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Thermal and Structural Analysis of V.A.R System by Using Exhaust GAS of I.C Engine Heat Recovery using CATIA & ANSYS Tools

by

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Abstract:

This is deals with performance of V A R system is used to produce refrigeration effect by using hot exhaust gases of internal combustion engine. The Net heat in the generator from hot flue gases to aqua ammonia strong solution is purely depends upon the heat transfer surface area and shape of the design.

The COP of the vapor absorption refrigeration system mainly depends upon the heat delivered at refrigeration cabin to the heat supplied at the generator. So if available heat from engine exhausted gases is high in generator contact surfaces then the net heat supplied to the refrigerant will be more there by COP may increase.

INTRODUCTION

1.1 REFRIGERATION

It is a process of removing heat from a substance under controlled conditions. It also includes the process of reducing and maintaining the temperature of a body below the general temperature of its surroundings.

1.2 APPLICATIONS OF REFRIGERATION PROCESS

The applications of refrigeration are Domestic refrigerator, freezer, defrosting in refrigerators ,water coolers ,refrigerated trucks ,marine air conditioning ,ice manufacture ,cold storages ,quick freezing etc

When transporting temperature-sensitive foodstuffs and other materials by trucks, trains, airplanes and seagoing vessels, refrigeration is a necessity.

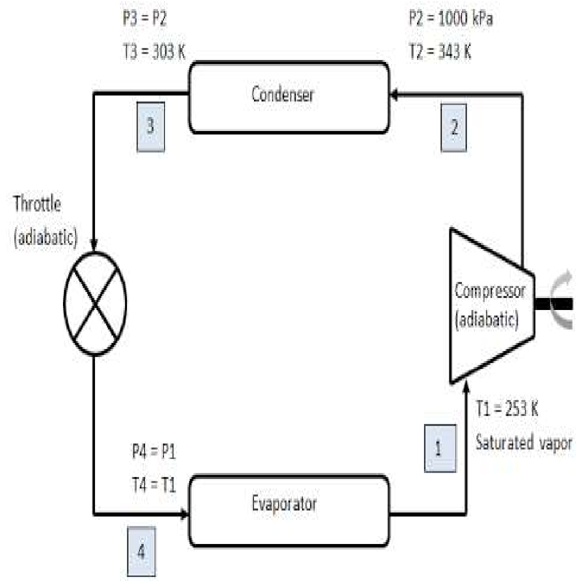
Dairy products are constantly in need of refrigeration, and it was only discovered in the past few decades that eggs needed to be refrigerated during shipment rather than waiting to be refrigerated after arrival at the grocery store. Meats, poultry and fish all must be kept in climate-controlled environments before being sold.

This refrigeration process also used to liquefy the gases like oxygen, nitrogen, Propane and methane.

For example: In compressed air purification, it is used to condense water vapor from compressed air to reduce its moisture content. In oil refineries, chemical plants, and petrochemical plants, refrigeration is used to maintain certain processes at their needed low temperatures (for example,in alkylation of butanes and butane to produce a high octane gasoline component). Metal workers use refrigeration to temper steel and cutlery.

1.3 VAPOUR COMPRESSION REFRIGERATION SYSTEM

The Vapour Compression Refrigeration system plays an important role in all the applications of refrigeration and air-conditioning. The refrigeration & air conditioning is necessary due to uneven production of products. The air-conditioning is necessary due to advancement in human life and uneven weather conditions. In Vapour Compression Refrigeration system the working substance is called as refrigerant. The refrigerant by absorbing heat from products or space then converts into vapour. This vapour refrigerant is compressed in compressor to the desired condenser pressure. This is the working principle of Vapour Compression Refrigeration system. The compressor is a heart Vapour Compression Refrigeration of system. To compress the vapour refrigerant to desired condenser of heat extracted or removed from space or product to produce cooling effect. The performance of the system is defined in terms of coefficient of performance (C.O.P). It is the ratio between refrigeration effects to the work done in compressor. The COP of the system can be influence by evaporation and condenser pressure.



