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PERFORMANCE ANALYSIS OF AIR CONDITIONING SYSTEM FOR AN AUTOMOBILE BASED ON AMMONIA -WATER VAPOUR ABSORPTION REFRIGERATION SYSTEM RUN BY EXHAUST WASTE HEAT OF DIESEL ENGINE

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ABSTRACT

The air conditioning system of automobiles is mainly uses Vapour Compression Refrigerant System (VCRS) which absorbs and removes heat from the space to be cooled and throws out the heat to atmosphere. In vapour compression refrigerant system, the system utilizes power from engine shaft as the input power to drive the compressor of the refrigeration system, hence the engine has to produce extra work to run the compressor of the refrigerating system utilizing extra amount of fuel. This loss of power of the motor vehicle for refrigeration can be ignored by utilizing another refrigeration system i.e. a Vapour Absorption Refrigerant System (VARS). As well known the machines based on VARS required low grade energy for operation. Hence in such types of system, a physicochemical process replaces the mechanical process of the VCRS by utilizing energy in the form of heat rather than mechanical work. We used as a experimental set up installed at I.C .Lab of Agnos college of technology in RKDF University Bhopal Madhya Pradesh. In this set up take a 5 liters capacity four cylinders four stoke diesel engine coupled with rope brake dynamometer and connected with three fluid 0.8 KWh/day ammonia water vapour absorption refrigeration system and run by exhaust waste heat of diesel engine. The whole setup is very useful in actual automobile air condition system and totally environmental friendly.

KEYWORDS: Four stroke four cylinder Diesel engine, Three fluid ammonia water absorption system, Environment Friendly refrigerant.

INTRODUCTION

Refrigeration is the process of removing heat from a surrounded space, or from a substance, and moving it to a place where it is unobjectionable. The primary purpose of refrigeration is lowering the temperature of the enclosed space or substance and then sustaining that lower temperature as compare to surroundings. Cold always takes place due to absence of heat, hence in order to decrease a temperature, one removes heat, instead of adding cold. Different researchers done work in this field are given;

P. Sathiamurthi[1], He tried to find the possibility to design a refrigeration unit inside an automobile using the waste heat from the engine exhaust of the vehicle based on Vapour Absorption Refrigeration System is realistic. For Environmental safety point of view he made this system is Eco-friendly as it involves the use of Ammonia as a refrigerant and is not responsible for Green House effect and depletion of ozone layer.

M. Hosoz , M. Direk[2], Their project is successful in designing and developing an automobile air conditioning system using engine waste heat based on Vapour Absorption Refrigeration System. They used R-134a and DMF as a refrigerant and absorbent respectively. They substitute the compressor by the four components i.e. Generator, Pump, Absorber, & Pressure Reducing Valve out of which only the pump consumes a little power that too is very weak as compared to the Compressor, and facilitate in saving fuel.

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Satish K. Maurya, Saurabh Awasthi; Suhail A. Siddiqui[3], their aim is to design an automobile air conditioning system using waste heat of engine exhaust based on Vapour Absorption Refrigeration System. The revival and consumption of waste heat not only conserves fossil fuel but also reduces the amount of waste heat. The study shows the accessibility and chances of waste heat from internal combustion engine.

T. Endo, S. Kawajiri, Y. Kojima, K. Takahashi, T. Baba, S. Ibaraki, T. Takahashi[4], they researched the use of waste heat for vehicle engine that applied Rankine cycle from the perspective of available energy. The Rankine cycle system was installed in a hybrid motor vehicle and to change steam temperature and pressure according to the load variation the automatic control system was constructed this is done to verify the system.

N. Hossain And S Bari[5], The exhaust gas of diesel engines can be an important heat source to offer supplementary power and advances overall efficiency of engine. Geometric variables including baffle, number of tubes, length design and are all examine individually. After examine how these parameters manipulate heat exchanger effectiveness, tube heat exchanger is planned.

S. Karellasa, A.-D. Leontaritisa, G. Panousisa, E. Bellos A, E. Kakaras[6],Their work is to find the possibility of waste heat recovery for a cement industry. The exhaust gases of preheater and clinker cooler are the heat sources for the heat recovery systems. Two different cycles were examined, (1) a water-steam cycle and (2) ORC with isopentane as working fluid. They Concluded, the most appropriate cycle for a heat source at a temperature greater than 350ºC is the water steam cycle.

