IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

nCORETech

LBS College of Engineering, Kasaragod

Vol. 4, Special Issue 6, March 2017

Utilisation of Exhaust Heat from Engine for Air Conditioning

Anand Sankar M[1], Abhijith DK[2], D Suresh[3], Muhammed Ijlal O[4]

Student, Mechanical Engineering, LBS College of Engineering, Kasaragod, India [1,2,3,4]

Abstract: Chlorofluorocarbon and hydrochlorofluorocarbon refrigerants have been widely used in conventional cooling systems and in vehicle air conditioning. Major commercial refrigerant, Chloro-fluoro carbons (CFCs), are going to be phase out shortly as part of Montreal Protocol since they caused the phenomenon called greenhouse effect and depletion of ozone layer. In the case of automobiles approximately 10% of the energy available at the crankshaft in a gasoline/diesel operated vehicle is used for operating the compressor of the vehicle's air -conditioning system. This is a huge loss if one takes into account the fact that the thermal efficiencies of most gasoline/diesel operated vehicles range from 20-30% when in pristine condition. The bottom line is that a great deal of fuel is consumed for air conditioning. In addition to this is the refrigerant usually R12 or R22 leaks easily. Being a secondary refrigerant, it is also harmful to the environment. Therefore, due to adsorption air-conditioning technology attracted much attention recently as an alternative solution its advantage of environmental friendliness. This system as it powered by waste heat can help to reduce required energy and thermal pollution. In this paper, an exploration has been done to research the possibility of waste heat recovery and its subsequent utilization in air conditioning system of a vehicle.

Keywords: Engine Waste Heat-Air Conditioning System-Adsorption cooling-Adsorber bed-Desorption.

I. INTRODUCTION

Energy is an important entity for economic development of any country. Most of this energy consumed in power conservationdevises and electricity usage. There is a significant increase in this energy consumption in heating, ventilation, and air conditioning (HVAC). Due to serious problems of energy shortage and global environment issues, utilizations of waste heat and renewable energy become one of the most interesting research fields. HVAC refrigerants in traditional cooling systems contain Chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC). Such components with high ODP (Ozone depletion potential) and GWP (globalwarming potential) accelerate the depletion of the Earth's ozone layer. Therefore, alternative solutions to current cooling systems arerequired. A cooling technology known adsorption cooling system powered by waste and/or renewable energy sources is an attractive solution Adsorption cooling systems powered by solar energy have attracted much attention in recent decades due to its matchin between sun shine and the required cooling effect. Adsorption cooling system has numerous advantages, such asusing low grade heat source temperature, employing of natural refrigerants such as water, less moving mechanical parts, noiseless,Lowmaintenance and environment-friendly.Available energy in exit stream of many energy conversiondevices goes as waste, if not recovered or utilized properly. Approximately 30 to 40% of total energy supplied in internalcombustion engine (ICE) is converted to useful mechanical work.The remaining energy is expelled directly to the environmentthrough engine cooling systems and exhaust gases resulting intoentropy rise and serious environmental problems.Exhaustgas stream from ICE carries away about 30% of the heat of thecombustion.

II. PRINCIPLE

Adsorption is a reversible process bywhich a fluid molecule is fixed onto a solid matrix, typically asurface or a porous material. When the molecule is fixed, it loosesome energy: adsorption is exothermic. An adsorption cycle for refrigeration orheat pumpingdoesnot use any mechanical energy, but onlyheat energy. Moreover, this type of cycle basically is a four temperature discontinuous cycle.An adsorption unit consists of one or several adsorbers plus a condenser plus an evaporator, connectedto heat sources.The adsorbersystem consisting of the adsorbersexchangesheat with a heating system at hightemperatureanda cooling system at intermediate temperaturewhile the system consistingof the condenser plus evaporator exchanges heat with another heat sink at intermediate temperatureand a heat source at low temperature. Vapour istransported between the adsorber(s) and thecondenser+evaporator.

The cycle consist of four periods:
1: HEATING AND PRESSURISATION
During this period, the adsorber receives heat while beingclosed. The adsorbent temperature increases, which induces a

pressure increase, from the evaporation pressure up to the Condensation pressure.This period is equivalent to the "compression" incompression cycles.

