ME396, Senior Design I

ME Lab 3 – Take Home

Steady State Thermal Analysis

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I. Introduction

The objective of the Ansys simulation is to redesign the pump housing cover that will be used in a motorcycle engine. The aim is to select an appropriate material that produces a temperature distribution such that the top of the cover does not exceed 40°C. Concepts including heat resistance, strength, and thermal conductivity are considered in the simulation. The goal of the redesign is to prevent burns to the rider in case contact occurs with human skin and the top of the housing cover.

II. Problem Statement

The simulation consists of obtaining a temperature for the top of a pump housing cover that does not exceed 40°C. The boundary conditions are: The flange part of the pump housing is mounted to a pump held at a constant 60°C, the interior surfaces of the pump are held at a constant temperature of 90°C by the fluid, and simplified convection using stagnant air is applied with 20°C. Film coefficient of 10 $\frac{w}{m^2}$ is also assumed for the convection. Steady State Thermal analysis is also assumed. The materials used in the simulation were aluminum alloy and polystyrene. The metrics used in the simulation are °C for temperature and $\frac{w}{m^2}$ for the total heat flux. The mesh statistics include 16479 nodes and 9443 elements.

III. Method

The three methods I used to achieve a lower temperature profile for the top cover are increasing the distance in the material, adding cooling fins on the top cover, and changing the material to polystyrene.

From Fourier's law of Heat Conduction equation:

$$q_{conduction} = -kA\frac{\Delta T}{\Delta x}$$

When Δx is increased, the ratio gets smaller and $-kA$ are multiplied by a smaller number resulting in a lower value for the heat transfer rate. I applied this same principle by increasing the width, 10mm of two surfaces marked by green fig 1.

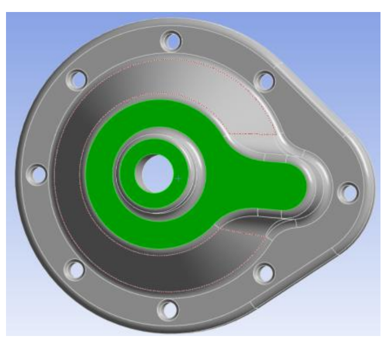

Figure 1: Non-redesigned geometry.

Additionally, I added fins to the top cover because that is where the convection boundary condition was applied. The intent of the fins is to increase surface area that is exposed to the stagnated air. Consequently, the rate of heat transfer from the surface to the fluid increases and the surface temperature decreases.

Lastly, I tested two materials, aluminum alloy and polystyrene. Aluminum alloy was used for experimental purposes. Polystyrene was used because of its low thermal conductivity (0.034 to 0.038 $\frac{w}{m*K}$). Having a low thermal conductivity fits the purpose of insulation. Thus, the heat transfer rate from the interior to the exterior will be reduced. The fins and increased width are shown below in fig. 2.

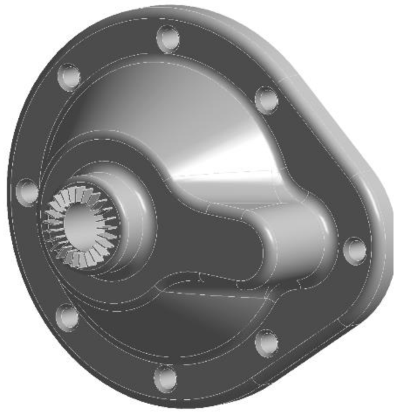

Figure 2: Redesigned Geometry.

