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Technical note

Design and characterization of a linear micropositioner based on solenoid and compliant mechanism

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ABSTRACT

This article presents the development of a linear micropositioner for a micro electrical discharge machine (μEDM). A linear open-loop micropositioner was developed using a solenoid-flexural element architecture. The power system varies the force delivered by the solenoid using the technique of pulse width modulation (PWM). The capabilities of the micropositioner were evaluated by displacing a 1 kg mass over a 30 μm distance, and tracking its position with an linear variable differential transformer (LVDT) with a resolution of 0.5 μm. Experimental data was collected using a data acquisition system developed in LabView. Results show that the micropositioner is capable of achieving accuracies that fall within the limits of uncertainty of the LVDT. The displacement behavior of the micropositioner presents hysteresis due to its electromagnetic constitution and the friction presented by the linear guides that support the working mass. The impact of the open-loop control parameters on the hysteresis of the micropositioner was evaluated over a series of consecutive controlled movements.

1. Introduction

New generations of products require the manufacture of small components, with sizes that range in the meso-micro scale (1–0.001 mm). Microelectromechanical systems (MEMS) and micro medical devices that are inserted into the human body are examples of microproducts that are in use today. Conventional large scale machines are not suitable for the fabrication of these types of parts, because they consume excessive energy, space and material when applied in these size ranges [1].

The development of micromachines has become a technological trend for the manufacture of small devices. Micromanufacturing refers to any method used to manufacture large volumes of micro products whose geometries extend less than 100 μm in any direction. Micromachining requires new machine designs, including not only novel structural elements, but also new actuators, sensors and controls. Designers of these new machines strive to reduce cost without sacrificing performance. Micromachines rely on micropositioners that are designed to achieve high precision positioning, in the range of micrometers, with high repeatability [2].

The electro discharge machining process is one of the most extensively used non-conventional non-contact processes for material removal [3]. By definition, the implementation of μEDM, demands the capacity to provide position within a few μm. Commercial micropositioning systems can be found to meet this resolution. However, most of the commercial available solutions for micropositioning are for general purpose applications, which makes them expensive for the requirements of the application.

This paper presents a micropositioner design that is suitable for μEDM. To specify the requirements of the positioning system, the characteristics of the μEDM process are described. Potential micropositioner architectures are contrasted with the requirements imposed by the μEDM process. After this, a proposed positioned architecture that meets the demands of the process is presented. The proposed system was built and tested. Experimental validation was done using a systematic approach based on a DoE, where the effect of different parameters of the micropositioner were evaluated to achieve the best accuracy on the final displacement point. Finally a combination of control parameters that increase precision in the final displacement position of the micropositioner is presented.

1.1. The μEDM process and its micropositioning requirements

In μEDM, the tool and workpiece are not in contact, and consequently there are virtually no forces produced during material removal operations. The material removal process is carried out using controlled energy discharges from the electrode, that produces small craters over the workpiece surface. In addition, the tool motion relative to the part is relatively small, and consequently inertial forces are also very small. The work by Flores [4] with

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