Christy V Vazhappilly[7], He tried to replace heating coil generator system of absorption refrigeration system by plate frame type heat exchanger, and run by exhaust gases of the IC engine. Moreover, the presented heat in the exhaust gases has to be estimated based on real I.C-Engine cycles. The work cycle has to be simulated, and a full model of the condenser and absorber has to be developed and proven.

Abdullah, M.O., & Hien, T.C. [8] They used two types of sources of energy to find out transitory temperature performance of three fluid (H_2O–NH_3–H_2) absorption system's elements. The two sources of energy are liquid petroleum gas and electric energy from grid. They added third source of energy i.e. solar energy for economical study. The analysis indicates the electric energy from grid is best one for short term purpose.

Aman, J., Ting, D.S.K., & Henshaw[9],Their work is focused on to capitalize the efficiency of an absorption chiller used in residential cooling application with the use of solar energy which is a driving source of low temperature. In results, the COP of the system raises with increase in temperature of heat source and the temperature of evaporator but when the absorber and condenser temperatures increase COP decreases.

Darwish, N.A., Hashimi-Al, S.H., & Mansoori[10] They analyzed Robur absorption–refrigeration water–ammonia (ARWA) system using Aspen Plus flowsheet simulator. They invent some alterations to robur cycle which shows potential increase in coefficient of performance (COP).

Atishey Mittal, Devesh Shukla, Karan Chauhan[11], They tried to install a refrigeration unit inside a vehicle which is based on vapour absorption refrigeration run by exhaust gases from engine. They used ammonia instead of chloro floro for the sake of environment safety, because ammonia is a natural gas and is not responsible for green house effect. Object of this paper is to developed a environment friendly automobile air conditioning system run by exhaust waste heat of diesel engine.

WORKING OF THREE FLUID VAPOUR ABSORPTION REFRIGERATION SYSTEM

This type of refrigeration is usually used for domestic purposes only as it is complex in the construction and working. This type of refrigerator was known as three fluid refrigeration system. The elimination of water pump from the absorption system with the complete absence of moving parts and work input. The main purpose of removing the pump was to make the machine noiseless. It uses refrigerants as solvent and an inlet gas for inlet of the system. The inert gas is continued to the lower side of system only by its system. It is possible to maintain the uniform pressure throughout the system and after sometimes permitting the refrigerant to evaporate at low temperature corresponding to its partial pressure. In the high pressure side system, there exists only the refrigerant which is subjected to total pressure of the system so that it is condensed by using normal cooling water as it done in other system. In lower side of the system, the total pressure is sum of the partial pressure of hydrogen which is used as an inert gas. The liquid ammonia which comes into the evaporator as the partial pressure of ammonia is

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low. The strong aqua ammonia solution is heated in generator by the application of external heat source. The water vapour carried with ammonia vapour is removed in separate form as shown in figure. Then the dry ammonia vapour is passed into the condenser and it condensed by using external cooling source .The liquid ammonia flows under gravity in the evaporator and it evaporates. The mixture of hydrogen and ammonia vapour is passed into the absorber and the weak solution from aqua ammonia from the separator is allowed to follow into the absorber, through tray this weak aqua ammonia solution comes into contact with hydrogen separated. This strong solution is further passed to the generator and it completes the cycle. There is no pump to create the pressure differential between condenser and evaporator or not an expansion valve. The hydrogen returns to the evaporator having no affinity for the absorbent. The hydrogen is held in this condition by the v tube due to small pressure difference in the system .The solution is circulated through absorber and generated by thermal action alone. The paths are so arranged that the liquid refrigerant flows through evaporator by gravity, only care is to be taken to keep hydrogen isolated in the proper part of the system otherwise pressure will be unbalanced and the machine will stop.

