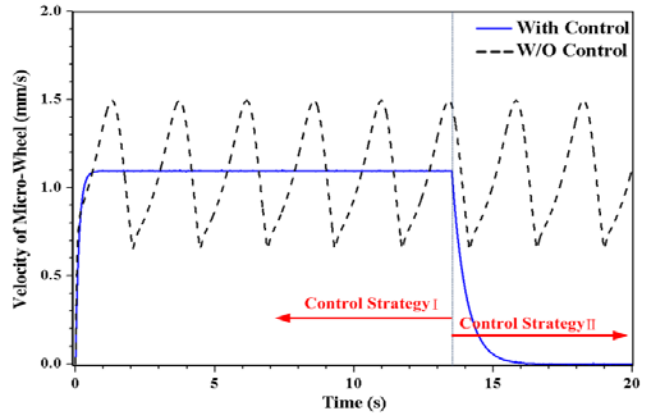


Fig. 12 Velocity of Micro-wheel under Sliding Mode Control

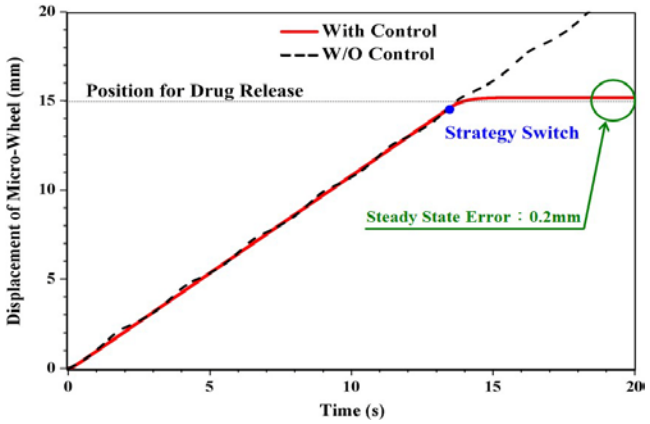


Fig. 13 Displacement of Micro-wheel under Sliding Mode Control

At the beginning, *Control Strategy I* is engaged since the micro-wheel is far away from the drug-release spot. From Fig. 12, it can be observed that the velocity of micro-wheel is increased to the desired velocity and then retained at a constant speed. In addition, the jerk, which occurs under open-loop circumstance, has been successfully suppressed. On the other hand, as the micro-wheel comes close to the drug-release spot, *Control Strategy II* is engaged to replace *Control Strategy I* so that the micro-wheel is slowed down and finally stops at the drug-release spot. To sum up, the expected performance of the micro-wheel is quite satisfactory. The corresponding control current to realize the motion of micro-wheel in Fig. 13 is shown in Fig. 14.

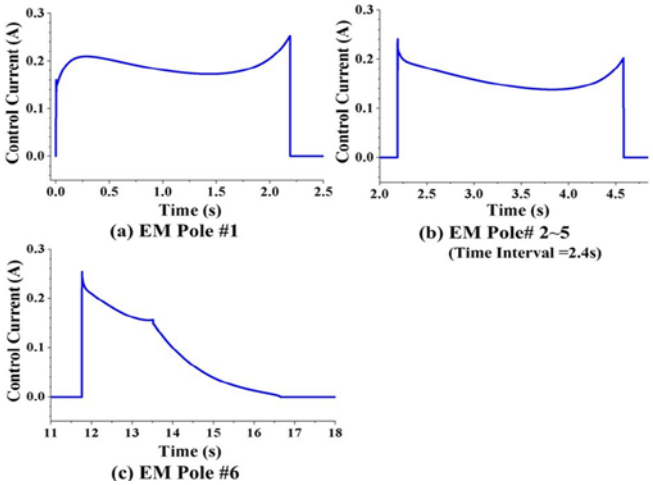


Fig. 14 Control Current of EM Poles in Sequence

The applied control currents at *EM Poles* #2-5 are identical, and the time interval between any two adjacent poles energized in shift is 2.4 seconds. Moreover, the maximum of the control current is limited by 0.25 A to avoid burn-up of the coils at EM poles.

## *V. CONCLUSION*

A drug-delivery micro-wheel system, composed by an auto-rolling micro-wheel and a micro-drug release mechanism, is proposed. First of all, the micro-wheel is designed to possess the simple characteristics of movement and small size (maximum diameter under 5 mm). By taking advantage of strong driving force provided by magnetic poles in which the iron cores are embedded inside, the micro-wheel is able to roll over rapidly. The average velocity can reach 1.094 mm/sec under applied current 0.2 A at EM (Electro-magnetic) poles. Secondly, the commercial software, *Ansoft Maxwell*, is employed to verify the proposed design of EM poles such that the numbers of the micro-solenoids and windings of the coils are the best for realization of the micro-wheel by taking cost and overall size into consideration. Finally, two strategies based on sliding mode control for the micro-wheel rotation are developed and verified by intensive computer simulations. Not only the micro-wheel can move to the drug-release spot precisely, but also the jerk, which occurs under open-loop circumstance, can be successfully suppressed. To sum up, the proposed MEMS-based micro-wheel theoretically has the potential to fulfill micro-drug-delivery applications in medical service.

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