A Seminar Report

On

GENERIC VISUAL PERCEPTION

Submitted by

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Third Year

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CERTIFICATE

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This is to certify that the seminar report entitled **"Autombile engine cooling system"** is a bonafide work carried out by **BODHISATWA CHOWDHURY (Roll No. 10200715011),** under my supervision. The report is submitted to the Mechanical Engineering Department, Kalyani Government Engineering College, Kalyani, Nadia. In my opinion the report in the present form is in partial fulfillment of the entire requirement as specified by the Kalyani Government Engineering College and as per regulation of West Bengal University of Technology. In fact, it has attained the standard necessary for submission.

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Automobile engine cooling:-

1.Introduction :-

Internal combustion engine cooling uses either air or a liquid to remove the waste heat from an internal combustion engine. For small or special purpose engines, air cooling makes for a lightweight and relatively simple system. The more complex circulating liquid-cooled engines also ultimately reject waste heat to the air, but circulating liquid improves heat transfer from internal parts of the engine. Engines for watercraft may use open-loop cooling, but air and surface vehicles must recirculate a fixed volume of liquid.

Heat engines generate mechanical power by extracting energy from heat flows, much as a water wheel extracts mechanical power from a flow of mass falling through a distance. Engines are inefficient, so more heat energy enters the engine than comes out as mechanical power; the difference is waste heat which must be removed. Internal combustion engines remove waste heat through cool intake air, hot exhaust gases, and explicit engine cooling.

Engines with higher efficiency have more energy leave as mechanical motion and less as waste heat. Some waste heat is essential: it guides heat through the engine, much as a water wheel works only if there is some exit velocity (energy) in the waste water to carry it away and make room for more water. Thus, all heat engines need cooling to operate.

Cooling is also needed because high temperatures damage engine materials and lubricants. Cooling becomes more important when the climate becomes very hot.[1] Internal-combustion engines burn fuel hotter than the melting temperature of engine materials, and hot enough to set fire to lubricants. Engine cooling removes energy fast enough to keep temperatures low so the engine can survive.[2]

Some high-efficiency engines run without explicit cooling and with only incidental heat loss, a design called adiabatic. Such engines can achieve high efficiency but compromise power output, duty cycle, engine weight, durability, and emissions.

2.Necessity of engine cooling system:-

To get the work done from internal combustion engine,we have to burn air-fuel mixture inside the cylinder.When the combustion of air-fuel mixture takes place in the engine cylinder,a temperature as high as 2500 degree centigrade is reached.To withstand such a high temperature we have to use very high melting point material for construction of engine.Practically it is less possible because,"Platinum" a metal which has one of the highest melting point,melts at above 1800 degree centigrade.

It has been practically found that out of total heat generated by internal combustion engine due to combustion of fuel,only 30% of heat is converted in useful work,out of remaining 70% about 40 % is carried by exhaust gases into the atmosphere during exhaust stroke.The rest of 30% must be passed to atmosphere by some suitable arrangement.

Here we find the necessity of cooling.In addition to overheating,large temperature differences may lead to distortion of the engine components due to set up of thermal stresses.If the cooling system is not provided to internal combustion engine,the lubricating oil film would break down and the lubricating oil will decompose to give gummy and carbon deposits.
In lack of Cooling system,a complete seizure of the piston,bearing and other important parts will occur.Due to this,there will be more frequent replacement of the components are required.It will also increase the repairing cost and breakdown period.The engine life will be reduced considerably.

It should also be noted that higher temperatures lower the volumetric efficiency of the engine,promote pre-ignition and tendency of the engine to detonate.The object of cooling is achieved by any of the two methods,
01)Air Cooling
02)Water Cooling

3.Properties of an efficient cooling system:-

The following are the two main properties desired of an efficient cooling system,

01)It must be capable of removing only about 30% of the heat generated in the combustion chamber.Too much heat removal will lower the thermal efficiency of the engine.
02)It should remove heat at a fast rate when engine is hot.It is also required to be

very slow cooling at the starting of the engine,so that the different working parts of the internal combustion engine reach their operating temperature in a short time period.

