学 位 論 文 内 容 の 要 旨
DISSERTATION ABSTRACT

博士の専攻分野の名称　博士（工学）　氏名　李 軍鋒

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Phase Resistance Feedback Control and Modeling of Thick SMA Actuators
(太径 SMA アクチュエータの相抵抗フィードバック制御とモデル化に関する研究)

Shape memory alloy (SMA) actuators have great potential in niche applications where space, weight, cost and noise are crucial factors. These applications include mobile robots, micro robot manipulation, smart structures, and artificial muscles. Despite many of the advantages, they remain mostly as experimental actuators due to their perceived slow response speed, low accuracy and controllability. In the past, research had focused on position and force control of thin SMA wires, because they can be cooled fast in air and as it is easy to obtain rapid response speed for SMA actuators in this manner. Due to hysteresis and significant nonlinearities in the behavior of shape memory alloy actuators, it is difficult to obtain rapid response speed of SMA actuators, which have limited the application of these actuators, especially for thick SMA wires. In this thesis, effective control systems are applied to achieve rapid response speed control of SMA wire actuators.

In this thesis, experimental tests are conducted in chapter 3 to show the existence of latency duration during the heating and cooling process for thick SMA wires 0.5mm in diameter. Appropriate heating times are decided to obtain the latency duration with ‘on-off’ binary control. It is important to avoid overheating of SMA wires which leads to long latency duration and slow to cool when the power is turned off. In addition, the experimental results show that the ambient temperature has an effect on the cooling speed. Therefore, the ambient temperature needs to be stable when the experiments conducted.

Then, an approach is proposed in chapter 4 to design and control a thick SMA actuator to achieve rapid response speed control with two connected SMA wires. In the proposed method, a structure with two connected SMA wires is designed and then the concept of phase

resistance is defined to use it as feedback in the response speed control system. Phase resistance feedback control (PRFC) minimizes cooling time by shortening the long latency duration of thick SMA wires. To accurately identify phase resistances, experiments showed that it is important to determine the major hysteresis loop. Experimental results that demonstrate the advantages and justify the concepts are also presented.

Subsequently, another method is proposed in chapter 5, the phase resistance with displacement feedback control (PRDFC), combing both the phase resistance and displacement as feedback, minimizes cooling time by shortening the long latency duration of thick SMA wires. PRDFC using segmented SMA wires shortens the latency duration of SMA wire, which coordinates with each other to make sure the continuity of output displacement. Two sets of experiment are tested using the step and ramp signals as reference input. Experimental results show that rapid response speed is achieved using this method in comparison with the case in which only displacement is used as feedback.

In chapter 6, a successful empirical relation is proposed in order to model the major and minor hysteresis loops of behavior for SMA actuators, which considers the amount of the austenite fraction transformed at a temperature based on Liang and Rogers model.

Finally, the conclusions of the whole work are described and the future works are presented in chapter 7.