1.5 COMPONENTS OF VAPOUR COMPRESSION REFRIGERATION SYSTEM

The major components of vapour compression refrigeration system are

Compressor
Condenser
Expansion valve
Evaporator

1.5.1. COMPRESSOR

A refrigerant compressor is a machine used to compress the vapour refrigerant from the evaporator and to raise its pressure. so that the corresponding saturation temperature is higher than that of the cooling medium.

It gives motive force to the whole refrigeration system since the compression of refrigerant requires some work to be done on it, therefore a compressor must be driven by some mover (i.e. motor).

Compressor may be called as a heart of any vapour compression system. The rapid development

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of refrigeration systems is made possible due to the developments in compressor technologies.

CLASSIFICATION OF COMPRESSORS

The compressor may be classified in many ways, but the following are some important forms.

1. According to method of compression
   a. Reciprocating compressor
   b. Rotary compressor,
   c. Centrifugal compressors
1. According to the no. of working strokes
   a. Single acting compressor, and
   b. Double acting compressor

2. According to no. of stages
   a. Single stage (or single cylinder) compressors, and
   b. Multi stage (or multi cylinder) compressors
3. According to the method of drive employed
   a. Direct drive compressors, and
   b. Belt drive compressors
4. According to the location of the prime mover
   a. Semi hermetic compressor (direct drive, motor and compressor in separate housings),
   b. Hermetic compressors (direct drive , motor and compressor in same housings)
   c. Open type compressor.
5. According to the pressure compressors
   a. Low pressure compressors
   b. Medium pressure compressors,
   c. High pressure compressors.

HERMETIC SEALED COMPRESSOR

Hermetic compressor as shown in Fig.1.1 is one which is enclosed in a welded shell along with its motor and totally sealed from the atmosphere. Low pressure refrigerant from the ion evaporator enters the casing through a section line. The rotor of the electric motor is press fitted on to the vertical crank shaft and its stator is secured in the casing. The motor windings are directly exposed to the cool vapour refrigerant entering the casing and after compression, the high pressure and temperature vapour refrigerant of leakage of refrigerant with less noisy.

LITERATURE REVIEW

Due to the world wide attempt to find energies which are alternative, vapour absorption refrigeration has become a major system for many refrigeration applications. In which thermal energy is available in the V.A.R system can very well substitute the V.C.R system. The fact of I.C Engine is a high amount of thermal energy associated with the exhaust gases is wasted. An average energy balance of the energy available in the combustion of fuel in an automobile engine shows that 30% of available energy converted into break power, approximately 30% available energy lost at the radiator and around 30% of available energy is wasted as heat at the exhaust system and reaming energy unaccounted heat loss. Even for a relative small engine, 10 kW of heat energy can be utilized from the exhaust gas. This heat is enough to power an absorption refrigeration system to produce a refrigeration capacity of 4 kW. In this thesis, energy from the exhaust gas of an internal combustion engine is used to power an vapour absorption refrigeration system. In this thesis an absorption refrigeration system is designed and part of the refrigeration system is analyzed. Modeling and analysis is done in Ansys. Thermal analysis is done on generator [1].

In our day to day life fuel consumption increasing and environmental pollution is increasing there by global warming increasing. The V.A.R.S offers the possibility of using heat to provide refrigeration effect. For the refrigeration process the required heat input is collected from the exhaust gases of automobiles thereby we can minimize the global warming due to automobiles [2].

The source of power for producing refrigeration effect is heat energy from exhaust gases of internal combustion engine. These hot flue gases heat energy used to run the aqua ammonia vapour absorption refrigeration system which is used to run air conditioning system there by fuel consumption as well as running cost of moving vehicle will reduces [3].

The aqua ammonia V.A.R.system is an economically attractive concept due to the usage of exhaust waste heat energy which is coming from the I.C engines of automobiles, and hot flue gases which is moving through chimney of boiler in steam power plant [4].

By using low grade thermal energy which is coming from I.C engine exhaust gases are used to run the vapour absorption refrigeration system there by atmospheric pollution, global warming gets reduced [5].

A detailed experimental work was carried out to validate the results in real engine operation. Theoretical results show how the absorption refrigeration system decreases the intake air flow temperature down to Temperature around 5 °C and even lower by using the bottoming waste heat energy available in the exhaust gases in a wide range of engine operating conditions. In addition, the theoretical analysis estimates the potential of the strategy for increasing the engine indicated efficiency in levels up to 4% also at the operating conditions under evaluation. Finally, this predicted benefit in engine indicated efficiency has been experimentally confirmed by direct testing [6].

