USING PYFOAM TO AUTOMATE THE CFD STUDY OF A REEFER TRUCK

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Abstract: For example, CFD is used in the automobile and food sectors to create and evaluate products. The small-scale firms don't want to spend a lot of money on open source solutions nowadays. In terms of commercial and industrial CFD OpenFOAM software, it is capable of handling a multi-physics challenge. For instance, the OpenFoam solver is a C++ encoded numerical tool for solving diverse fluid flows and heat transfer under a large number of differential equations where the analyser needs to scratch his head to acquire the results. An OpenFoam CFD model of a Reefer truck chamber with variable temperatures and velocities was created and analysed in the current research. Different intake angles and duct placements are tested in the truck chamber. PyFoam, a Python scripting interface included in OpenFoam, is used to automate the whole CFD process by allowing suppliers or customers to directly enter the coolant temperature and intake angle. The python code was used to verify the inlet angles of 20 and 45 degrees for the reefer truck CFD simulation.

Keywords*: CFD, Heat transfer, OpenFoam, PyFoam, Reefer truck.

INTRODUCTION

There has been a dramatic rise in global food production due to the growing global population and increasing wealth [1]. An continuing strategy for dealing with food product transportation is to use new transportation technologies and ways of conveyance.

A problem that had to be dealt with One of the most basic electrical devices, the local fridge is used to keep food fresh and sanitary on manufacturing lines and in homes. nourishment waste. Buyers frequently believe that food is sheltered when kept in fridges with 4°C temperature specification [2]. Be that as it may, nourishment can at present ruin and can possibly cause foodborne diseases when delivered unchilled.

A. Research Objective

We've noticed that scholars have automated just the solver component of analysis, according to several papers cited. Automated preprocessing, solution, and postprocessing are all part of this paper's scope. Using python scripting, we've made it so that customers and clients may apply boundary conditions without having to scratch their heads. Salome is used to extract the python script used for the geometry automation.

B. Reefer Truck

Perishable goods and other temperature-sensitive items are transported in "reefers," which in the trucking industry are refrigerated trailers that are attached to semi-trucks. For optimal food safety and long-term utilisation, these vehicles must maintain a constant temperature within a few degrees of the food's breaking points [3]. There are a variety of ways to keep the vehicle cool, including:

CO2 ice in the form of a cryogen coolant keeps the material cold.

In addition, there are diesel-powered generators that are connected to the chamber that is being

drained.

Need for Reefer Truck

Reefer trucks now transport PCs, therapeutic supplies, plasma, blood, meats, seafood, and produce [4], all of which need to be chilled before they can be delivered to their final destination. To ensure the safety and security of food, medicine, and medical supplies for people all over the globe, transportation preservation is essential in modern society [5].

Thirty-seven percent of India's perishable produce is lost due to a lack of refrigerated transportation trucks. To guarantee that the food is safe, there are a number of particular food safety rules and legislation [6]. The advancements in food preservation technology have allowed us to store a broad variety of foods for extended periods of time while maintaining their freshness as closely as possible under the conditions

Medicines that save people's lives may now be found in anything from pharmaceuticals to great art,synthetic compounds and building materials. Solidified items don't require any additional additives since microorganisms don't develop when the temperature of the sustenance is beneath -9.5°C, which is adequate all alone in avoiding nourishment deterioration.

C. Computational Fluid Dynamics

CFD plays a significant part in the testing and analysis of numerous things or machines, such as aeroplanes, automobiles, and so on. Analysts and engineers no longer have to ponder the seemingly intractable problems they faced decades ago. Planes may be viewed and comprehended simply, for example, by estimating the airflow around an automobile. OpenFoam has been utilised as a CFD tool in this work in order to simulate the air flow within a refrigerated truck chamber. It is necessary to develop a CFD methodology that can produce high-fidelity CFD reproductions quickly and consistently, and return information to a driver code (e.g., IHDE) for reconciliation in the structure/investigation cycle to meet the objectives of the multi-material science models recently mentioned. [8].

$$\frac{D\rho}{Dt} + \rho\frac{\partial U_i}{\partial x_i} = 0 \tag{1}$$

$$\rho\frac{\partial U_j}{\partial t} + \rho \cup i\frac{\partial U_j}{\partial x_i} = -\frac{\partial p}{\partial x_j} - \frac{\partial \tau_{ij}}{\partial x_i} + \rho g_j \tag{2}$$

$$\rho C_\mu\frac{\partial T}{\partial t} + \rho C_\mu u_i\frac{\partial T}{\partial x_i} = -P\frac{\partial U_i}{\partial x_i} + \lambda\frac{\partial^2 T}{\partial x_i^2} - \tau_{ij}\frac{\partial U_j}{\partial x_i} \tag{3}$$

There are three equations in this set: one for continuity, another for momentum, and a third for energy..