2: HEATING AND DESORPTION + CONDENSATION

During this period, the adsorber continues receiving heatwhile being connected to the condenser, which nowsuperimposes its pressure.The adsorbent temperature continues increasing, whichinduces desorption of vapour. This desorbed vapour isliquefied in the condenser.The condensation heat is released to the second heat sink atintermediate temperature.

This period is equivalent to the "condensation" incompression cycles.

3: COOLING AND DEPRESSURISATION

During this period, the adsorber releases heat while being closed. The adsorbent temperature decreases, which induces the pressure decrease from the condensation pressure down to the evaporation pressure.This period is equivalent to the "expansion" in compression cycles.

4: COOLING AND ADSORPTION + EVAPORATION

During this period, the adsorber continues releasing heat while being connected to the evaporator, which now superimposes its pressure.The adsorbent temperature continues decreasing, which induces adsorption of vapour. This adsorbed vapour is vaporized in the evaporator.The evaporation heat is supplied by the heat source at low temperature.This period is equivalent to the "evaporation" in compression cycles.

- Basically, the cycle is intermittent because cold production is not continuous: cold production proceeds only during part of the cycle.When there are two adsorbers in the unit, they can be operated out of phase and the cold production is quasicontinuous.
- When all the energy required for heating the adsorber(s) is supplied by the heat source, the cycle is termed single effect cycle.Typically, for domestic refrigeration conditions, the coefficient of performance (COP) of single effect adsorption cycles lies around 0.30.4.When there are two adsorbers or more, other types of cycles can be processed.
- In double effect cycles or in cycles with heat regeneration, some heat is internally recovered betweenthe adsorbers, which enhances the cycle performance.

III. AIR CONDITIONING OF VEHICLES

AC system of vehicle consists of an engine powered by acompressor activated by a magnetic electric clutch. AC systemimposes an extra load to the vehicle's engine which increasesvehicle fuel rated consumption and increases emissions. Themechanical compressor for AC system in vehicles could increasethe fuel consumption by about 12–17% for subcompact for mostmid-size car passengers. In the case of high-speed ignition engines, which are mostcommon in passenger cars, the total weight of the AC system isexpected to be 15–20 kg. Cooling load of passenger cars consists ofradiant heat input through windows, about 970 kcal/h, heattransmitted through walls, about 330 kcal/h, heat input accompaniedwith natural air ventilation, about 2000 kcal/h, and heatevolution from passengers, about 400 kcal/h .Needs forreduction of fuel consumption in vehicles helped the advancementof energy management systems for vehicles and their accessorycomponents.

Maximum exhaust gas temperature can reach about800 1C while minimum exhaust gas temperature is about 400 1C.In addition, the maximum exhaust gas temperature occurs athigh-speed and high-load operating conditions. On the otherhand, cooling water temperature at outlet under mapping characteristicscan be reached up to 90 1C and it is being unlike theexhaust gas temperature, cooling water temperature nearly has nofluctuations. Contrast of temperature characteristics betweenexhaust gas and cooling water determines the difference of theirenergy characteristics especially exergy characteristics.Effect of heat transfer in engines was analysed in terms ofdesign parameters such as compression ratio and cut-off ratio.

Effects of heat transfer from engine cylinder on exhaust temperaturewere also investigated for different heat transfer and combustionmodes. It is observed that output work and exhaust temperature proportionally increased with the decrease of heattransfer for a fixed combustion rate and cut-off ratio.

IV. ADSORPTION COOLING SYSTEMS AND THEIR EVALUATION

The primary component of any adsorption cooling system is asolid porous surface material with a large surface area and a largeadsorptive capacity. Initially, this surface remains unsaturated.When vapour molecules contact the surface, an interaction occursbetween the surface and the molecules and the molecules areadsorbed on to the surface. The working principle of the basic adsorption cooling cycle isrepresented in Clapeyron diagram Theoretically, the cycleconsists mainly of four phases: pressurization process at constantadsorbed mass (isosteric heating phase) from point (1) to point(2), desorption at constant pressure (isobaric heating phase) frompoint (2) to point (3), depressurization at constant adsorbed mass(isosteric cooling phase) from point (3) to point (4), and adsorptionat constant pressure (isobaric cooling phase) from point (4) topoint (1).