IV. Results

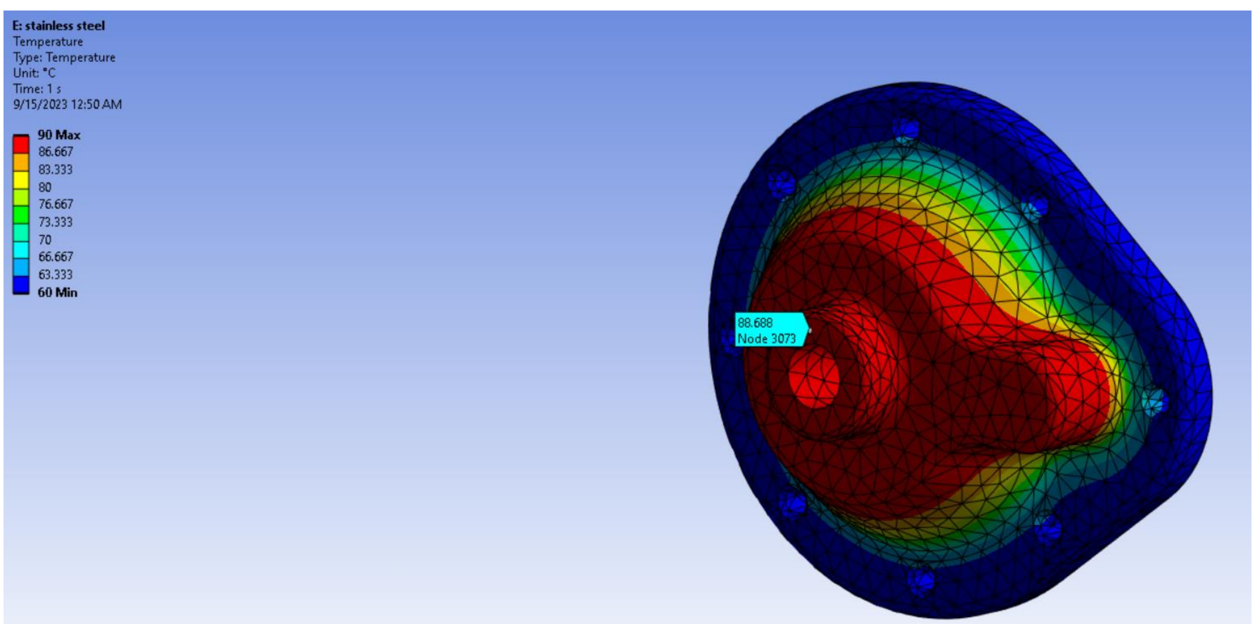

Figure 3: Temperature contour of stainless steel.

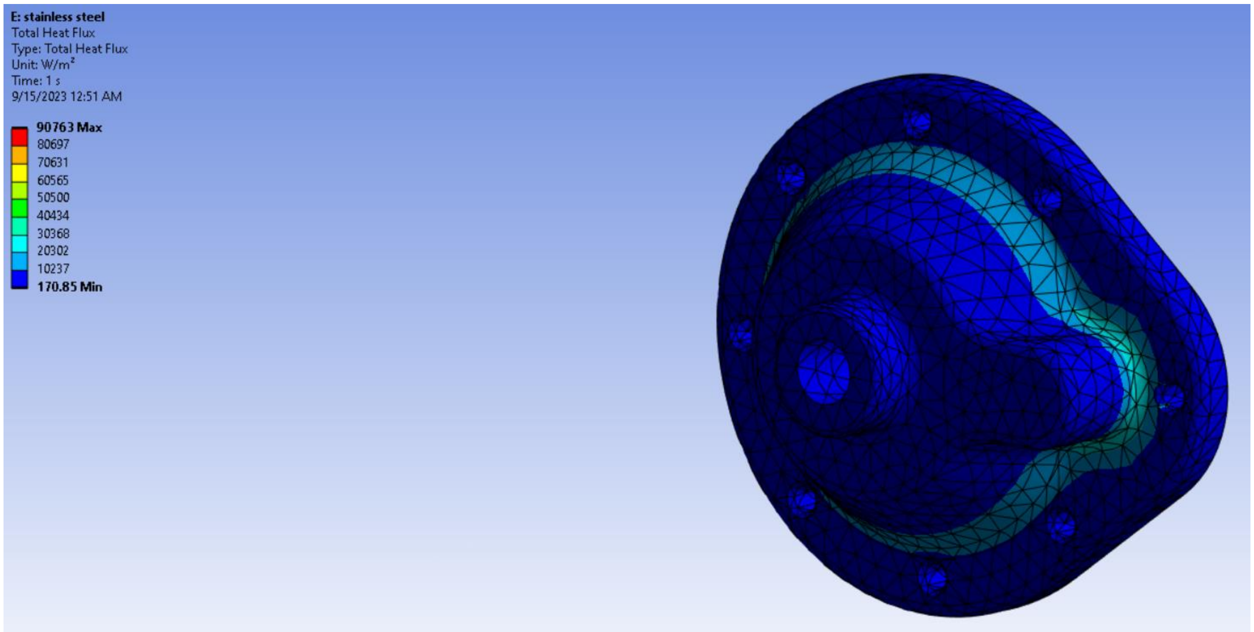

Figure 4: Total heat flux contour of stainless steel.

