REVIEW STUDY ON EXHAUST OF A DIESEL ENGINE THERMAL STORAGE

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ABSTRACT

Exhaust gas which occurs as a result of the combustion of fuels such as natural gas, gasoline/petrol, diesel, fuel oil or coal. It is discharged into the atmosphere through an exhaust pipe or flue gas stack. The main objective of the proposed project is to utilize heat from the exhaust gases of a diesel engine and convert heat to useful work. Energy supplied to an engine is the heat value of the fuel consumed. But only a part of this energy is transferred into useful work. From heat balance sheet of a typical CI engine we find out that the total heat loss is around 33-45%, of which 33% is due to exhaust gases and the rest is lost to the surroundings. If we can reduce this figure by 10% also then it will be a substantial contribution.

Keywords:- combustion of fuels such as natural gas, gasoline/petrol, diesel, fuel oil or coal, exhaust gases, boiling point fluid.

INTRODUCTION

1.1 General

In case of a diesel engine the total heat loss is around 33-45%, of which 33% is due to exhaust gases and the rest is lost to the surroundings.Here, conditions in the engine are different from in a spark-ignition engine, because power is controlled by controlling the fuel supply directly, not by controlling the air supply. As a result, when the engine is running at low power, there is enough oxygen present to burn the fuel, and diesel engines only make significant amounts of carbon monoxide when running under load.

In thermal power stations, mechanical power is produced by a heat engine that transforms thermal energy, often from combustion of a fuel, into rotational energy. Most thermal power stations produce steam, and these are sometimes called steam power stations. Not all thermal energy can be transformed into mechanical power, according to the second law of thermodynamics. Therefore, there is always heat lost to the environment. If this loss is employed as useful heat, for industrial processes or district heating, the power plant is referred to as a cogeneration power plant or CHP (combined heat-and-power) plant.

1.2 Present methods to reduce exhaust gas temperature

i) Turbocharging
ii) Exhaust gas recirculation (EGR)

1.3 Turbocharging

A turbocharger, or turbo, is an air compressor used for forced-induction of an internal combustion engine. The purpose of a turbocharger is to increase the mass of air entering the engine to create more power. However, a turbocharger differs in that the compressor is powered by a turbine driven by the engine's own exhaust gases. The major parts of a turbocharger are turbine, wheel, turbine housing, turbo shaft, compressor, compressor housing and bearing housing. A turbo is a small radial fan pump driven by the energy of the exhaust flow of an engine. A turbocharger consists of a turbine and a compressor on a shared axle. The turbine inlet receives exhaust gases from the engine causing the turbine wheel to rotate. This rotation drives the compressor, compressing ambient air and delivering it to the air intake manifold of the engine at higher pressure, resulting in a greater mass of air entering each cylinder. In some instances, compressed air is routed through an intercooler before introduction to the intake manifold. The objective of a turbocharger is the same as a supercharger; to improve upon the size-to-output efficiency of an engine by solving one of its cardinal limitations. A naturally aspirated automobile engine uses only the downward stroke of a piston to create an area of low pressure in order to draw air into the cylinder through the intake valves. In the automotive world, boost refers to the increase in pressure that is generated by the turbocharger in the intake manifold that exceeds normal atmospheric pressure. Turbocharger parts are costly to add to naturally aspirated engines.

Heavily modifying OEM turbocharger systems also require extensive upgrades that in most cases requires most (if not all) of the original components to be replaced. Turbochargers require numerous additional systems if they are not to damage an engine.

1.4 Exhaust gas recirculation

The main objective of this method to reduce the amount NOx produced. EGR works by re-circulating a portion of an engine's exhaust gas back to the engine cylinders. Intermixing the incoming air with re-circulated exhaust gas dilutes the mix with inert gas, lowering the adiabatic flame temperature and (in diesel engines) reducing the amount of excess oxygen

EGR in Diesel Engines:- In modern diesel engines, the EGR gas is cooled through a heat exchanger to allow the introduction of a greater mass of re-circulated gas. Unlike SI engines, diesels are not limited by the need for a contiguous flame-front; furthermore, since diesels always operate with excess air, they benefit from EGR rates as high as 50% (at idle, where there is otherwise a very large amount of excess air) in controlling NOx emissions. Adding EGR to a diesel engine reduces the specific ratio of combustion gases int the power stroke. This reduces the amount of power that can be extracted by the piston. EGR tends to reduce the amount of fuel burned in the power stroke. This is evident by the increase in particulate emissions that corresponds to EGR.

1.5Economisers

Economisers, are mechanical devices intended to reduce energy consumption, or to perform another useful function like preheating a fluid.In case of coal fired power stations they are referred to as feedwater heaters and heat the condensate from turbines before it is pumped. Economizers are commonly used as part of a heat recovery steam generator in a combined cycle power plant. In an HRSG, water passes through an economizer, then a boiler and then a superheater. The economizer also prevents flooding of the boiler with liquid water that is too cold to be boiled given the flow rates and design of the boiler. A common application of economizers in steam powerplants is to capture the waste heat from boiler flue gas and transfer it to the boiler feedwater. This raises the temperature of the boiler feedwater thus lowering the needed energy input, in turn reducing the firing rates to accomplish the rated boiler output. Economizers lower stack temperatures which may cause condensation of acidic combustion gases and serious equipment corrosion damage if care is not taken in their design and material selection.