Energy efficiency has been a major topic of discussions on natural resources preservation and costs reduction. Based on estimates of energy resources reduction at medium and long terms, it is vital to develop more efficient processes from energy and exergy standpoints. Environment preservation must also be considered through energy optimization studies. An important point to mention absorption refrigeration systems is the continuing substitution of chlorinated fluorocarbons (CFCs) by alternative refrigerants, according to the Montreal Protocol, signed in 1987 by 46 countries and revised in 1990 to protect the ozone layer Other motivating factors are the continuous optimization of the performance of internal combustion engines and the increasing utilization of air conditioning in vehicles, as it reaches the status of essential need for modern life. Internal combustion engines are potential energy sources for absorption refrigeration systems, as about one third of the energy availability in the combustion process is wasted through the exhaust gas. Thus, use of the exhaust gas in an absorption refrigeration system can increase the overall system efficiency. [7].

a lot of low grade heat goes waste along with the exhaust gases. Absorption refrigeration systems always attract the users to utilize the low grade waste heat wherever it is available Therefore, in this work, a simulation model of an Indian combined cycle Power plant coupled with exhaust heat operated ammonia-water absorption refrigeration system has been developed to investigate the performance of the combined system according to Indian atmospheric conditions which vary throughout the year. Energy and exergy analysis reveals that by having this arrangement, in summer season but, in winter the variation of plant performance with the variation of ammonia condenser temperature has also been studied. [8].

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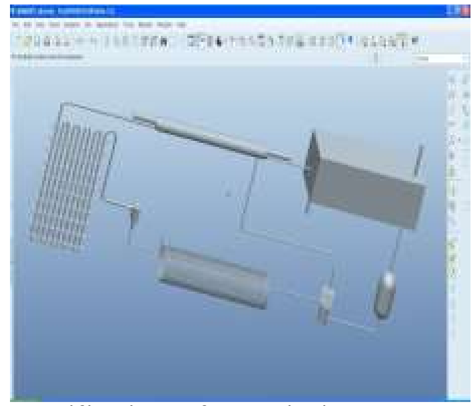
Absorption refrigeration system is appropriate for waste heat utilization of the exhaust for freezing applications. However, it should be noted that the exhaust condition of the diesel engine is not stable because the power output of the diesel engine varies along with the electrical load. The exhaust condition, for instance, might be at non-steady state due to the rapid changes of electrical power output, probably leads to unstable operation of the absorption refrigeration unit. Even worse, the unit might be shut down because of insufficient removal of the rectification heat. Although the power can be always produced at its possible highest capacity in some cogeneration systems because it can be integrated with the electrical grid, the power output of the generator always Changes according to the power demand for an islanding energy system. [9].

The basic objective of developing a vapour absorption refrigerant system for cars is to cool the space inside the car by utilizing waste heat and exhaust gases from engine. The air conditioning system of cars in today's world uses "Vapour Compression Refrigerant System" (VCRS) which absorbs and removes heat from the interior of the car which is the space to be cooled and further rejects the heat to be elsewhere. Now to increase an efficiency of car beyond a certain limit vapour compression refrigerant system resists it as it cannot make use of the exhaust gases from the engine. In vapour compression refrigerant system, the system utilizes power from engine shaft as the input power to drive the compressor of the refrigerant system, hence the engine has to produce extra work to run the compressor of the refrigeration system utilizing extra amount of fuel [10].

DESIGN AND ANALYSIS OF GENERATOR



Specification of practical generator from base paper

Volume of generator V = 2.9941 m3
Length of generator L = 0.85m
Diameter of generator d = 0.021m

