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A high-precision constant wire tension control system for improving workpiece surface quality and geometric accuracy in WEDM

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Abstract: In wire electrical discharge machining (WEDM), there are inevitable phenomena of wire deflection and vibration because wire electrode is slender and flexible, and these phenomena are closely related to workpiece surface quality and geometric accuracy. Besides, the phenomena of wire deflection and vibration have a direct relationship with wire tension. In this paper, a high-precision constant wire tension control system is built to restrain wire deflection and vibration so as to improve workpiece surface quality and geometric precision. Firstly, the factors resulting in wire tension fluctuation are briefly introduced. Additionally, the constant wire tension control system is designed on the basis of the structure improvements of wire winding system and closed-loop control. And then, the high-precision transfer function of this control system is deduced by the method of system identification, and three intelligent algorithms are utilized to tune the parameters of PID controller. Next, the wire tension control experiment and cutting experiment are carried out to evaluate the performance of this control system. Experiment data indicate that this control system has good ability of controlling wire tension without obvious overshoot. In addition, it is proved that this control system can obviously improve workpiece surface quality and geometric error, such as surface topography, cutting kerf width, corner error and taper cutting error. This proposed constant wire tension control system is worthy of popularization and application in practical manufacturing field.

Keywords: WEDM; Constant wire tension control system; Workpiece surface quality; Geometric accuracy

1 Introduction

Except for with the ability of machining any conductive materials regardless of hardness, WEDM can also manufacture many workpieces with complex shape, such as mold cavity, tapered face, narrow slit and small deep hole. Hence, WEDM plays more and more important role in mould, instrument, automobile, aerospace and other high-end manufacturing industries [1]. Different with electrical discharge machining (EDM), the electrode of WEDM is a slender and flexible wire. In machining process, the wire electrode is subjected to several forces, such as discharge exploding force, electrostatic force, uneven thermal stress, electromagnetic force and dielectric damping force. Then, the phenomena of wire deflection and vibration inevitably occur which significantly influence the workpiece surface quality and geometric accuracy [2][3]. As described in previous researches [4][5][6][7], the amplitudes of wire deflection and vibration are of the order of a few tens to a few hundred microns. Besides, the phenomena of wire deflection and vibration have a closely relation to wire tension, and there is interaction between wire vibration and wire tension. Hence, precisely controlling wire tension is an effective way to restrain wire deflection and vibration so as to improve the workpiece surface quality and geometric accuracy.

Recently, several constant wire tension control systems were designed for controlling wire tension and increasing the geometric precision of workpiece. Wang et al. [8] utilized a gravity takeup for maintaining constant wire tension in micro reciprocated wire-EDM. But, this system was an open-loop control system. Li et al. [9] and Shi et al. [10][11] focused on controlling wire tension by a adjusting wheel in high-speed WEDM, and a simulation system of wire tension was established on the basis of mathematical model and the LabVIEW software. Han et al. [12] and Yongcheng et al. [13] added swing roll and adjusting rod to suppress the fluctuation of wire tension, respectively. Li et al. [14] changed the vertical height of tension adjusting slider for reducing the wire tension variation, and the