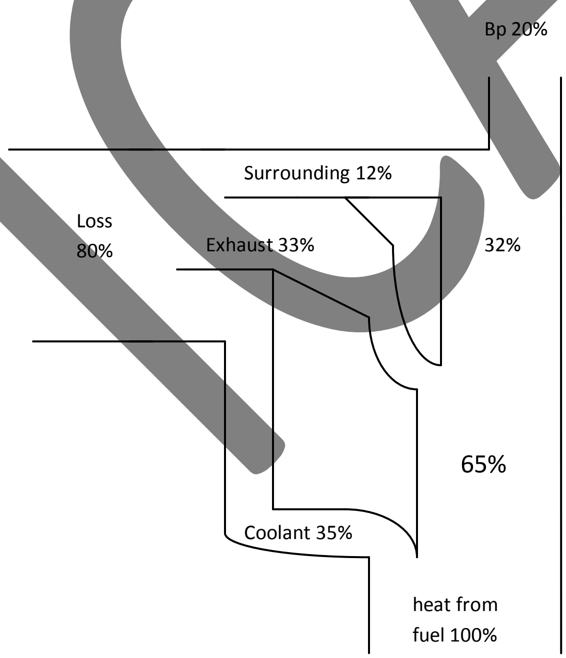

Figure 1 Sankey Diagram

DIESEL ENGINE

2.1 General

A diesel engine is an internal combustion engine which operates using the diesel cycle. Diesel engines have the highest thermal efficiency of any internal or external combustion engine, because of their compression ratio. Diesel engines are manufactured in two stroke and four stroke versions. The diesel internal combustion engine differs from the gasoline powered Otto cycle by using a higher compression of the air to ignite the fuel rather than using a spark plug for this reason it is known as compression ignition and the petrol engine is referred as spark ignition engine. In the diesel engine, only air is introduced into the combustion chamber. The air is then compressed with a compression ratio typically between 15 and 22 resulting into a 40 bar (about 600 psi) pressure compared to 14 bar (about 200 psi) in the gasoline engine. This high compression heats the air to 550 °C . At about this moment (the exact moment is determined by the fuel injection timing of the fuel system), fuel is injected directly into the compressed air in the combustion chamber.

2.2 Four stroke CI engine

The ideal sequence of operation for the four stroke CI engine is as follows:

i) Suction stroke:- Only air is inducted during the suction stroke. During this stroke intake valve is open and exhaust valve is closed.

ii) Compression stroke:- Both valves remain closed during compression stroke.

iii) Expansion or power stroke:- Fuel is injected in the beginning of the expansion stroke. The rate of injection is such that the combustion maintains the pressure constant. After the injection of fuel is over the products of combustion expand. Both valves remain closed during the expansion stroke.

iv) Exhaust stroke:- The exhaust valve is open and the intake valve remains closed in the exhaust stroke.

2.3 Valve timing diagram

The typical valve timing diagram for a four stroke CI engine is as follows:

IVO up to 30 degree before TDC

IVO up to 50 degree after BDC

EVO about 45 degree before BDC

EVO about 30 degree after TDC

Injection about 15 degree before TDC

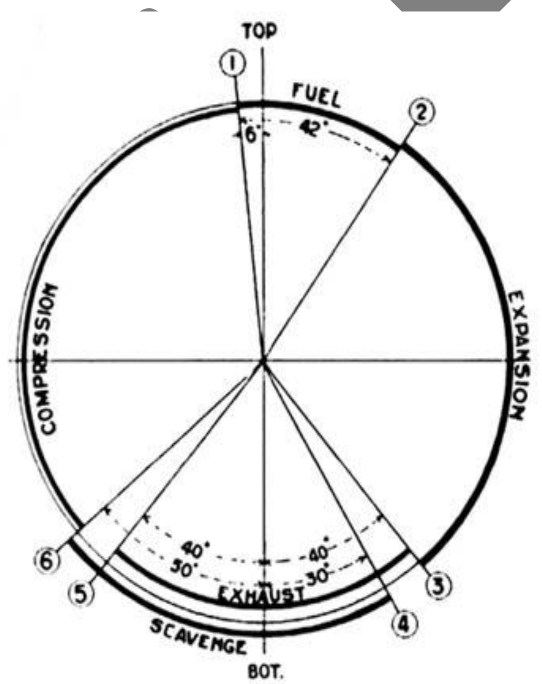

Figure 2 Valve timing Diagram

2.4 Two stroke CI engine

i) Intake begins when the piston is near bottom dead centre. Air is admitted to the cylinder through ports in the cylinder wall (there are no intake valves). Since the piston is moving downward at this time, aspiration due to atmospheric pressure isn't possible. Therefore a positive displacement blower or hybrid turbo-supercharger (a turbocharger that is mechanically driven from the crankshaft at low engine speeds) is employed to charge the cylinder with air. In the early phase of intake, the air charge is also used to force out any remaining combustion gases from the previous power stroke, a process referred to as scavenging. As the piston passes through bottom dead center, the exhaust valves will be closed and, owing to the pressure generated by the blower or turbocharger, the cylinder will be filled with air. Once the piston starts upward, the air intake ports in the cylinder walls will be covered, sealing the cylinder. At this point, compression will commence. Note that exhaust and intake actually occur in one stroke, the period during which the piston is near the bottom of the cylinder.

ii) As the piston rises, compression takes place and near top dead center, fuel injection will occur, resulting in combustion, driving the piston downward. As the piston moves downward in the cylinder it will reach a point where the exhaust valves will be opened to expel the combustion gases. Continued movement of the piston will expose the air intake ports in the cylinder wall, and the cycle will start anew. Note that the cylinder will fire on each revolution, as opposed to the four-stroke engine, in which the cylinder fires on every other revolution. There are two ports inlet port and exhaust port. At first stroke both the suction and compression takes place.

2.5 Advantages of a diesel engine over other internal combustion engine

i) They burn less fuel than a gasoline engine performing the same work, due to the engine's high efficiency and diesel fuel's higher energy density than gasoline.
ii) They have no high-tension electrical ignition system to attend to, resulting in high reliability and easy adaptation to damp environments.
iii) They can deliver much more of their rated power on a continuous basis than a gasoline engine.
iv) The life of a diesel engine is generally about twice as long as that of a gasoline engine due to the increased strength of parts used, also because diesel fuel has better lubrication properties than gasoline.
v) Diesel fuel is considered safer than gasoline in many applications. Although diesel fuel will burn in open air using a wick, it will not explode and does not release a large amount of

flammable vapour

HEAT EXCHANGER

3.1 General

A heat exchanger is a device built for efficient heat transfer from one medium to another, whether the media are separated by a solid wall so that they never mix, or the media are in direct contact. The hot fluid gets cooled, and the cold fluid gets heated.

