Innovation of An Air Conditioning System with the Integration of the Bel Colemn Cycle and the Thomson Effect using Hilsch Vortex Tube: Novel Approach

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Abstract **- Expansion in energy interest just as ecological contemplations, for example, ozone layer consumption powers the individual to thoroughly consider the protected options for refrigerants utilized in cooling frameworks. In this paper, squander fumes gases of truck motor are utilized to cool the air. Here the cooling framework depends on Reversed Brayton cycle. The utilization of air as refrigerant defeats all ecological detriments of refrigerant like R12, R22, and so forth, which influences the ozone layer exhaustion. With the progression of super apparatus, we can build the COP of Reversed Brayton cycle. Turbocharger is utilized to remove energy from squander exhaust just as to pack barometrical air alongside heat exchanger. Further a turbocharger is utilized as super expander to cool the air and work of turbine is utilized to convey compacted air to the motor.**

Index Terms **- Turbocharger, COP, bel colemn cycle and the Thomson effect using hilsch vortex tube, etc.**

I.INTRODUCTION

Presently a day a large portion of the car cooling frameworks being used depend on the fume pressure refrigeration cycle, and the necessary capacity to the framework is given to the blower by the vehicle motor through an attractive grip. Such force supply to blower significantly affects motor fuel utilization and force move to tires, especially for financial class vehicles. Cooling framework utilizes refrigerants. Dichloro difloro methane (R12), Trichloro mono floro methane (R11), Monochloro trifloro methane (R13), Carbon tetra florite (R14) are some usually utilized refrigerants which are liable for ozone layer exhaustion, and nursery impact. To beat these referenced burdens, power the individual to thoroughly consider the protected options for refrigerants utilized in cooling frameworks. In this undertaking, we have utilized Air (R729) as a refrigerant. The objective of this work is to plan and build up a primer investigation on the achievability of utilizing an option car cooling framework dependent on the Brayton cycle to be amassed utilizing a super pressure intercooling framework design accessible in the market which runs on the fumes gases from truck motor. The objective of this task is to exhibit that a cooling framework can be made from existing car turbocharger parts and furnish worthy cooling with an insignificant presentation punishment.

II. LITERATURE SURVEY

To give air cooling to the driver of a truck is never given significance in India, the fundamental explanation is the utilization of accessible strategies for air cooling influences the fuel utilization and the underlying expense of the truck. Anyway, the soonest endeavor at building up a mechanical solace cooling framework for a vehicle is owing to William Whiteley, who in 1884 recommended putting squares of ice in plate under pony drawn carriages and passing up joining a Fan to the axle. For car cooling regularly fume pressure refrigeration cycle is utilized. The cycle run on motor force and burns-through around 10% of the absolute force delivered by the motor and subsequently expands the fuel utilization [2].

Crafted by this paper relies on the Air Refrigeration cycle. The machine chipping away at this are called Air Cycle Machines (ACM). The thought of utilizing air-cycle cooling for this sort of utilization is well-founded by hypothesis, however pragmatic impediments in executing the framework can extensively diminish the presentation of an ACM. An

examination bunch at Queen's University, Belfast, has planned and executed a supercharger-based ACM for refrigerated trailers in street transport applications. [3]. [11] The gathering actualized a two-wheel bootstrap cycle like the one in this task. The essential blower is gear driven from the driving rod, and it takes care of packed air to the commonplace bootstrap ACM. The supercharger is devoted to supply air to the ACM. The turbocharger-based varies from the supercharger-based unit in light of the fact that there is energy accessible that would have been squandered during the turbine sidestep measure, waste-gating, without the presence of the ACM. Rather than squandering this energy, it tends to be used for driving the ACM with no extra expense to the motor. This is basically free cooling, or boundless COP. Since the utilization of a turbocharger as the air source permits expanded maximum restrictions of execution than the supercharger-based framework, there is an improved probability of achievement.

