Chapter 18
Predictive Modeling and Optimization of Cutting Forces Through RSM and Taguchi Techniques in the Turning of ASTM B574 (Hastelloy C–22)

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ABSTRACT

In this chapter, the impact of cutting parameters (depth of cut, cutting speed, feed, flow, rake angle, lead angle) on cutting forces in the turning process with regard to ASTM B574 (Hastelloy C-22) material has been investigated. Variance analysis has been applied in order to determine the factors affecting the cutting forces. The optimization of the parameters affecting the surface roughness has been obtained using response surface methodology (RSM) based on the Taguchi orthogonal experimental design. The accuracy of the developed models required for the estimation of the force values (Fx, Fy, Fz) is quite successful. In this study, where the R2 value has been used as the criterion/measure, accuracy values of 93.35%, 95.03%, and 95.09% have been achieved for Fx, Fy, and Fz, respectively. As a result of the ANOVA analysis, the most effective parameters for Fx at a 95% confidence interval are depth of cut, feed rate, flow, and rake angle. The most effective parameter for Fy is depth of cut, while the most effective parameters for Fz are depth of cut, feed rate, and flow, respectively.

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INTRODUCTION

Cutting forces affecting cutting tools constitute an important step in terms of metal removal as part of the machining process. Cutting forces are one of the main parameters to be considered in designing and manufacturing cutting tools and auxiliary equipment. Cutting forces vary depending on parameters such as cutting speed, rake angle, depth-of-cut, feed rate and the material of the piece being worked. In order to determine the production cost of a part in the machining processes, the impact of cutting parameters on cutting forces needs to be known. Processes such as determining the required power and accurate sizing of the tool/machine can be realized with a knowledge of the cutting forces. In addition, in order for machines to be long lasting and in order to increase production quality, stresses caused by the effects of forces and strain should be well analysed (Gok, 2015).

In machining, the aim is to reach the maximum high-quality production volume at the lowest cost. Surface roughness and machining time in turning operation are the most important parameters for the product quality. The main purpose is to minimize the surface roughness and the machining time. There are many factors that affect the surface roughness. The basic idea of our work is to investigate the cutting forces and other affecting factors which are very effective on surface roughness. Basically, when the cutting force increases, the amount of vibration of the lathe rises. The increase in vibration causes surface roughness, which is undesirable. Reduction of surface roughness can be achieved by minimizing the cutting forces. Such minimization depends on optimizing the cutting parameters. In recent years, intensive studies have been carried out in academic and commercial fields on parameter optimization in machining.

Brief information about some of the studies that have examined the influence of cutting parameters on cutting forces in the literature are as follows: Abou-El-Hossein et al. (2007) have carried out an experimental study to estimate the forces that occur during the processing of AISI P20 steel. As a result of ANOVA analysis, it would appear that the most effective parameters in terms of cutting force are depth-of-cut and feed. In order to achieve minimum cutting force, Zhao et al. (2008) have optimized the combinations of rotation speed and feed rate in machining by using the particle swarm optimization (PSO) method. Wang et al. (2008) has investigated the effect of the cutting parameters of high heat-resistant F91 steel on cutting forces, and he has developed an exponential function for strength estimation. As a result of such optimization, it is emphasized that low force/strength values cause higher material removal rates and lower tool wear. Lalwani et al. (2008) have investigated the effect of cutting parameters on surface roughness and cutting forces using RSM and sequential approach. As a result, linear and quadratic models have been developed to explain the relation between the parameters. Aggarwal et al. (2008) have optimized surface roughness, cutting force, tool life and power consumption by using liquid nitrogen in the machining of AISI P-20 tool steel. They used the RSM for the experiments. Bouacha et al. (2010) have investigated the change of tool wear and cutting forces against the change of cutting speed and workpiece hardness by turning AISI 52100 steel (at 64 HRC hardness) using a CBN (cubic boron nitride) tool. They studied the effects of the cutting parameters on each other using ANOVA analysis. They determined that the important parameters affecting surface roughness are cutting speed and feed rate. Basmaci (2012) has examined the effects of MQL and dry conditions on Hastelloy C-22. Devillez et al. (2007) have investigated the impact of dry turning on surface integrity and they have investigated