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CFD Simulation of a Car Air Conditioning System Based on an Absorption Refrigeration Cycle Using Energy from Exahust Gas of an Internal Combustion Engine

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Abstract: **Air conditioning is the process of altering the properties of air (primarily temperature and humidity) to more favorable conditions. A rough energy balance of the available energy in the combustion of fuel in a motor car engine shows that one third is converted into shaft work, one third is lost at the radiator and one third is wasted as heat at the exhaust system. Even for a relative small car-engine, 15 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 5 kW. Where thermal energy is available the absorption refrigerator can very well substitute than the vapour compression system. An absorption refrigerator is a refrigerator that uses a heat source (e.g., solar, kerosene-fueled flame, waste heat from factories or district heating systems) to provide the energy needed to drive the cooling system.**

In this thesis, energy from the exhaust gas of an internal combustion engine is used to power an absorption refrigeration system to air-condition an ordinary passenger car. All the required parts for the absorption refrigeration system is designed and modeled in 3D modeling software CREO parametric software. Thermal analysis is done on the main parts of the refrigeration system to determine the thermal behavior of the system. Analysis is done in ANSYS.

I. INTRODUCTION

Refrigeration is the process of casting off warmness from an enclosed or controlled space, or from a substance, and transferring it to an area in which it's miles unobjectionable. The number one cause of refrigeration is lowering the temperature of the enclosed area or substance after which keeping that decrease temperature as evaluate to surroundings. Cold is the absence of heat, therefore on the way to lower a temperature, one "removes warmness", rather than "including cold." The basic objective of growing a vapour absorption refrigerant system for vehicles is to cool the distance inside the automobile through making use of waste heat and exhaust gases from engine. The air con gadget of motors in these days's world makes use of "Vapour Compression Refrigerant System" (VCRS) which absorbs and gets rid of heat from the interior of the car that's the space to be cooled and in addition rejects the heat to be somewhere else. Now to increase an performance of vehicle past a sure restriction vapour compression refrigerant device resists it because it can't employ the exhaust gases from the engine. In vapour compression refrigerant machine, the machine makes use of electricity from engine shaft as the input electricity to force the compressor of the refrigerant device, subsequently the engine has to provide greater work to run the compressor of the refrigeration gadget using more amount of gasoline. This loss of electricity of the car for refrigeration may be left out via using another refrigeration machine i.E. A "Vapour Absorption Refrigerant System" i.E low grade warmth operated structures. It is well known that an IC engine has an efficiency of about 35-forty%, which means that only one-0.33 of the energy within the gas is transformed into beneficial paintings and approximately 60-65% is wasted to environment. In which 28-30% is lost with the aid of cooling water and lubrication losses, round 30-32% is lost in the form of exhaust gases and the rest by way of radiation, and many others. In a Vapour Absorption Refrigerant System, a physicochemical manner replaces the mechanical process of the Vapour Compression Refrigerant System via the usage of electricity in the form of heat in place of mechanical work. The warmness required for running the Vapour Absorption Refrigerant System can be acquired from that is wasted into the ecosystem from IC engine. Hence to utilize the exhaust gases and waste warmness from an engine the vapour absorption refrigerant device may be placed into practice which will increase the overall performance of a car.

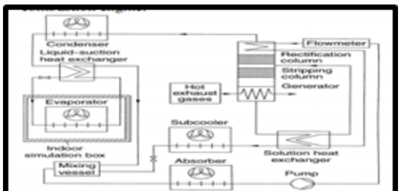


Figure : The essential components of the air-cooled absorption system.

II. LITERATURE REVIEW

The air conditioning machine of automobiles in nowadays's global uses "Vapour Compression Refrigerant System" (VCRS) which absorbs and gets rid of heat from the indoors of the automobile. The system utilizes power from engine shaft as the enter energy to drive the compressor of the refrigerant machine. The loss of energy of the engine to run the VCR system can be disregarded through using another refrigeration gadget i.E. A "Vapour Absorption Refrigerant System". In a Vapour Absorption Refrigerant System, a physicochemical procedure replaces the mechanical manner of the Vapour Compression Refrigerant System by using the use of energy inside the shape of heat in place of mechanical work. The experimental work to make use of the waste warmness from exhaust gases from an engine for the vapour absorption refrigerant machine with R-134a as refrigerant and DMF as absorbent. The experimental consequences indicated that car performance enhances, noise reduces, renovation will become simpler, and tremendously dependable. The statistics received from experimentation is provided analyzed in thispaper.

INTRODUCTION TO CAD

Computers are being used increasingly for both design and detailing of engineering components in the drawing office. Computer-aided design (CAD) is defined as the application of computers and graphics software to aid or enhance the product design from conceptualization to documentation. CAD is most commonly associated with the use of an interactive computer graphics system, referred to as a CAD system.

INTRODUCTION TO PRO/ENGINEER

Pro/ENGINEER, PTC's parametric,integrated3D CAD/CAM/CAE solution, is used by discrete manufacturers for mechanical engineering, design and manufacturing. This powerful and rich design approach is used by companies whose product strategy is family-based or platform-driven, where a prescriptive design strategy is critical to the success of the design process by embedding engineering constraints and relationships to quickly optimize the design, or where the resulting geometry may be complex or based upon equations. Pro/ENGINEER provides a complete set of design, analysis and manufacturing capabilities on one, integral, scalable platform.

