Multiphysics Multi-Material Topology Optimization of a Thermal Actuator with COMSOL Multiphysics®

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INTRODUCTION: Design of a thermally driven actuator with two different metal materials is discussed. To achieve best, it is desired to use a metal material with both high coefficient of thermal expansion and Young's modulus. However, as shown in Fig. 1, most of the material with high Young's modulus has relatively small coefficient of thermal expansion, or vice versa. Therefore, it is hard to find an ideal material for the design.

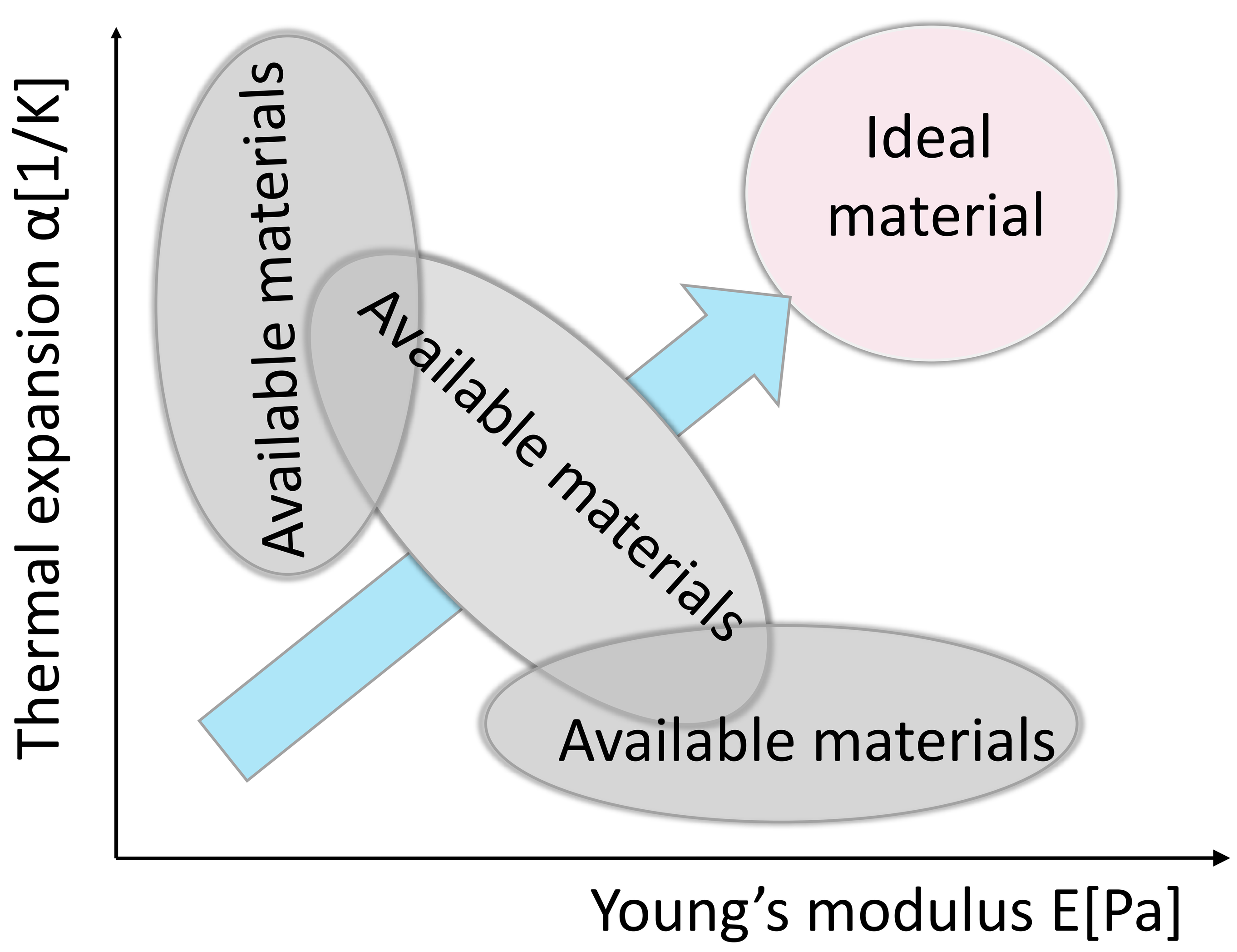

Figure 1. Available material properties and desired ideal material

Here we consider two materials, one has high coefficient of thermal expansion but small Young's modulus, the other has high Young's modulus but small coefficient of thermal expansion. By optimizing the distribution of two materials at the same time, superior performance was obtained by assigning the materials to right places to utilize each materials' strong point.

