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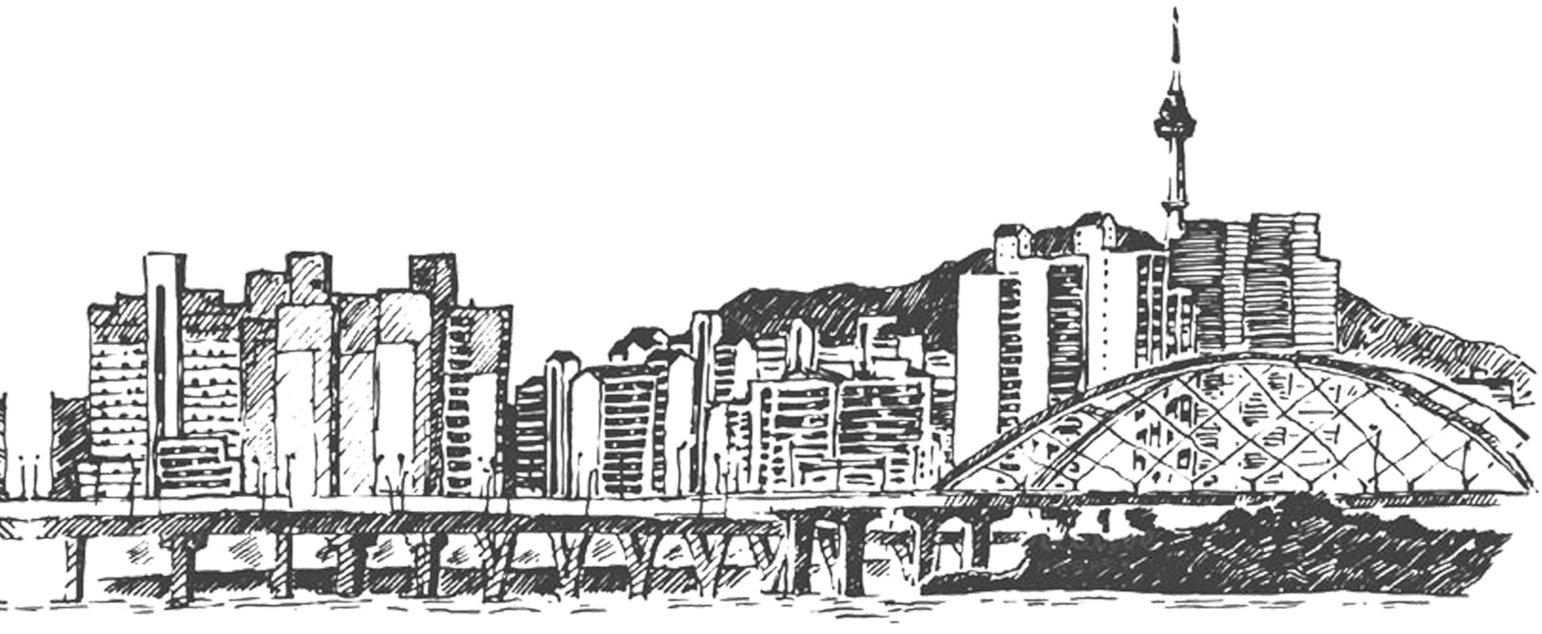

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MODIFIED DESIGN OF THERMAL COMPENSATOR FOR OVERHEAD POWER LINE WIRES AND THERMAL MODELS

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Abstract. *A thermal compensator from SU754541 patent is a simple and effective device for compensation of overhead power line wires thermal elongation. This paper contains the thermal analysis of the original and modified designs of the thermal compensator, and it is conducted by the finite element method using Ansys Student 2023 R1 software. The analysis showed that the original design does not work when power line wire is heated by current, and the modified design, instead, can work both when heated by the maximum ambient temperature and in some cases when heated directly from the wire. The results of the conducted research can be used in the further design evolution of thermal compensators.*