INTRODUCTION TO FEA

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition.In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

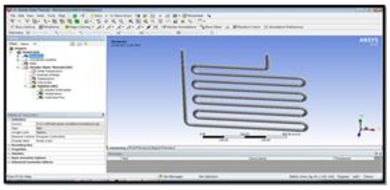
INTRODUCTION TO ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations. ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping.

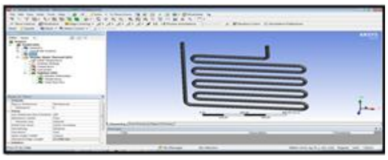
III. RESULTS & DISCUSSIONS

THERMAL ANALYSIS OF CONDENSER

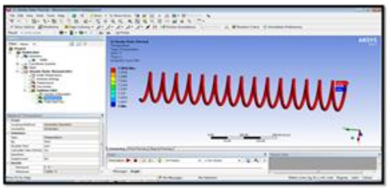
GEOMETRY MODEL



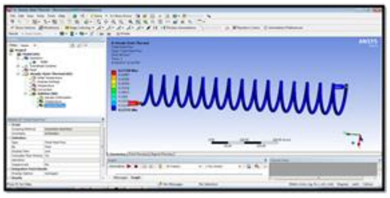
MESHED MODEL



BOUNDARY CONDITIONS
FLUID- WATER
MATERIAL- COPPER
TEMPERATURE DISTRIBUTION



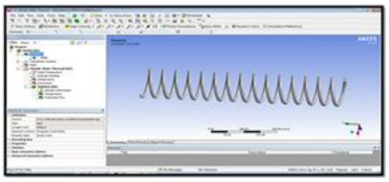
HEAT FLUX



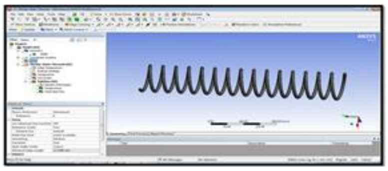
MATERIAL- ALUMINUM
TEMPERATURE DISTRIBUTION

HEAT FLUX

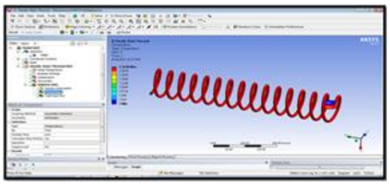
THERMAL ANALYSIS OF EVAPORATOR
GEOMETRY MODEL



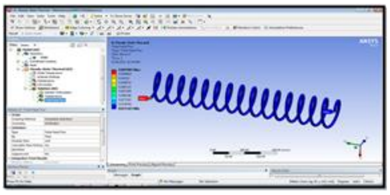
MESHED MODEL



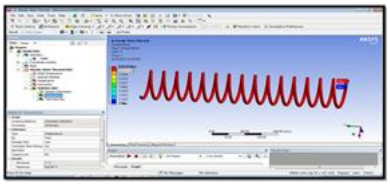
BOUNDARY CONDITIONS
MATERIAL- COPPER
TEMPERATURE DISTRIBUTION



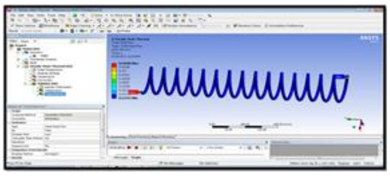
HEAT FLUX



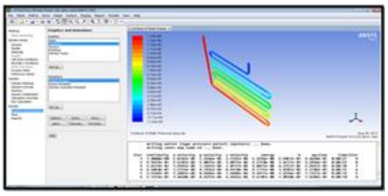
MATERIAL- ALUMINUM
TEMPERATURE DISTRIBUTION



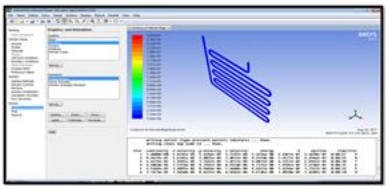
HEAT FLUX



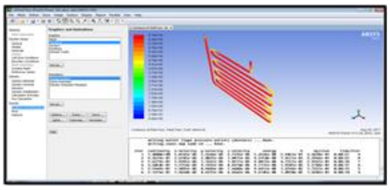
CFD ANALYSIS OF CONDENSER
FLUID- WATER
PRESSURE DROP



VELOCITY



HEAT TRANSFER COEFFICIENT



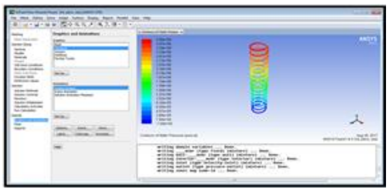
MASS FLOW RATE & HEAT TRANSFER RATE

Mass Flow Rate	(kg/s)
inlet	2.6064684
interior-___msbr	-6807.0132
outlet	-2.6390946
wall-___msbr	0
Net	-0.032626152
Total Heat Transfer Rate	**(w)**
inlet	815883.56
outlet	-826097.63
wall-___msbr	0
Net	-10214.063