3.2 Types of heat exchangers

- Shell and tube heat exchanger
- Plate heat exchanger
- Regenerative heat exchanger

3.3 Shell and tube heat exchanger

Shell and tube heat exchangers consist of a series of tubes. Two fluids, of different starting temperatures, flow through the heat exchanger. One flows through the tubes (the tube side) and the other flows outside the tubes but inside the shell (the shell side). Heat is transferred from one fluid to the other through the tube walls, either from tube side to shell side or vice versa. The fluids can be either liquids or gases on either the shell or the tube side. Heat exchangers with only one phase (liquid or gas) on each side can be called one-phase or single-phase heat exchangers.

3.4 Plate heat exchanger

Another type of heat exchanger is the plate heat exchanger. One is composed of multiple, thin, slightly-separated plates that have very large surface areas and fluid flow passages for heat transfer. This stacked-plate arrangement can be more effective, in a given space, than the shell and tube heat exchanger. Advances in gasket and brazing technology have made the plate-type heat exchanger increasingly practical.

3.5 Regenerative heat exchanger

A third type of heat exchanger is the regenerative heat exchanger. In this, the heat (heat medium) from a process is used to warm the fluids to be used in the process, and the same type of fluid is used either side of the heat exchanger (these heat exchangers can be either plate-and-frame or shell-and-tube construction). These exchangers are used only for gases and not for liquids. The major factor for this is the heat capacity of the heat transfer matrix.

3.6 Flow Arrangement

- Parallel flow
- Counter flow
- Cross flow

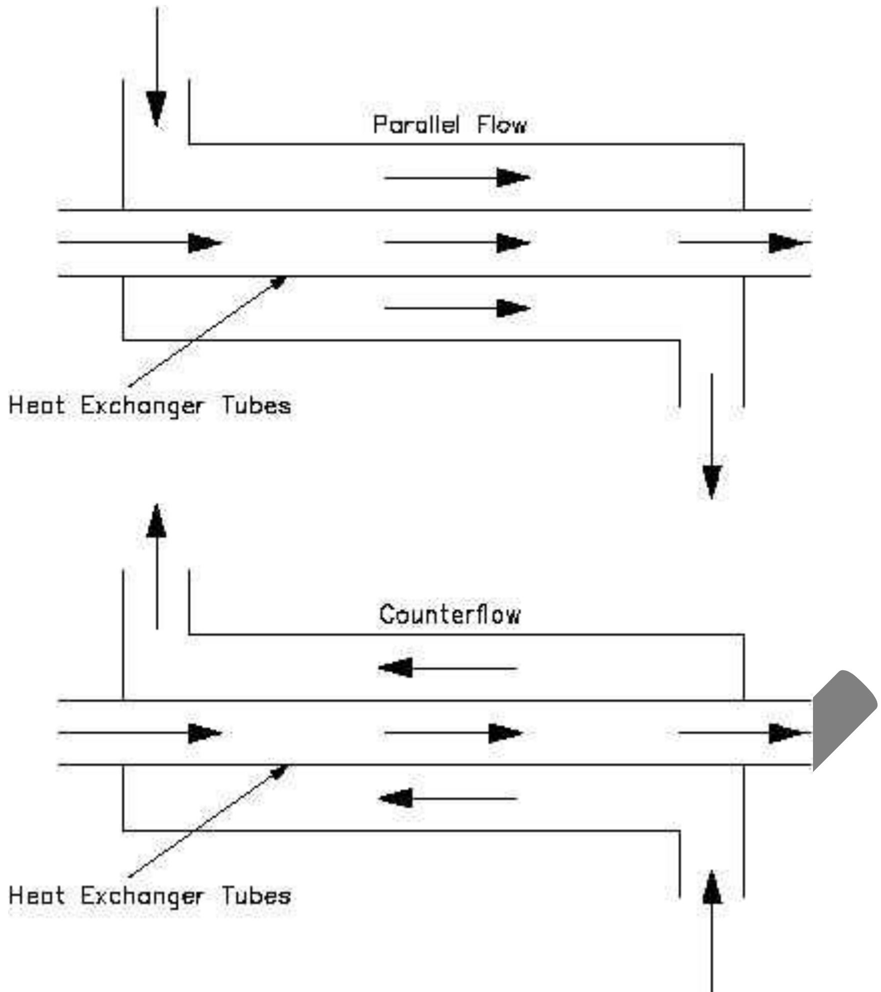

Figure 3 Parallel and Counter flow heat exchanger

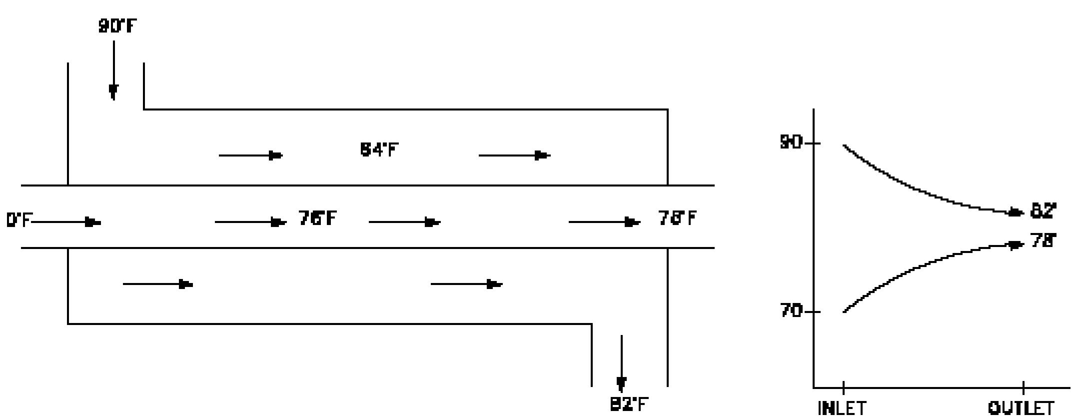

Figure 4 Parallel flow graphical representation

3.7 Parallel flow

In parallel-flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side.