I. METHODOLOGY

In the following Fig.1, the project's detailed method is shown in its entirety. The procedure involves a variety of steps, including a literature review, modelling, a cfd solver, and several boundary conditions.

Fig.1. CAD model of reefer truck containing cargos

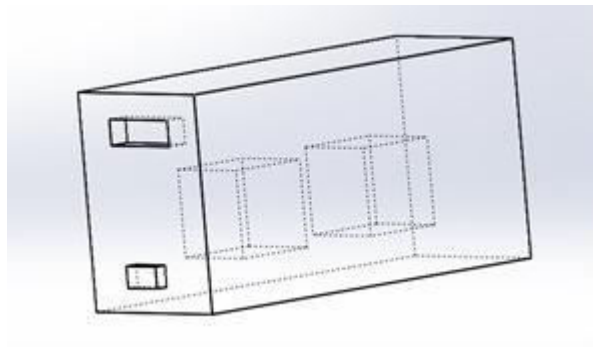## II.   MODELLING AND ANALYSIS

A. Pre-Processing

Various papers have been used to determine the size of a refrigerated truck container, and an average value has been used as a basis for our modelling.

Table- I: Geometry Dimensions

Dimension	Value(m^3)
Inlet duct	1*0.3*0.25
Outlet duct	0.5*0.3*0.15
Reefer truck	5*2.5*2

Dimension	Value(m^3)
Inlet duct	1*0.3*0.25
Cargo	0.5*0.5*0.5

Salome Meca 2017 V0.2 was used to model the truck container, as illustrated in Fig. 2. For automation purposes, we decided to utilise this programme since it allows us to easily extract the geometry python script.
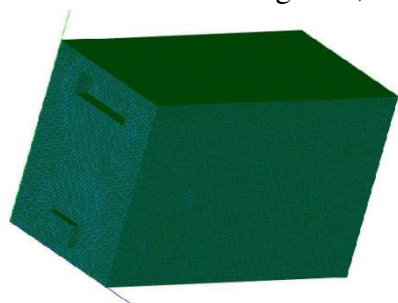

Fig.2. CAD model of reefer truck containing cargos

After modelling, various faces of the container has been assigned to input the boundary conditions such as inlet, outlet, wall and container wall.
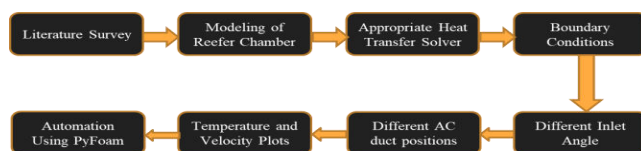
B. Meshing

It's possible to mesh in Salome as well. As can be seen in Figure 3, the mesh employed is Tetrahedral

Mesh.

Fig.3. Tetrahedral meshing of the model

The mesh quality is defined in the following Table2

Table- II: Mesh Information

Type of mesh	Tetrahedral
Mesh size	0.05
Cells	618881
Nodes	109781
Max aspect ratio	5.64818

C. OpenFoam

Many researchers use this software because of its many advantages, the most important of which is that it is free because it is open source, meaning that anyone can use it without having to pay a dime. In contrast to commercial software, which requires licencing fees, this free software produces results that are identical to those produced by commercial software.

OpenFoam Software has a variety of standard C++ solvers that are used for a variety of applications. A heat transfer simulation was performed on this model. The buoyantBousinesqSimpleFoam solution was selected since we were working with an incompressible, steady-state heat transfer problem [9]. The generic form of the Navier Stokes equation is seen in equation 4.