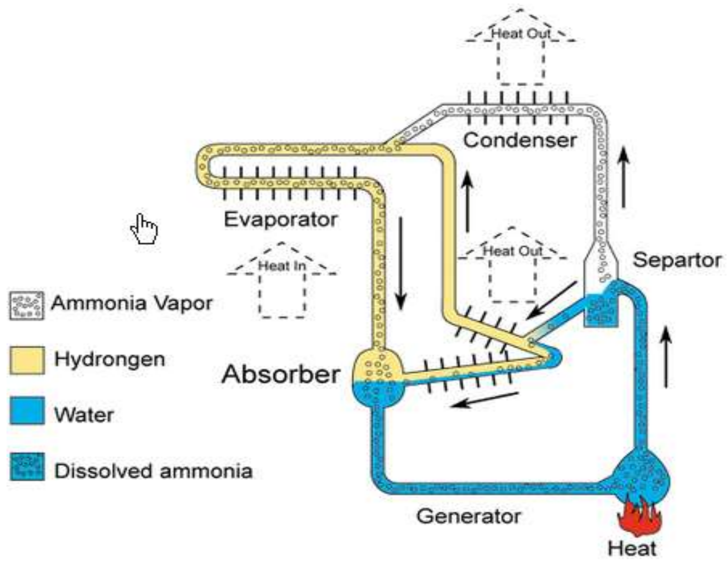

Fig1 Three fluids (Ammonia-Water-Hydrogen) vapour absorption refrigeration system

EXPRIMENTAL SETUP

The experimental setup consists of a four-stroke four cylinder, air-cooled compression ignition engine connected with absorption refrigerator. A fuel tank having five litre capacity fitted with diesel engine.

Table1. Specification of diesel engine

MANUFACTURER'S NAME	Kirlosker
RATED SPEED	2500 rpm
BRAKE POWER	25 KW
STROKE LENGTH	92 mm
FUEL USED	Diesel
DIAMETER OF CYLINDER	78 mm
DYNAMOMETER	Rope Brake Type
NUMBER OF CYLINDER	Four
NUMBER OF STROKE PER CYCLE	Four
ANEMOMETER DIAMETER IN mm	68 mm
COMPRESSION RATIO	18

Table2. Specification of absorption refrigerator

MODEL NO.	DW40
CAPACITY	40 Litres
RATED VOLTAGE	230 Volt
RATED FREQUENCY	50 Hz

INPUT POWER	65 Watt
ENERGY CONSUMPTION (Kwh/24h)	0.8

FIG 2 -ACTUAL EXPRIMENTAL SETUP OF 4 STROKE 4 CYLINDER DIESEL ENGINECOUPLED WITH ROPE BRAKE DYNMOMETER AND CONNECTED WITH THREE FLUID VAPOUR ABSORPTION RFRIGERATION SYSTEM

TABLE 3. DIESEL ENGINE TEST RESULTS

S.NO.	LOAD (kg)	SPEED (rpm)	FUEL (kg/sec)	MEP (BAR)	AIR (Kg/sec)	C.V. (MJ/kg)
1	5	2165	0.00252	4.2	0.02854	39.672
2	10	2156	0.00265	5.2	0.02854	39.672
3	15	2115	0.00290	6.3	0.02854	39.672
4	20	2063	0.00335	7.1	0.02854	39.672

TABLE 4. DIESEL ENGINE TEST RESULTS

S.NO.	IP (KW)	BP (KW)	η_m (%)	η_v (%)	η_{ith} (%)	η_{bth} (%)	ISFC (Kg/Kw-hr)	BSFC (Kg/Kw-hr)	A/F
1	12.8	5.5	38	76.3	14	5.7	0.622	1.57	11.1
2	16.7	10.9	62	77.1	15.8	9.2	0.554	0.91	10.6
3	18.9	16.1	81	78.7	16.2	12	0.527	0.59	9.4
4	23.1	21.2	89.2	82	16.7	14.9	0.522	0.52	8.5

TABLE 5. RESULTS OF THREE FLUID VAPOUR ABSORPTION REFRIGERATION SYSTEM

S. N.	Load (kg)	T1 (^{0}C)	T2 (^{0}C)	T3 (^{0}C)	T4 (^{0}C)	Coefficient of performance (COP)	V (VOLTS)	I (AMPERE)	Power V*I (WATT)	Exhaust Gas Temperature of Diesel Engine(°C)
1	5	45.1	35.7	35.9	41	0.64	179.8	0.25	44.95	250
2	10	51.6	37.1	33.6	41	0.93	179.8	0.25	44.95	290
3	15	64.3	39.6	32.1	41	1.3	179.8	0.25	44.95	310
4	20	79.1	41	30.2	41	1.34	179.8	0.25	44.95	358