Rectangular type generator specifications

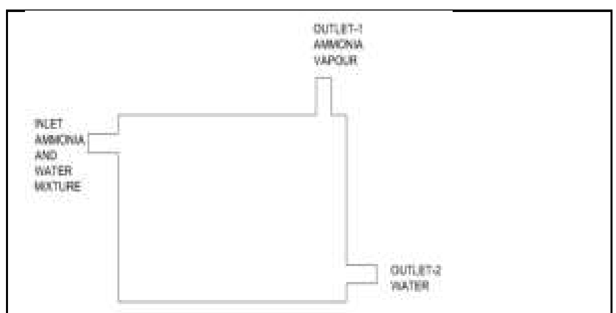


Fig.-1 RECTANGULAR TYPE GENERAYOR

- Volume of generator V = 2.9941 m3
- Thickness of generator T = 0.001m
- Length of generator L = 0.85m
- Height of generator H = 0.346m

Hemispherical type generator specifications

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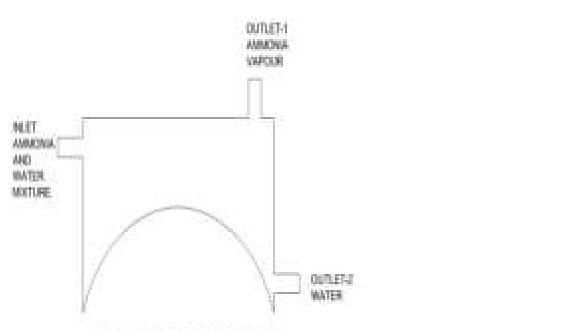


Fg-2 HEMISPHERICAL TYPE GENERATOR

Length of generator L = 0.85m
Height of genera H = 0.6799m
Thickness of generator T = 0.001m
Volume of generator V = 2.9941 m3

INTRODUCTION TO ANSYS

ANSYS Is an American Computer-aided engineering software developer headquartered south of Pittsburgh in Cecil Township, Pennsylvania, United States.

ANSYS Mechanical is a finite element analysis tool for structural analysis, including linear, nonlinear and dynamic studies. This computer simulation product provides finite elements to model behavior, and supports material models and equation solvers for a wide range of mechanical design problems. ANSYS Mechanical also includes thermal analysis and coupled-physics capabilities involving acoustics, piezoelectric, thermal–structural and thermo-electric analysis.

BASIC PROCESS IN ANSYS

1. PRE PROCESSING: Creation of geometry, meshing, defining problem
2. PROCESSING: solving the problem
3. POST PROCESSING: Result.

STEPS FOLLOWED TO DESIGN AND ANALYSIS ON THE TWO DIMENSIONAL GENERATOR

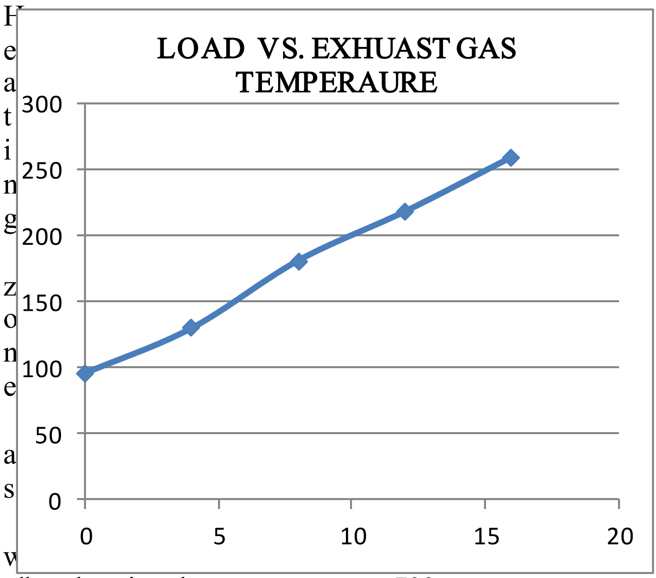
1. CREATION OF GEOMETRY
2. MESHINING
3. PROBLAM ASSIGNING (SETUP)
4. SOLUTATION
5. RESULT

CREATION OF GEOMETRY

Open the ansys work bench.
Select fluid flow (fluent)
Select the geometry
Select 2D type analysis
Open geometry window
Select the units in mm
Sketch the 2D view in XY plane and give the dimensions as shown in fig 4.1.4.2

PROBLEM ASSIGNING

Open setup window and assign the boundary conditions as mass flow rate
Inlet
Outlet as pressure out let
Wall as wall
Heating zone as wall and assign the temperature as 700c



Select model as
Energy: on
Viscous from laminar to K-E (2equation)
Multiphase: on

