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Diameter Error Prediction Using Fuzzy Logic for Cast Nylon 6 Turning Operation

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Abstract

A prediction model using fuzzy logic system for cast nylon 6 turning work piece diameter error forecasting was developed. The cutting parameters consisting of feed rate, depth of cut and cutting speed were determined as input variable of 75 fuzzy rules of input membership function. The diameter error values from 11 levels of fuzzy rules of output membership function were arranged as prediction outputs. Turning was carried out at 3 levels of turning speed and 5 levels feed rate then depths of cut were accomplished. Both experimental and predicted work piece diameter errors were used for validation. After that factors affecting on diameter error, precision and accuracy of the prediction values were statistically analyzed. The experimental results revealed that length of work piece and cutting speed did not effect on diameter error. However, depth of cut and feed rate affected on diameter error with total causal effect values at 0.6553 and 0.3085, respectively. Prediction of diameter error by the developed fuzzy system has an average absolute error at 0.535 μm and R^2 at 0.988 compared with the experimental data. The precision of prediction was not significantly different from the experimental data at 95% of confidence interval. Therefore, the developed fuzzy system can predict diameter error in turning operation with high accuracy and precision.

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Keywords: Cast Nylon 6; Diameter Error; Fuzzy Logic; Prediction

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1. Introduction

Generally, quality of the machined part is evaluated based on dimensional accuracy and quality of finished surface. The dimensional accuracy are considered by measurement of the size (length, height, width and diameter). The geometric properties such as straightness, angularity, cylindricity and circularity are used for evaluation of dimensional accuracy. The dimensional error, a difference between actual size dimension and designed size dimension is used for validation of the level of the size dimension accuracy. Furthermore, various errors during machining operation may effect to dimensional error of the machined workpiece for example machine tool movement errors, machine tool structural error and cutting force-induced error (Xiaoli L. and Du R., 2002). The machine tool movement errors cause by the dynamics of the driving system, clearance of power transmission system and wear of machine tool guide way. The machine tool structural errors result in thermal expansion errors and geometric errors. Whereas, the cutting force-induced errors affect to machine tool deflection, cutter deflection, workpiece deflection, thermal expansion, tool wear and chatter. Machinability also effects to dimensional error of a workpiece which is machined on the lathe (Liu Z.Q., 2000). The variables affects to machinability are machine tool variables, cutting tool variables, cutting condition variable, workpiece material variable and extra variables (LEE M. and LEE C., 2011). The machine tool variables consist of accuracy of machine, machine power, and machine structure stiffness, etc. The cutting tool variables are considered in tool material, tool shape, contact characteristics in tool and workpieces, etc. The cutting condition variables are cutting speed, feed rate and depth of cut. The work material variables are chemical composition, shape and size of workpiece, strength, hardness, etc. The extra variables are cooling lubrication and thermal effect, etc.

Previously, geometric and dimensional error are concerned based on the deformation and other mechanical properties of a workpiece (Liu Z.Q., 2000) (Eyüp S.T. and C Ç., 2005) (LEE M. and LEE C., 2011). Whereas, the deformation of a workpiece depends on material properties. The cast nylon 6 polymer are high modulus, thermal and fatigue resistance and it is used as a main material for several mechanical parts such as large rollers, gears, bushings and bearings. Prediction of the machined diameter error is required to be made in advance in order to achieve high accuracy of workpiece dimension. However, the prediction diameter error of cast nylon 6 cannot easily predict on the shop floor. Therefore, a new prediction method based on cutting conditions is necessary for machining operation. Thus, this work presents a prediction model for a diameter error in cast nylon 6 turning operation using fuzzy system.

2. Diameter Error Model

2.1. Diameter Error Definition

In this paper, the diameter error was defined as deviations of the actual diameter on a circular contour along the cylindrical turning operation. The simple inspection method used the micrometer to verify the diameter deviations of the cylindrical workpieces. These deviations are caused by various error sources such as geometric, machine motion, thermal, cutting force, cutting tool material, and tool life.

2.2. Dimensional Error Model and Analysis in Machining

Lui Z.Q. (2000) applied the finite different method for calculating the deformations of multi-diameter workpieces during turning by using the cantilever beam and two fixed supports mathematical analysis. Based on the results of calculation, a modified correction method to compensate for the deflections is presented for turning operations.