Project Report

AUTOMATIC SNOW MELTING ROADS

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Abstract:

Snow accumulation on roads poses serious challenges, including increased traffic fatalities, reduced road capacity, and higher maintenance costs. To address these issues, various snow-melting systems have been developed. This study investigates the efficacy of a ground source heat pump snow melting system. Simulational results demonstrate the system's ability to heat the road surface and efficiently melt snow rapidly. The term paper explores the feasibility of snow-melting systems using geothermal energy piles in major cities, highlighting their efficiency and cost-effectiveness compared to traditional methods. However, challenges such as ground thermal imbalance are addressed, emphasising the importance of considering local geological conditions. Suggestions to enhance effectiveness include further consideration of flow rates of the fluid at feed and the material and pressure conditions.

Keywords: Snow melting system, Ground source heat pump, Geothermal energy piles, Road safety

Introduction

The presence of snow accumulation on highways throughout the winter season poses several difficulties and dangers. Snow on roadways decreases traction, resulting in a heightened likelihood of accidents and crashes. In addition, snow can obstruct road markers and signage, so adding to the complexity of navigation for drivers. In addition, the process of snow melting and then refreezing can generate ice patches, resulting in highly slippery and dangerous driving conditions. Accumulation of snow can impede the flow of water in drainage systems, resulting in the occurrence of floods in specific areas and increasing the likelihood of hydroplaning. In addition, the process of removing snow, although essential for ensuring road safety, can impede the smooth flow of traffic and present logistical difficulties for transportation authorities.

To tackle these difficulties, snow-melting systems have become increasingly popular in a wide range of environments, such as residential, commercial, and industrial settings. These technologies obviate the necessity of conventional snow removal techniques such as shovelling and ploughing, hence improving safety, and decreasing labour expenses. Geothermal hot water or steam can be used as an innovative method to melt snow on pavements, providing environmental advantages and higher efficiency when compared to mechanical or chemical options.

Additional approaches to melting snow and ice, such as harnessing waste heat from the exhaust or employing infrared devices, have also been investigated. Nevertheless, conventional techniques like salting and sanding are deemed to be less efficient, particularly in extremely low temperatures, and might result in corrosion-related harm to buildings.

Hydronic snow melting systems, employing gas-fired or electric boilers to warm the working fluid, are prevalent but can consume a significant amount of energy. There is an increasing focus on creating snow-melting solutions that are both sustainable and cost-effective. This involves prioritising the use of renewable energy sources to minimise the impact on the environment and reduce energy

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usage.

Scientists have examined the possibility of utilising sustainable energy sources for snow melting systems, with a focus on the significance of implementing eco-friendly designs to reduce $CO2$ emissions and optimise energy efficiency.

The Growth for the global snow melting systems market is shown in figure 1.

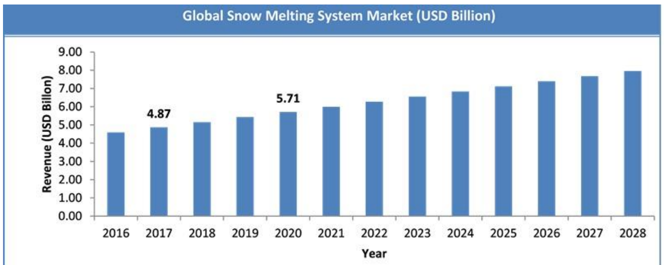

Figure 1: Global Snow melting Systems Market (USD Billion)

Method

The computational fluid dynamics (CFD) simulations were conducted using ANSYS Fluent software to analyze the fluid flow characteristics in the snow melting system. The methodology involved three main steps: pre-processing, solving, and post-processing.

<u>1. Pre-processing:</u>

- The pre-processing phase began with the creation of the system's geometry, including all relevant components of the heat pump as shown in figure 2.

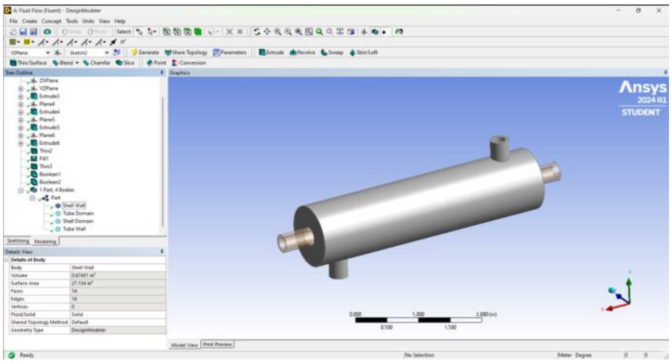

Figure 2: Shell and Pipe geometry

- Mesh generation was performed to discretize the geometry into finite elements, ensuring accuracy in capturing flow behavior and thermal gradients.