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Assign materials water phase-1 and ammonia phase-2
Adding from materials library

SOLUTION

Assign hybrid initialization Calculate for 100 iterations for steady state analysis

RESULT

Take the results from Contours for turbulence, pressure. Vectors for turbulence, pressure XY plots for turbulence, pressure

RESULTS AND DISCUSSIONS

5.1 EXPERMENTAL RESULTS

TABLE 5.1 EXPERMENTAL RESULTS OF THE 5HP 4STROKE SINGLE CYLINDER DIESEL ENGINES

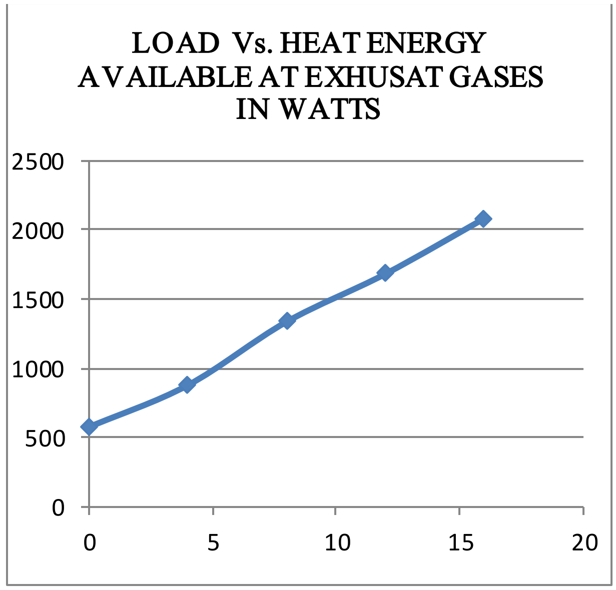
S.NO	LOAD METER READING IN KG	EXHUAST GAS TEMPERAURE	HEAT ENERGY AVAILABLE AT EXHUSAT GASES IN WATTS
1	0	94	576.23
2	4	127	879.1
3	6	154	1096.8
4	8	179	1333.2
5	10	199	1507.2
6	12	216	1683.2
7	14	240	1894
8	16	256	2082.2

GRAPH 5.1 FOR LOAD vs. EXHAUST GAS TEMPERATURE OF 5HP 4STROKE SINGLE CYLINDER DIESEL ENGINE

The exhaust gas temperature gradually increase with respect increase in load due high combustion

GRAPH 5.2 FOR LOAD V/S HEAT ENERGY AVAILABLE AT EXHAUST GASES OF 5HP 4STROKE SINGLE CYLINDER DIESEL ENGINE

The exhaust gas available heat energy gradually increase with respect to increase in load due to gradually increase in fuel consumption



GRAPH 5.3 FOR LOAD vs. EXAUST GAS TEMPERATURE OF THE HM-50 MPFI VERSION 4STROKE 4-CYLINDER PETROL ENGINE

The exhaust gas temperature gradually increase with respect increase in load due high combustion

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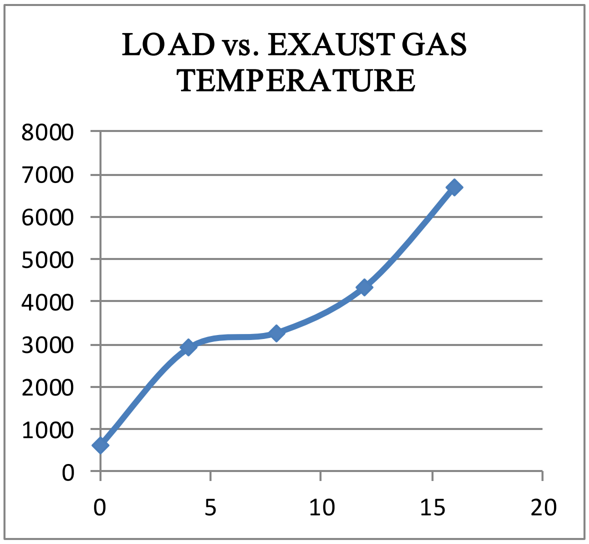
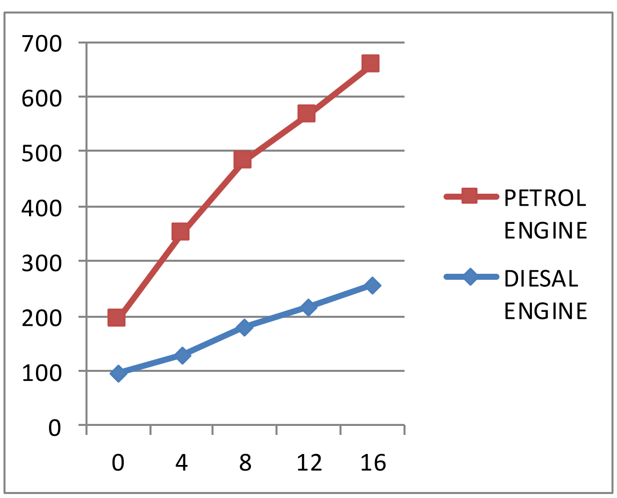