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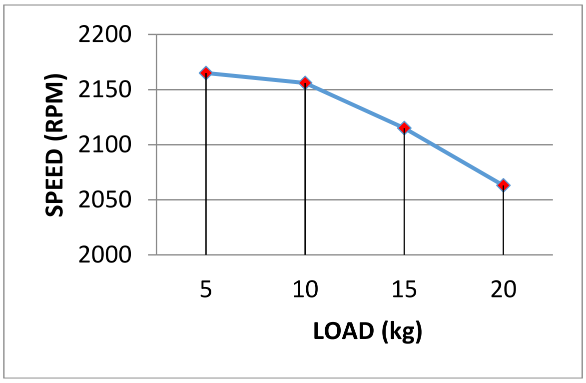
Where,
T1 = Temperature before generator. T2 = temperature after condenser
T3 = Temperature of evaporator, T4 = temperature of environment

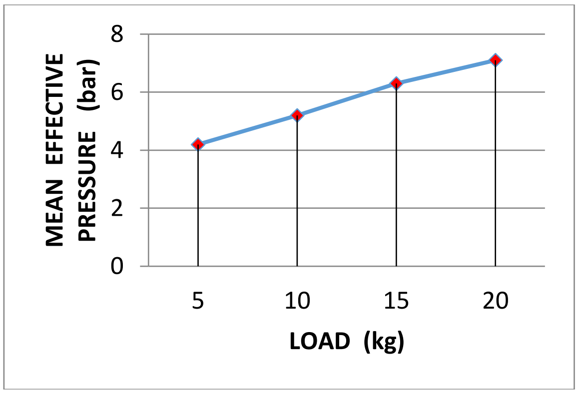
COP = {(T1-T4) T3}/ {T1 (T4-T1)}

RESULTS AND DISCUSSION

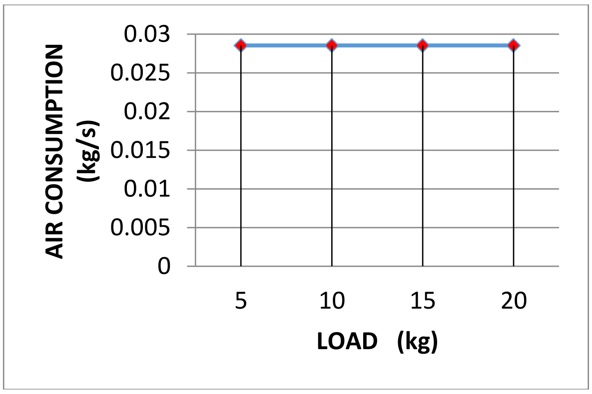


(a)

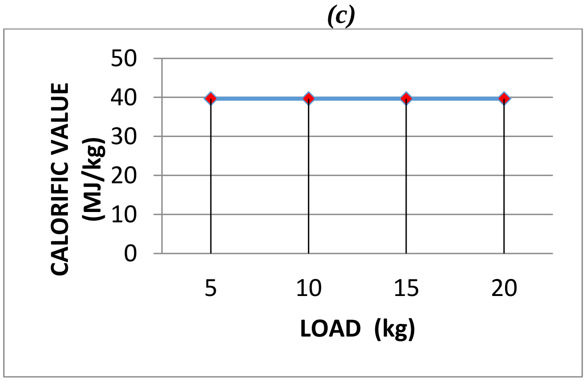
(b)



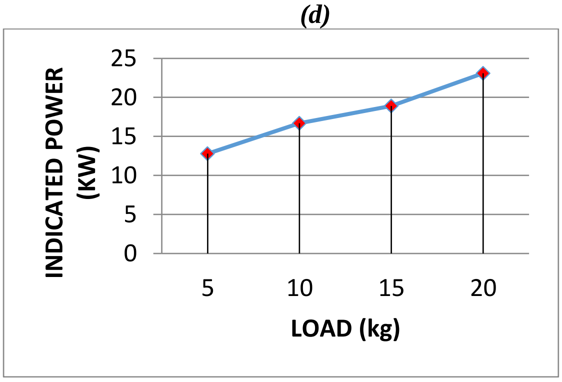
(c)



