Numerical Investigation of Heat Transfer in an Attic Duct Model

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Introduction: Air ducts play an important role in the energy efficiency of residential homes across the country. While transporting the conditioned air from the HVAC system to the conditioned space, 30-40% of the thermal energy can be lost due to conduction [1]. The loss of thermal energy can reduce the HVAC efficiency to up to 18% [2]. Air ducts can be responsible for up to 12% of the air leakage or 30% of the air leakage area of residential houses [3,4]. Although ducts are located in non-conditioned areas of the building, they usually significantly increase the risk of energy losses. The ORNL attic test module was used in this work for modeling by COMSOL to analyze heat flux and temperature prediction.

Figure 1. The ORNL attic module

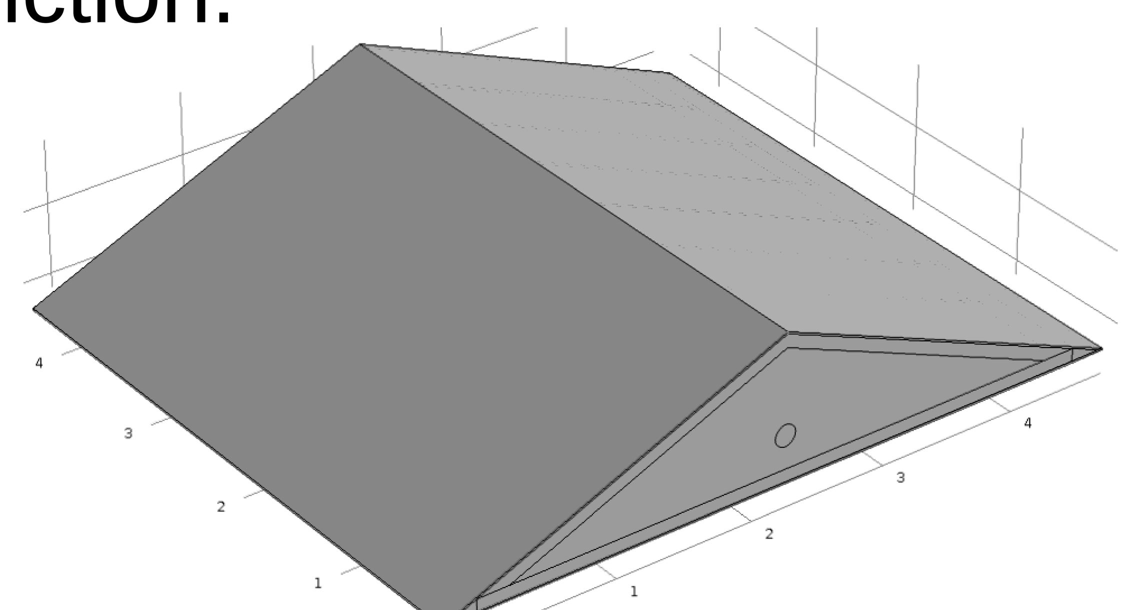

Figure 2. Geometric model in COMSOL

Computational Methods: The model solves a thermal balance for the attic and the air flowing in the cylindrical duct by the k-ε turbulence model together with heat transfer in fluids and solids and extends the attic duct model by taking surface-to-surface radiation into account. To account for the heat flux in the duct surface, the highly conductive layer boundary condition is applied:

$$-\mathbf{n}\cdot(-k\nabla T) = -\nabla_t\cdot(-d_s k_s \nabla_t T)$$

Here, ∇_t is the tangential derivative, d_s is the layer thickness, and k_s is the thermal conductivity of the duct.