GRAPH 5.4 FOR LOAD vs. HEAT ENERGY AVAILABLE AT EXHAUST GASES OF THE HM-50 MPFI VERSION 4-STROKE 4-CYLINDER PETROL ENGINE

The exhaust gas available heat energy randomly increase with respect to increase in load due to increase in fuel consumption

COMPERISION BETWEEN PETROL AND DIESEL ENGINE EXHUST GAS TEMPERATURE AT DIIFFERENT LOADS



GRAPH 5.5 FOR COMPERISION BETWEEN PETROL AND DIESEL ENGINE EXHUST GAS TEMPERATURE

COMPERISION BETWEEN PETROL AND DIESEL ENGINE EXHUST GAS HEAT ENERGY AT DIIFFERENT LOADS

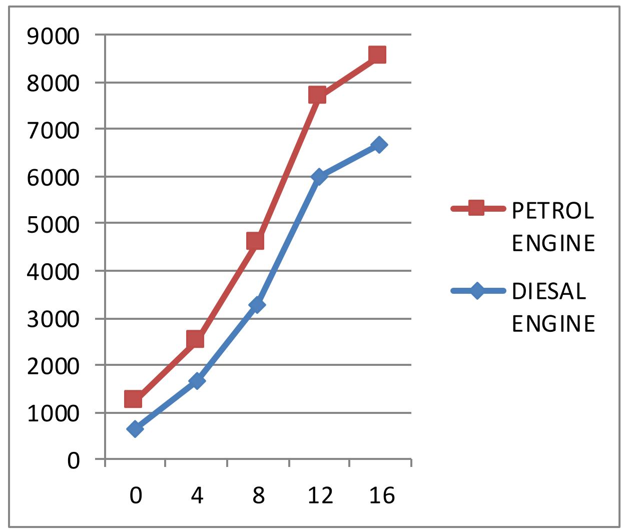
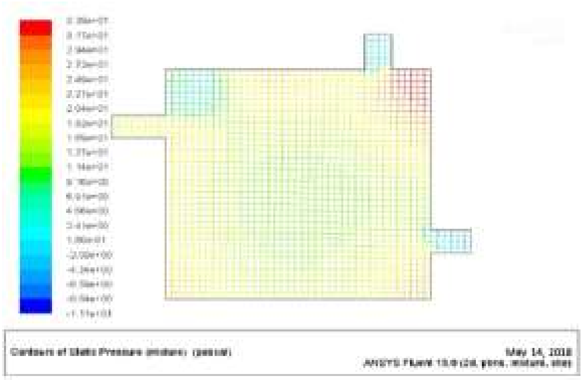