- Mesh involves the creation of small domains for the pipe and the shell. As shown in figure 3.

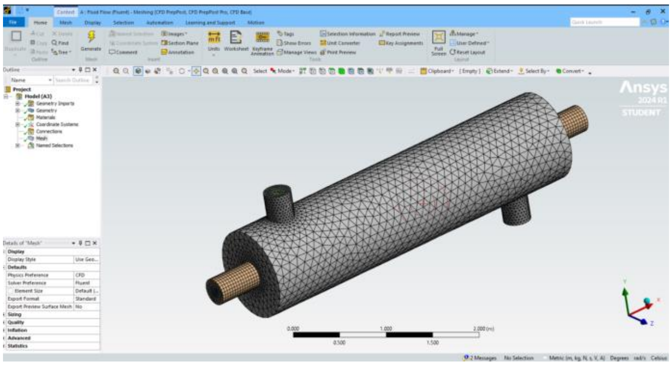

Figure 3: Shell: triangular domains, Pipe: rectangular domains

<u>2. Solving:</u>

- The solving stage involved several key components:

- Discretization of the governing equations, including the Navier-Stokes equations for fluid flow and the energy equation for heat transfer.

- Application of appropriate boundary conditions to simulate real-world operating conditions, such as fluid inlet/outlet conditions, road surface temperature, and heat pump operation.

- Selection of suitable numerical solvers to solve the governing equations efficiently and accurately, considering factors such as convergence rate and stability.

<u>3. Post-processing:</u>

- Post-processing encompassed the analysis and visualization of simulation results to extract meaningful insights:

- Analysis of fluid flow patterns, temperature distributions, and heat transfer rates to assess system performance.

- Visualization of results through contour plots, streamlines, and temperature profiles to aid in interpretation and comparison.

This comprehensive methodology facilitated a detailed investigation into the thermal behavior and performance of the snow melting system, providing valuable insights for optimization and further research.

Results and Discussion

We conducted a thorough examination of the heat transfer occurring between a tube and shell system. Our research specifically investigated temperature profiles, velocity contours, pressure contours, as well as temperature and velocity streamlines. Both the tube and shell are made of copper, and water is used as the fluid in both parts. Our investigation focused on the transfer of thermal energy between the water containing geothermal energy, which was kept at a temperature of 90°C, and the surrounding components.