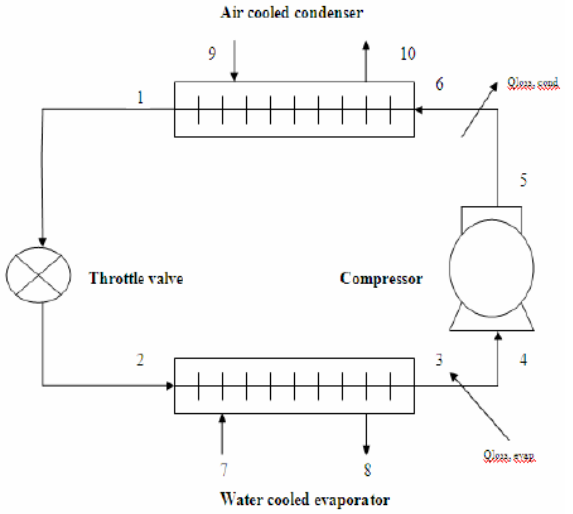

Fig.3.1 Basic Block Diagram of Refrigeration Cycle

The fumes gases emerging from motor runs the turbocharger and ousted out to the environment. The turbocharger sucks outside air from air, packs it. The packed air has high temperature and pressing factor. The compacted air is then sent it to intercooler. The intercooler is water cooled. In intercooler the warmth is dismissed at consistent strain to coursing water. The high temp water is shipped off radiator where it is cooled via wind stream. The water siphon is utilized to circle water again in the intercooler. The high pressing factor and low temperature air is ship off another turbocharger which is utilized as a super expander where it runs the turbine of development side. The packed air gets extended because of which its temperature again diminishes. This cooled air at that point conveyed to truck lodge by means of pipes. The blower side of super expander sucks the climatic air, pack it and ships off motor.

III. THERMODYNAMIC ANALYSIS

Thermodynamic investigation incorporates the investigation of the fundamental air refrigeration cycle, the investigation of the exhibition of the parts and cooling load assessment.

IV. AIR REFRIGERATION CYCLE

Turn around brayton cycle is a significant cycle habitually utilized in air cycle refrigeration frameworks. This might be considered as an alteration of switched Carnot cycle, as the two isothermal cycles of Carnot cycle are supplanted by two isobaric heat move measures. This cycle is additionally called as Joule or Bell-Coleman cycle. Fig (a) and (b) shows the schematic of a shut, switch Brayton cycle and furthermore the cycle on T-s graph. As appeared in the figure, the ideal cycle comprises of the accompanying four processes. [6]

