A PNEUMATIC POSITIONING DEVICE COUPLED WITH PIEZOELECTRIC SELF-MOVING MECHANISM

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ABSTRACT

This paper reports a new pneumatic positioning device coupled with a piezoelectric self-moving mechanism to overcome the main disadvantages of the inherent poor positioning accuracy obtained by traditional pneumatic cylinder. The new driving mechanism is to mount a piezoelectric Impact Drive Mechanism (IDM) to the controlled sliding table driven by the pneumatic cylinder. Based on the configuration, the first step of positioning process is to actuate the sliding table with rough position accuracy but with the benefits of high-speed and large-range due to the pneumatic cylinder. The second step is to drive the sliding table with high position accuracy by utilizing the impact force of IDM. The experimental results show that the controlled sliding table is successfully positioned in 0.236 s with rough accuracy of 10 \(\mu\)m and with the stroke of 100 mm by utilizing the pneumatic cylinder, and the final positioning accuracy of 10 nm with respect to the terminated position of the first-stage control is obtained in 1.479 s due to the actuations of IDM. It is shown that the pneumatic positioning device coupled with IDM has attractive practical applications in the field of precision industry.

KeyWords: Piezoelectric element, pneumatic cylinder, impact force, precision positioning, self-moving mechanism, IDM.

I. INTRODUCTION

Due to the advantages of high-speed ability and large travel range, the pneumatic control system has become one of the main technologies in the field of automation. However, because the air is compressible in nature and the nonlinear friction force always exists between the sliding surfaces of piston and the tube, it is very difficult to position a sliding table with positioning accuracy under micron-order by a pneumatic control system.

For improving the positioning performance of the pneumatic control system, many studies were reported. The most simple and basic method is to use two solenoid valves to improve the positioning accuracy of a pneumatic cylinder. The system could reach the positioning accuracy of 0.4 mm [1]. Without changing the mechanical structure, further studies were mainly focused on implementing the controllers by software with different strategies, e.g., the Pulse-width modulation (PWM) and Proportional-integral-differential (PID) controllers were integrated to actuate the simple ON/OFF solenoid valves with the positioning accuracy of 0.21 mm [2]; a fuzzy PWM controller was implemented to improve the positioning accuracy up to 0.1 mm [3]; using two-stage velocity and position feedback controllers could reach the positioning accuracy of 5 \(\mu\)m [4]; utilizing an on-line learning Neuro-fuzzy controller with tuning scaling factor could reach the positioning accuracy of 5 \(\mu\)m [5]. According to the above results, the most excellent positioning accuracy obtained by the pneumatic positioning system could reach only a few microns.

Concerning the pneumatic actuator that is applied in the high-precision industry, the authors had reported the combined piezo-pneumatic actuator [6] recently. This novel hybrid actuator featuring both large operational range and 10 nm-order positioning ability is successfully merchandised [7]. This device was aimed at providing an excellent adjusting tool for the assembly works of small and precision components such as the connectors of optic fiber. Its operation principle was based on the utilization of the long stroke of pneumatic cylinder for carrying