3.8 Counter flow

In counter-flow heat exchangers the fluids enter the exchanger from opposite ends. The counter current design is most efficient, in that it can transfer the most heat from the heat (transfer) medium.

3.9 Cross flow

In a cross-flow heat exchanger, the fluids travel roughly perpendicular to one another through the exchanger.

For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger. The exchanger's performance can also be affected by the addition of fins or corrugations in one or both directions, which increase surface area and may channel fluid flow or induce turbulence.

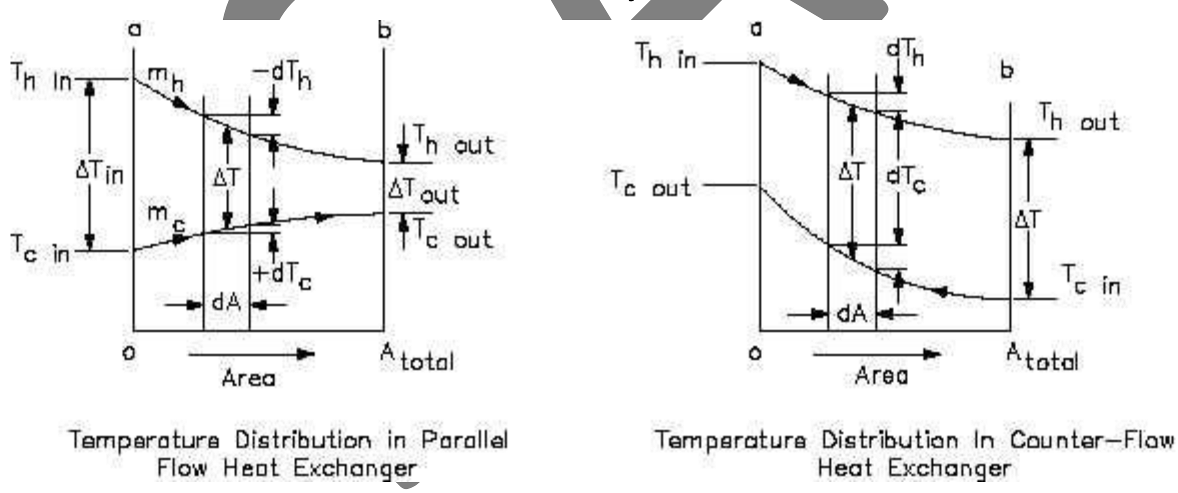

Figure 5 Temperature distribution in parallel and counter-flow

LMTD

The log mean temperature difference is used to determine the temperature driving force for heat transfer in flow systems, most notably in heat exchangers. The LMTD is a logarithmic average of the temperature difference between the hot and cold streams at each end of the exchanger. The larger the LMTD, the more heat is transferred. The use of the LMTD arises straightforwardly from the analysis of a heat exchanger with constant flow rate and fluid thermal properties.

For Countercurrent flow (i.e. where the hot stream, liquid or gas, goes from say left to right, and the cold stream, again liquid or gas goes from right to left), is given by the following equation:

$$LMTD = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln\left(\frac{T_1 - t_2}{T_2 - t_1}\right)}$$

And for Parallel flow (i.e. where the hot stream, liquid or gas, goes from say left to right, and so does the cold stream), is given by the following equation:

$$LMTD = \frac{(T_1 - t_1) - (T_2 - t_2)}{\ln\left(\frac{T_1 - t_1}{T_2 - t_2}\right)}$$

Where,

T1 = Hot Stream Inlet Temp.

T2 = Hot Stream Outlet Temp.

t1 = Cold Stream Inlet Temp.

t2 = Cold Stream Outlet Temp

The general form of the equation is

$$LMTD = \frac{\Delta T_L - \Delta T_R}{\ln\left(\frac{\Delta T_L}{\Delta T_R}\right)}$$

Where,

T_L= Temp. Difference at the left side of the heat exchanger (when the streams flow horizontally)

T_R = Temp. Difference at the right side of the heat exchanger (when the streams flow horizontally)

COMPRESSORS

4.1 General

A gas compressor is a mechanical device that increases the pressure of a gas by reducing its volume. Compressors are similar to pumps: both increase the pressure on a fluid and both can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the volume of a gas. Liquids are relatively incompressible, so the main action of a pump is to pressurize and transport liquids.

4.2 Types of Compressors

- Centrifugal Compressor
- Rotary Compressor
- Reciprocating Compressor
- Axial flow compressor