A thermal compensator from SU754541 patent has a simple construction and is designed to compensate overhead power line wire thermal elongation depending on the maximum ambient temperature. Compensation of overhead power line wires thermal elongation allows the use of lower power line towers or a greater distance between them when constructing new power lines. When installing thermal compensators on existing power lines, it is possible to increase their operational safety due to an increase in distance between wires and the ground or objects that are situated under the wires. This original design of the thermal compensator and its principle of operation are described in detail in [1; 2]. The use of alloys with the shape memory effect (SME) allows combining temperature sensitive function and actuation function in one element. This makes the device simple, self-sufficient and autonomous. One disadvantage of the above-mentioned thermal compensator is that it is designed only to operate at the maximum ambient temperature. However, overhead power line wires can work at fairly high temperatures, for example, steel-aluminium wires of the “AC” type can have a long-term permissible operating temperature of 90 °C. The sag in such conditions can be significantly greater than at the maximum ambient temperature, and it can create more hazards (especially for permanently overloaded power lines). Therefore, there may be a need to use thermal compensators that operate only when power line wire is heated by current or both when wire is heated by current and in the case of the maximum ambient temperature.

The first object for analysis is the original design of the thermal compensator using the finite element method (FEM). It was conducted using Ansys Student 2023

R1 software. For this analysis, a fragment of "AC120/19" wire with 2 m length was selected. The temperature sensitive element of the thermal compensator is 1 m long (a distance between internal edges of wire clamps) and has the same diameter as the wire (15.2 mm). The temperature sensitive element is connected to the wire with the clamps that provide a tight contact between the wire and the temperature sensitive element. The clamp has a length of 5 cm and a wall thickness of 5 mm. The material of the wire and the clamps is aluminium (isotropic thermal conductivity – 237 W/(m·K)), the material of the temperature sensitive element is nitinol alloy in a martensitic phase (isotropic thermal conductivity – 8.6 W/(m·K)). The type of analysis is "Steady State Thermal". A mesh was created automatically with a small correction of one of the clamps using the "Hex Dominant" method. Model settings – the wire has a stable temperature of 90 °C, all model elements were in convection conditions (the ambient temperature – 22 °C, the heat transfer coefficients or film coefficients (as realistic coefficients for air [3]) – 10 and 100 W/(m^2·K)). The result of analysis (solution) is temperature.

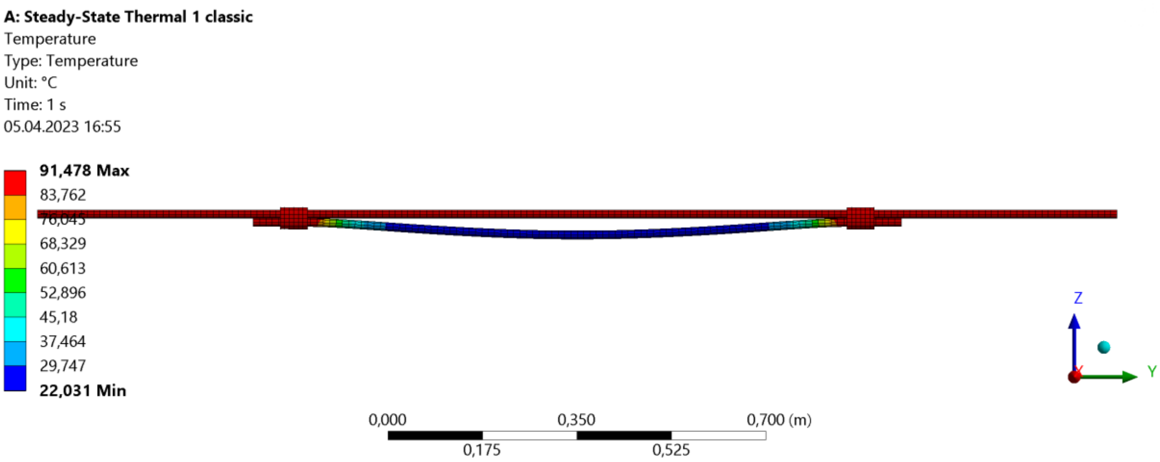

Fig. 1. **Simulation result for the original thermal compensator design with the heat transfer coefficient of 10**

