

# ADSORPTION AIR CONDITIONING FOR AUTOMOBILES USING WASTE HEAT RECOVERED FROM EXHAUST GASES

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**Abstract** Diesel operated system consumes 10% of the energy of the crankshaft when used to operate the compressor in the air conditioning system. This is higher loss in the diesel operated system. Operation of conventional air conditioning systems uses refrigerants such as R12 or R22. These are refrigerants also harmful to the environment. Conventional system causes ozone layer depletion and global warming effect by CFCs or HCFCs. That's why new technology is required that is green air conditioning system. In this project Silica gel-water working pair is used as refrigerant for the system. Silica gel forms bond with water. Which is cheaper and eco-friendly? Cooling effect is produced by recovering the waste heat from exhaust gases

**Key Words:** Adsorbent, refrigerant, waste heat, Adsorption, Air conditioning.

## 1. INTRODUCTION

In vapour compression cycle having compressor delivers the vapour refrigerant at high temperature to condenser. The Compressor uses power from engine itself. The vapour compression air conditioning system has some drawbacks, that's why another better alternative is needed. That is adsorption air conditioning system.

Adsorption is the processes in which liquid molecules fixed on the solid surface. If molecules is fix then they loses the some form of energy. So that's why adsorption is exothermic reaction. Example silica gel is used in much process this will act like an adsorbent. Silica gel adsorbs the water molecules. So it will form the pair with water. In this process adsorption-desorption processes and some thermodynamic process takes place.

## 2. Literature review:

Sato etal[1] introduced multiple-stage adsorption air conditioning system. This system efficiency is increase.

Zhang[2] is presented the adsorption cooling system powered by the waste heat diesel engine. Zeolite-water is the working pair in this. Finned double-tube heat exchanger was used as the adsorber. COP of the system is 0.38. Specific cooling power of the system is 25.7W/Kg.

Wang etal[3] work on the adsorption air conditioning for the bus that is powered by the waste heat from the exhaust gases. Working pair is the Activated Carbon and Ammonia. density is 900Kg/m<sup>3</sup>. Additional adsorbent fit into the adsorber. Total weight of adsorber is 248Kg. area of occupied is 1.0m<sup>2</sup>.

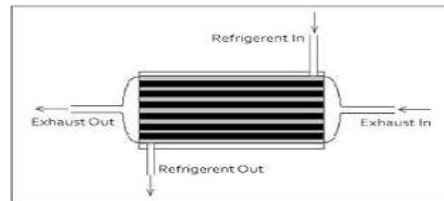
Lu etal[4] did experiment on performance of the adsorption air conditioning system driven by the exhaust heat from the diesel locomotive. The system uses one adsorbent bed and uses zeolite-water as pair to provide chilled water in drivers cab. The experimental result for adsorption system is feasible. So it can be applied for the space conditioning under running conditions. Average refrigeration power is 3-4.2 KW. This is not suitable for some applications because of its size and high regenerative temperature

## 3. Major Parts of ADAC

- i. Generator
- ii. Condenser
- iii. Evaporator
- iv. Fan & Motor
- v. Shut off valves
- vi. Receiver

i) Generator:

In this work a generator is designed the new model of generator. Through the copper tube exhaust gases are passed. Inside, the cylinder volume is filled with the silica gel-water as the working pair. In this design nine copper tubes are set evenly help to transfer the heat in between the exhaust gases to that of working pair. In this inlet and outlet of refrigerant are the two valves are attached. Each cylinder having the two openings they provide space for the cooling water and exhaust gases by this they flow through the tubes evenly as shown in Fig-1:



**Fig-1 Generator**

ii) Condenser:

In this high pressure and high temperature refrigerant is condensed. It releases its heat to the surroundings. When the medium of condensing is air or water.

iii) Evaporator:

In this refrigerant at low pressure and low temperature is evaporated and changed into the vapour. It gives cooling effect to the surroundings. Liquid vapour refrigerant absorbs its latent heat from surroundings.

iv) Fan & Motor:

By using this condenser is cooled by the circulation of air through the fan. By this gives the cooling effect. Motor is run by the power of the engine crankshaft.

v) Shut off valves:

By using this we want to avoid the unwanted direction of the refrigerant. In this expansion valve is to control the direction of refrigerant by half open.

vi) Expansion device:

This device also called throttle valve or refrigerant control valve. This receives high pressure and high pressure liquid type of refrigerant and they pass by means of reducing its temperature and pressure. Some of the refrigerant evaporates when it passes through the device like expansion device.

vii) Receiver:

This storage of liquid refrigerant and there is no leakage. This will prevent the leakage. This structure will look like hollow cubical shape box. For this two openings are there for refrigerant in and out. This is use when the excess the exhaust gases and the back pressure.

**3.1 Working process of ADAC**

This system having four processes they are

i) Generation/Desorption:

If the hot exhaust gases passed through the generator. The cycle will star Silica gel-Water working pair at the room temperature it is at the adsorbed state. When the temperature of the working pair is increased from the adsorbate surface start the releasing of adsorbent. By this desorption process will coming to the picture means desorption process is started. by this process pressure is increased in the cycle, so the temperature of the exhaust is above 200°C, at this temperature the liquid adsorbent gets evaporated and go out from the generator moves towards the condenser side.