If you are using Water cooled engine,then are little chances of freezing of water in cold weather conditions,if we keep engine without use for very long time. To overcome this problem,we have to mix anti freezers in cooling water.

- Get the engine up to optimum operating Temperature as quickly as possible and maintains it at that temperature.
- Controls the heat produced in combustion chamber, so that the engine parts are not damaged & the oil does not break down.
- The temp. of component must be maintained within certain limit in order to obtain maximum performance of engine. Adequate cooling is then a fundamental requirement associated with reciprocating I.C.engine. [3]

4.Types of cooling system:

The different Types of cooling system are

1. Air cooling system
2. Liquid cooling system
3. Forced circulation system
4. Pressure cooling system

4.1.Air-Cooled System :

The simplest type of cooling is the air-cooled, or direct, method in which the heat is drawn off by moving air in direct contact with the engine Several fundamental principles of cooling are embodied in this type of engine cooling. The rate of the cooling is dependent upon the following:

1. The area exposed to the cooling medium.
2. The heat conductivity of the metal used & the volume of the metal or its size in cross section .
3. The amount of air flowing over the heated surfaces.
4. The difference in temperature between the exposed metal surfaces and the cooling air.

4.2.Liquid-cooled system;

Nearly all multi cylinder engines used in automotive, construction, and material-handling equipment use a liquid-cooled system. Any liquid used in this type of system is called a COOLANT.

A simple liquid-cooled system consists of a radiator, coolant pump, piping, fan, thermostat, and a system of water jackets and passages in the cylinder head and block through which the coolant circulates. Some vehicles are equipped with a coolant distribution tube inside the cooling passages that directs additional coolant to the points where temperatures are highest.

Cooling of the engine parts is accomplished by keeping the coolant circulating and in contact with the metal surfaces to be cooled. The operation of a liquid- cooled system is as follows:

The pump draws the coolant from the bottom of the radiator, forcing the coolant through the water jackets and passages, and ejects it into the upper radiator tank. The coolant then passes through a set of tubes to the bottom of the radiator from which the cooling cycle begins.

The radiator is situated in front of a fan that is driven either by the water pump or an electric motor. The fan ensures airflow through the radiator at times when there is no vehicle motion. The downward flow of coolant through the radiator creates what is known as a thermosiphon action. This simply means that as the coolant is heated in the jackets of the engine, it expands. As it expands, it becomes less dense and therefore lighter. This causes it to flow out of the top outlet of the engine and into the top tank of the radiator. As the coolant is cooled in the radiator, it again becomes more dense and heavier. This causes the coolant to settle to the bottom tank of the radiator.

The heating in the engine and the cooling in the radiator therefore create a natural circulation that aids the water pump. The amount of engine heat that must be removed by the cooling system is much greater than is generally realized. To handle this heat load, it may be necessary for the cooling system in some engine to circulate 4,000 to 10,000 gallons of coolant per hour. The water passages, the size of the pump and radiator, and other details are so designed as to maintain the working parts of the engine at the most efficient temperature within the limitation imposed by the coolant.[4]

4.3.Pressure cooling system

4.3.1.Radiator Pressure Cap :-

The radiator pressure cap is used on nearly all of the modern engines. The radiator cap locks onto the radiator tank filler neck Rubber or metal seals make the cap-to-neck joint airtight. The functions of the pressure cap are as follows:

1. Seals the top of the radiator tiller neck to prevent leakage.
2. Pressurizes system to raise boiling point of coolant.
3. Relieves excess pressure to protect against system damage.
4. In a closed system, it allows coolant flow into and from the coolant reservoir.

The radiator cap pressure valve consists of a spring- loaded disc that contacts the filler neck. The spring pushes the valve into the neck to form a seal. Under pressure, the boiling point of water increases. Normally water boils at 212°F.