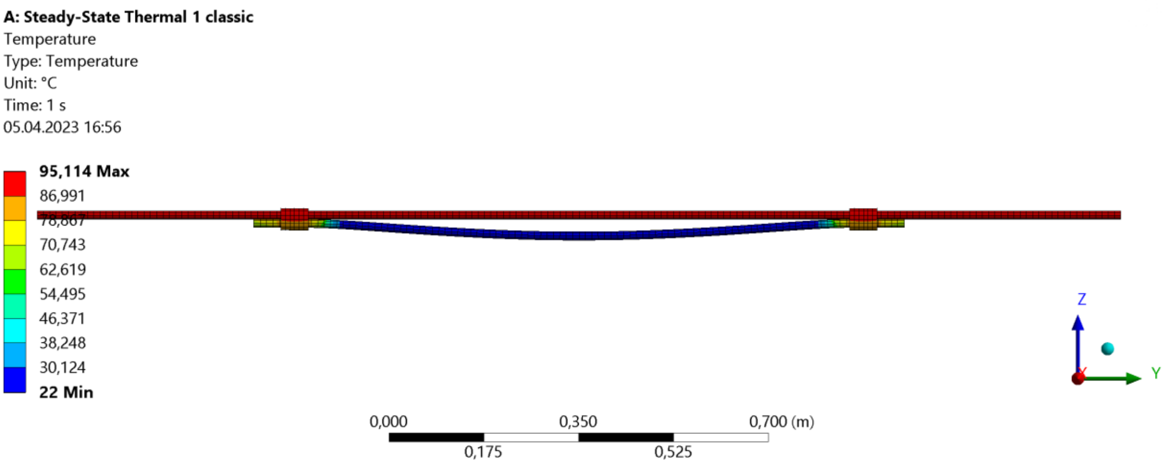

Fig. 2. **Simulation result for the original thermal compensator design with the heat transfer coefficient of 100**

Fig. 1 and fig. 2 show that in both cases, most of the temperature sensitive element is at the ambient temperature. Therefore, it will not work when the wire is heated by current.

A modified design of a thermal compensator that has its temperature sensitive element in thermal contact with a wire is proposed. In one of the possible implementations, the temperature sensitive element is pressed against the wire by a cylindrical spring. In this case, the spring is made with such an inner diameter that it is slightly smaller than the sum of diameters of the wire and the temperature sensitive element. For further analysis, the spring material is steel with isotropic thermal conductivity of 60.5 W/(m·K). For a detailed analysis of temperature distribution inside the temperature sensitive element, its mesh is made more detailed using the "MultiZone" method with an element size of 0.003 m.

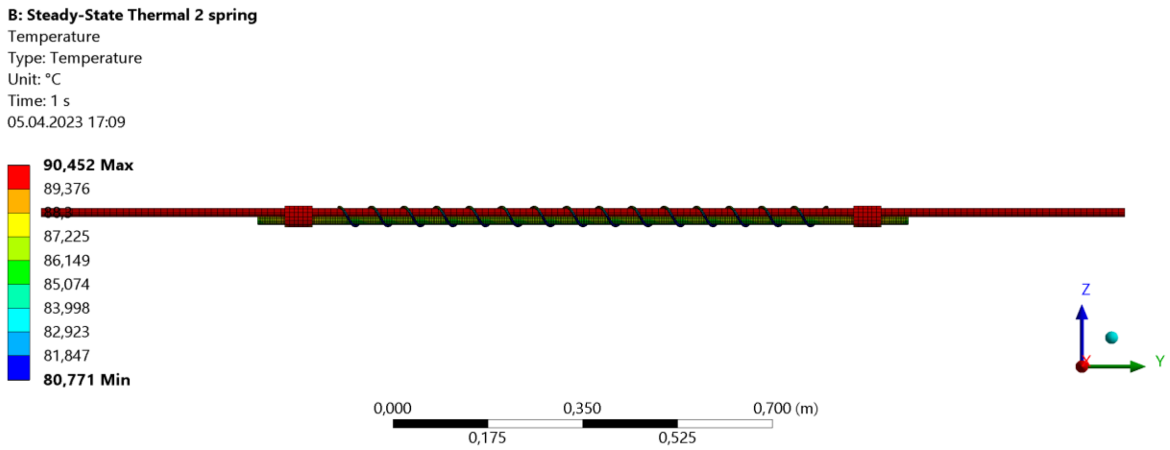

Fig. 3. **Simulation result for the modified thermal compensator design with the heat transfer coefficient of 10**