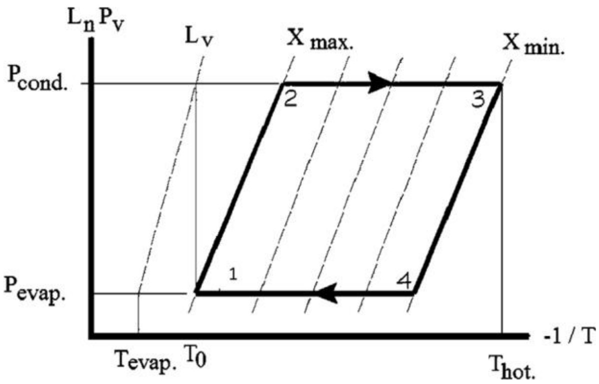

Fig 1.Clapeyron diagram

Different adsorption cycles were designed to proof the concept.In vehicles, however, waste-heat is abundant and addedweight; cost and complexity due to heat recovery cycles wereproblematic. As such, adsorption cooling systems with only massrecovery cycle suffices for vehicle AC applications.In the vehicles, the needed cooling system should has arelatively low mass. From this point of view SCP (specific coolingpower), adsorption bed to adsorbent mass ratio, and COP (coefficient of performance) are selected to evaluate the performance ofadsorption cooling systems in this study. SCP represents theachieved cooling power by the system per kg of the adsorbentCOP represents the ratio between cooling energy of the system tothe input energy.The SCP increases by increasing adsorbate refrigerant amount,enthalpy difference, and decreasing the cycle time.

In order to choose an adsorption pair to be used in one ofadsorption cooling system applications, a comparison between theadsorption cooling systems based on the assorted adsorbent–refrigerant pairs was reviewed. The comparison focused onCOP of the systems and minimum delivered evaporation temperaturebased on the required driving source temperature.The most common adsorption pairs in adsorption coolingapplications are activated carbon–methanol, Activated carbon–ammonia, Zeolite–water, Silica gel–water and Calcium chloride–ammonia.

V. POSSIBILITY OF HEAT RECOVERY AND AVAILABILITY FROM I.C. ENGINE

Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then “dumped” into the environment even though it could still be reused for some useful and economic purpose. This heat depends in part on the temperature of the waste heat gases and mass flow rate of exhaust gas. Waste heat losses arise both from equipment inefficiencies and from thermodynamic limitations on equipment and processes. For example, consider internal combustion engine approximately 30 to 40% is converted into useful mechanical work. The remaining heat is expelled to the environment through exhaust gases and engine cooling systems. It means approximately 60 to 70% energy lossesas a waste heat through exhaust (30% as engine cooling system and 30 to 40% as environment through exhaust gas).

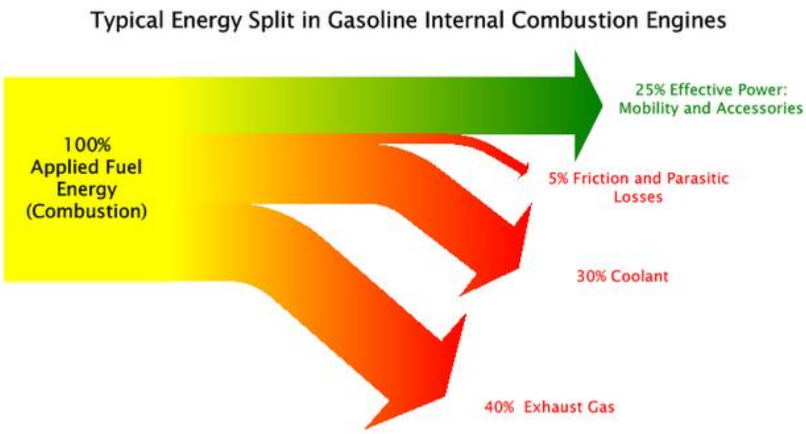

Fig 2. Typical energy split in IC engines

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

nCORETech

LBS College of Engineering, Kasaragod

Vol. 4, Special Issue 6, March 2017

Exhaust gases immediately leaving the engine can have temperatures as high as 842-1112°F [450-600°C]. Consequently, these gases have high heat content, carrying away as exhaust emission. Efforts can be made to design more energy efficient reverberatory engine with better heat transfer and lower exhaust temperatures; however, the laws of thermodynamics place a lower limit on the temperature of exhaust gases Fig. 2 show total energy distributions from internal combustion engine.