**ii)Condensation:**

Refrigerant coming from the generator to the condenser this process will start. Condenser is the air cooled type. In this entering refrigerant having the high temperature and high pressure, this will give heat exchange with atmosphere. Refrigerant condensed in the condenser and comes out it is in the form of liquid state. This liquid refrigerant is collected in the receiver.

**iii)Evaporator:**

Refrigerant from the receiver pass to the expansion valve by the action of throttling By this evaporation will takes place. In this process surroundings will be cooled the liquid refrigerant absorb heat from the surroundings.

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Adsorbents are three types they are

**i)Physical Adsorbents:**

Physical adsorbents are the activated carbon, activated carbon fibre, silica gel and zeolite.

Activated carbon: They form working pair with methanol or ammonia. Activated carbon and methanol mostly used working pair because this is having the more adsorption quantity less adsorption heat is the 1800-2000 KJ/Kg. more heat consumption done in the desorption phase because of the adsorption heat. Less adsorption heat is required for better coefficient of performance.

Activated Carbon formed by the wood, peat, coal, fossil oil, chark bone, coconut shell and nut stone. Adsorption is intimated by functional group that is attached with the carbo atomic ring. Arene group increases adsorption while sulfonic decreases.

Silica gel: This forms working pair with the water. Adsorption heat is 2500KJ/Kg for this working pair. For this pair desorption temperature is very less, but above 50°C. Desorption temperature is not higher than 120°C. It is commonly less than 90°C.

It is the amorphous synthetic silica. It is rigid, continuous not of colloidal silica. It is attached to small grains of hydrated  $\text{SiO}_4$ . This is used for adsorption center because it is in hydroxyl in structure. It forms hydrogen bonds with polar oxides, they are water and alcohol. Adsorption quantity is increases polarity increases. In this hydroxyl structure is adsorbs the water molecules.

Zeolite: This can forms the working pair with the water. For this adsorption heat is more than the silica gel-water working pair. It is 3300-4200 KJ/Kg. adsorption quantity of the Zeolites is related to the proportion of the Si and Al. adsorption quantity is more when this proportion is small. Adsorption and desorption heat for this working pair is high, and also desorption temperature also high. It is 250-300°C. They can be destructed when temperature is more than this 600-700°C.

ii) Chemical Adsorbents:

They are metal chlorides, metal hydrides, and metal oxides.

iii) Composite Adsorbents:

They are used to develop chemical adsorbents. They can be combination of the chemical adsorbent and the porous medium they may be or not the physical adsorbent. They are activated carbon, graphite, carbon fibre etc.

#### **OBJECTIVE OF THE STUDY:**

- To design model a generator suitable for the Air-Conditioning recovery of heat energy from exhaust.
- For this project temperature of exhaust gases is 200°C, to perform simulation and to know the temperature distribution.
- Finally calculate the optimum thickness of the copper for silica gel desorption.

#### **4. METHODOLOGY**

- For this system know the adsorption air conditioning processes in details.
- Simulation of copper tube cylinder which is present in the generator is done by using ANSYS 15.0 software.
- First Create the model of cylinder cross section in the ANSYS in Transient thermal and fluid flow (fluent), finally simulation result is observed.

Final selection of working pair

i) Economy:

This system has to construct the model at the minimum cost. That is possible when the clear object of the system is in mind. In this project uses the silica gel it as the adsorbent. It is very less cost than the other adsorbents.

ii) Availability:

Keep in mind the availability of working pair in which cities. That may be considered in the near city. In this system selected working pair is silica-gel water.

iii) Suitability to application:

I.C engines can produce the temperature is 200°C. The desorption temperature of silica gel-water pair had to maintain this temperature. Zeolite-water pair desorption temperature is 250°C, it is negligible.

Activated char coal with working pair use the temperature is above 120°C so it is also negligible. This is negligible because decomposition of methanol takes place above this temperature.

Keep in mind all this points we selected the silica gel-water as working pair. Desorption temperature 120°C this is optimum temperature. Some other future also there they are it is cheap, handling of this also easy, easy to transport and use. This is available in the Aurangabad.

#### **5. MATHEMATICAL CALLUCULATIONS:**

In this discussed how the temperature and pressure changes will effect on the variation in the concentration of adsorbent adsorbed on the adsorbate.

Adsorption will effected by two quantities they are temperature and pressure.

x- Concentration, P<sub>e</sub>-evaporating pressure

P<sub>c</sub>-condensing pressure

Adsorption-desorption of equilibrium of physical adsorption in microspores measured by means of Dubinin-Astakhov(D-A) equation.

$$x=x_0 \exp[-k(t/t_s-1)^n] \quad \text{-----} \quad \text{---(1)}$$

or

$$x=x_0 \exp[-D(\ln P_s/P)^n] \text{-----} \text{---(2)}$$

x<sub>0</sub>, k, D, and n are coefficients they are different for working pair and they not same for the same working pair also they depend on the adsorbent.