Considering only the temperature sensitive element, it can be seen that the spring has a certain cooling effect. This can be seen on the underside of the temperature sensitive element:

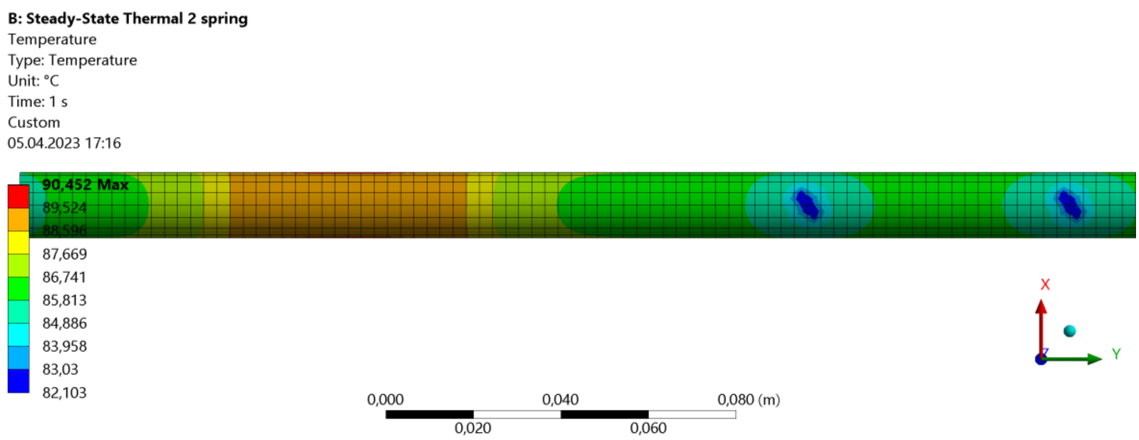

Fig. 4. **Underside of the temperature sensitive element of the modified thermal compensator design with the heat transfer coefficient of 10**

In fig. 4 areas of minimum temperature correspond to points of contact of the temperature sensitive element with the spring. An area of increased temperature is visible on the left part of the temperature sensitive element. It corresponds to the clamp node.

The most interesting for analysis are contact zones of the temperature sensitive element with the spring. Further, we will take a closer look at one of these areas.

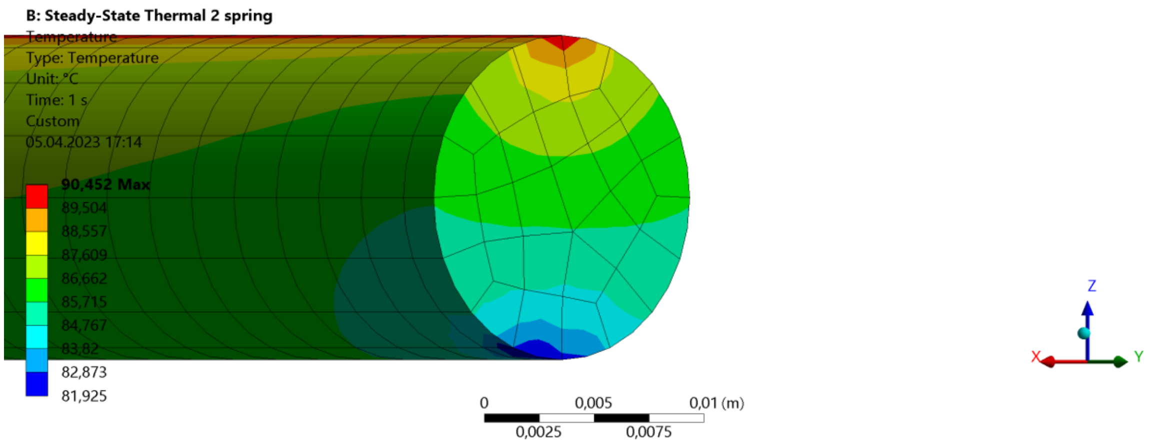

Fig. 5. **Cross-section of the temperature sensitive element at its contact point with the spring (the heat transfer coefficient is 10)**