- Diaphragm compressor

4.3 Centrifugal compressor

Centrifugal compressor, (sometimes referred to as radial compressors) are a special class of radial-flow work-absorbing turbomachinery that includes pumps, fans, blowers and compressors. Centrifugal compressors use a muskan rotating disk or impeller in a shaped housing to force the gas to the rim of the impeller, increasing the velocity of the gas. A diffuser (divergent duct) section converts the velocity energy to pressure energy. They are primarily used for continuous, stationary service in industries such as oil refineries, chemical and petrochemical plants and natural gas processing plants. They are also used in internal combustion engines as superchargers and turbochargers. Centrifugal compressors are used in small gas turbine engines or as the final compression stage of medium sized gas turbine. Centrifugal compressors are used throughout industry because they have fewer rubbing parts, are relatively energy efficient, and give higher airflow than a similarly sized reciprocating compressor (i.e. positive-displacement). Their primary drawback is that they cannot achieve the high compression ratio of reciprocating compressors without multiple stages. Centrifugal fan/blowers are more suited to continuous-duty applications such as ventilation fans, air movers, cooling units, and other uses that require high volume with little or no pressure increase. In contrast, multi-stage reciprocating compressors often achieve discharge pressures of 8,000 to 10,000 psi (59 MPa to 69MPa). One example of an application of centrifugal compressors is their use in re-injecting natural gas back into oil fields to increase oil production. Additionally for aircraft gas-turbines; centrifugal flow compressors offer the advantages of simplicity of manufacture and relatively low cost. This is due to requiring fewer stages to achieve the same pressure rise. The fundamental reason for this stems from a centrifugal compressor's large change in radius (relative to a multi-stage axial compressor); it is the change in radius that allows the centrifugal compressor to generate large increases in fluid energy over a short axial distance.

4.4 Rotary compressor

A rotary screw compressor is a type of gas compressor which uses a rotary type positive displacement mechanism. The mechanism for gas compression utilises either a single screw element or two counter rotating intermeshed helical screw elements housed within a specially shaped chamber. As the mechanism rotates, the meshing and rotation of the two helical rotors produces a series of volume-reducing cavities. Gas is drawn in through an inlet port in the casing, captured in a cavity, compressed as the cavity reduces in volume, and then discharged through another port in the casing. The effectiveness of this mechanism is dependent on close fitting clearances between the helical rotors and the chamber for sealing of the compression cavities. Rotary screw compressors are used in a diverse range of applications. Typically, they are used to supply compressed air for general industrial applications. Trailer mounted diesel powered units are often seen at construction sites, and are used to power air operated construction machinery.

4.5 Reciprocating compressor

Reciprocating compressor or piston compressor is a positive-displacement compressor that uses pistons driven by a crankshaft to deliver gases at high pressure. The intake gas enters the suction manifold, then flows into the compression cylinder where it gets compressed by a piston driven in a reciprocating motion via a crankshaft, and is then discharged. Primarily, it is used in a great many industries, including oil refineries, gas pipelines, chemical plants, natural gas processing plants and refrigeration plants. Small reciprocating compressors from 5 to 30 horsepower (hp) are commonly seen in automotive applications and are typically for intermittent duty. Larger reciprocating compressors well over 1,000 hp (750 kW) are still commonly found in large industrial and petroleum applications. Discharge pressures can range from low pressure to very high pressure (>6000 psi or 41.4 MPa). In certain applications, such as air compression, multi-stage double-acting compressors are said to be the most efficient compressors available, and are typically larger, noisier, and more costly than comparable rotary units.

4.6 Axial flow compressor

Axial-flow compressors are dynamic rotating compressors that use arrays of fan-like aerofoils to progressively compress the working fluid. They are used where there is a requirement for a high flow rate or a compact design. Axial compressors can have high efficiencies; around 90% polytropic at their design conditions. However, they are relatively expensive, requiring a large number of components, tight tolerances and high quality materials.

Axial-flow compressors can be found in medium to large gas turbine engines, in natural gas pumping stations, and within certain chemical plants. Axial compressors consist of rotating and stationary components. A shaft drives a central drum, retained by bearings, which has a number of annular aerofoil rows attached. These rotate between a similar number of stationary aerofoil rows attached to a stationary tubular casing. The rows alternate between the rotating aerofoils (rotors) and stationary aerofoils (stators), with the rotors imparting energy into the fluid, and the stators converting the increased rotational kinetic energy into static pressure through diffusion. A pair of rotating and stationary aerofoils is called a stage. The cross-sectional area between rotor drum and casing is reduced in the flow direction to maintain axial velocity as the fluid is compressed.

4.7 Diaphragm compressor

Diaphragm compressor is a variant of the classic reciprocating compressor with backup and piston rings and rod seal. The compression of gas occurs by means of a flexible membrane, instead of an intake element. The back and forth moving membrane is driven by a rod and a crankshaft mechanism. Membrane and the compressor box come in touch with pumped gas.

DIAPHRAGM PUMP

5.1 General

A diaphragm pump is a positive displacement pump that uses a combination of the reciprocating action of a rubber, thermoplastic or teflon diaphragm and suitable non-return check valves to pump a fluid. Sometimes this type of pump is also called a membrane pump.

5.2 Types of diaphragm pump

- In the first type, the diaphragm is sealed with one side in the fluid to be pumped, and the other in air or hydraulic fluid. The diaphragm is flexed, causing the volume of the pump chamber to increase and decrease. A pair of non-return check valves prevent reverse flow of the fluid.
- As described above, the second type of diaphragm pump works with volumetric positive displacement, but differs in that the prime mover of the diaphragm is neither oil nor air; but is electro-mechanical, working through a crank or geared motor drive. This method

flexes the diaphragm through simple mechanical action, and one side of the diaphragm is open to air.

- The third type of diaphragm pump has one or more unsealed diaphragms with the fluid to be pumped on both sides. The diaphragm again are flexed, causing the volume to change.

The action is similar to that of the cylinder in an internal combustion engine. When the volume of a chamber of either type of pump is increased (the diaphragm moving up), the pressure decreases, and fluid is drawn into the chamber. When the chamber pressure later increases from decreased volume (the diaphragm moving down), the fluid previously drawn in is forced out. Finally, the diaphragm moving up once again draws fluid into the chamber, completing the cycle.

5.3 Applications

- Diaphragm pump have good suction lift characteristics, some are low pressure pumps with low flow rates; others are capable of higher flows rates, dependent on the effective working diameter of the diaphragm and its stroke length. They can handle sludges and slurries with a good amount of grit and solid content.
- It is low shear pump.
- It can be upto 97% efficient.
- It has good self priming capablilities.
- It can handle highly viscous liquids.