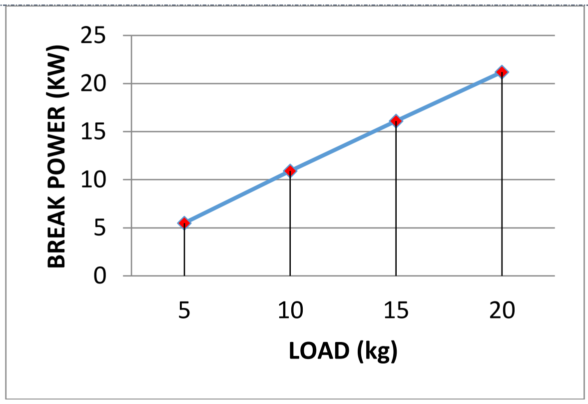
(d)



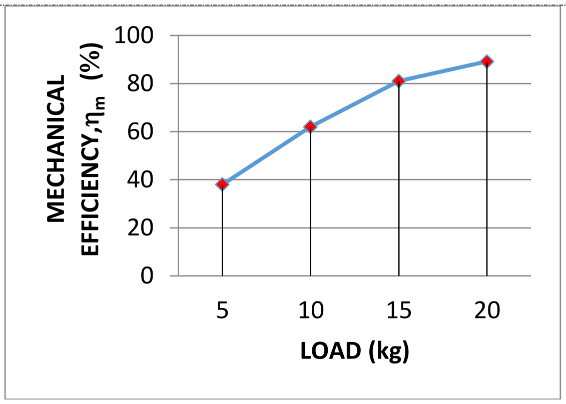
(e)



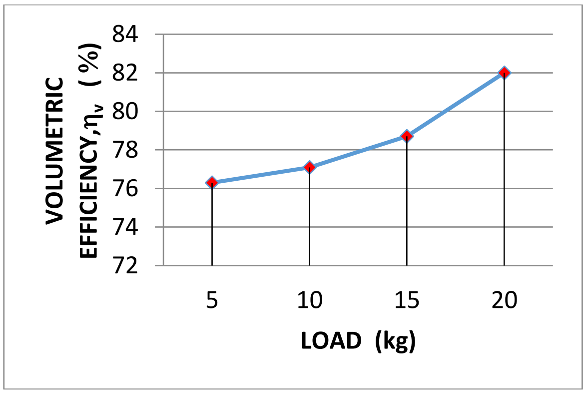
(f)

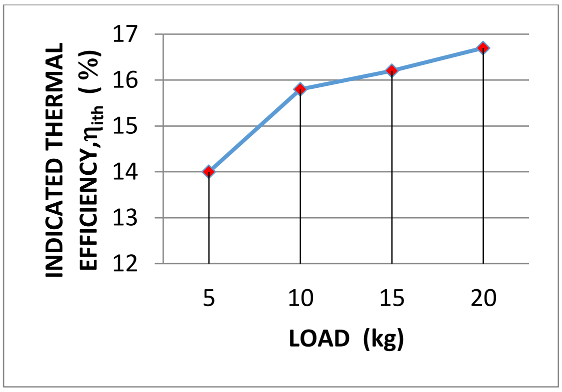

BREAK POWER (KW)
25
20
15
10
5
0
5
10
15
20
LOAD (kg)

(g)

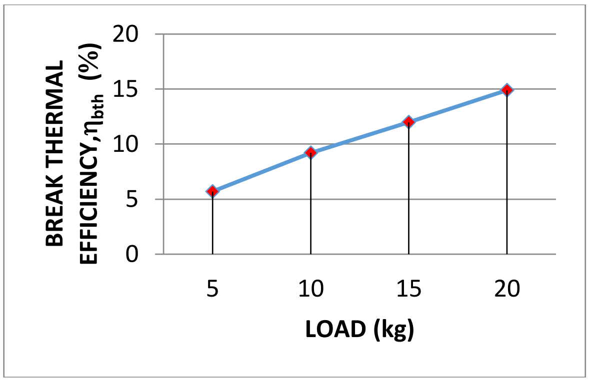

MECHANICAL
EFFICIENCY,η_m (%)
100
80
60
40
20
0
5
10
15
20
LOAD (kg)