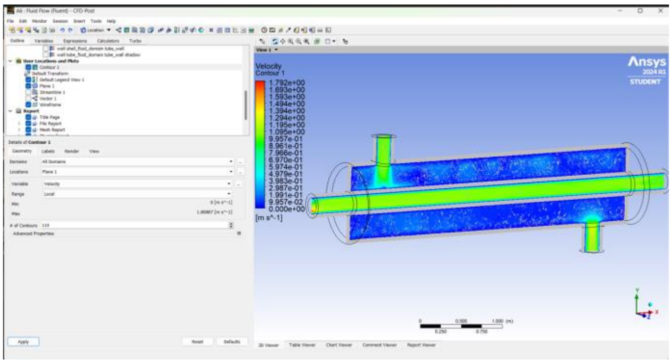

Figure 4: Velocity Contour

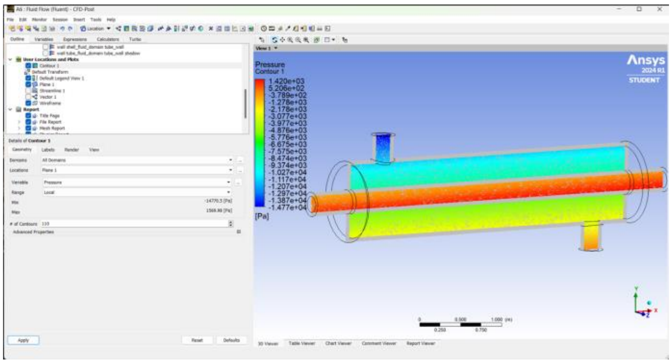

Figure 5: Pressure Contour

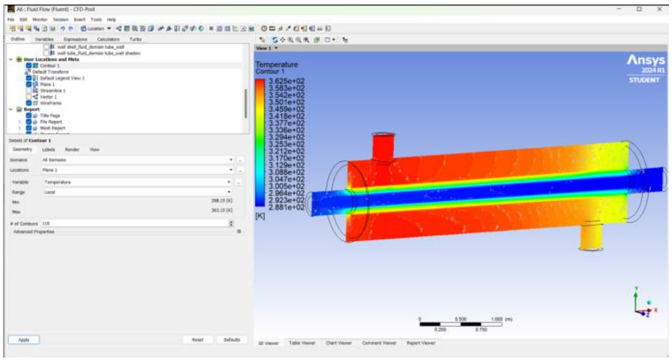

Figure 6: Temperature Contour

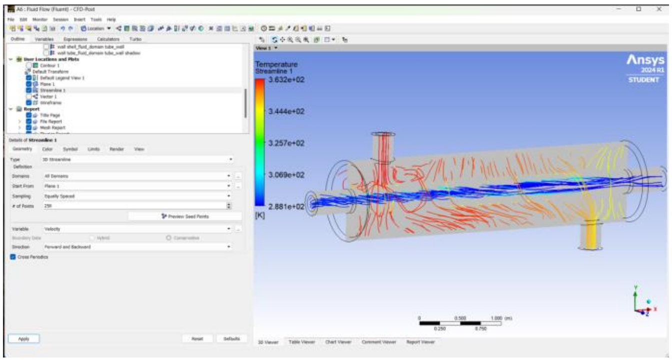

Figure 7: Temperature Streamline

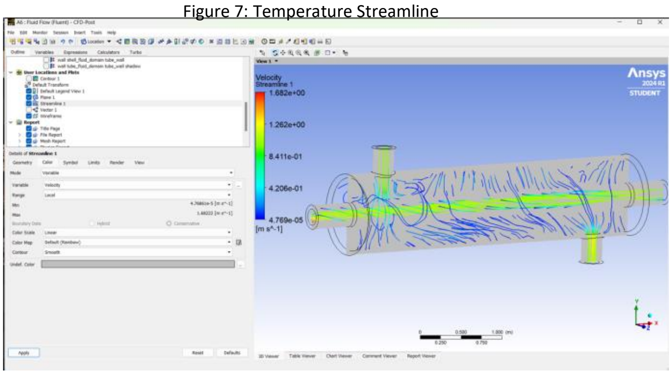

Figure 8: Velocity Streamline

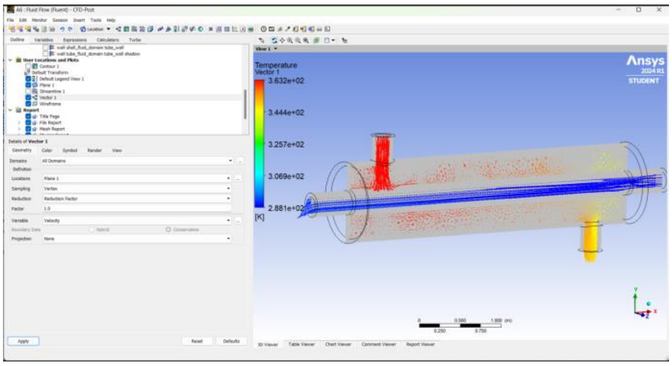

Figure 9: Temperature Vector

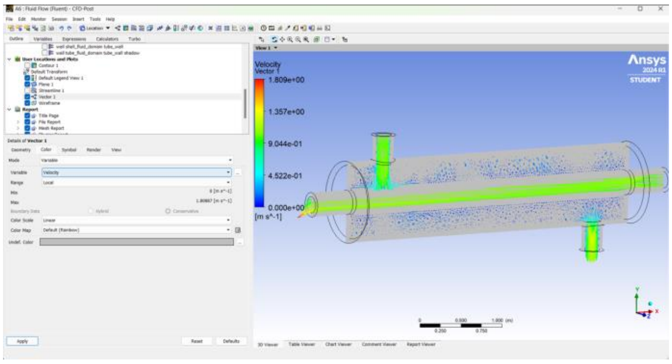

Figure 10: Velocity Vector

Conclusions:

In conclusion, this study underscores the importance of snow-melting systems in addressing road safety concerns posed by snow accumulation. The investigation into ground source heat pump and geothermal energy pile systems highlights their potential as innovative and sustainable solutions. Utilizing computational fluid dynamics simulations, valuable insights were gained into system performance, aiding in optimization efforts. Emphasizing eco-friendly designs and renewable energy sources is crucial for minimizing environmental impact and maximizing energy efficiency in snow-melting technologies.

GitHub Link:

https://github.com/PremBhugraIITD/CLL251_Term_Project

Notes and references

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