The earliest known experiment with a solar diaphragm pump was carried out by Tellier in the 1880s. The primary fluid (water) was circulated between the collector array and a vapour generator in which trichloro-tri-fluoroethane R-113 was evaporated. The pump was assembled on a stand 2 m above a water supply tank with provision for the discharge of water from the pump to a height of up to 3 m above the pump body. This pumping system was able to operate in a closed cycle\ but the overall efficiency was low compared with that in an open cycle. With the help of a hydraulically coupled feed pump\ the condensed working fluid was returned from the condenser to the vapour generator. On a clear sunny day with an average solar insolation of about 749 W m. The water flow rate was found to be at an overall efficiency of 0.21%.

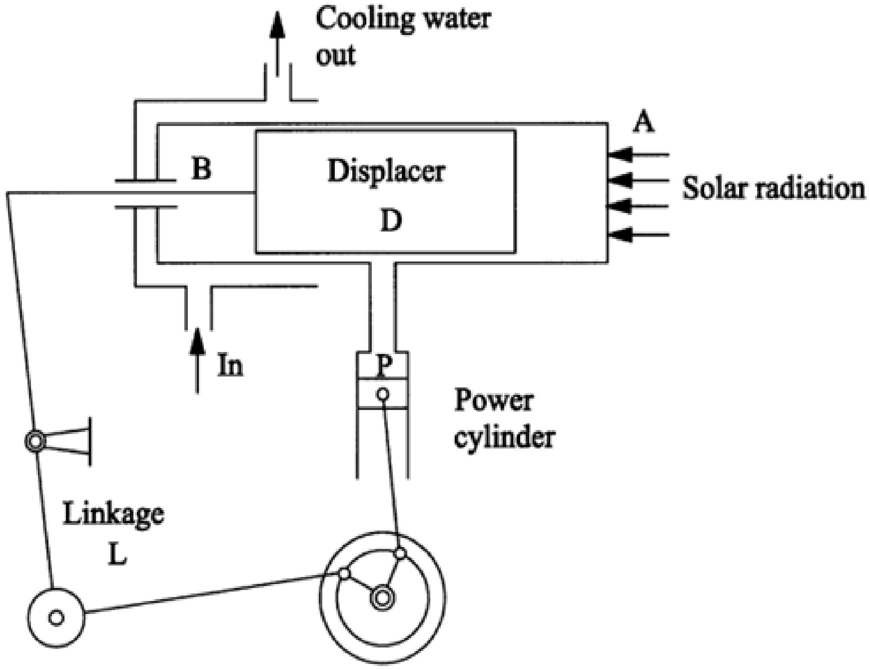

Figure 6 Schematic diagram of Hot air engine

Another example of a diaphragm pump was investigated by Sharma and Singh as shown in Fig6. They studied a model of a low lift diaphragm pump working with an automatic valve mechanism. The pump operated based on the Rankine cycle with freon!002 as a working fluid[The solar plate collector used had an exposed area of 0.3m. Liquid freon was vapourized in the collector and the vapour pushed a rubber diaphragm which in turn pumped the water.

