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International Journal of Machine Tools & Manufacture 45 (2005) 941–948
INTERNATIONAL JOURNAL OF MACHINE TOOLS & MANUFACTURE DESIGN, RESEARCH AND APPLICATION
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Parametric curve machining of a CNC milling EDM

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Received 9 August 2004; accepted 20 October 2004
Available online 9 December 2004

Abstract

A buffered digital differential analyzer (BDDA) algorithm in a computerized numerical controller (CNC) performs milling electric discharge machining (milling EDM'ing) of a curve constructed from a sequence of segments using a traditional computer-aided manufacturing (CAM) system. The proposed algorithm interpolates more than one segment in a sampling interval and supports the effective machining of a parametric curve when the electrode crosses the connection between the short segments. The accuracy of both the speed and the trajectory of motion can be ensured without the time function of the parameter specified by two terms of a Taylor expansion, such as in a real-time parametric curve interpolator. The proposed algorithm is compared with the reference–word interpolation and real-time polynomial interpolation used in a milling EDM to confirm improvements of erosion speed.

Keywords: Milling EDM; Gap control; Parametric curve; CNC; Command control; Digital differential analyzers; Buffer storage; Interpolation; Computer architecture; Machining

1. Introduction

The milling electrical discharge machine (Milling EDM) evolved from the computerized numerical controlled (CNC) contouring EDM [1–4]. A rotating cylindrical tool electrode follows a programmed path to yield a part of the desired shape, like a cutter used in conventional computerized numerical controlled (CNC) milling. Most erosion occurs at the bottom of the electrode, many works address the compensation of the electrode during milling EDM'ing [5–7]. The vertical position of the electrode should be compensated for according to the discharge parameters and the distance moved in the horizontal direction. The speed in the horizontal direction should be set to a very low value to prevent the electrode from contacting the workpiece, because generating conducting carbon and metal particles in the gap quickly and stochastically change the gap length. Only a few works have addressed the improvement in rate of erosion when the horizontal speed varies with the gap.

When the electrode moves along the horizontal segments that are generated using computer-aided manufacturing (CAM) software, the gap controller regulates the speed of the interpolator in a CNC according to the fed back discharge voltage, as is done in the vertical direction in a die-sinking EDM. However, many segments are required to reduce the cord error of the segmental contour.

In milling EDM'ing, the actual forward and withdrawal speeds fall when the electrode crosses the connection between pairs of the segments. As in milling by cutting metal, the actual speed during the final interpolation of a segment is also less than the prescribed value [8,9]. The highly required forward speed reduces the idle time of the discharge pulses. The required high withdrawal speed avoids pollution and arcing in the gap. The discharge performance falls when the speed does not reach the value obtained using the gap controller, because of discharge termination and arcing in the gap.

The interpolator, defined parametrically, employed to generate positional commands, is installed in the CNC to reduce the number of segments. A real-time interpolator depends only on the first two derivatives of the Taylor's expansion [8–10]. The use of the discrete form of the parameter that is governed by the desired feed rate,

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doi:10.1016/j.ijmachtools.2004.10.011

approximates the use of Taylor's expansion enabled calculations, which can be performed quickly when the motion is being controlled. However, high-performance hardware is required to implement complex computation and segmentation.

The traditional interpolator and the segment process in a simple CNC are well developed [11–13]. This work seeks to apply such technology to improve the milling EDM'ing a parametric curve. A simple control algorithm for a CNC, called the buffered digital differential analyzer (BDDA), gives commands along a sequence of line segments that have been generated by a CAM system using a fixed increment of parameter u constrained by the chord error. The new control algorithm, rapidly interpolating and using a memory buffer, reveals that a common digital differential analyzer (DDA) programmed outside the interrupt service routine (ISR) can continuously interpolate more than one segment (block) in a sampling interval, whenever the programmed lengths of the continuous segments are very short. Therefore, the generation algorithm reaches the required speed obtained using the gap controller along a segmental curve. When Taylor's expansion is not employed to determine the increments of the parameter, the accuracy of the chord and speed and the rate of erosion are normally confirmed using a polynomial example [8,9].

2. Milling electric discharge machining

A cylindrical electrode rotates around the main axis (Z-axis) and moves in the horizontal direction. As shown in Fig. 1, discharge occurs from the edge and the bottom of the electrode when the gap between the electrode and the workpiece is small. The resulting depth of a layer to be eroded is governed by the depth of the electrode embedded in the workpiece, the discharge conditions and the rate of motion in the horizontal direction. The electrode rotates to ensure that it is worn homogeneously. The vertical position of the electrode can be regulated by the toll wear predictions [5–9]. The motion on a horizontal layer is controlled using a two-axis servo controlled system, which can be implemented as a traditional CNC system, although the required feed f_r must be regulated according to the actual discharge conditions, including the ignition delay T_d. The rapid and stochastic generation of the metal and carbon particles always disturbs the gap. Therefore, the gap controller, unlike conventional machine tools, cannot drive the electrode in the horizontal direction at a constant feed rate [14,15].

The complex shape can be defined using a computer-aided design tool (CAD), and can be transformed into a series of segmental lines using a computer-aided manufacturing tool (CAM). The motion of the electrode on a layer follows the sequence of segmental lines from the CAM. After the part program is received from the CAM system, as shown in Fig. 2, the computerized numerical controller (CNC) interpolates these points by applying a reference–word interpolation algorithm [13] in the fixed time triggered interrupt service routine (ISR). The feed rate f_r is determined by a gap controller [14,15], which is not a constant, to maintain the discharge in the gap. The wear compensation is also determined in the ISR, which modifies the current position of the electrode on the main axis (axis Z), according to the output of the wear compensation algorithm [5–7]. The position is also controlled once according to the results of the interpolation in the XY direction, and of the wear compensation in the Z direction.

3. Traditional parametric curve motion

In a CAM system, a parametric curve generation algorithm in the X-Y plane can generate points $A(u)$ on a two-dimensional curve, as shown in Fig. 3

$$A(u) = A_x(u)\vec{X} + A_y(u)\vec{Y} \quad (1)$$

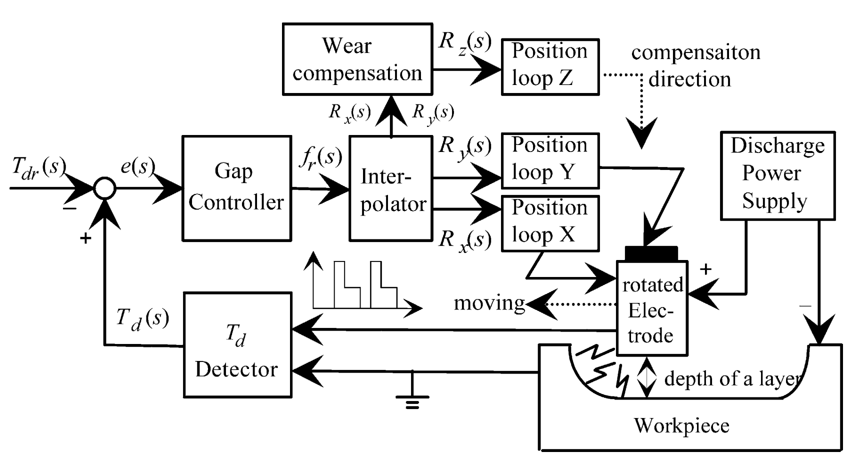

Fig. 1. Block diagram of motion control on milling EDM.