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Structural and Thermal Analysis of Copper Coil Using ANSYS

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***Abstract*— In granular machine during extrusion process temperature of water increases this leads wastage of water. Using copper coil, it is possible to maintain the temperature of water. In this present work, structural and thermal analysis of copper coil using ANSYS has been carried out. Analysis is performed for ensuring the safety, stability, and longevity of structures to find temperature distribution, temperature gradient, and heat flowing in the model, as well as the heat exchanged between the model and its environment. Copper coil is modeled using SOLIDWORKS software. Thermal analysis has been executed to find temperature distribution, temperature gradient, and heat flowing in the model, as well as the heat exchanged between the model and its environment. Further structural analysis is carried out for determination of the effects of loads on physical structures and their components. After structural analysis, it is observed that, maximum principle stress induced in copper coil is 41.994MPa and minimum principle stress is -8.9271MPa. Through the thermal analysis, it is seen that, at inlet temperature of water passing through copper coil is 7°C at that point maximum stress is 7.0737MPa and minimum is 6.9945MPa. At outlet of coil, the temperature of water is 15°c at that point maximum stress is 15.005MPa and minimum stress is 14.937MPa.**

***Keywords*— ANSYS, SOLIDWORKS, Structural, Thermal, Copper coil.**

I. INTRODUCTION

An evaporator is the heat exchanger where the refrigerant circulating inside the refrigeration circuit absorbs the thermal energy from the environment, which is then cooled. There are three main types of evaporators for industrial chillers, they are coil type, shell and tube type and plate type.

A. Copper evaporator coil

Copper Coil is one of the components that are needed in air conditioning and refrigerant system. The Coil is used as a path for the refrigerant to flow between system components and to contain it from escaping to the atmosphere. Round copper tube, flat fin coils. These coils can be seen in a few applications that cover residential, commercial and industrial settings. Typical components are condensers, evaporators and water heating coils. The history of round tube, flat fin coils dates back over 100 years and today, they are being successfully modified to fit modern demands. Copper components also offer antimicrobial properties and these advantages are discussed.

B. Heat Transfer

Heat transfer engineers face increasing requirements for energy efficiency and a push to use refrigerants that are less damaging to the atmosphere. To lower costs, there are demands for smaller, more compact systems that save on materials and refrigerants. Smaller diameter, internally enhanced copper tubing referred to as "Microgroove™" tubes, can meet these demands with minimal investment or change to well established manufacturing practices. This study aims to make and analysis of copper coil evaporator design alternatively for cooling the working fluid namely water (H2O). The evaporator designed has a length of 800mm and width 300 mm with diameter 12mm kept in the tank having dimensions length 1820mm and width 470mm. The inlet temperature of water is 40°C after passing with through copper coil its temperature reduces up to 15°C. This leads to enhance the quality of granules, reduces use of water and leads to increase efficiency.

II. LITERATURE REVIEW

Filippini [1] describes the evolution of heat exchanger geometry of condenser aiming to improve product efficiency and to lower internal volume. Additional benefits of this configuration are high production flexibility combined with well known system for soldering condenser to piping on job site.

Fang et.al.[2] In order to promote the application of small diameter copper tubes in HVAC industry, louvered and slotted fin-tube heat transfer surfaces with tubes of 4mm is designed. Numerical simulations are conducted firstly to predict characteristics of the reference fin with tubes of 7mm. Nine kinds of louvered fin and slotted fin models are made respectively by compounding levels on each factor founded on the equal-level orthogonal array L9(34), and the results provide us with approximate optimized values for each affecting factor. Then, based on combination of the nearly optimized values, the new louvered fin and slotted fin structures with 7 tubes of 4mm are proposed and simulated, respectively. The result shows not only the heat transfer capability of the new fin can satisfy the requirements for the reference louvered fin, but also the material of copper tubes of the new heat exchanger is greatly reduced.