Fig 5.1 CONYOURS OF STATIC PRESSURE



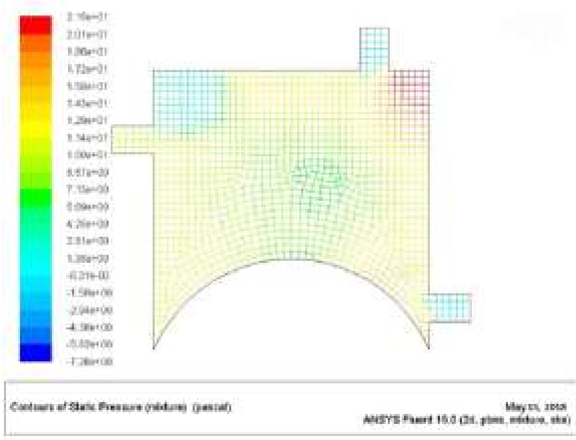
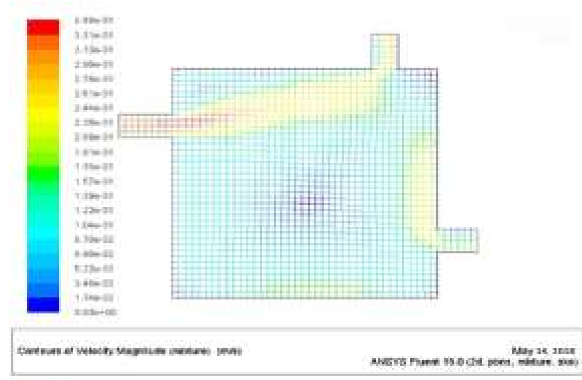


