Electro-thermo-mechanical Analysis of SMA Actuator

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ABSTRACT

Shape Memory Alloy (SMA) is a smart material converting thermal energy to mechanical work, which can be used in many different mechatronic systems like actuators as well as sensors [1-3]. Transformation behaviour exploited in SMA material is thermally induced shape change, often labeled the shape-memory effect. A material component may be deformed or strained at low temperatures and when heated, it reverses this strain and remembers its prestrained shape. Deformable martensite phase transforms to a more stable austenite phase at higher temperatures. Thermally activated SMA applications require temperature control to optimize the effect of shape memory. Typical application areas of SMA are aerospace industry - composite structures that have SMA wires embedded can be used to change the shape of an airplane wing; vibration damper systems - vibrational dampers, comprised of composite materials using prestrained, embedded SMA wire; medical applications - medical applications use the superelastic property of SMA, and many of them are in the expanding field of minimally invasive surgery.

The paper deals with coupled electro-thermo-mechanical analysis of actuator made of shape memory alloy in FEM code ANSYS [4]. The actuator is made of Nickel–Titanium (NiTi) wire that is heated by Joule heat caused by electric current and naturally air-cooled. Critical part of SMA actuator from thermal point of view is connection of thermocouple sensor to NiTi wire, which is used to control NiTi thermal power, and the design of SMA wire connection to the system. Our research is focused on investigation of different thermocouple locations on SMA wire and the different form of connections on SMA wire temperature distribution as well as the influence of design of SMA wire connection to the system on effective active length of SMA actuator. These two parts of SMA wire are cooled more than the rest of the actuator and measured temperature by thermocouple is deformed by thermal conduction caused by sensor. The influences are investigated by coupled electro-thermal analysis, where hysteresis of electric and thermal properties caused by phase change austenite-martensite are considered. Natural convection of surrounding air, which is used to cool down SMA wire, is computed using correlation equations. After obtaining the SMA wire temperature distribution, mechanical analysis of SMA actuator with different loading conditions is computed. The final step will be investigation of efficiency of SMA actuator to convert electric power to mechanical power for different investigated cases of thermocouple locations and different loadings.

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