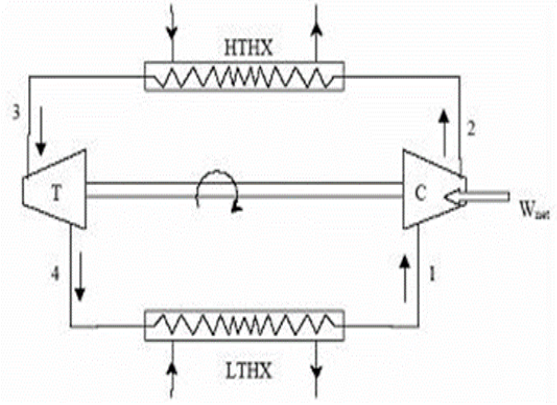

Fig.4.1Schematic of a closed reverse Brayton cycle

Process 1-2: Reversible, adiabatic compression in a compressor

Process 2-3: Reversible, isobaric heat rejection in a heat exchanger

Process 3-4: Reversible, adiabatic expansion in a turbine

Process 4-1: Reversible, isobaric heat absorption in a heat exchanger

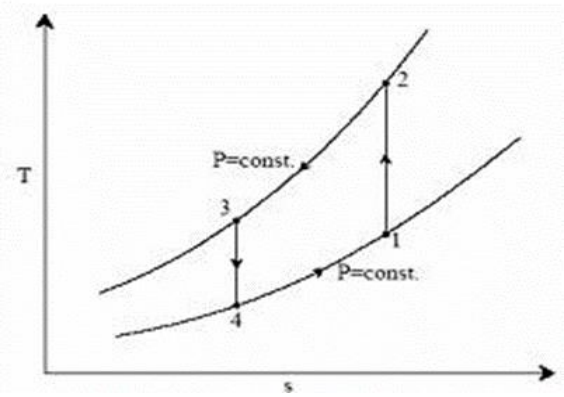

Fig2. Reverse Brayton cycle in T-s plane

THE BELL COLEMAN CYCLE

The Bell Coleman Cycle (likewise called as the Joule or "opposite" Brayton cycle) is a refrigeration cycle where the working liquid is a gas that is compacted and extended however doesn't change stage. Air is regularly this working liquid. The Bell Coleman Cycle likewise called as the Joule or "converse" Brayton cycle. It is a refrigeration cycle where the working liquid is a gas that is compacted and extended yet doesn't change stage.

Air cycle refrigeration frameworks use air as their refrigerant, packing it and extending it to make warming and cooling limit. The utilization of air cycle is one of these, offering a considerate substitute for CFC refrigerants just as decreased energy utilization and capital expenses for focused applications.

Refrigerants are given files on what their expected impact on unnatural weather change and ozone consumption are, and alkali is the one in particular that seems not to cause both of these. Smelling salts is poisonous and combustible, yet when utilized in frameworks planned with present day innovation, it is a protected refrigerant to utilize.

THOMSON EFFECT:

The Thomson effect is the generation of reversible heat when an electrical current is sent through a conducting material that is subjected to a temperature gradient. Joule-Thomson effect, the change in temperature that accompanies expansion of a gas without production of work or transfer of heat. At ordinary temperatures and pressures, all real gases except hydrogen and helium cool upon such expansion; this phenomenon often is utilized in liquefying gases. Joule-Thomson coefficient is defined as the rate of change of temperature with pressure during an isenthalpic process or throttling process. It is defined in terms of thermodynamic properties and is itself a property. Joule-Thomson coefficient gives slope of constant enthalpy lines on temperature—pressure diagram.

VORTEX TUBE:

The vortex tube, otherwise called the Ranque-Hilsch vortex tube, is a mechanical gadget that isolates a packed gas into hot and cold streams. The gas arising out of the "hot" end can arrive at temperatures of 200 °C (392 °F), and the gas rising up out of the "chilly end" can reach −50 °C (−58 °F).[1] It has no moving parts.

Pressurized gas is infused extraneously into a twirl chamber and quickened to a high pace of pivot. Because of the funnel shaped spout toward the finish of the cylinder, just the external shell of the packed gas is permitted to escape at that end. The rest of the gas is compelled to return in an inward vortex of diminished measurement inside the external vortex.

In thermodynamics, the Joule Thomson impact depicts the temperature change of a gas or fluid when it is constrained through a valve or permeable fitting while kept protected so that no warmth is traded with the climate. This technique is known as a choking cycle or Joule Thomson measure.

4.2 Theory and Methodology

The hypothesis and general system is created dependent on known temperatures, help pressing factor, and driving conditions. Warmth should be eliminated from the compacted air before it enters the super expander. Warmth should be taken out from the water after it leaves the intercooler. Fundamental warmth exchanger investigation is utilized to examine both the intercooler and radiator. The means are followed to finish the investigation as underneath [5]

1. Analyze the blower stream rate.
2. Analyze the water-air radiator and dissect the intercooler.
3. Analyze the temperature drop in super expander.
4. Cooling burden assessment
5. COP computations

To play out a thermodynamic investigation for an Air molding framework, the mass and energy balance conditions are applied to every part in the framework. Regarding the figure and applying the warmth

balance, the working conditions are gotten from the framework. The restricting conditions are chosen. The climatic air at 400C and channel temperature of water in intercooler is 50 0C. Considering the temperature of intercooler and radiator, the pressing factors are chosen. Different pressing factors and temperature are chosen dependent on information from references and reasonable conditions. Estimations of enthalpy are acquired from Steam Table the design of a cooling framework is appeared in table 1 beneath. The framework is to work under after conditions.

