, when combined can lead to a very distinctive results in terms of machined surface quality and tool wear. However, it is very difficult to define the best combination that provides a lower roughness value and, at same time, maximizing the tool life. In addition, it is essential to reduce costs without reducing the quality of results. The quality of the machined surface is normally evaluated by measuring surface roughness, which is a fundamental characteristic of the surface quality. Typically, the surface roughness is obtained experimentally, being also possible, according to some researchers, be predicted by means of mathematical algorithms, Suresh *et al.* (2003), Sing and Rao (2007), although, these studies are very consuming process and expensive. To obtain the best combination of parameters it is necessary to test a large number of combinations, which is impractical for the industry. Optimization techniques are an interesting solution to minimize the number of combinations of experimental tests.

In the last decades, many optimization techniques have been developed for machining, Aggarwal and Singh (2005), being the most used fuzzy logic, Palanikumar *et al.* (2006), genetic algorithms, Wang and Jawahi (2004), Taguchi method, Yang and Tarng (1998), grey relational analysis, Tzenga *et al.* (2009), and the surface response method Myers and Montgomery (1995). In this work was implemented the Taguchi method for the minimization of surface roughness in milling operation.

The Taguchi method, Ross (1996), is based on the statistical design of experimental tests that can economically satisfy the process for optimizing the manufacture of a part. One of the advantages of this method is that several factors are considered at once, including the noise factors. This method is a powerful tool, but needs to be combined with other statistical tools, such as analysis of variance (ANOVA), principal component analysis (PCA), Moshat *et al.* (2010) or relational analysis, Lin (2004) to extend the results of the Taguchi.

Some authors have studied the machining process by associating the Taguchi method, Nalbant *et al.* (2007), Hasçahk and Çaydas (2008), Ribeiro *et al.* (2017), to optimize the most common controllable parameters like cutting speed, feed rate and depth of cutting. The goal on all these works is to reduce surface roughness by applying the Taguchi-based method and determine the machining parameters which have the most important contribution for the surface finishing. However, there are some parameters that weren't accounted, such as temperature, vibrations and tool wear.