A. Benefits of 'waste heat recovery' can be broadly classified in two categories

1. Direct Benefits: Recovery of waste heat has a direct effect on the combustion process efficiency. This is reflected by reduction in the utility consumption and process cost.

2. Indirect Benefits: a) Reduction in pollution: A number of toxic combustible wastes such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and particulate matter (PM) etc., releasing to atmosphere. Recovering of heat reduces the environmental pollution levels. b) Reduction in equipment sizes: Waste heat recovery reduces the fuel consumption, which leads to reduction in the flue gas produced. This results in reduction in equipment sizes. c) Reduction in auxiliary energy consumption: Reduction in equipment sizes gives additional benefits in the form of reduction in auxiliary energy consumption in automobile engines significant amount of heat is released to the environment. For example, As much as 35% of the thermal energy generated from combustion in an automotive engine is lost to the environment through exhaust gas and other losses. The amount of such loss, recoverable at least partly or greatly depends on the engine load [Among various advanced concepts, Exhaust Energy Recovery for Internal Combustion (IC) engines has been proved to not just bring measurable advantages for improving fuel consumption but also increase engine power output (power density) or downsizing, further reducing CO2 and other harmful exhaust emissions correspondingly

B. Possibility of waste heat from internal combustion engine

Today's modern life is greatly depends on automobile engine, i.e. Internal Combustion engines. The majority of vehicles are still powered by either spark ignition (SI) or compression ignition (CI) engines. CI engines also known as diesel engines have a wide field of applications and as energy converters they are characterized by their high efficiency. Small air-cooled diesel engines of up to 35 kW output are used for irrigation purpose, small agricultural tractors and construction machines whereas large farms employ tractors of up to 150 kW output.

Water or air-cooled engines are used for a range of 35-150 kW and unless strictly air cooled engine is required, water-cooled engines are preferred for higher power ranges. Earth moving machinery uses engines with an output of up to 520 kW or even higher, up to 740 kW. . Diesel engines are used in small electrical power generating units or as standby units for medium capacity power stations. Since, the wasted energy represents about two-thirds of the input energy and for the sake of a better fuel economy, exhaust gas from Internal Combustion engines can provide an important heat source that may be used in a number of ways to provide additional power and improve overall engine efficiency.

C. Availability of Waste Heat from I.C. Engine

The quantity of waste heat contained in a exhaust gas is a function of both the temperature and the mass flow rate of the exhaust gas:

$$Q=M.Cp.dT$$

Where, Q is the heat loss (kJ/min); is the exhaust gas mass flow rate (kg/min); is the specific heat of exhaust gas (kJ/kg°K); and is temperature gradient in °K. In order to enable heat transfer and recovery, it is necessary that the waste heat source temperature is higher than the heat sink temperature. Moreover, the magnitude of the temperature difference between the heat source and sink is an important determinant of waste heat's utility or "quality". The source and sink temperature difference influences the rate at which heat is transferred per unit surface area of recovery system, and the maximum theoretical efficiency of converting thermal from the heat source to another form of energy (i.e., mechanical or electrical). Finally, the temperature range has important function for the selection of waste heat recovery system designs.

TABLE I TEMPERATURE RANGE FROM DIESEL ENGINE

Sl no:	Engine	Temperature(°C)
1	Single Cylinder Four Stroke Diesel Engine	456
2	Four Cylinder Four Stroke Diesel Engine (Tata Indica)	448
3	Six Cylinder Four Stroke Diesel Engine (TATA Truck)	336

