INTEGRATION OF WATER CHILLER AND AIR COOLER

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ABSTRACT: *This is an idea of integrating both the units, water chiller and air cooler by considering the power consumption and their individual cost. Water Chillers and Air Coolers has become a need for every individual. By recognising the demand, a new unit in their combination is designed. Both the units work on single compressors. A T-Joint is attached containing a split valve to divide the refrigerant to both the units. An Arduino code driven servo motor is used to control the flow of the refrigerant through the valve. Computational Fluid Dynamics were carried to check the pressure drop in T-Joint. Design and modelling of the geometry was prepared in SOLIDWORKS and the analysis of the T-Joint in ANSYS 2021R2.*

Key words: Water Chiller, Air Cooler, Split Valve, Refrigerant, Arduino.

1. Introduction:

Power consumption is increasing day by day in the present world as usage is increasing. Mostly the major consumption of power is due to using refrigerators and air conditioning systems for industrial, household and other purposes. Focusing on this issue a new unit with two different purposes; air cooler cum water chiller is prepared, where both the units are integrated into a single unit. Both individual units are used to cool the space or a substance and this desired output can be achieved by using a Vapour Compression Refrigeration System (VCRS) in which a compressor, evaporator, condenser and an expansion valve are the major parts [2]. Same vapour compression refrigeration system is used after integration with a single compressor, single condenser, single expansion valve and two different evaporators. An extra split valve is used to split the refrigerant for the both evaporators. One evaporator is used to cool the water and other evaporator is used for air cooler. In the normal air cooler honeycomb pads were used with a fan, but in this unit an evaporator itself was used as a cooling pad which actually gives a better cooling effect than honey comb pads. Low pressure vapour refrigerant enters into the compressor for compression after which the pressure and temperature of the refrigerator increases and then the vapour refrigerant enters into the condenser in which the phase of the refrigerant changes to liquid and then enters into the expansion valve where both the pressure and temperature decreases and therefore the phase of the refrigerant is liquid plus vapour. Refrigerant enters into the T-Joint having a split valve where the refrigerant splits into two different opposite sides, to the evaporators at the water tank and in front of a fan to pass cool air. Then the pressure decreases and again the vapour enters into the compressor.

1.1 Reciprocating Hermetic Compressor:

Hermetically sealed compressor is a welded steel casing, both compressor and motor are placed where these two are connected by a common shaft. Here the compressor and motor are situated in a single unit this makes the unit small in size which can be carried easily from one place to another.

But, in traditional type compressors the compressor and motor are placed in different units, this makes the hermetic compressor an unique one.

1.2 Refrigerant:

Commonly used R134a is taken as refrigerant in the study.

R134a is also known as Tetrafluoroethene (CF3CH2F) from the family of HFC refrigerants. With the discovery of the damaging effect of CFCs and HCFCs refrigerants to the ozone layer, the HFC family of refrigerants has been widely used as their replacement. It is now being used as a replacement for R-12 CFC refrigerant in the area of centrifugal, rotary screw, scroll and reciprocating compressors. It is safe for handling purposes because it is non-toxic, non-flammable and non-corrosive.

1.3 Split Valve:

The split valve fits in a newly designed T-Joint which is used to bisect the refrigerant to two distinct units. The valve inside is water tight and connected to the servo motor from outside. The servo gets inputs from Arduino uno and rotates accordingly. Through this, a significant flow is achieved as per requirement.

2. Integrating using T-Joint:

Assembly for unification of both units was inspired from a refrigerator tank at our university. The complete design was made into two parts; outdoor unit and indoor unit. Indoor unit consists of an air cooler and water chiller with an expansion valve whereas the outdoor unit consists of a compressor, condenser and a fan, to pass out the heat from the condenser. The outdoor unit is attached to the lower side of the main unit. A newly designed T-Joint is used to unite both the evaporators as shown in schematic diagram of fig-1. A T-Joint is added between expansion valve and evaporators, so that refrigerant can be managed to flow into two separate evaporators at a time. The refrigerant gets split into two paths and enters into the evaporators of both the water chiller and the air cooler. The temperature limits are monitored and maintained by a temperature sensor.