With the rapid development of the economy, the market capacity for air conditioning has been gradually expanding. The requirements for air-conditioning quality have also been gradually increasing. Copper tubes play a very important role in the air conditioner. The technology requirements of copper tubes similarly get more demanding. Particularly for the copper tubes in the heat exchanger, the requirements are even higher. Therefore, it has become even more important to utilize the copper tubes to better satisfy the requirements of the air-conditioning industry. For the copper tube manufacturing industry, the development trend has been widely acknowledged to be the pursuit of low cost, high efficiency and high quality. [3]

Ding et.al.[4] small-diameter tube heat exchanger development is conducted. This paper presents some pilot studies on circuit performance carried on by simulation approach. A discretized computational model and general simulation program are developed, in which a special circuit data structure is introduced. By using this model and the program, a simulation design 8 works of small-diameter (Φ5mm) tube condensers is presented for replacing of a conventional condenser with a larger diameter (Φ7mm) tube of RAC. Due to the decrease in tube-side flowing cross section area, small-diameter tube heat exchanger commonly has a much higher refrigerant pressure drop. In this paper, the study of using Φ5mm diameter tube for replacing Φ7mm diameter tube in condenser is conducted.

A. RESEARCH GAP

There are different types of evaporators like copper coil, etc. Majority of literature just explained about evaporator and copper coil [1-8]. Very less research has been done on the analysis of copper coil. Before using it copper coil first we have to do structural thermal analysis so there is scope for the same.

B. OBJECTIVES

- To decrease water temperature to make heat transfer faster by copper coil. In granular machine during extrusion process temperature of water increases this leads wastage of water. Using copper coil, we can maintain the temperature of water.
- Structural and Thermal analysis of copper coil using ANSYS to ensure the safety, stability, and longevity of structures.
- To find temperature distribution, temperature gradient, and heat flowing in the model, as well as the heat exchanged between the model and its environment.

III. METHODOLOGY

Following steps are followed:

Determining of how much temperature to be maintaining, according to that selection of coil material and dimensions of coil, instated of aluminum coil copper coil is used because copper have low specific heat and heat up, Cools faster than aluminum.

1. Prepare 3D Module of water tank and copper coil:

The 3D drawing of water tank on SOLIDWORKS is done as shown in Fig.1 for ensuring accuracy in design process with dimension length 1820mm, width 470mm, height 480mm.

Then copper coil is drawn in the tank and extruded it. We have designed copper coil on SOLIDWORKS software with dimensions as follow: Copper coil:

Length: 800mm
Width: 300mm
Inner dia.:12mm
Water inlet temp: 400c
After cooling process: 150c

2. Structural analysis of copper coil:

Through Structural analysis using the ANSYS software enables determination of the effects of loads on physical structures and their components. Structures subject to this type of analysis include all that must withstand loads, such as water, machinery.

3. Thermal analysis of copper coil:

Copper coil under goes thermal analysis using ANSYS through this analysis the software enables temperature distribution, temperature gradient, and heat flowing in the model, as well as the heat exchanged between the model and its environment.

4. *Evaluation of results:*

After conducting the analysis and evaluation of the result outcome is determined.

5. Final conclusion:

After evaluation the conclusion reveals valuable and significant findings.

IV. 3D MODEL OF COPPER COIL AND WATER TANK

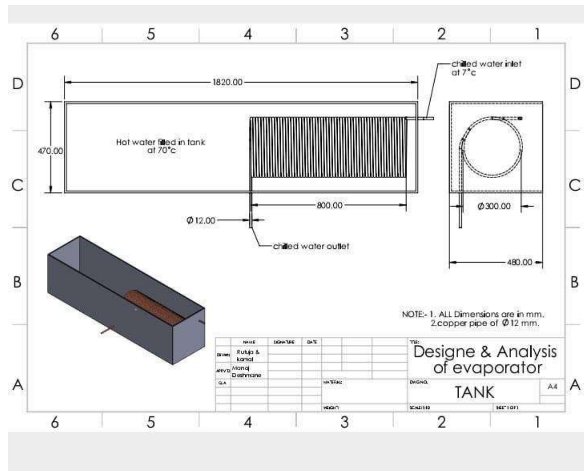

Fig..1 Model of copper coil

V. THERMAL ANALYSIS STEPS

A. Geometry

Geometry Import: Import or create the geometry of your thermal system in ANSYS Workbench as shown in Fig.2. Ensure that the model is properly defined, including the dimensions, material properties, and boundary conditions.