Fig 5.2 CONTOURS OF VELOCITY



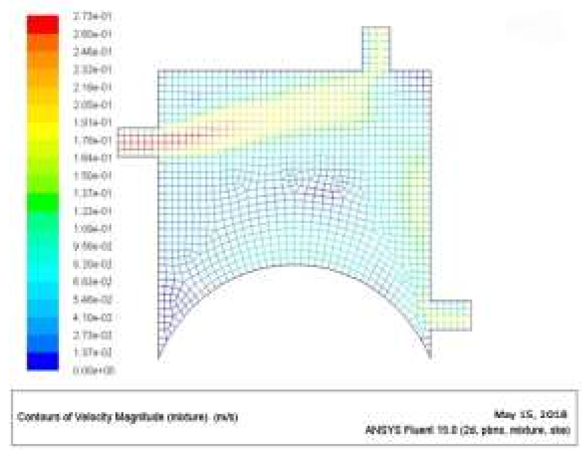


Fig 5.3 VELOCITY VECTORS COLORED BY STATIC PRESSURE

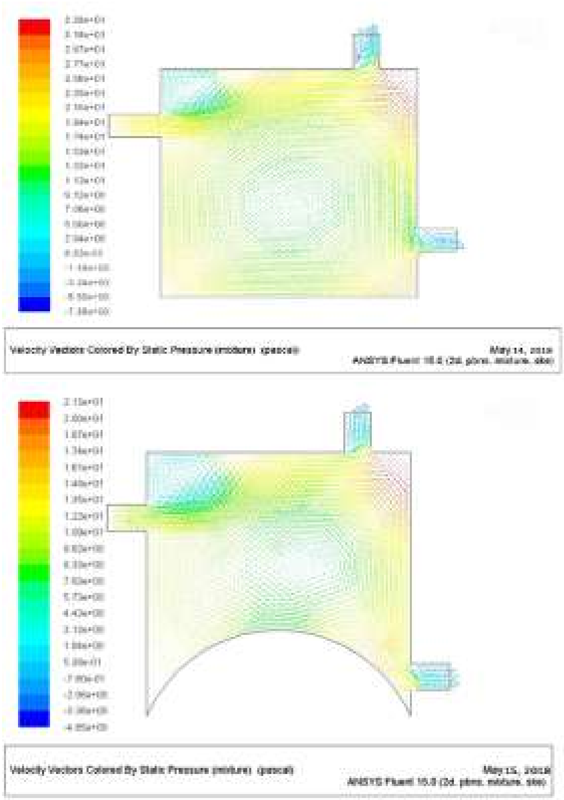


Fig 5.4 VELOCITY VECTORS COLORED BY VELOCITY

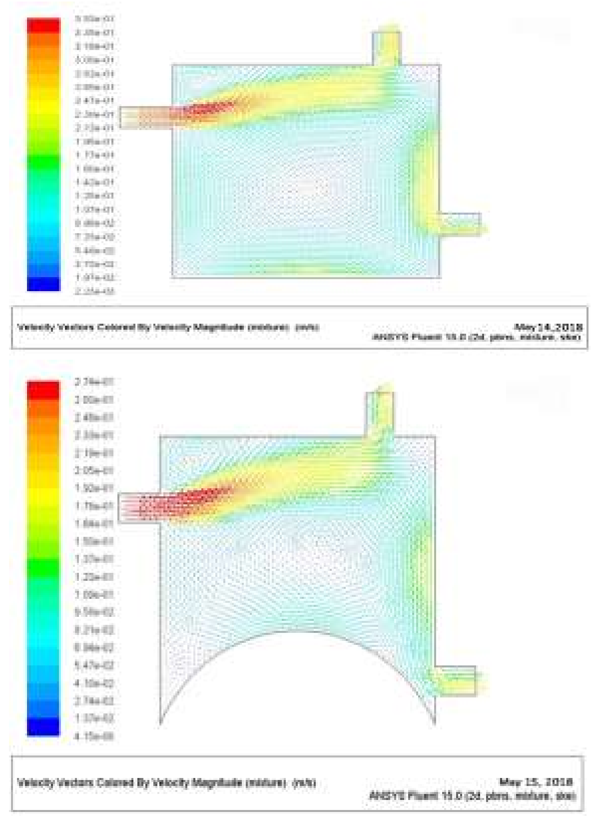
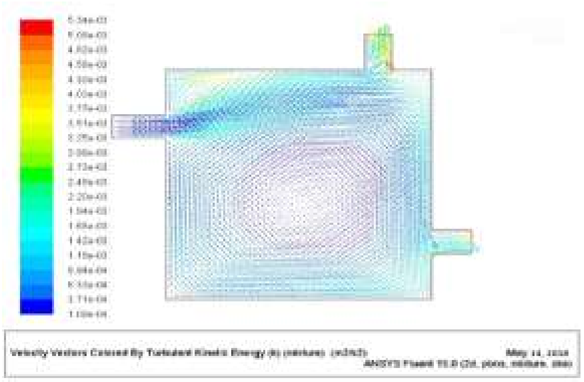
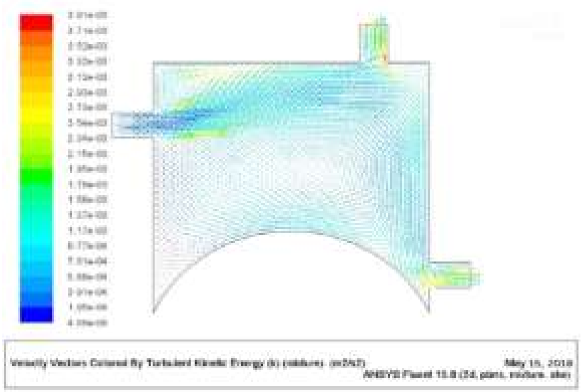


Fig 5.5 VELOCITY VECTOR COLORED BY TURBULENT KINETIC ENERGY





CONCLUSION

The exhaust gases heat energy for 4-Stroke single cylinder 5HP diesel engine at 16 Kg load is 2083.2 Watts which is sufficient to operate 0.1984 Ton vapour absorption refrigeration system.

The exhaust gases heat energy for HM-50 MPFI version 4-Stroke 4 cylinder petrol engine is 6672.8 Watts which is sufficient to operate 0.635 Ton vapour absorption refrigeration system.

Out of the selected petrol, diesel engines exhaust gas temperature is high for petrol engine so these petrol engine exhaust gas temperature is used as input to the generator.

We know from the empirical relations of vapour absorption refrigeration system the cop is function of Tg,Tc,Te, by keeping Tc,Te as constant., the C.O.P of vapour absorption system proportional to Tg.

So in petrol engine exhaust gas temperature is high there by generator temperature will be high then C.O.P of V.A.R.S will be more.

The Net heat energy transfer from hot flue gases to ammonia vapor is for rectangular shape generator is 480.0 Watts.

The Net heat energy transfer from hot flue gases to ammonia vapor is for hemispherical shaped edge is 570.0 watts.

From the results Net heat transfer in generator is high for hemispherical shaped heating zone as compared to rectangular shaped heating zone.

Hemispherical type generator Efficiency 18.59% which is better than rectangular type generator Efficiency 15.75%.

By the efficient heat transfer in hemispherical shaped heating zone then generator performance is increased then C.O.P of V.A.R.S is improved.

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