The reefer truck's inlet and exit ducts are located on the same side of the vehicle, ensuring that all of the truck's characteristics remain consistent. No-slip boundary conditions are enforced at the wall, where the velocity is set to zero. The Reynolds number and other factors are used to compute the alphaT, nut, and other parameters as well. Table.III shows additional boundary conditions.

$$\frac{\partial(\rho\phi)}{\partial t} + \frac{\partial}{\partial x_i}\left(\rho u_i \phi - \Gamma_\phi \frac{\partial \phi}{\partial x_i}\right) = q_\phi \tag{4}$$

Table- III: Boundary Conditions

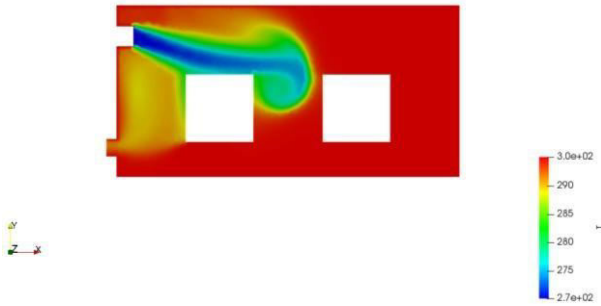| Boundary conditions	Values
Refrigeration capacity	0.6 tonnes
Inlet velocity angle	20^0
Inlet air temperature	270K
Room temperature	295K

RANS-based realizableKE model for incompressible flow, in which K defines turbulence scale and epsilon determines the turbulence energy, is the standard turbulence model that we have chosen.
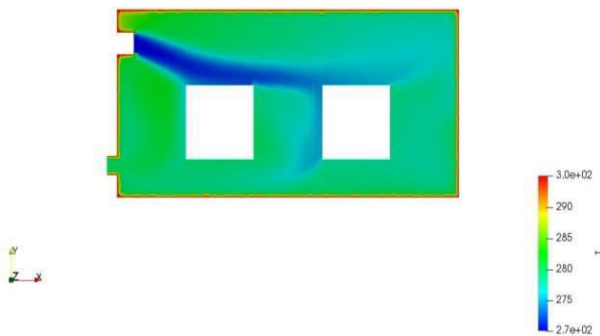
D. Post Processing

OpenFoam's built-in ParaFoam programme is used to view the findings. The contour lines, temperature, and velocity plots are shown on the monitor. GnuPlot, a third-party programme, is used to plot the temperature vs. distance graph.

ParaFoam's Temperature Contour is shown in Figures 4 and 5. Other variables, such as velocity, pressure, and residuals, may also be examined. The intake velocity has been examined in two separate scenarios, i.e. 20 and 45 degrees, at two different angles. The location of the output duct may also be

adjusted to meet the needs of the customer..

Fig.4. ParaFoam results at 50 time step

Fig.5. Parafoam results at 160 time step

III. AUTOMATION

Automated systems have become commonplace in the modern world so that customers don't have to ache their heads while completing a task. Python is a superb programming language that is suitable for scientific computations and widely used. Python is often used to make tedious and time-consuming tasks more efficient and enjoyable. [10],[11].

A. Prerequisites

The following databases and libraries to be installed by the user in order to run smoothly:

As of Python 2.7,

• Gnuplot \s• PyFoam

Geometry Automation

Salome software's geometry script is used to automate the geometry process. The reefer truck container's dimensions, such as its length, width, and height, must be entered by the user. Next, the maximum number of cargo allocations permitted to be stacked in each of the three dimensions (x, y, and z) is determined by assigning a spacing between boxes in all three directions.

- Step 1: Assigning the truck's dimensions input (a) = "n length (A) =
- height (B) is the input Input ("width (C) = ")
- [32] -> Box 1 = geompy.MakeBoxDXDYDZ(" + str); (a)

- Strings a, c, and d are added at the end of the text.

- Geometry script will automatically update the data provided by the user in the aforementioned command.

- Next, determine the maximum number of boxes to output by running the following code: print "x direction ="

- iterate over each element of the array and print 'y direction = ' (r+f)/(f+0.5) ='z direction = '


```
Enter the spacing between boxes in

 x direction (D) = 0.5
 y direction (E) = 0.2
 z direction (F) = 0.25

Calculating.......


Maximum allocations of boxes allowed in

 x direction =   4
 y direction =   3
 z direction =   2
```

Fig.6. Maximum allocation of boxes

Each of the three working areas (p, q, and r) is where the cargoes are piled.As you can see in this diagram (x, y, z), there are three distinct distances between the boxes.This is the third step. Putting the boxes in their proper placesEnter the x-direction x-box count here. Input ("Enter box number in y direction =") input ("Enter the number of boxes in the z direction = ")"The geometry script updates the user-supplied data, and an error message is shown if an incorrect value is issued.