On an upper part of the temperature sensitive element (fig. 5) is a zone of the highest temperature – a contact point between the temperature sensitive element and the wire. On a lower part – a contact point between the wire and the spring. A temperature difference is about 8 °C. At the maximum temperature of the wire, the temperature sensitive element will obviously be in an activated state. Analogous to the original design, the temperature sensitive element will take a shape of an arc, while tightening the wire and reducing the sag. Accordingly, the material of the temperature sensitive element will be in an austenitic phase. This case is not considered, because the geometry of the thermal compensator will not change significantly (for such a thermal analysis), it is more important that the contact between the wire and the temperature sensitive element will remain solid. Also, this case is less important for this analysis, because isotropic thermal conductivity of an austenitic phase of nitinol is more than twice as high as that of a martensitic phase, so the temperature difference between the hottest and coldest points on the temperature sensitive element will be smaller. In addition, to start a transition from an austenitic phase to a martensitic phase, temperature must drop below a starting point of a transition from a martensitic phase to an austenitic phase due to hysteresis. Accordingly, in an austenitic phase, the temperature sensitive element will be more stable to temperature fluctuations.

Next we will consider the same cross-section with the heat transfer coefficient of 100.

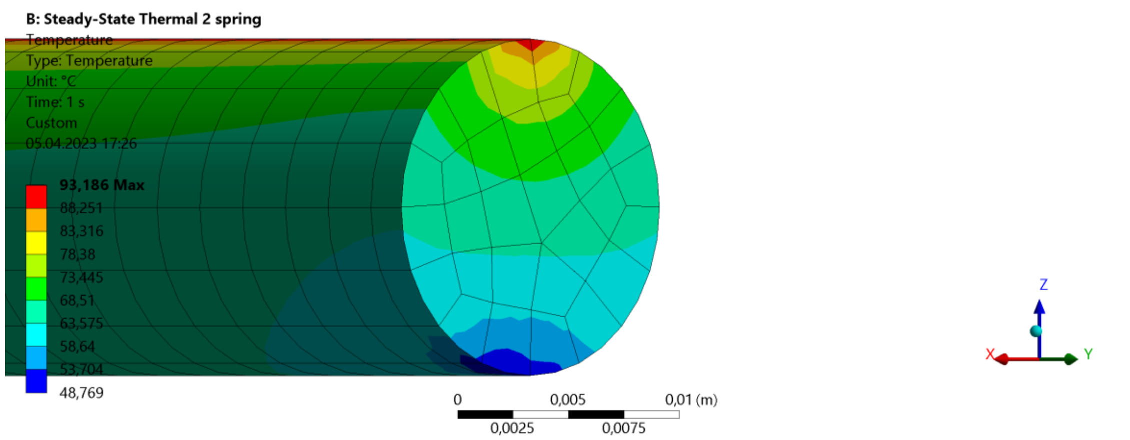

Fig. 6. **Cross-section of the temperature sensitive element at its contact point with the spring (the heat transfer coefficient is 100)**

In fig. 6 we can see that a temperature difference between a contact point of the temperature sensitive element with the spring and a contact point of the temperature sensitive element with the wire is about 44 °C. In this case, for a complete phase transformation of the shape memory alloy, it is necessary to choose the operating temperature of the temperature sensitive element significantly lower than the maximum temperature of the wire. This imposes a limit on the operating temperature.