T-adsorption temperature (K)

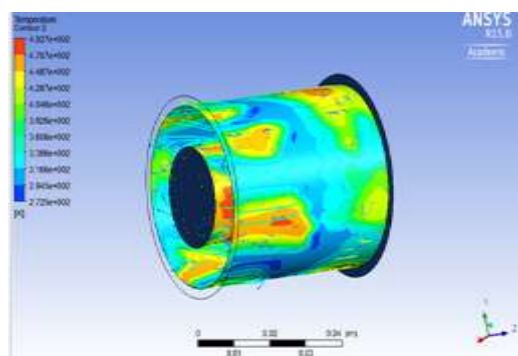
T<sub>s</sub>-saturated temperature of adsorbent (K)

P<sub>s</sub>-saturated pressure, P-pressure of the system

1. Silica gel and water  
n=1.7, x<sub>0</sub>=0.35, D=6\*10<sup>-6</sup>
2. Zeolite and water  
k=5.36, x<sub>0</sub>=0.261, n=1.73
3. activated carbon and ammonia  
k=3.57, x<sub>0</sub>=0.29, n=1.38
4. Activated carbon methanol  
k=13.38, x<sub>0</sub>=0.45, n=1.5

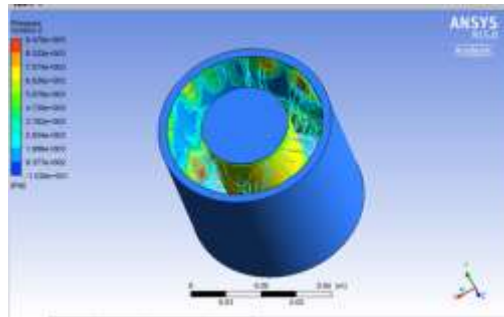
## 6. MODELING AND SIMULATION

This model is created by using ANSYS software. By using the dimensions to get the desorption temperature of silica gel. After creation of model meshing is done to get the accurate result. This model is kept in the generator. Same like this nine tubes are placed in the generator with equal space between each other. Exhaust gases passes through the tubes and inside the cylinder volume filled with the silica gel-water working pair. In the Fig-2: Temperature distribution it will show how the heat is transferred between the working pair and exhaust gases. After giving the input and output for exhaust gases and silica gel-water as working pair. Input temperature of exhaust gases is 200°C. It will give maximum and minimum temperatures.



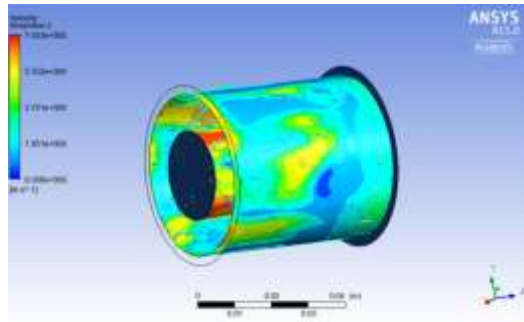
**Fig-2 Temperature distribution**

In this Fig-3: will give Pressure distribution this system gives temperature distribution but also give pressure and heat flux distributions. By giving the boundary conditions for all this energy is in on position. It will give minimum and maximum pressures.



**Fig-3: Pressure distribution**

In this Fig-4: will indicate the distribution of the velocity. For this system giving magnitude of the velocity is 5 m/s. They will indicates the motion of the exhaust gases and working fluid. By using this system increasing the efficiency of the system future will depends on this system only. By using this system we will get cooling effect.



**Fig-4: Velocity distribution**

**Calculation of availability of waste heat from I.C engines**

Exhaust gas having the quantity of waste heat is directly proportional to the temperature and mass flow rate of exhaust gases.

$$Q=m.C_p.\Delta T \text{ -----(3)}$$

Where 'Q' is the heat loss(KJ/s)

'm' is the exhaust gas mass flow rate(Kg/s)

'Cp' is the specific heat of the exhaust gas(KJ/Kg-K)

ΔT is temperature gradient in K

$$\text{Heat flow}(Q) = 0.014*1.1*(200-39.6) = 2.4701 \text{ KW}$$

$$\text{Heatflux}(Q/A) = 2.47016/(2*3.14*0.0050*0.05)= 1573.35 \text{ KW/m}^2$$

above model is created in the ANSYS 15.0 version this is available in our collage

**7. CONCLUSION**

In this system selected the silica gel-water as the working pair. Desorption temperature of the silica gel is the not higher than 120°C but this is a above the 50°C. it is generally 90°C. For this system cooper tube wall thickness is about 10-15mm. this will affect the adsorbent temperature and adsorption capacity. By using adsorption system it is eco-friendly system. Than exhaust.

They save the 95% electricity consumption than the VCR. Future will definitely run by the adsorption system. VCR system because it uses only heat energy as input not mechanical work. This low grade energy produced from the automobiles.

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