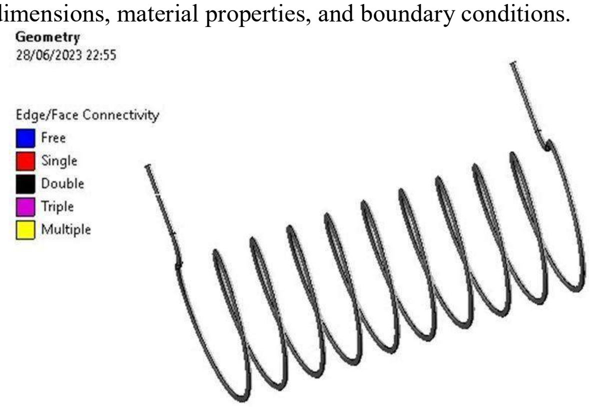

Fig.2 Geometry of copper coil in ANSYS

B. Materials Selection

TABLE 1 PROPERTIES OF COPPER

Density	8.94e-06 kg/mm³
Young's Modulus	1.25e+05 MPa
Thermal Conductivity	0.394 W/mm·°C
Specific Heat	3.85e+05 mJ/kg·°C
Tensile Yield Strength	33.5 MPa
Tensile Ultimate Strength	152 MPa
Nonlinear Behavior	False
Full Details	Click To View Full Details
Statistics	
Assigned Bodies	1

C. Thermal Boundary Condition

TABLE 2 THERMAL BOUNDARY CONDITIONS

Sr. No	Name Selection	Temperature (^{o} C)	Heat Transfer Coefficient (W/mm^2/K)
1	Inlet wall	7	340
2	Outlet wall	15	340

Define the boundary conditions for your thermal analysis. Specify the temperature or heat flux values at the boundaries of the system. You can also apply convection or radiation boundary conditions if necessary.

VI. STRUCTURAL ANALYSIS

A. Geometry

Import or create the 3D geometry of the structure you want to analyze using ANSYS Design Modeler or any other CAD software as shown in Fig. 3. Ensure that the geometry is clean and free from any errors or gaps.

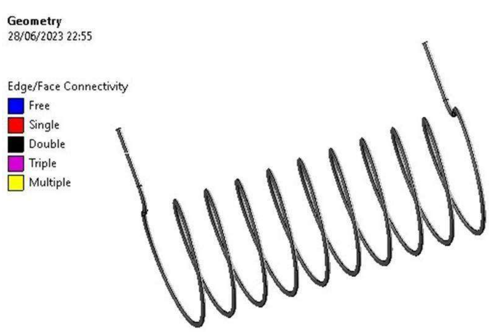

Fig.3 Geometry in ANSYS

B. Structural Boundary Condition

Apply boundary conditions to the model to simulate the real-world loading and constraints. This includes fixing certain degrees of freedom (constraints) and applying loads (forces, pressures, etc.) to appropriate locations. ANSYS 23Workbench allows you to define different types of boundary conditions, such as displacement constraints, fixed supports, distributed loads, etc.

C. Total Deformation

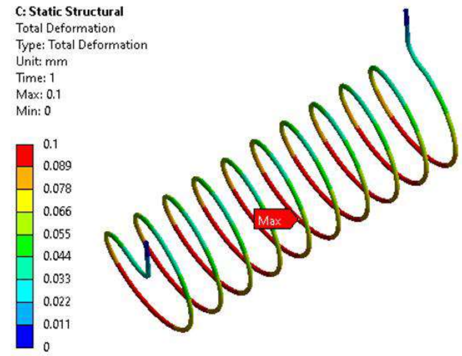

Fig.4 Total Deformation

Total deformation is the deformation option that you can see all the deformation results related to your model, in three coordinates (X, Y, and Z).

D. Equivalent Stress

Equivalent stress is widely used to represent a material's status for ductile material. Engineers use this simple scalar value to determine if the material has yield or failed.

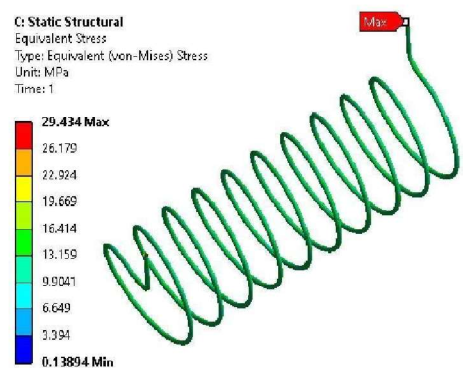

Fig.5 Equivalent stress

E. Results Visualization

Once the analysis is complete, ANSYS Workbench provides various post processing tools to visualize and interpret the results. You can plot stress distributions, displacement contours, deformation animations, and other relevant quantities to evaluate the behavior of the structure under the applied loads.

