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Evaluation of form error at semi-spherical tools by use of image processing

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Abstract

In this study, a method is proposed for dimensional measurements of semi-spherical parts for the standard tool electrodes used in Electrical Discharge Machining (EDM). The tool electrode to be measured is magnified by a profile projector. Pictures of some equatorial plane projections of the electrodes are captured by a digital camera before and after machining. The pictures were calibrated with the geometric camera calibration. Then, the profiles are extracted from their background using the adaptive threshold, which is an image processing method. 2D coordinates are first obtained and then converted to 3D coordinates. Using the obtained data, sphericity and radius are calculated by means of the minimum zone method. It is seen that the proposed method can be used for determining the EDM tool electrodes' form error.

Keywords: Sphericity; Form error; Minimum zone method; Adaptive threshold; Geometric camera calibration; EDM

1. Introduction

Due to the form errors occurred while spherical components are manufactured and used, the problem of evaluating deviations from spherical form is frequently encountered in engineering applications like standard EDM (Electrical Discharge Machining) tool electrodes. EDM is a production method with which it is possible to machine hard material into complicated shape with accurate dimension. The traditional die sinking EDM uses the preshaped tool electrode to generate an inverted image of the tool on the workpiece and has certain disadvantages. Producing the 3D shaped tool is expensive. Often three male tools are needed called rough, semi-finish and finish and these can be quickly worn. Furthermore, the tool and workpiece gap configuration often results in flushing difficulties; short circuit damage and high relative electrode wear. To increase the flexibility and expand the application areas of EDM machining, a new technology named Contour or CNC EDM milling emerged in 1980s. Different from conventional EDM machining in which a formed electrode is

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used, this method applies a standard cylinder or ball ended cylinder as the tool electrode [1,2]. Nowadays, researchers have investigated that the cylindrical or semi-spherical tool electrodes can be used in EDM without making male tool electrode necessary to yield a part of the desired shape [2–4]. Many methods for determining the tool wear have been developed and proposed in the literature [3,5].

Because the ball ended cylindrical tool electrode is used in EDM, sphericity need to be defined initially. ISO 3290 defines the deviation from spherical form as the greatest radial distance in any radial plane between a sphere circumscribing the ball surface and any point on the ball surface [6,7]. These radial planes and magnitude of the deviation are called, respectively, equatorial planes and sphericity. Sphericity is usually measured by numerical evaluation of ball profile in two or three equatorial plane at 90° to each other [7].

Measurement of all of the points on a spherical surface is costly and time consuming [8]. So, it is more practical to obtain information about surface by assessing the locally measured data on a spherical surface. The local measurements must be taken with high accuracy and obtained data are carefully assessed. There are several measurement systems to obtain the data. One of these systems is the coordinate measuring machine (CMM) which is used to obtain 3D coordinates. To calculate sphericity, several algorithms can be applied to 3D coordinate data obtained from spherical surface by CMM [8]. In another measurement system, a cross-sectional profile on an equatorial plane is measured using a roundness measuring system with stylus used to measure rotating specimen [9]. Also, noncontact measuring systems are developed to use the measured object itself as a reference eliminating spindle errors, such as three point method and laser measuring systems [10,11].

Due to both inevitable errors and the tolerances in manufacturing techniques, it is not possible to manufacture a perfect sphere by any production method. Therefore, it is aimed to find out the two concentric geometrical spheres which circumscribe and inscribe to the produced sphere and also, the radial distance between these two concentric geometrical spheres must be at the smallest possible value. The radial distance to be defined as geometric tolerances is called sphericity.

In this study, a practical method is proposed for measurement of spherical tool electrodes used in EDM. Different equatorial planes on the sphere surface are magnified with a profile projector. Then, pictures of these profiles are captured by using a digital camera and calibrated. The profiles are extracted from their background using adaptive threshold. The coordinates are obtained from the edge of the profile and converted from 2D to 3D. Finally, sphericity is calculated by means of a developed computer program.

2. Experimental details

The EDM machine used in experiments has a maximum current output of 25 A. Ball ended cylindrical tool electrodes are electrolytic pure copper and the workpiece specimens are C1345 steel. The tool electrode radii and machining parameters are determined by considering values to be encountered in standard tool electrodes in EDM as shown in Fig. 1. The samples have a cylindrical portion 2 mm long as a reference value for measurements. The diameters of tool electrodes were chosen to be 5, 10 or 15 mm and the power level of 220, 413 W, spark time (t_s)/pause time (t_p) of 26/10, 400/50 μs. The experiments were made for all combinations of radii and machining parameters. And, each experiment was repeated three times successfully by using same parameters. In each experiment, the

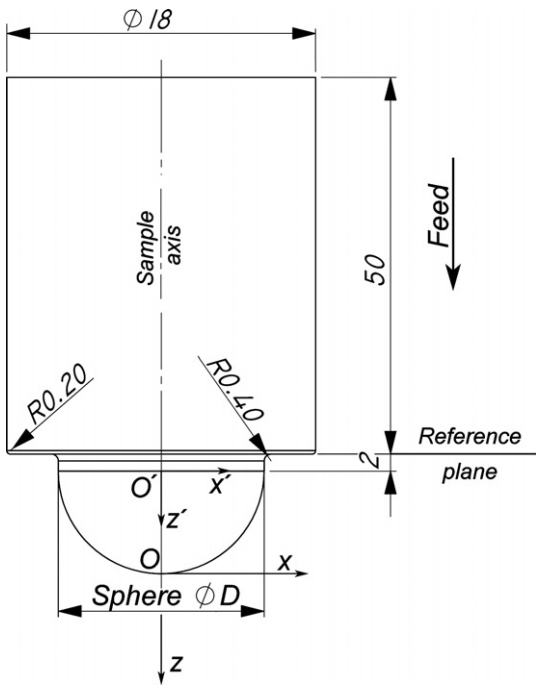

Fig. 1. The tool electrode ($D = 5$, 10 or 15 mm).