COMPUTATIONAL METHODS: The object subjects to both mechanical and thermal load as shown in Fig.2. Thermal expansion effect was taken into account. The objective is to design a thermal actuator which can best withstand the mechanical load F when subject to a temperature difference between its two ends. Total material can be used need to be =<40% in each volume fraction.

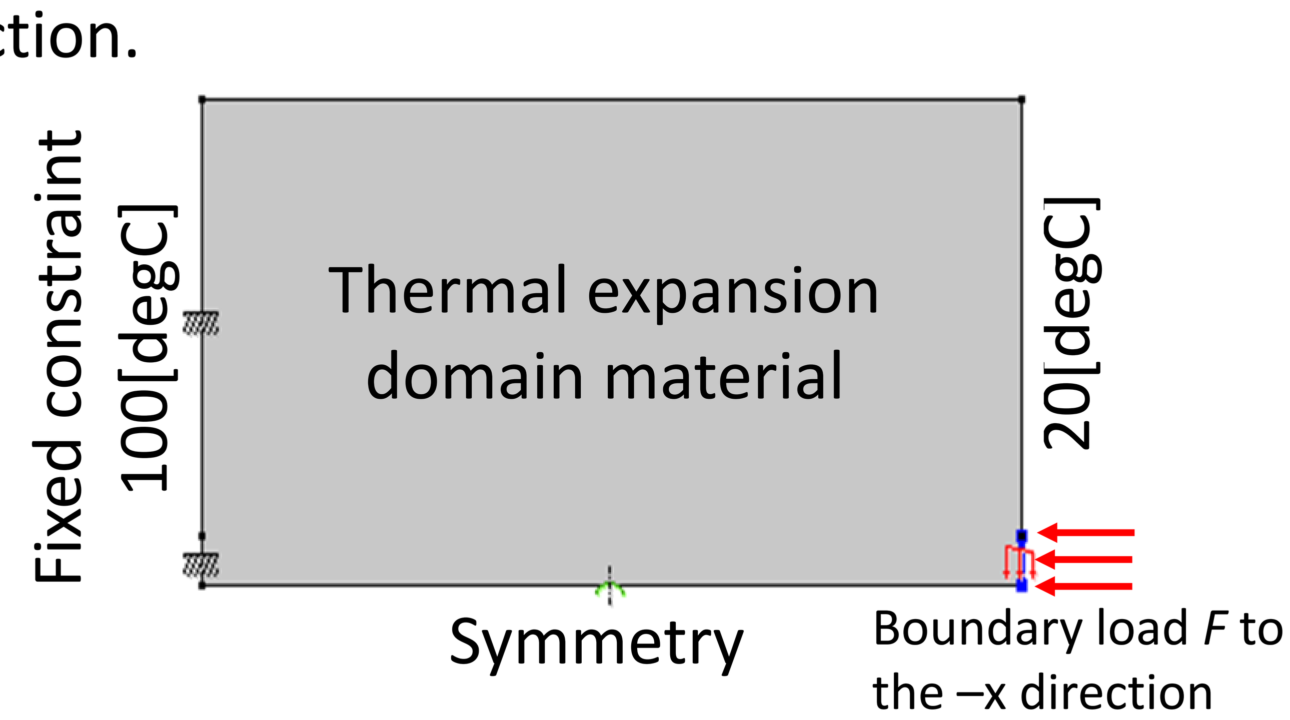

Figure 2. Problem definition for thermal expansion problem

Density method with consideration of handling two materials was used for topology optimization of the device. Effective material properties such as Young's modulus and thermal conductivity were determined using interpolation scheme which based on power-law method.

$$E = \rho 0^p \cdot (\rho 1 \cdot E1 + (1 - \rho 1) \cdot E2)$$

$$nu = \rho 1 \cdot nu1 + (1 - \rho 1) \cdot nu2$$

where $(\rho 0, \rho 1) \in [0,1]$, $\rho 0$ indicates the presence of material or void in the domain ($\rho 0 = 0$ for void and 1 for mixed material), $\rho 1$ indicates the presence of material 1 or material 2 in the non-void part of the domain ($\rho 0 = 0$ for material 1 and 1 for material 2); p is the power of the SIMP method.