Results:

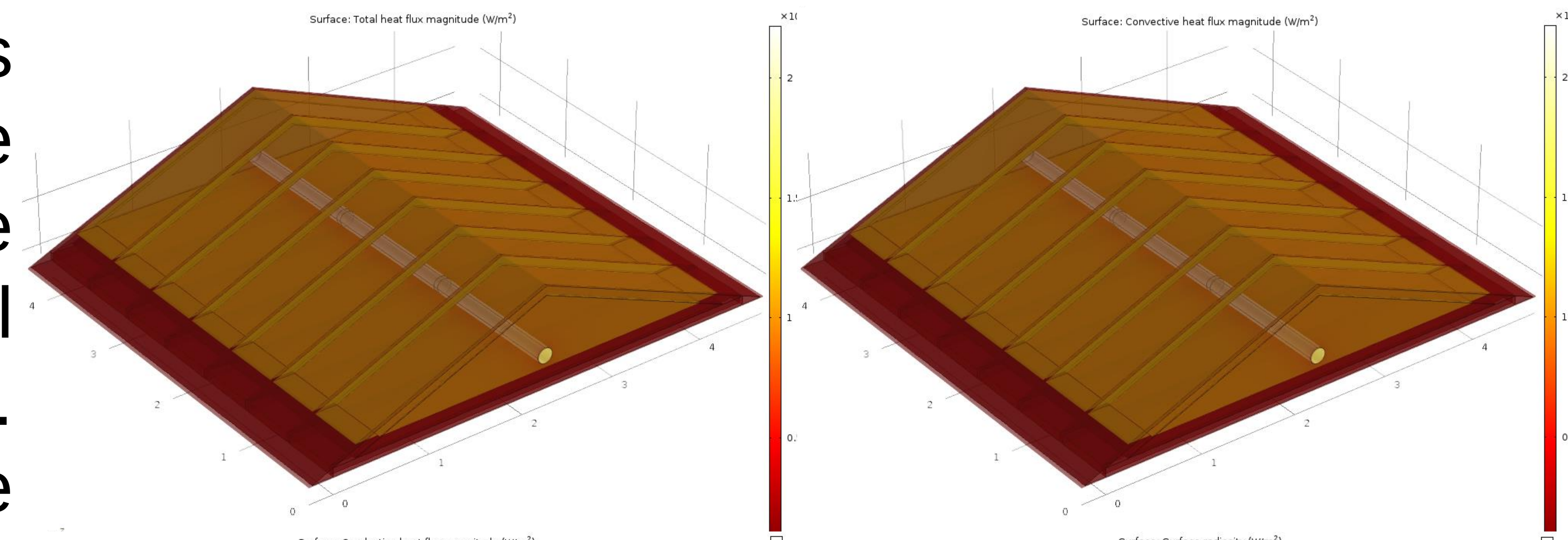

Figure 3. (1) Total heat flux; (2) Convective heat flux

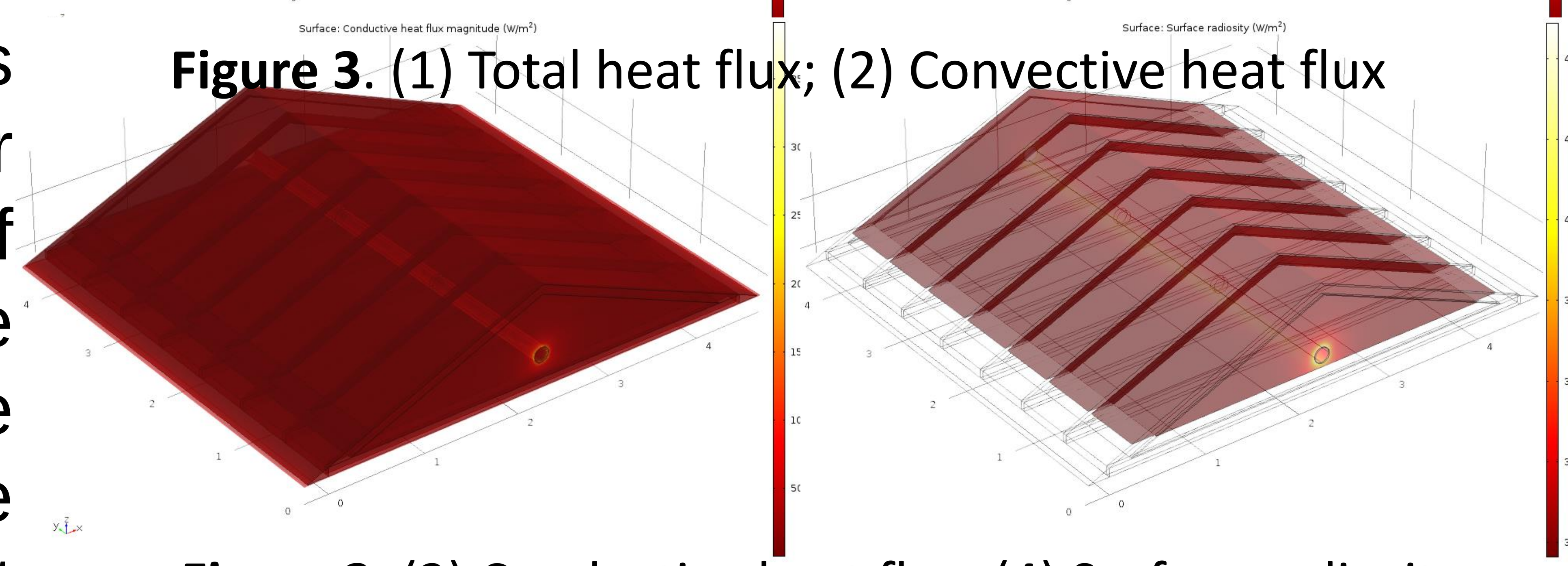

Figure 3. (3) Conductive heat flux; (4) Surface radiosity

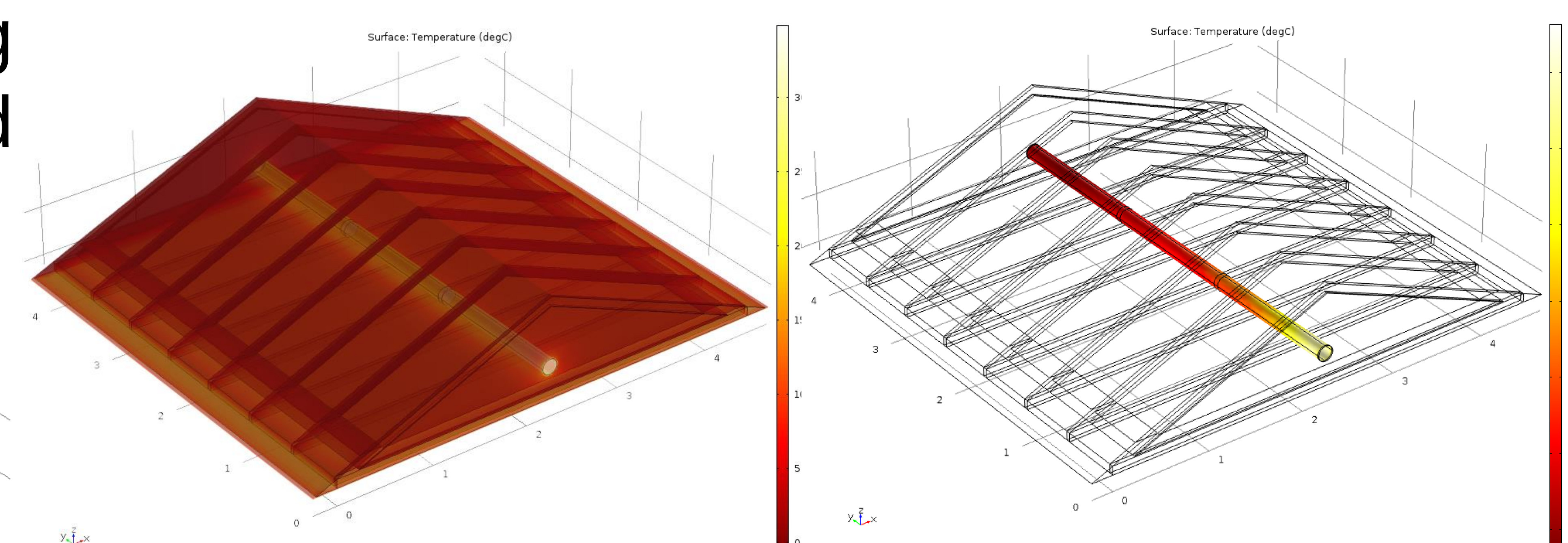