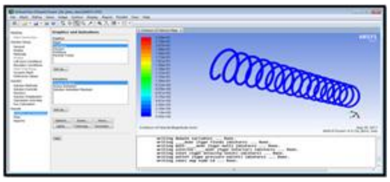
CFD ANALYSIS OF CONDENSER

FLUID- WATER

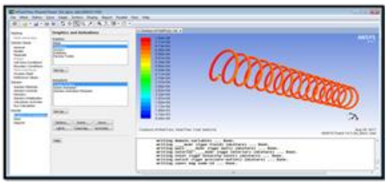
PRESSURE DROP



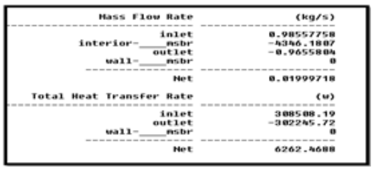
VELOCITY



HEAT TRANSFER COEFFICIENT



MASS FLOW RATE & HEAT TRANSFER RATE



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          Mass Flow Rate                 (kg/s)
-------------------------------- --------------------
                   inlet              0.98557758
     interior-____msbr               -4346.1807
                  outlet             -0.9655804
         wall-____msbr                        0
       ----------------- --------------------
                     Net              0.01999718

Total Heat Transfer Rate                    (w)
-------------------------------- --------------------
                   inlet              308508.19
                  outlet             -302245.72
         wall-____msbr                        0
       ----------------- --------------------
                     Net              6262.4688
```

RESULT TABLE

CONDENSER

Fluids	Materials	Temperature (°C)		Heat flux (w/mm²)
		Max.	Min.	
Water	steel	38	34.714	0.097461
	Aluminum alloy	38	36.529	0.11095
	copper	38	37.41	0.11765
	Titanium alloy	38	31.109	0.071858
R134A	steel	38	32.828	0.15101
	Aluminum alloy	38	35.312	0.186044
	copper	38	36.969	0.20571
	Titanium alloy	38	28.473	0.097288

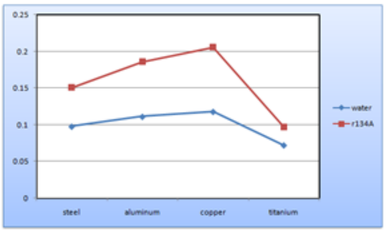
EVAPORATOR

Fluids	Materials	Temperature (°C)		Heat flux (w/mm²)
		Max.	Min.	
Water	steel	8.3241	7	0.090738
	Aluminum alloy	7.5802	7	0.095554
	copper	7.2158	7	0.097907
	Titanium alloy	10.168	7	0.078762
R134A	steel	9.2272	7	0.15279
	Aluminum alloy	8.0129	7	0.16696
	copper	7.3841	7	0.17428
	Titanium alloy	11.882	7	0.12163

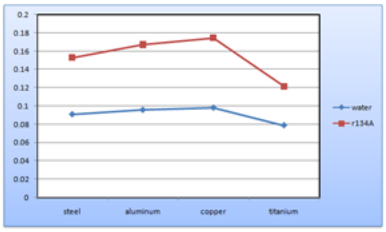
CFD ANALYSIS RESULTS

Models	Fluids	Pressure drop(Pa)	Velocity (m/s)	Heat transfer coefficient (w/m2-k)	Mass flow rate(kg/s)	Heat transfer rate (W)
Condenser	Water	1.32e+06	2.47e+01	6.78e+04	0.032626152	10214.063
	R134A	5.74e+03	2.49e+01	3.69e+02	0.00012858864	9.7034912
Evaporator	Water	3.68e+06	2.30e+01	7.48e+04	0.01999718	6262.4688
	R134A	2.13e+04	2.20e+01	4.47e+02	0.00014976	11.298492

CONDENSER



EVAPORATOR



IV. CONCLUSION

Thermal analysis was done in two main components i.e condenser & evaporator though the results obtained. This result will have to be improved for further development. It can be concluded that:

I. for the working of vapor absorption refrigeration system generally achieved by burning the fuel in a separate combustion chamber and then supplying the Generator of a Vapor Absorption Refrigeration System with the products of its combustion to produce the required refrigerating effect. However this prospect is eliminated since it requires a separate fuel and a separate combustion chamber which makes it uneconomical and the system becomes inefficient.

ii. The above draws back will eliminated by utilizing the heat of combustion which is wasted into the atmosphere. By designing a generator capable of extracting the waste heat of an IC engine without any decrease in engine efficiency, a Vapor Absorption Refrigeration System can be brought to work. Since this arrangement does not require any extra work expect a small amount of work required for the pump, which can be derived from the battery, this system can be used in automobiles where engine efficiency is the primary consideration.

iii. In this project CREO parametric software is used for the design of components & used ANSYS for the analysis

iv. By observing the analysis results, total heat flux is more for copper than remaining three materials for both condenser and evaporator. So using copper is better.

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