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

nCORETech

LBS College of Engineering, Kasaragod

Vol. 4, Special Issue 6, March 2017

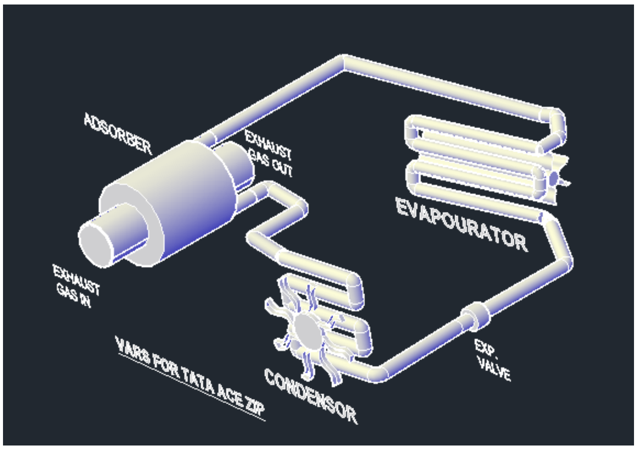

Fig 3. Design of VAdRS using AUTOCAD

D. Heat Loss through the Exhaust in Internal Combustion Engine

Heat loss through the exhaust gas from internal combustion is calculated as follows.
Assuming, Volumetric efficiency (Ŋ) is 0.8 to 0.9
Density diesel fuel is 0.84 to 0.85 gm/cc
Calorific value of diesel is 42 to 45 MJ/kg
Density air fuel is 1.167 kg/m3
Specific heat of exhaust gas is 1.1-1.25 KJ/kg°K
Vehicle choosed:TATA ACE ZIP
Engine Specification:
Engine: Single cylinder 4stroke
Model: Greaves 600 W/BS III
Capacity: 611cc
Output:12.6bhp@3000rpm
Torque:35.1Nm@1600rpm
Comp. Ratio: 18.5:1
SFC: 0.22kg/kwhr
Exhaust heat loss through diesel engine
Compression ratio (Vr) = (Vc+Vs)/Vc
18.5Vc=Vc+6.11*10^-4
Vc= (6.11*10^-4)/17.5=3.49*10^-5m3
SFC=ṁf/power
ṁf (Mass flow rate of fuel (on the basis of specific fuel consumption))
=SFC*power=220*12.6=2772g/hr=0.77g/s
Volume rate=Vs*N=(6.11*10^-4)*1500=0.9165m3/min.
Ŋ(Volumetric efficiency)=volume of air/swept volume=ṁa/ρNVs
ṁa=ŋρNVs=0.9*1.167*1500*6.11*10^-4=0.9626kg/min.
=0.01604kg/s
Mass flow rate of exhaust gas(ṁe)=ṁf+ṁa
=0.00077+0.01604=0.01681kg/s
Availability of waste heat in engine(Q)=ṁe.Cp.dT
=0.01681*1.1*(336-30)=5.65kW=**7.5bhp**

VI. EXPERIMENTAL RESULTS

The experiments have been carried out on the prototype fabricated using engine exhaust as heat source. The temperatures are note down at 30 minutes interval of time. The results are tabulated as in table 2 and plotted as in the accompanying figure4 to .

TABLE IIIII TEMPERATURES OBTAINED

Time min	Exhaust Temperature (Texh)^{0}K	Condenser Temperature (Tc)^{0}K	Evaporator Temperature (Te)^{0}K
0	305	305	305

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

nCORETech

LBS College of Engineering, Kasaragod

Vol. 4, Special Issue 6, March 2017

30	433	308	299
60	563	311	294
90	629	313	289
120	754	315	285
150	796	317	283
180	863	319	280
210	875	320	280

