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STRUCRUAL OPTIMIZATION FOR THE DESIGN OF COMPLIANT THERMAL ACTUATORS BASED ON THE LEVEL SET METHOD

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ABSTRACT

Compliant mechanisms are a new type of mechanism, designed to be flexible in order to achieve a specified motion as a mechanism. Such mechanisms can function as compliant thermal actuators in Micro-Electro Mechanical Systems (MEMS) by intentionally designing configurations that exploit thermal expansion effects in elastic material when appropriate portions of the mechanism structure are heated. Compliant thermal actuators of this type have been designed using a trial and error approach, but creating high performance actuators this way is difficult.

Topology optimization [1] is a highly flexible structural optimization method, allowing changes not only in shape but also in the topology of target structures, and it can yield high performance structural configurations. Sigmund [2] successfully used topology optimization in the design of compliant thermal actuators, however numerical problems such as grayscales and hinges [3], [4] are often encountered.

The level set based structural optimization method [5], [6] is a new structural optimization method where target structural configurations are implicitly represented using the level set function, and optimal configurations are obtained by updating the level set function governed by the Hamilton-Jacobi Equation, based on shape

sensitivities. This method has been applied to typical structural optimization problems such the stiffness maximization problem [5], [6] and eigen-frequency problems [7]. Furthermore, the above numerical problems can be easily avoided when using this method for the design of compliant structures, by applying the boundary expression method.

This paper presents a new structural optimization method for the design of compliant thermal actuators that are constructed based on the level set method and the Finite Element Method (FEM). First, an optimization problem is formulated that addresses the design of compliant thermal actuators considering the magnitude of the displacement at the output port. Next, the topological derivatives [8] that are used when introducing holes during the optimization process are derived. Based on the formulation and the level set method, a new structural optimization algorithm is constructed that employs the FEM when solving the equilibrium equations and updating the level set function. The re-initialization of the level set function is performed using a newly developed geometry-based re-initialization scheme [9]. Finally, several design examples are provided to confirm the usefulness of the proposed structural optimization method.

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