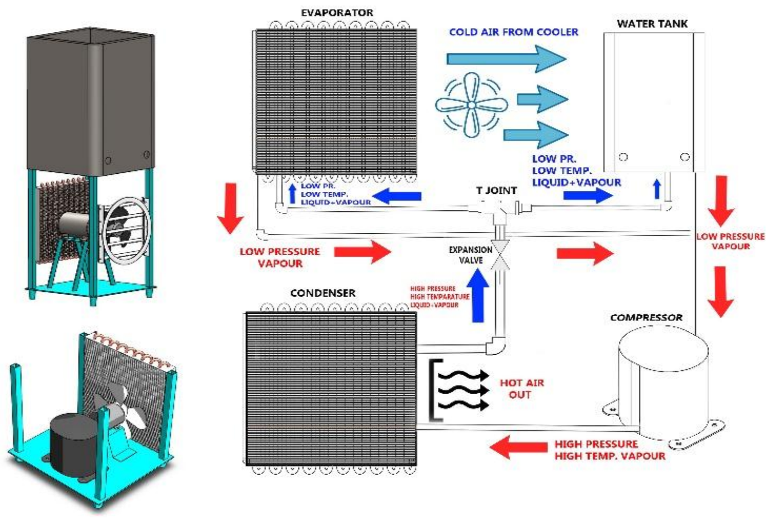

Fig-1: Solid modelling of Indoor unit and Outdoor unit; The schematic diagram of the entire unit after integration.

3. CFD Procedure:

3.1 Geometry Preparation:

The T-Joint with three openings, which is used to integrate two units is designed in Solidworks and imported to Ansys Workbench in '.STEP' or '.IGS' format for fluid analysis.

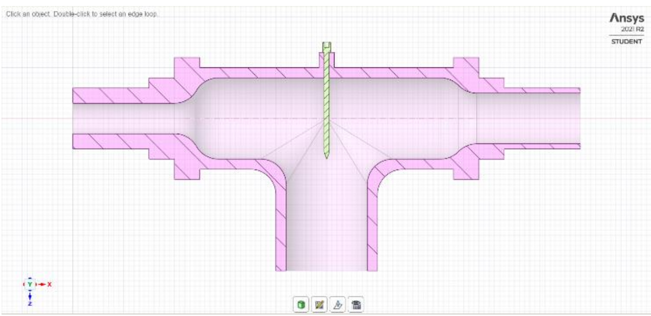

Fig-2: Cross section view of T-Joint with split valve at centre position.

3.2 3D Meshing:

Mesh for the geometry as in fig-2 was generated in Ansys Fluent. Inflation was added on the wall side to control the shear force. Named Selections were added to the T-Joint as 'inlet' and 'outlet' at respective inlet and outlets.

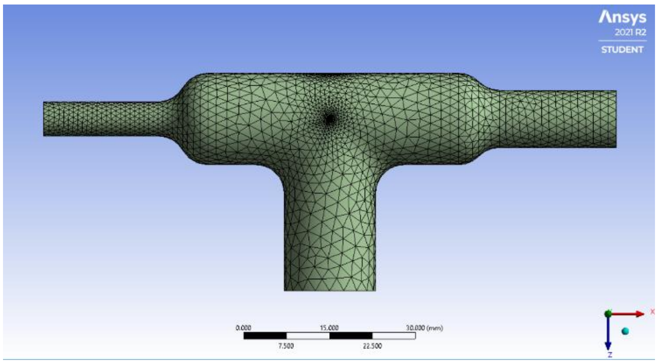

Fig-3: 3D unstructured tetrahedral mesh of T-Joint.