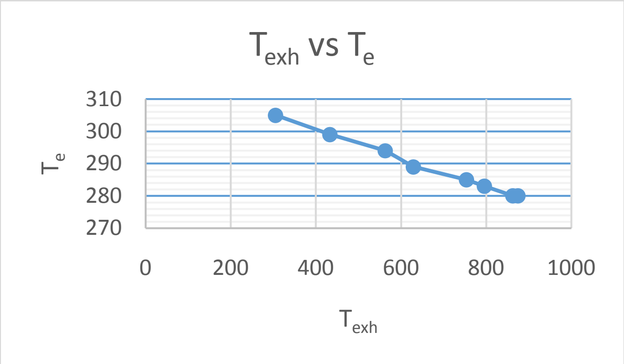

Fig 4. Exhaust temperature vs Evapourator temperature

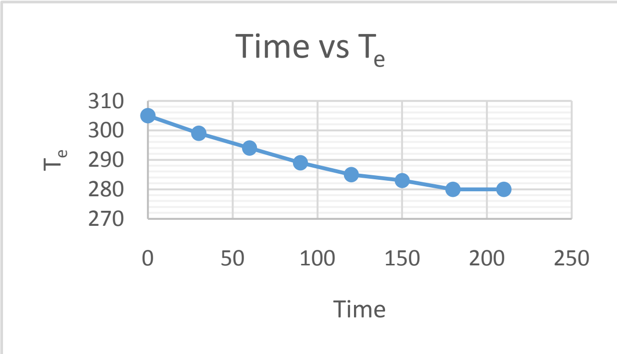

Fig 5.Time vs Evapourator temperature

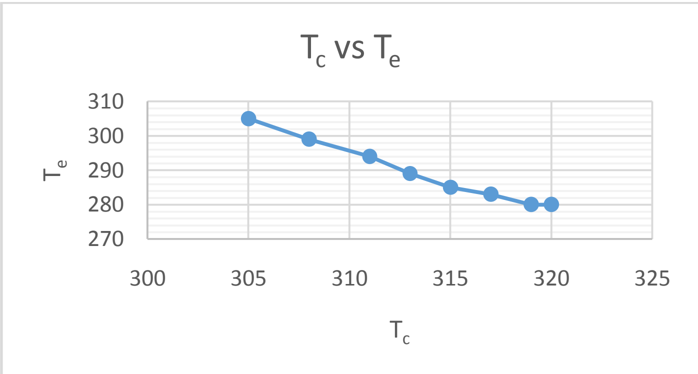

Fig 6. Condenser temperature vs Evapourator temperature

VII. CONCLUSION

It has been identified that there are large potentials of energy savings through the use of waste heat recovery technologies. Waste heat recovery defines capturing and reusing the waste heat from internal combustion engine for heating, generating mechanical or electrical work and refrigeration system. It would also help to recognize the improvement in performance and emissions of the engine. If these technologies were adopted by the automotive manufacturers then it will be result in efficient engine performance and Low emission. It can be concluded that the vapour adsorption cooling system powered by exhaust heat of automobile can be suitable to produce cooling effect. COP of the such system is less as compare to the traditional VCRS system but COP can be increase by doing some improvement in the cycle and increasing the source temperature of desorption process in thermodynamic cycle. Adsorbent material and refrigerant pairs are also deciding factor for the design of the AC system as depending upon the adsorption and desorption process temperature.After literature review in the field of alternative cooling systems powered by heat, adsorption air cooling systems with activated carbon and NH3 as adsorbent refrigerant pair is selected and used in the present system. In the present system solid material is used as adsorber which makes the system suitable for mobile applications.

ACKNOWLEDGMENT

First and foremost I offer my sincerest gratitude and respect to my guide, **Dr. Aboobacker Kadengal**, PG Dean, Department of Mechanical Engineering, L.B.S.College of Engineering, Kasaragod for his invaluable guidance and

suggestions to me during my study. I consider myself extremely fortunate to have had the opportunity of associating myself with him for one year. The thesis was made possible by his patience and persistence.
After the completion of the thesis, I experience feeling of achievement and satisfaction. Looking into the past, I realize how impossible it was for me to succeed on my own. I wish to express my deep gratitude to all those who extended their helping hands towards me in various ways during my short tenure at L.B.S. College of Engineering, Kasaragod.
I express my sincere thanks to **Dr. Mohammed Shekoor T**, Principal L.B.S. College of Engineering, Kasaragod, Mr. JowharMubarak, Assistant Professor and Head of the Mechanical Engineering Department for providing me the necessary facilities in the department and also for the valuable advices.
I would like to thank all the faculties and staffs of the Department of Mechanical Engineering for providing the support to complete my thesis. I greatly appreciate and convey my heart full thanks to my classmates and all those who helped me in completion of this work.
I am especially thankful to my parents for their love, sacrifice, and support. They are my first teachers after I came to this world and have set great examples for me about how to live, study, and work.

REFERENCES

[1] Mohamed Hamdya, Ahmed A. Askalanyb,n, K. Harbya, Nader Kora (2015) "An overview on adsorption cooling systems powered by waste heat from internal combustion engine",Renewable and Sustainable Energy Reviews, 51 (2015) 1223-1234.
[2] Michel Pons.(2016)" Principles of adsorption cycles for refrigeration or heat pumping ", pp 1-8.
[3] J. S. Jadhao, D. G. Thombare.(2013) "Review on Exhaust Gas Heat Recovery for I.C. Engine,"International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 12.
[4] Dim Dim Kumar, S A Mohan Krishna, S Kasthurirengan, G B Krishnapp (2016) "An experimental investigation on adsorption refrigeration system using silica gel-water, "Volume 1 Issue 1, Page 56-63.