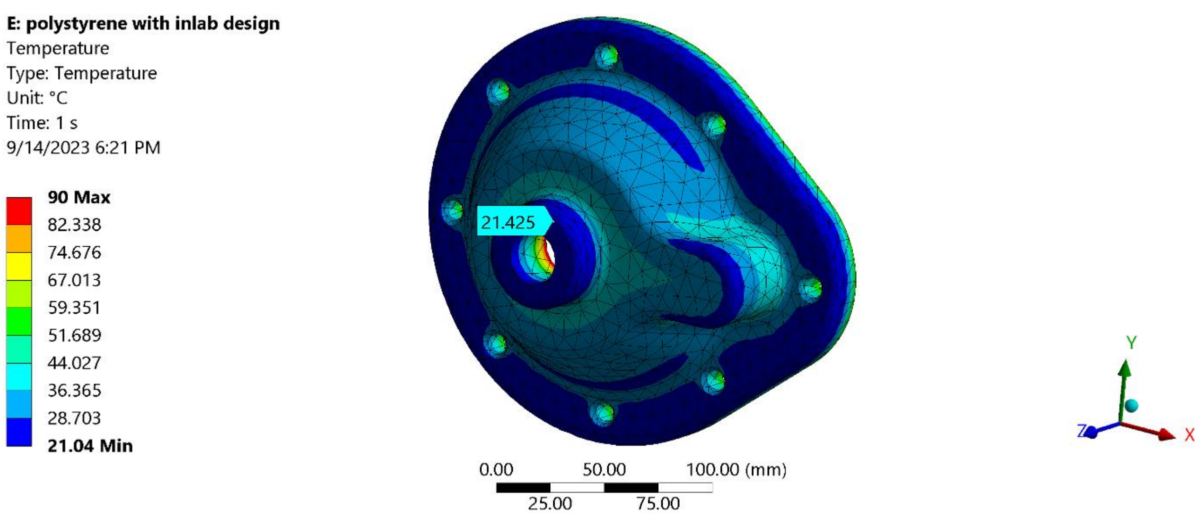

Figure 5: Temperature contour of Polystyrene with in-lab design.

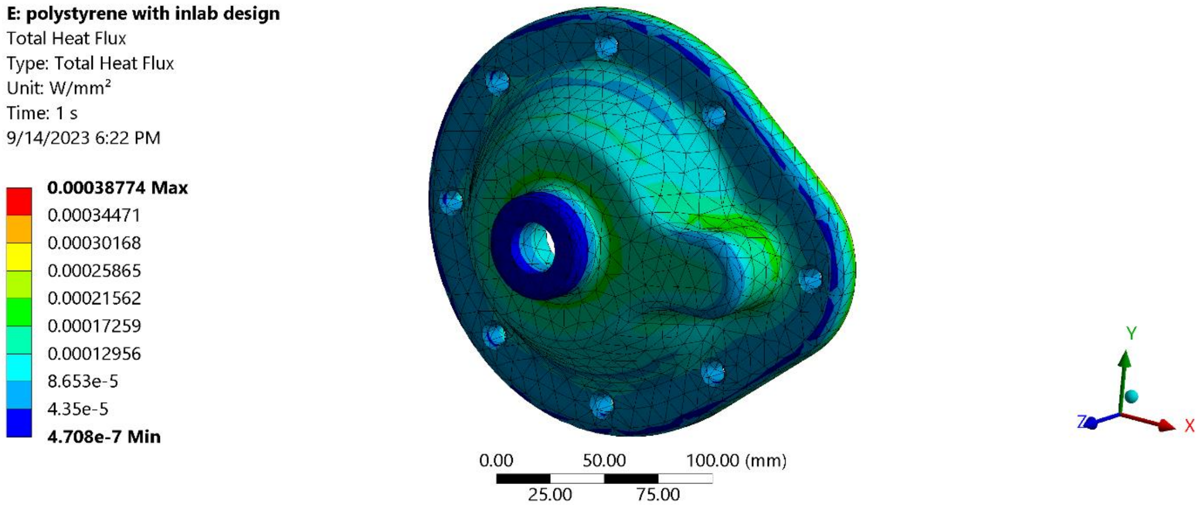

Figure 6: Total heat flux contour of in-lab design.