3.3 Table-1: Simulation Setup in Ansys Fluent

4.1 General	Mesh	Scale
		Check
		Report Quality
		Display
	Solver Type	Pressure Based
	Solver Velocity Formulation	Absolute
	Time	Steady
4.2 Models	Heat Exchanger-off	
	Multiphase-off	
	Energy-off	
	Radiation-off	
	Viscous	Laminar
4.3 Materials (From FLUENT database)	Material type-Fluid	Freon(R134a)
		Density=1210 kg/m^3
		Specific Heat=1400j/kg-k
		Thermal Conductivity= 0.0824(liquid) 0.0145(vapour)

4.4 Cell-Zone Condition	Type-fluid	Freon(R134a)
	Operating Condition	Pressure= 101325 Pascal
		Gravity=9.81 m/s^2
4.5 Boundary Conditions	Inlet	Pressure-Inlet
	Interior-Volume	Interior
	Outlet	Mass-Flow-Outlet
	Wall	Wall
4.6 Reference Values	Compute from	Inlet
		Area = 1 m^2
		Density = 1305.8 kg/m^3
		Enthalpy = 0 J/kg
		Length = 1m
		Pressure = 0 Pascal
		Temperature = 288.16 K
		Velocity = 19.22517 m/s
		Viscosity = 0.000254 kg/m-s
		Ratio of Specific Heats = 1.4
4.7.Solution Methods	Pressure-Velocity Coupling	Scheme- Simple
	Spatial Discretization	Gradient – Least Square Cell Based
		Pressure - Standard
		Momentum - Second order upwind
4.8 Solution Controls	Under Relaxation Factors	Pressure= 0.3
		Density= 1
		Body Forces= 1
		Momentum= 0.7
4.10 Solution Initialization	Initialization Methods	Standard Initialization

	Compute from	Inlet
	Reference Frame	Relative to Cell Zone
	Initial Values	Z Velocity= -19.22517 m/s
		Gauge Pressure=0 Pascal
	INITIALIZE	
Run Calculation	Number of iteration	100
	Reporting Interval	1
	Profile update Interval	1

Valve moment inside T-Joint:

The three operating conditions are:

1. Refrigerant flow to both units
2. Refrigerant flow only to Air Cooler
3. Refrigerant flow only to Water Chiller

Split Valve is controlled using an Arduino module that operates on inputs received through temperature sensors. A servo motor is connected to the valve and the moment is governed by Arduino codes at required three conditions. Initially when both units are in switch on mode, the valve will be in zero degrees, which means the same amount of flow to both the units. After a certain time, when the water tank attains a certain temperature i.e 10 degree celsius, then through sensors, inputs are sent to the Arduino and the valve starts functioning. By the arduino code, the split valve moves 45 degrees clockwise, so that the maximum amount of refrigerant will flow to the air cooler. And when the temperature in the water tank drops below the setup level, the valve comes back to its initial position as zero degrees. At times, we do not require an air cooler, then an arduino connected controlled switch rotates the split valve by 45 degrees anti-clockwise and allows maximum flow to the water chiller only. With the three different directions of split valve, Air Cooler and Water Chiller are integrated.

3.4 Post Processing:

After the setup and processing the solution, results are analysed. In the three different operating conditions, the pressure and velocity of refrigerant are different, which are crucial to monitor to avoid valve damage. The simulation setup is same at every condition and it only differs in the amount of refrigerant flow.

However, the fluid behaviour inside T-Joint is studied and the analysis were carried out at a given input pressure and mass flow outlet. The pressure contour and velocity flow were displayed as in fig-4 and fig-5 respectively.

Refrigerant flow to both cooler and chiller:

The refrigerant must flow to both the units through the valve. At this condition the valve must be in centre to allow the flow to both the units. Generally this condition occurs at the initial start of the whole unit.