(h)

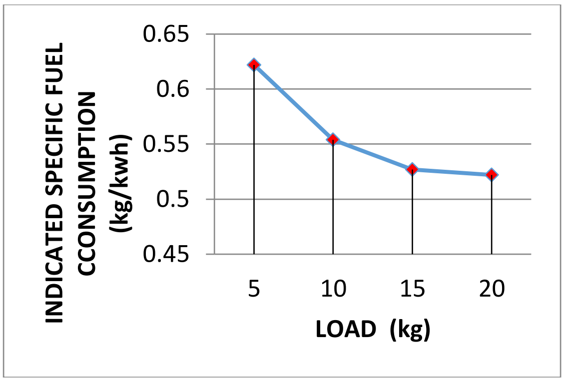

VOLUMETRIC
EFFICIENCY,η_v (%)
84
82
80
78
76
74
72
5
10
15
20
LOAD (kg)


INDICATED THERMAL
EFFICIENCY,η_{ith} (%)
17
16
15
14
13
12
5
10
15
20
LOAD (kg)

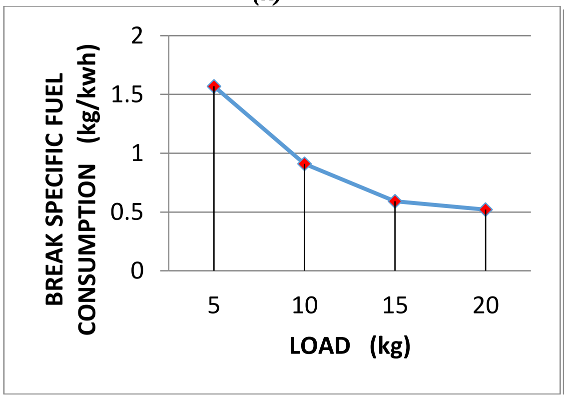
(i) *(j)*


BREAK THERMAL
EFFICIENCY,η_{bth} (%)
20
15
10
5
0
5
10
15
20
LOAD (kg)

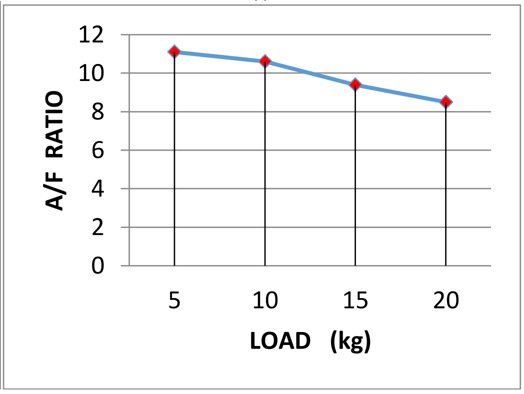
(k)


INDICATED SPECIFIC FUEL
CCONSUMPTION
(kg/kwh)
0.65
0.6
0.55
0.5
0.45
5
10
15
20
LOAD (kg)

(l)


BREAK SPECIFIC FUEL
CONSUMPTION (kg/kwh)
2
1.5
1
0.5
0
5
10
15
20
LOAD (kg)

(m)


A/F RATIO
12
10
8
6
4
2
0
5
10
15
20
LOAD (kg)

(n)