Figure 4. (1) Temperature of attic duct model; (2) Temperature of the duct

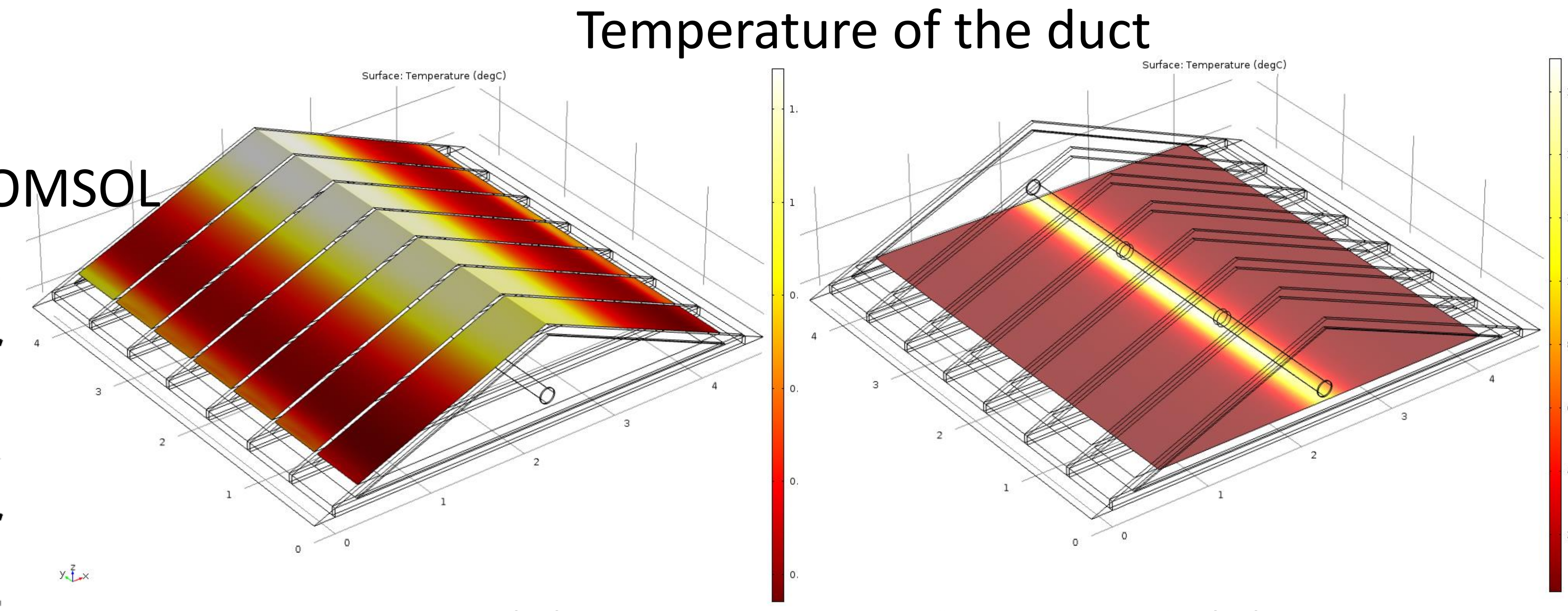

Figure 4. (3) Temperature of attic roof; (4) Temperature of fiber glass insulation

Conclusions: Convective heat flux in the duct dominates the heat transfer in this attic duct model. The heat loss due to conduction and radiation can be reduced by changing duct material having a low conductivity and emissivity.

References:

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