A Helmholtz equation based regularization was used as a filter for the design variables. Projection method was also applied for reducing the grayscale in the optimization results.

The Solid Mechanics interface, Heat Transfer in Solids interface and Optimization interface of COSMOL Multiphysics are used to model this problem.

RESULTS:

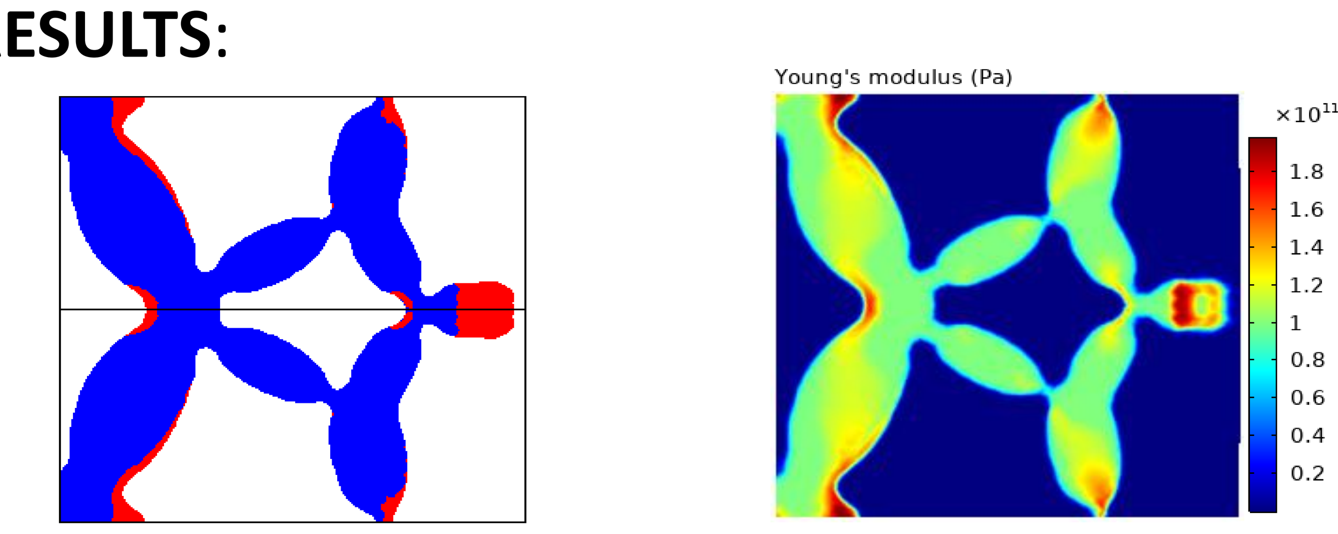

Figure 3. Left: Optimized material distribution, red is for material 1 and blue is material 2 (filtered); Right: Effective Young's modulus