For real thermal compensators, temperature sensitive elements of smaller diameters will more realistically be used. We will consider the case when the temperature sensitive element has a diameter twice as small as the diameter of the wire. At the same time, all other parts of the model remain the same. To fasten the temperature sensitive element to the wire, the same clamps with appropriate adapters can be used, as shown in the figure below (the material of the adapters is aluminium):

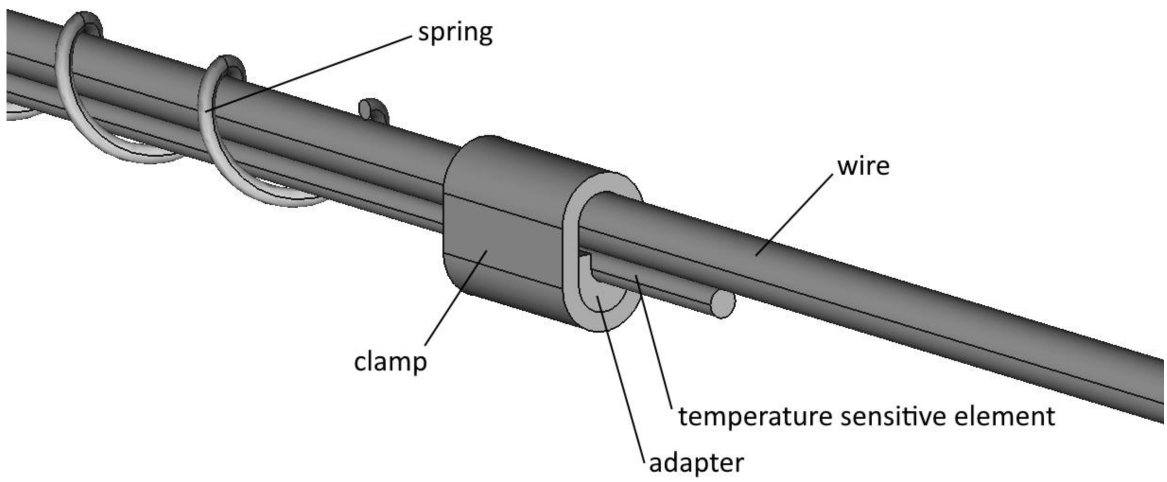

Fig. 7. **Clamp node of the thermal compensator**

For a detailed analysis of temperature distribution inside the temperature sensitive element, its mesh is made more detailed using the "MultiZone" method with an element size of 0.002 m. Simulation results are shown below:

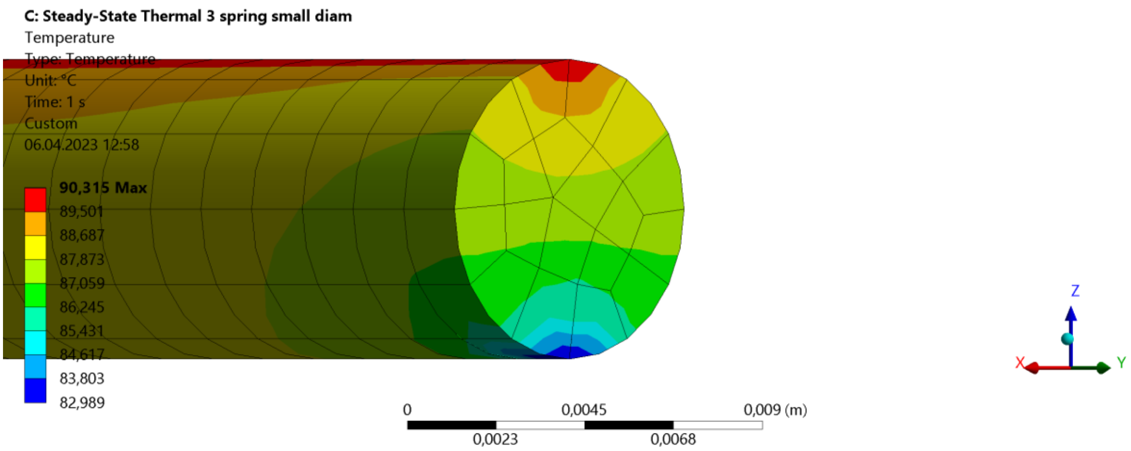

Fig. 8. **Cross-section of the temperature sensitive element with twice as small diameter as the wire at its contact point with the spring (the heat transfer coefficient is 10)**