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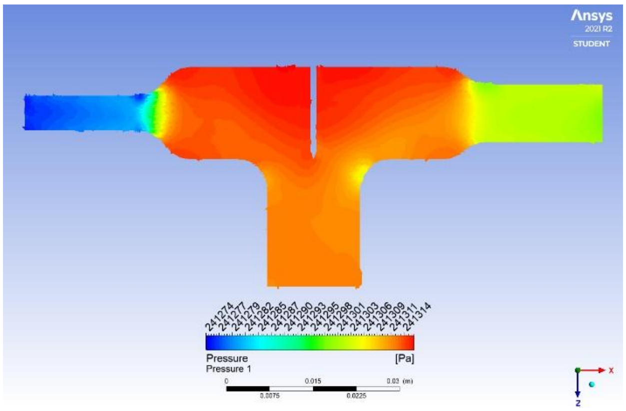

Fig-4: Pressure contour of refrigerant inside T-Joint.

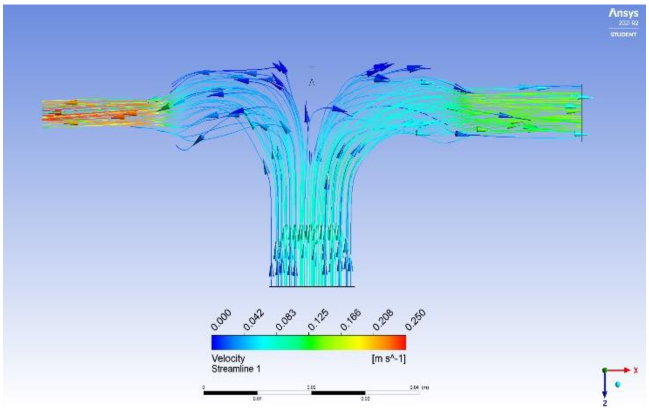

Fig-5: Velocity streamline of fluid inside T-Joint.

Sample arduino code for valve movement:

```
#include <Servo.h>
 Servo myservo;  // create servo object to control a servo
 int pos = 0;    // variable to store the servo position
 void setup() {
  myservo.attach(9);  // attaches the servo on pin 9 to the servo object
  pinMode(5,INPUT);//for getting temperature as input
  pinMode(6,INPUT);//for getting input from switch
  pinMode(7,INPUT);//for getting input from switch
}
 void loop() {
  for (pos = 0; pos <= 45; pos += 1) { // goes from 0 degrees to 45 degrees
    // in steps of 1 degree
    myservo.write(pos);            // tell servo to go to position in variable 'pos'
```

```
 if (digitalRead(5)==12)//if the temperature is 12 degrees
 {
   delay(15);                     // waits 15 ms for the servo to reach the position
 }
 }
 if (digitalRead(6)==HIGH)//if switch is on
 {
 for (pos = 0; pos <= 45; pos -= 1) { // goes from 180 degrees to 0 degrees
  myservo.write(pos);            // tell servo to go to position in variable 'pos'
  delay(15);                     // waits 15 ms for the servo to reach the position
 }
 }
 if (digitalRead(7)==HIGH) //if another switch is on
 {
 for (pos = 0; pos <= 45; pos += 1) { // goes from 0 degrees to 180 degrees
  myservo.write(pos);            // tell servo to go to position in variable 'pos'
  delay(15);
 }
 }


}
```

RESULT:

At Inlet:

Mass Flow rate: 0.0218 kg/s

Mass Flow Average of Pressure: 241312 Pa

Mass Flow Average of Velocity: 0.084299 m/s

At Outlet:

Mass Flow rate: 0.02176 kg/s

Mass Flow Average of Pressure: 241292 Pa

Mass Flow Average of Velocity: 0.172263 m/s

CONCLUSION:

Pressure drop is negligible between the inlet and outlet of T-joint; Hence no loss of pressure by addition of joint. Moreover, the unit comprises the benefits of Air cooler and Water Chiller which would be cost effective to people who cannot afford the units individually. Installing it in crowded places like bus stations, auditoriums can make them popular.

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