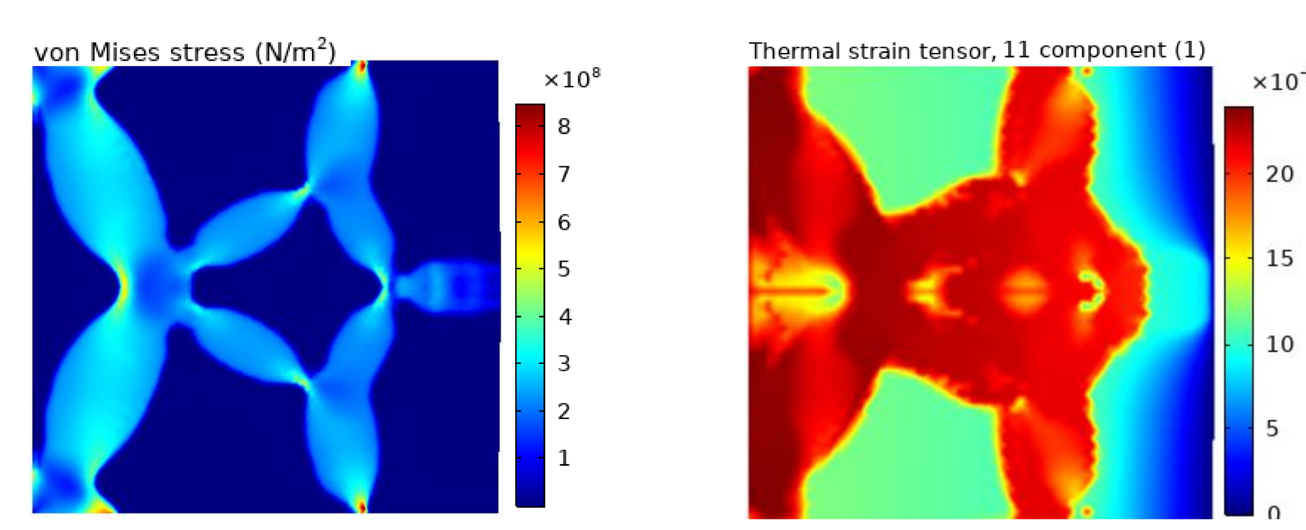

Figure 4. Left: von Mises stress;
Right: Thermal strain tensor, 11 component

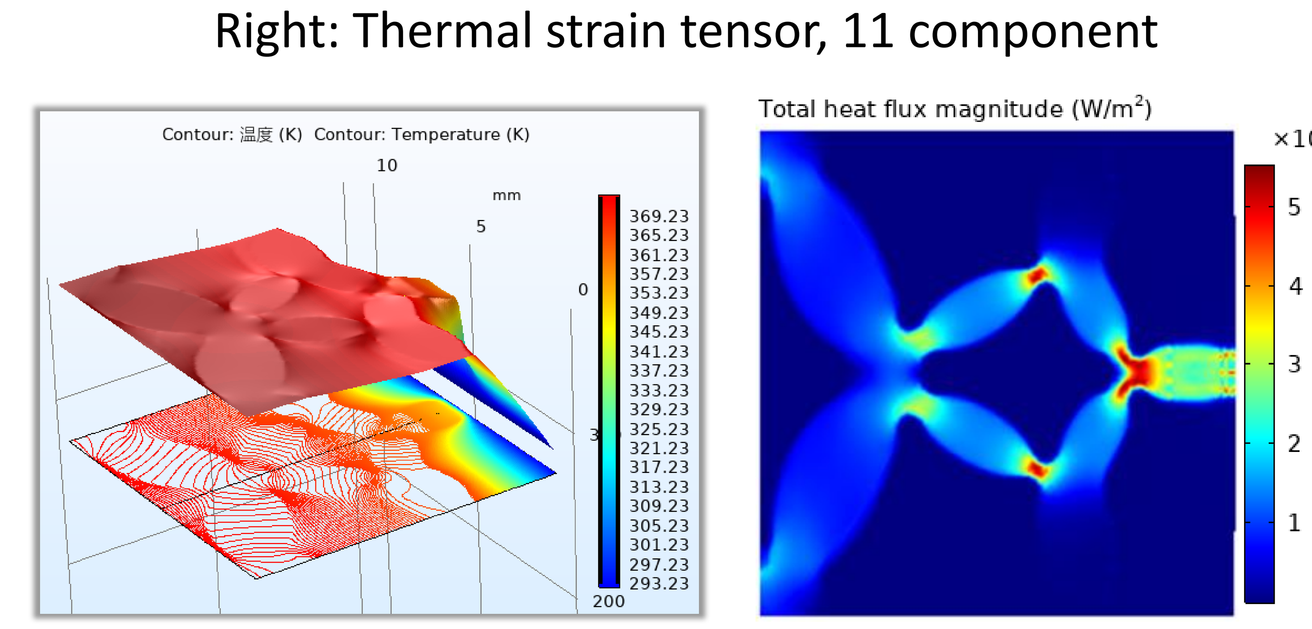

Figure 5. Left: Temperature distribution with height expression;
Right: Total heat flux magnitude

CONCLUSIONS: Topology optimization for multi-physics, multi-material problem was discussed. The results can be used to provide non-intuitive design idea for innovative micro devices and make the most use of available material properties.

REFERENCES:

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