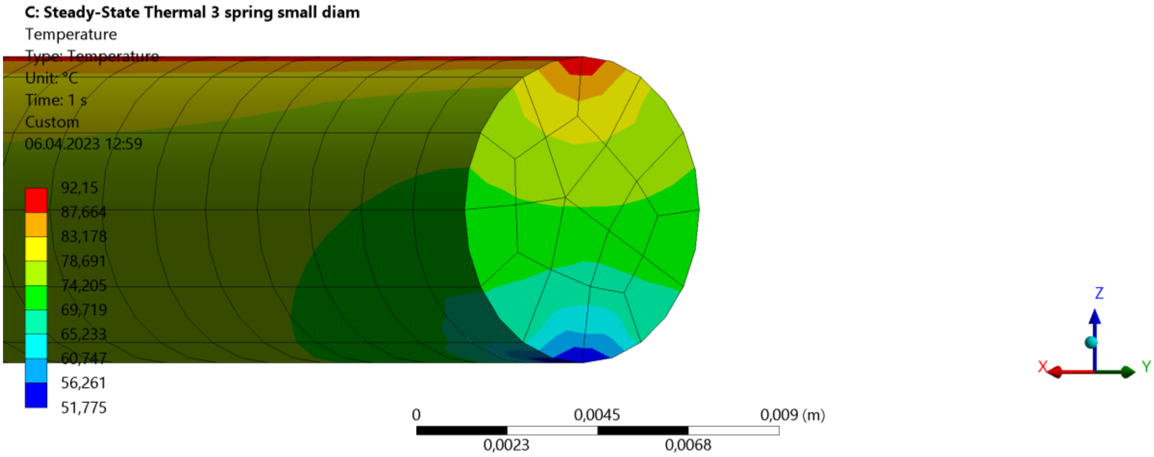

Fig. 9. **Cross-section of the temperature sensitive element with twice as small diameter as the wire at its contact point with the spring (the heat transfer coefficient is 100)**

In this case, a temperature difference between the contact point of the temperature sensitive element with the spring and the contact point of the temperature sensitive element with the wire is about 7 °C (with the heat transfer coefficient of 10) and 40 °C (with the heat transfer coefficient of 100), which is several degrees less than in the previous case.

Conclusions. Thermal analysis using the FEM showed that the thermal compensator of the original design does not work when the power line wire to which it is attached is heated by current. This fact limits its use. The proposed thermal compensator of a modified design can be heated directly from the wire. Therefore, if the original algorithm for selecting the operating temperature of the thermal compensator is preserved, operation of the modified version of the thermal compensator will be ensured at the maximum ambient temperature and when the power line wire is heated by current. At the same time, the features of the proposed design of the thermal compensator do not allow it to be used to compensate the thermal elongation of the wire caused exclusively by the maximum operating temperature of the wire. It was also found that in the proposed design of the thermal compensator, the diameter of the temperature sensitive element does not significantly affect the temperature distribution inside it.

References:

[1] Shesterenko, V., Mashchenko, O., & Romaniuk, V. (2018). Optimization of external power delivering system of object by mechanical influence on the work of power line wires. *Ukrainian Journal of Food Science*, *6*(1), 127-135. https://doi.org/10.24263/2310-1008-2018-6-1-15

[2] Shesterenko, V. Ye. (2004). *Systemy elektrospozhyvannia ta elektropostachannia promyslovykh pidpryiemstv* (pp. 598-604). Nova Knyha. ISBN 966-7890-82-1 [in Ukrainian]

[3] Ansys. (2020). Film Coefficient: Thermal Convection in Heat Transfer –Lesson 2. https://courses.ansys.com/wp-content/uploads/2020/08/Lesson-2-Film-Coefficient-tp.pdf