F. Result Evaluation

Analyze and interpret the results obtained from the analysis. Check if the structure meets the desired criteria, such as stress limits, deflection limits, or factor of safety requirements. If necessary, you may need to make design modifications and iterate the analysis to achieve an optimal design.

VII. RESULTS AND DISCUSSION

After doing the structural analysis, it is observed that maximum principle stress induced in copper coil is 41.994MPa and minimum principle stress is -8.9271MPa.

After doing the thermal analysis is observed that at inlet temperature of water passing through copper coil is 7^{o}C at that point maxima stress 7.0737MPa and minimum is 6.9945MPa. At outlet of coil the temperature of water is 15^{o}c at that point maximum stress is 15.005MPa and minimum stress is 14.937MPa.

A. Thermal Analysis

Fig.6 Steady state thermal analysis

Solution: Run the analysis using the solver. ANSYS Workbench will iterate through the solution until it converges to a steady state. The solver will calculate the temperature distribution throughout the model based on the specified boundary conditions and material properties.

B. Thermal analysis at inlet temperature

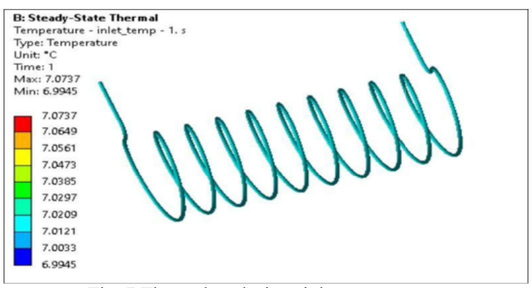

Fig. 7 Thermal analysis at inlet temperature

C. Thermal analysis at outlet temperature

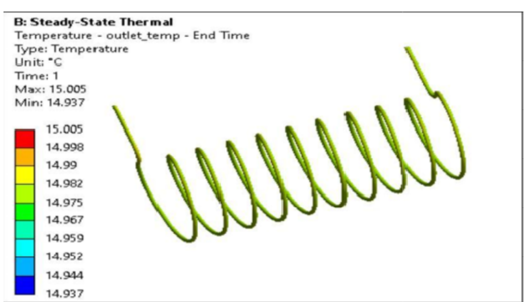

Fig. 8 Thermal analysis at outlet temperature Post-Processing

D. *Result Evaluation*

Analyze the results to draw conclusions about the system's thermal performance. Evaluate temperature gradients, identify hotspots, assess heat transfer rates, or compare temperatures against design limits. These insights can help you make informed decisions about improving your design or optimizing your thermal management strategies.

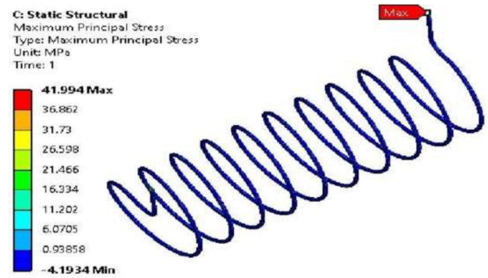

Fig.9 Maximum Principle Stress

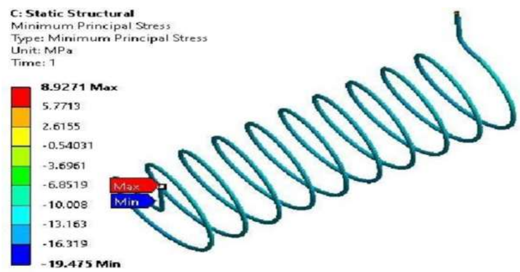

Fig.10 Minimum Principle Stress

VIII. CONCLUSION

Thermal analysis has been executed to find temperature distribution, temperature gradient, and heat flowing in the model, as well as the heat exchanged between the model and its environment. Further structural analysis is carried out for determination of the effects of loads on physical structures and their components. After structural analysis, it is observed that, maximum principle stress induced in copper coil is 41.994MPa and minimum principle stress is -8.9271MPa. Through the thermal analysis, it is seen that, at inlet temperature of water passing through copper coil is 7^{o}C at that point maximum stress is 7.0737MPa and minimum is 6.9945MPa. At outlet of coil, the temperature of water is 15^{o}c at that point maximum stress is 15.005MPa and minimum stress is 14.937MPa.

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