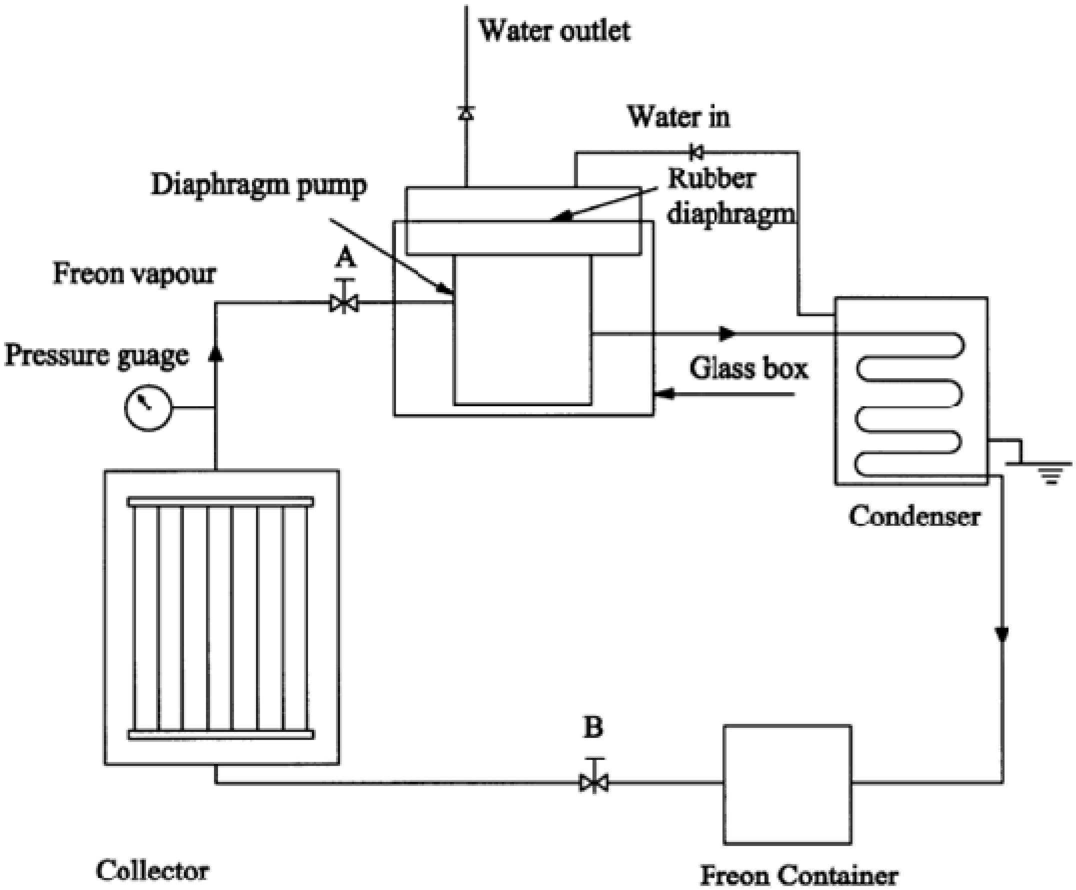

Figure 7 Diaphragm pump

PRESENT WORK

6.1 Experiment on twin cylinder diesel engine

Twin cylinder diesel engine specifications

- Vertical, double cylinder, water cooled, compression ignition, 4 stroke.
- Power output 10 h.p., running at 1500 rpm.
- Engine's moving part are lubricated by force feed and partly by splash lubrication.
- Sensible centrifugal type governor mounted on the camshaft gear.
- Water cooled engine is cooled by air flow generated with the help of a fan mounted on the flywheel called conventional cooling.
- Engine is designed for starting by hand.
- Test rig coupled with eddy current dynamometer loading.

To estimate the exhaust gas temperature, we conducted an experiment on the twin cylinder COMET Diesel engine available so that the exhaust gas temperature could be estimated.

The engine was tested at different loads starting from 5 kg to 30 kg at different time intervals, by connecting a thermocouple at the engine's exhaust.

The engine was running at a constant rpm of 1500 rpm.

The twin cylinder diesel engine was water cooled and a dynamometer was attached at the output.

6.2 Results of the experiment

Sl. No.	Load (kg)	Temperature (Celsius)
1.	0	280
2.	5	300
3.	10	340
4.	15	370
5.	20	400
6.	25	430
7.	30	440
	At full load	440

Table 1 Results of the experiment on twin cylinder CI engine

6.3 Heat Exchanger Design

Assumptions

M_a = Mass of air flowing

C_d = Coefficient of discharge

g = Acceleration due to gravity

H = Pressure Head

ρ_a = Density of air

ΔHw = Head of water

ρ_w = Density of water

M_f = Mass of fluid flowing.

Te = Exhaust gas temperature

To = Room temperature

M_l = Mass of the low boiling point fluid i.e. diethyl ether

Cpl = Specific heat constant of diethyl ether = 2.22 KJ /Kg K

ρ = density of diethyl ether = 0.71 g/c.c.

D = Diameter of the heat exchanger

6.4 Calculations

$$Ma = Cd\sqrt{2gH}$$

$$Ma = 2 * \frac{\pi}{4} d^2 * \rho a * Cd * 3600 * \sqrt{2g\, \Delta Hw\, \frac{\rho w}{\rho a}}$$

$$= 2 * \frac{\pi}{4} * (.02)^2 * 1.2 * 0.6 * 3600 * \sqrt{\frac{2*9.8*5.5*10}{1.2}}$$

= 48.84 kg/hr

$$M_f = 2.48\ kg/hr$$

$$Cpg = 1.005 \frac{KJ}{Kg\ K}$$

$$Te = 440℃$$

$$To = 30℃$$

Now, the equation of heat balance is :-

$M_l * Cpl * (T_2 - T_1)$ = $(Ma + M_f)\ Cpg * (Te - To)$

$M_l * Cpl$ (34.6 – 30) = (2.48+4.88) $*$ 1.005 $*$ (440 – 30)

$M_l * 2.22 * 4.6 = 7.36 * 1.005 * 410$

$M_l = 29.98\ kg/$hr

We know that,

Density = $\frac{Mass}{volume}$

$\rho = \frac{Ml}{V}$

$M_l = V * \rho$

$= \frac{\pi}{4} * L * D^2 * \rho$

= $\frac{\pi}{4}$ $*$1.5$*$ D^3 $*$ 0.71

Or,

Kg/hr = kg/$m^3 * m^3/s$

296.98/3600 = $\frac{\pi}{4} * 1.5 * D^3 * 0.71$

D^3 $= 0.0986745$ m

D = 0.462 m

= 462 mm

Hence the diameter of the heat exchanger to be designed was found out to be around 462 mm.

6.5 Specifications of the Heat exchanger fabricated

Diameter = 430 mm

Length = 450 mm

Thickness of the cylinder = 4.5 mm

Diameter of the copper pipe used = 12.6 mm

Diameter of the short MS pipe used = 25.4 mm

Length of the short MS pipe used = 152.4 mm

Length of the copper pipe = 2134 mm

Figure 8 Heat Exchanger fabricated

6.6 Selection of low boiling point fluid

For the purpose of experiment a low boiling point fluid was selected from the list of low boiling point fluids. Taking into consideration all the aspects the most appropriate fluid was Diethyl Ether.

6.7 Properties of Diethyl ether

Diethyl ether, also known as ether and ethoxyethane, is a clear, colorless, and highly flammable liquid with a low boiling point and a characteristic odor. It is the most common member of a class of chemical compounds known generically as ethers. It is an isomer of butanol. Diethyl ether has the formula CH_3-CH_2-O-CH_2-CH_3.

