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Model for surface topography prediction in peripheral milling considering tool vibration

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ABSTRACT

This paper presents a model for the prediction of surface topography in peripheral milling operations taking into account that the tool vibrates during the cutting process. The model includes the effect of tool vibrations in the equations of the cutting edge paths, which are transformed into equivalent polynomial equations and solved for discrete positions along the feed direction by applying a standard root finder. Through this procedure, surface topography generation is simplified with respect to other models in literature. The model allows the topography, the roughness values and the form errors of the milled surface to be predicted. Cutting test results show good agreement with model predictions.

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1. Introduction

Peripheral milling is a machining operation extensively employed in industry. Due to the increase in quality requirements of machined surfaces, the development of models for the prediction of surface topography in peripheral milling has attracted the attention of different researchers in recent years. One of the factors that has the most influence on the milled surface and can deteriorate surface quality, is the presence of tool vibrations during the cutting process. In literature, the effect of cutting process dynamics has been considered in the prediction of milled surface topography. In 1991, Montgomery and Altintas [1] considered the influence of milling dynamics on surface generation. Later, in Refs. [2–4], the effects of variable pitch end mills and run out, as well as vibrations, were included in order to predict dimensional surface errors and marks left by the tool on the milled surface due to feed and vibrations. In 1993, Ismail et al. [5] presented a surface generation model including the effects of tool run out, vibration and flank wear. Heisel and Milberg [6] presented a method for the identification of vibration from the analysis of marks on the milled surface. An analysis of surfaces generated by a flat end mill in micro-milling, explaining size effects, is presented in Ref. [7]. Recently, efforts to develop geometrical models for the prediction of surface topography including tool vibrations have been made. In Refs. [8,9], a geometric model of the machined surface is developed and used to predict its appearance and roughness by considering the sweep volume of the cutting edges along their paths and subtracting them from the workpiece. In Ref. [10], a method for simulating the surface topography based on measured tool displacements in peripheral milling is proposed.

In this paper, a model for the prediction of surface topography in peripheral milling taking into account tool vibrations is developed. First, in order to include tool vibrations in the model, they are expressed as a function of the rotation angle. Later, the equations describing cutting edge paths and accounting for tool vibrations are derived. Next the procedure developed for surface topography generation is proposed. This procedure simplifies surface topography generation with respect to other models in literature. Finally, the model is validated by comparing the surface topographies predicted by the model with the experimental ones.

2. Surface generation model

In this section a model for the prediction of surface topography in peripheral milling accounting for tool vibrations (Fig. 1) is presented. The model proposed in this paper is developed for both up- and down-milling. It is assumed that the workpiece is rigid.

2.1. Tool vibrations

The model incorporates the effect of tool vibrations on the surface topography in peripheral milling. In this paper, tool vibrations used to simulate the surface topography are obtained by measuring tool displacements at the shank during the cutting process and hence, the position of the tool centre point (TCP) is obtained. Modern machine tools are equipped with sensors to register cutting forces, vibration, etc. Making use of these data by the developed model, the surface topography generated in the workpiece can be predicted. The model also allows the topography prediction using TCP positions determined by modelling the cutting process dynamics. In both cases, the position of TCP given

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