Solver automation

Python-based PyFoam is used to automate the heat transfer solver in OpenFoam. Different boundary conditions such as refrigeration capacity, intake temperature and velocity inlet angle must be provided throughout this procedure by the user.

Pre-requisite library functions

The source code for PyFoam is here.

RunDictionary.

The import of the ParsedParameterFile is from the PyFoam.Applications package.

CaseReport In order to importCaseReport, os, and math

subprocesses may be imported

All of the aforementioned library functions are needed to enter mathematical equations, execute the procedure, and generate different results.

p=subprocess is the command to use to run the mesh file.

Popen ('ideasUnvToFoam', 'File.unv') is a command-line tool.

The method above reads a mesh file in '.unv' format and transforms it into a Foam object.

Input Constraints on an area

m is equal to the value entered into the input box "The following is the text of the paragraph:

Using an average of 0.5 to 2 tonnes of refrigeration capacity, we may calculate the following: "(p=(m/0.3))

$$a = input("\nInlet\ angle\ of\ velocity : ")$$

$$x = round(p * math.cos(a*math.pi/180.0),3)$$

$$y = round(-p * math.sin(a*math.pi/180.0),3)$$
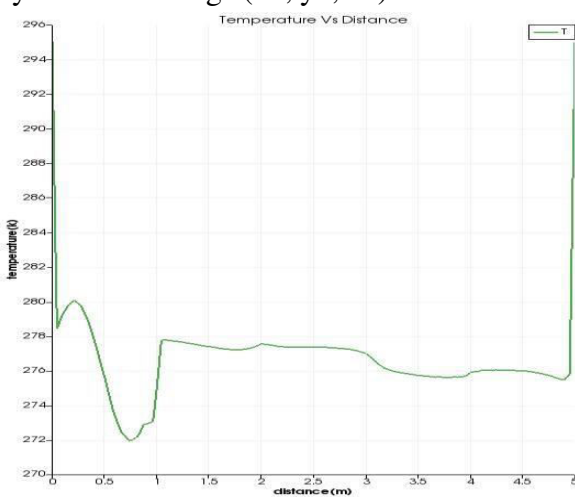
Running the Simulation

"buoyantBoussinesqSimpleFoam" is the name of the subprocess. When using Subprocess, the user may run their simulation with the solver's name already entered into the solver's field. The simulation will converge at a certain time step since it is in a steady state. Mesh size, geometry, deltaT, and velocity all have a role in the amount of time needed for a simulation.
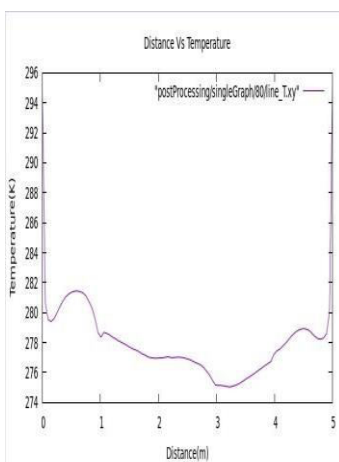
Plotting the graph

p=postProcess.Popen(['postProcess-func singleGraph']).

Figures 7 and 8 illustrate the graph, which was created using the third-party programme Gnuplot, which records the data for each time step.

(x1, y1, z1) and (x2, y2, z2) are the coordinate positions where the graph must be displayed before the user may see the findings (x2, y2, z2).

Fig.7. Gnuplot of Temperature v/s Distance for 45^0 angle

Fig.8. Gnuplot of Temperature v/s Distance for 20^0 Angle

IV. CONCLUSION

Businesses who get their products to market quickly, minimise stock expenditures, and maximise the use of their ground supply or transportation fleets are the ones that flourish in a centred profitable centre. An increasing number of businesses are automating their coordination processes by establishing supply chains that link them to their customers and suppliers. OpenFoam and PyFoam Tool have been used to automate CFD study of air flow inside a refrigerated vehicle. The user just has to enter the necessary data for cargo cooling. It is possible to choose the space between the boxes and it will automatically compute the maximum number of boxes that can fit on a pallet in any of the three directions. Aside from that, the whole CFD process, including the graphing of the data and the user's ability to change any parameters, is automated.

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