Properties	
Molecular formula	$C_4H_{10}O$ $C_2H_5OC_2H_5$
Molar mass	74.12 g/mol
Appearance	clear, colorless liquid
Density	0.7134 g/cm³, liquid
Melting point	−116.3 °C (156.85 K)
Boiling point	34.6 °C (307.75 K)
Solubility in water	6.9 g/100 ml (20 °C)
Viscosity	0.224 cP at 25 °C

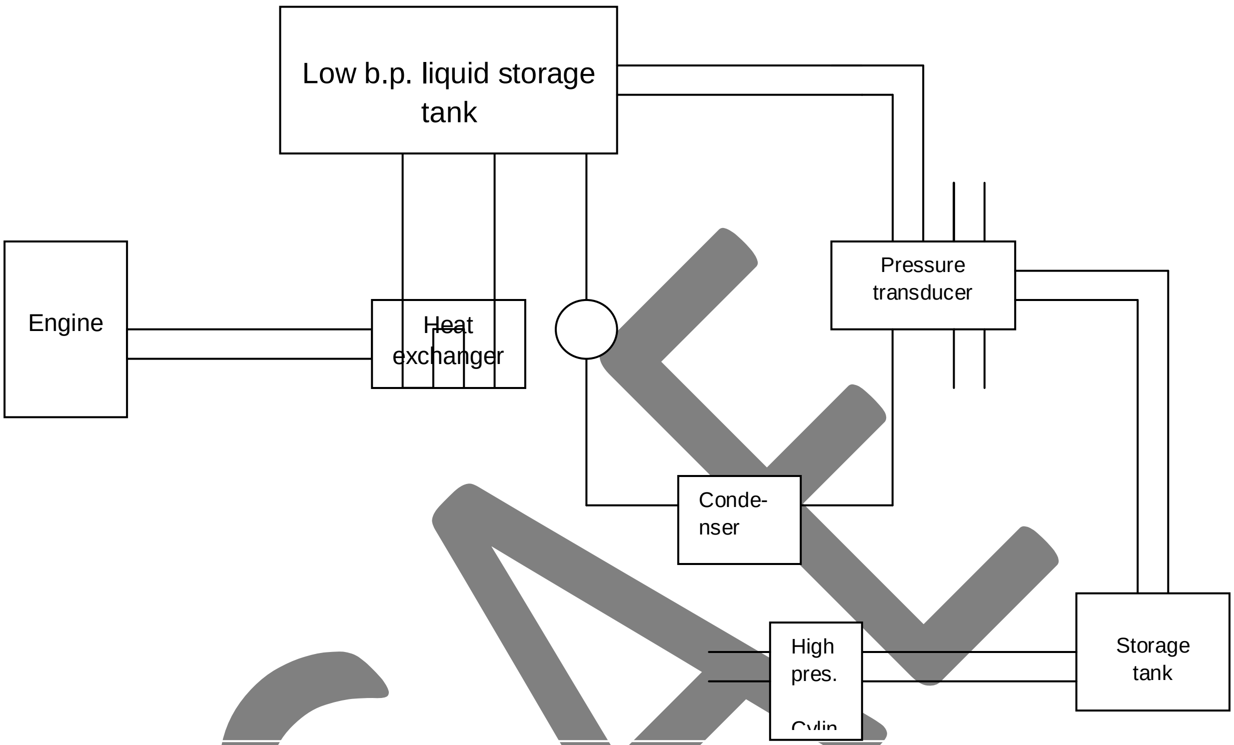

Figure 9 Schematic layout of the proposed project

RESULTS AND DISCUSSIONS

7.1 Results and discussions

The twin cylinder diesel engine was operated by initially taking diesel oil as the working fluid and then introducing a low boiling point fluid i.e. diethyl ether which will extract the heat from the exhaust gas and hence convert it into steam.

The mass flow rate of the low boiling point fluid was determined for optimum heat recovery. Due to the heat exchange, the liquid will become vapor and then it will be directed to the transducer

After conducting the experiment we find that the exhaust gas temperature increases with increasing load and reaches a maximum of 440^0C for full load condition. The experiment was carried out at different loads starting from 5 kg to 30 kg. The readings were also noted down for zero load case. When we used diethyl ether as the working fluid to extract heat we find that the exhaust gas temperature drops which may due to the heat extracted by the exhaust gas inside the heat exchanger.

SL. NO.	Load (kg)	V (Volts)	I (A)	Time for 20 c.c of fuel	Air inlet temp. (℃)	Exhaust gas temp. (℃)	Water inlet temp. (℃)	Water outlet temp (℃)	Vapor inlet pressure (bar)	Vapor outlet pressure (bar)	TFC (g/s)	Heat lost exhaust gas (kJ/hr)	Heat lost cooling water (kJ/hr)
1.	0	240	-	84	26	42	28	42	-	-	-	12892.5	18677.2
2.	5	240	5	76	26	42	28	42	-	-	0.11	13923.9	18677.2
3.	10	240	8	62	26	42	28	42	-	-	0.13	15986.7	18677.2
4.	15	240	12.5	53	26	42	28	42	-	-	0.16	17533.8	18677.2
5.	20	240	17.5	47	26	42	28	42	-	-	0.18	19080.9	18677.2

6.	25	240	22	34	26	42	28	42	-	-	0.25	20628	18677.2
7.	30	240	26	26	26	42	28	42	-	-	0.33	21146.4	18677.2

Table 2 Results of the Heat balance experiment carried with Diesel oil

Sl no.	Mass flow rate working fluid (g/s)	Load (Kg)	Air inlet temp (°C)	Exhaust gas temp (°C)	Water inlet temp (°C)	Water outlet temp (°C)	Vapor inlet pressure (bar)	Vapor outlet pressure (bar)
1.		0	26	270	28	42	0.30	0.50
.2.		5	26	285	28	42	0.40	0.55
3.		10	26	330	28	42	0.45	0.60
4.	0.008	15	26	355	28	42	0.50	0.70
5.		20	26	385	28	42	0.70	0.85
6.		25	26	410	28	42	0.80	1.00
7.		30	26	420	28	42	1.00	1.10

Table 3 Results of the experiment with diethyl ether as the working fluid

CONCLUSIONS

In this experiment we found out that while using a low boiling point fluid i.e. diethyl ether and testing it at different loads starting from 5 kg to 30 kg the exhaust gas temperature is reduced and the heat from the exhaust gas when passed through a blower with increased pressure can save input for multi stage compression. The exhaust gas temperature shows a reduction by 5-7% which may be explained due to the heat extracted by the low boiling point fluid.

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