Table 1: System Observations

Parameters	Symbols	Value
Inlet Temp. of air in Intercooler	t1	133 ^{0}C
Outlet Temp. of air in Intercooler	t_2	100 ^{0}C
Inlet temp. of water in radiator	T_1	70 ^{0}C
Outlet temp. of water in radiator	T_2	50 ^{0}C
Atmospheric temp.	T_a	40 ^{0}C

The various parameters are calculated with the help of standard formulas for all the components which are shown in table 2. Calculations are done using Jenelle Pope's work on Analysis of Turbocharger. [5]

Table 2: System Calculation

	Parameters	Value
Turbocharger	RPM	2400
	CFM	620.141
Radiator	ma	2.023
	m_w	0.26
	Q	16.35
	NTU	0.8129
	LMTD	18.26
	E	0.5
	UA	0.4336
Intercooler	ma	0.328
	m_w	0.26
	Q	10.923
	NTU	1.9146
	LMTD	53.49
	E	0.8
	UA	631.83

The cooling load required for cabin cooling is calculated by using standard method of load calculation. The various factors of heat load like solar radiation (roofs, walls, glasses) normal heat gain through glass, normal heat gain through wall, air infiltration, number of persons in cabin sensible heat load, Latent heat load can be calculated using ASHRAE Handbook. [7]

Table 3: System Observations

Parameters	value
Cabin Dimensions	(1.75×2.24×1.75) m^3
Cabin Temperature without cooling	45 ^{0}C
Sensible heat conduction through cabin structure by conduction	0.395 kW
Solar heat gain (sensible) through outside Walls and roof	0.760 kW
Heat gain due to infiltration	1.33 kW

V. RESULT AND DISCUSSIONS

Brief summary of the parameters required for plotting the graph to determine the characteristics from the plot.

Table 4: CFM over varying RPM and Boost

Boost in PSI	Pr	500 RPM	1000 RPM	1500 RPM	2000 RPM
1	1.06	55.19	110.3	165.5	220.7
5	1.34	69.25	138.5	207.7	277.0
10	1.68	86.83	173.6	260.5	347.3
15	2.02	104.4	208.8	313.2	417.6
20	2.36	121.9	243.9	365.9	487.9
22.5	2.53	130.7	261.5	392.3	523.1

1. The performance of turbocharger is shown in the graph plotted under Pr vs. Compressed flow rate.
2. From the graph it is observed that the efficiency of the turbo compressor is between 75% to 76%.
3. It may be noted that the Pr no. increase as the increase in compressed flow rate.
4. The temperature of the truck is found to be decreased by 10-15 ^{0}C.
5. From above, it can be concluded that, for providing cabin cooling for truck using engine exhaust air refrigeration cycle can be used.

VI. CONCLUSION

The fundamental reason for this paper is to plan the cooling framework for the truck lodge by utilizing the fumes gases and climatic air. This paper likewise points towards the conceivable change to be done in the present car cooling framework. Another target incorporates the solace cooling of the lodge to lessen the driver's weakness.

By chipping away at this undertaking, we discovered that the cooling framework dependent on air refrigeration cycle can be planned, gather and doable to run on the truck motor absent much by way of influencing its exhibition.

As the refrigerants are the wellspring of ozone layer consumption and nursery impact, the commencement of utilizing air refrigerant cycle in car cooling is the most ideal approach to diminish the unfavorable impacts of the refrigerants, for example, R12, R22 on climate. The utilization of air as refrigerant thoroughly dispenses with the utilization of refrigerants and along these lines decreases the ozone layer exhaustion. Consequently, we at long last presume that utilization of Air Refrigeration Cycle in car cooling framework will be the most ideal approach to plan the Automotive Air molding System.

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