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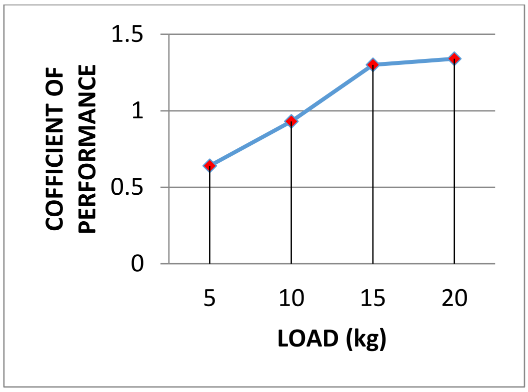
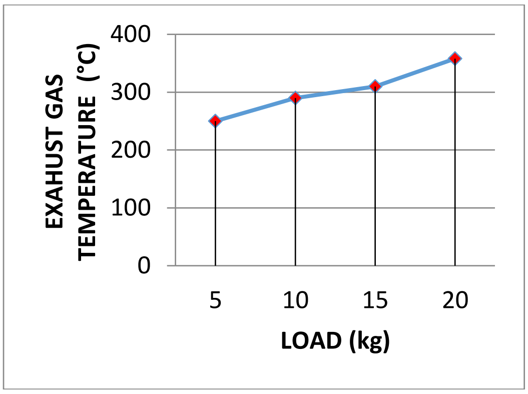


(o)



(p)

fig- 3 , (a) load vs speed, (b) load vs fuel consumption, (c) load vs mean effective pressure, (d) load vs air consumption, (e) load vs calorific value , (f) load vs indicated power, (g) load vs break power, (h) load vs mechanical efficiency, (i) load vs volumetric efficiency, (j) load vs indicated thermal efficiency, (k) load vs break thermal efficiency, (l) load vs indicated specific fuel consumption, (m) load vs break specific fuel consumption, (n) load vs air- fuel ratio, (o) load vs cofficient of performance , (p) load vs exhaust gas temperature.

For fig-3 (a)With increasing load percentage from 5kg to 20kg , we find there is decrease in speed from 2165 rpm to 2063 rpm, for fig-3 (b) With increasing load percentage from 5kg to 20kg there is increase in fuel consumption from 0.00252 kg/sec to 0.00335 kg/sec , For fig-3 (c)With increasing load percentage from 5kg to 20kg there is increase in mean effective pressure from 4.2bar to 7.1bar, For fig-3 (d)With increasing load percentage from 5kg to 20kg there is constant air consumption rate with 0.02854 kg/sec, For fig-3 (e)With increasing load percentage from 5kg to 20kg calorific value 39.672 MJ/kg is constant, For fig-3 (f)With increasing load percentage from 5kg to 20kg increase in indicated power from 12.8KW to 23.1KW, For fig-3 (g)With increasing load percentage from 5kg to 20kg increase in break power from 5.5KW to 21.2KW, For fig-3 (h)With increasing load percentage from 5kg to 20kg increase in mechanical efficiency from 38% to 89.2%, For fig-3 (i)With increasing load percentage from 5kg to 20kg increase in volumetric efficiency from 76.3% to 82%, For fig-3 (j)With increasing load percentage from 5kg to 20kg increase in indicated thermal efficiency 14% to 16.7%, For fig-3 (k)With increasing load percentage from 5kg to 20kg increase in break thermal efficiency from 5.7% to 14.9%, For fig-3 (l)With increasing load percentage from 5kg to 20kg decrease in indicated specific fuel consumption from 0.622 Kg/Kw-hr to 0.522 Kg/Kw-hr, For fig-3 (m)With increasing load percentage from 5kg to 20kg decrease in break specific fuel consumption from 1.57 Kg/Kw-hr to 0.52 Kg/Kw-hr, For fig-3 (n)With increasing load percentage from 5kg to 20kg decrease in air-fuel ratio from 11.1 to 8.5. For fig-3 (o)With increasing load percentage from 5kg to 20kg there is increase in coefficient of performance from 0.64 to 1.34, For fig-3 (p)With increasing load percentage from 5kg to 20kg there is increase in exhaust gas temperature from 250°C to 358°C.

CONCLUSIONS

It is possible to design an automobile air conditioning system using diesel engine heat based on three fluid ammonia water vapour absorption refrigeration System because of following ,

(1) Operation is smooth and also wearing and tearing is reduced due to absence of compressor.
(2) We utilise ammonia as refrigerant because it is easily available and it is also cheap .
(3) Since in ammonia, there is no chlorine atom which is responsible for ozone layer depletion so it is eco friendly in nature.
(4) Since one-third of energy of fuel is utilised by three fluid vapour absorption refrigerator which was wasted through exhaust gas shows that it is good to install absorption refrigerator

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