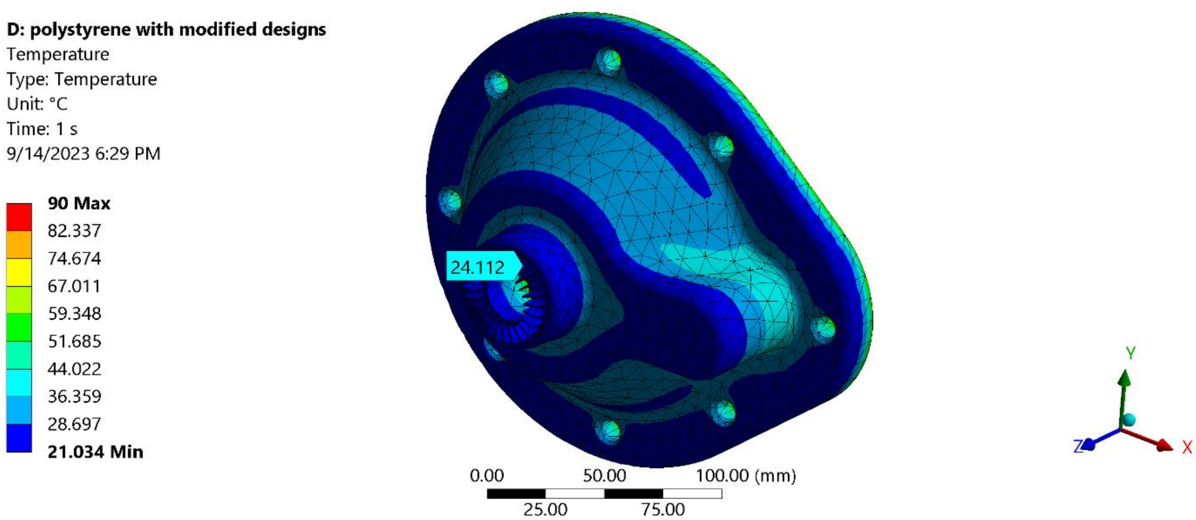

Figure 7: Temperature contour of Polystyrene with redesign.

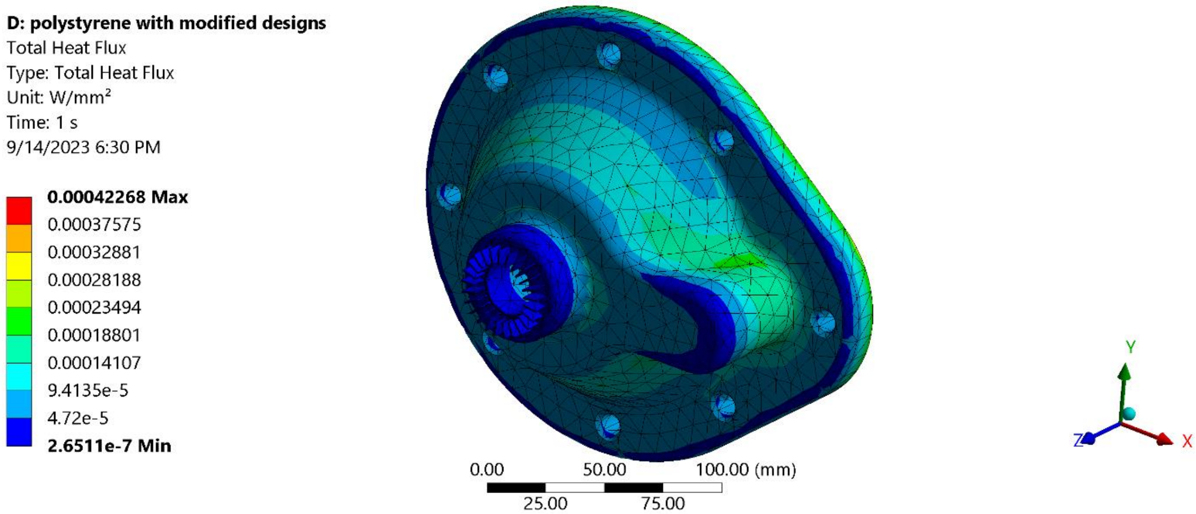

Figure 8: Total heat flux contour with polystyrene.

My simulations began with changing my material to stainless steel as its mechanical strength is high, but the probe at the cover in fig. 3 showed a temperature of 88°C. This was unacceptable according to the desired results of the simulation. Fig. 4 showed a heat flux contour with the lowest heat flux areas of all of my simulations. Next, I changed my material to polystyrene. Fig. 5 showed a temperature of 21°C. Per the requirements, I met the objective of the <= 40°C temperature on the exterior surface. To further improve and lower temperatures and heat flux, I added thickness and fins. Fig. 8 shows slower heat flux rates compared to fig 6. However, fig. 8 showed a temperature increase from 21°C to 24°C where the fins were located. I was expecting fins to reduce the temperature around that area as the heat was supposed to dissipate into the air thus a lower temperature. This requires further exploration to understand why. However, further trials could be run where the fin material is changed and/or investigating simulation error to try and understand what the source issue is.

Table 1: Design alternatives results (C1055-99 is used for sensation and injury)

Design Alternative	Material	Temperature at top of cover (C)	Sensation	Injury
Design 1	Stainless steel	88.688	Numbness	Irreversible
Design 2	Polystyrene	21.425	None	None
Redesign	Polystyrene	24.112	None	None

According to the C1055-99 results in table 1, stainless steel would result in irreversible injuries. Design 2 and the redesign with polystyrene both met the temperature requirement and caused no injuries.

V. Conclusion

The lab simulation aimed to redesign a motorcycle engine's pump housing cover to prevent surface temperatures exceeding 40°C, thereby reducing burn risks. While stainless steel proved mechanically strong, it led to unsafe temperatures, whereas polystyrene met safety criteria. Interestingly, the addition of cooling fins did not lower the temperature as expected, indicating the need for further investigation. Overall, polystyrene emerged as a suitable material, balancing thermal management and safety, but the role of design features like fins requires additional study.