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Optical Measurement of Tool Wear Parameters: Leveraging Machine Vision

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Abstract

Tool wears directly affect the quality of product and service life of tool. This paper proposes a machine vision-based measurement method for chisel edge wear of drills. Firstly, the full contour of a drill is extracted by local variance threshold segmentation. Secondly, the image is enhanced by using an adaptive contrast enhancement algorithm based on bidimensional local mean decomposition (BLMD). A threshold segmentation method is proposed to extract contour of the non-worn area. A new approach of inline automatic calibration of a pixel is proposed in this work. The captured images of carbide inserts are processed, and the segmented tool wear zone has been obtained by image processing. The vision system extracts tool wear parameters such as average tool wear width, tool wear area, and tool wear perimeter. The results of the average tool wear width obtained from the vision system are experimentally validated with those obtained from the digital microscope.

Keywords: Optical measurement; Tool wear parameters; Leveraging machine vision; Bidimensional local mean decomposition

Introduction

During the machining process, the tool has a direct influence on the machining quality of products. The good condition of the tool can make the processing efficient, high-yield and high-quality. In addition, it directly reduces processing costs and significantly improves the profit and competitiveness of manufacturing companies. Thus, the measurement of tool wear plays a vital role in product quality control during the manufacturing process [1].

Measurement of tool wear is extremely important to predict the useful life of tool inserts. This will be helpful to monitor and to study the effects of the tool wear on quality of machined work piece and economy of manufacturing process. There are two main methods to measure tool wear: indirect and direct methods. In the indirect method, tool wear is estimated with the signals coming from different types of sensors such as surface texture of machined workpiece, acoustics, vibration, feed forces, and current consumption. The tool wear prediction model is prepared based on the magnitude of collected signals [2]. Other method for the measurement of tool wear is the direct measurement over the tool wear zone. There are two main tool wear types: flank wear and crater wear. The flank wear is widely used to quantify the severity of tool wear. Characteristics of qualitative and quantitative morphology of tool wear are of great concern for researchers nowadays. More morphological features other than commonly considered parameter, i.e., average tool wear width, are required for better evaluation of the actual condition of tool which can affect machining process and quality of machined workpieces.

Tool wear generally results in loss in dimensional accuracy of finished products, possible damage to workpiece, and decrease in surface integrity and amplification of chatter. Detailed review for the tool condition monitoring indicates that the machine vision system can be extremely useful for the direct measurement of various types of tool wear [3]. Some statistical approaches are also useful in conjunction with machine vision system to find tool wear. Some researchers developed their own algorithm for the edge detection and segmentation of tool zone. White light interferometry and stereo vision technique are used for the measurement of volumetric wear in crater as well as flank wear region [4].

Some assumptions are also made to quantify the volume of wear region approximately. The wear at the tool nose was measured by assuming the part of cutting edge as a disk of radius equal to a tool nose radius [5]. Various geometrical parameters are determined for flank wear region by standardizing the wear region as an ellipse. Researchers suggested various tool wear parameters such as maximum wear land width, wear land area, wear land perimeter and compactness, length of major axis, length of minor axis, eccentricity, orientation, equivalent diameter, solidity and extent, end wear length, and nose radius and flank wear width.

A machine vision method for tool wear measurement based on image multi-scale decomposition method is proposed in this study [6]. Bidimensional local mean decomposition is employed to achieve adaptive contrast enhancement and extract the wear area of tool. The main contributions of this research are as follows: (1) The entire tool contour is extracted adaptively through local threshold segmentation and morphological filtering; (2) The tool wear image is decomposed into high-frequency and low-frequency components using BLMD to adaptively enhance the contour of tool wear; (3) The adaptive contrast enhancement is finished by enhancing the high-frequency components in the tool image. This increases the gray level difference of each area in the image of worn tool [7, 8]. The test results of the chisel edge wear on a drilling tool verify effectiveness of the proposed method. The proposed method presents better measurement performance than that of other typical measurement methods [9].

Tool wear measurement method

Firstly, the tool contour is extracted by local variance threshold

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segmentation and morphological filters. Secondly, the BLMD is used to decompose the tool image into high-frequency and low-frequency components. Then the contrast enhancement is finished on the refactored tool image after adaptively enhancing the high-frequency part [10].

Conclusion

The inline automatic calibration system was successfully implemented for the measurement of tool wear parameters. With this calibration system, there is no need for separate calibration of the vision system. The measurements of an average tool wear width with the present vision system are found to be in close agreement with that with the digital microscope. The average absolute error in measuring average tool wear width for all the twelve inserts was found to be 3.08%. Average wear width, wear area, and wear perimeter were seen increasing with the machining time. The scanning electron micrographs indicate severe abrasion marks and damage to the cutting edge in the case of higher machining time.

According to the gray distribution characteristics of the tool images, a machine vision-based tool wear measurement method is proposed in this study. The tool image is locally enhanced by BLMD and adaptive contrast enhancement. The tool wear is evaluated by calculating and measuring the wear area finally. The experimental results show that the proposed method can effectively measure the chisel wear area of the drill. The comparison results also show that the performance of the proposed method.

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