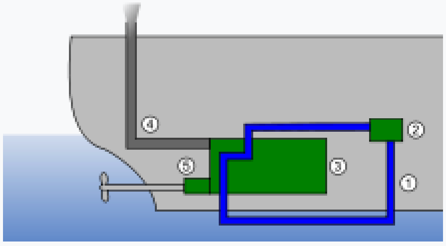
However, for every pound of pressure increase, the boiling point goes up 3°F. Typical radiator cap pressure is 12 to 16 psi. This raises the boiling point of the engine coolant to about 250°F to 260°F. Many surfaces inside the water jackets can be above 212°F. If the engine overheats and the pressure exceeds the cap rating, the pressure valve opens. Excess pressure forces coolant out of the overflow tube and into the reservoir or onto the ground.

This prevents high pressure from rupturing the radiator, gaskets, seals, or hoses. The radiator cap vacuum valve opens to allow reverse flow back into the radiator when the coolant temperature drops after engine operation. It is a smaller valve located in the center, bottom of the cap.

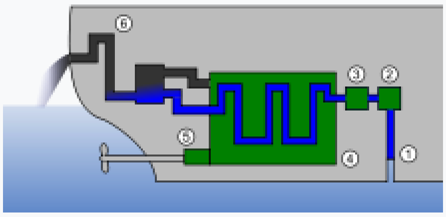
The cooling and contraction of the coolant and air in the system could decrease coolant volume and pressure. Outside atmospheric pressure could then crush inward on the hoses and radiator. Without a cap vacuum or vent valve, the radiator hose and radiator could collapse.[5]

Liquid cooling system:-

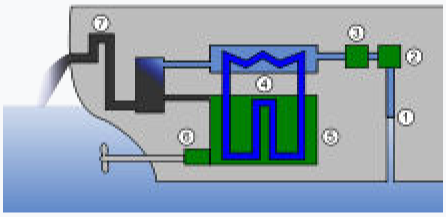
Today, most automotive and larger IC engines are liquid-cooled.[6][7][8]



Fig—1.A- A fully closed IC engine cooling system



Fig—1.B--Open IC engine cooling system



Fig—1.C--Semiclosed IC engine cooling system

Liquid cooling is also employed in maritime vehicles (vessels, ...). For vessels, the seawater itself is mostly used for cooling. In some cases, chemical coolants are also employed (in closed systems) or they are mixed with seawater cooling.[9][10]

5.Transition from air cooling:-

The change of air cooling to liquid cooling occurred at the start of World War II when the US military needed reliable vehicles. The subject of boiling engines was addressed, researched, and a solution found. Previous radiators and engine blocks were properly designed and survived durability tests, but used water pumps with a leaky graphite-lubricated "rope" seal (gland) on the pump shaft. The seal was inherited from steam engines, where water loss is accepted, since steam engines already expend large volumes of water. Because the pump seal leaked mainly when the pump was running and the engine was hot, the water loss evaporated inconspicuously, leaving at best a small rusty trace when the engine stopped and cooled, thereby not revealing significant water loss. Automobile radiators (or heat exchangers) have an outlet that feeds cooled water to the engine and the engine has an outlet that feeds heated water to the top of the radiator. Water circulation is aided by a rotary pump that has only a slight effect, having to work over such a wide range of speeds that its impeller has only a minimal effect as a pump. While running, the leaking pump seal drained cooling water to a level where the pump could no longer return water to the top of the radiator, so water circulation ceased and water in the engine boiled. However, since water loss led to overheat and further water loss from boil-over, the original water loss was hidden.

After isolating the pump problem, cars and trucks built for the war effort (no civilian cars were built during that time) were equipped with carbon-seal water pumps that did not leak and caused no more geysers. Meanwhile, air cooling advanced in memory of boiling engines... even though boil-over was no longer a common problem. Air-cooled engines became popular throughout Europe. After the war, Volkswagen advertised in the USA as not boiling over, even though new water-cooled cars no longer boiled over, but these cars sold well. But as air quality awareness rose in the 1960s,[11] and laws governing exhaust emissions were passed, unleaded gas replaced leaded gas and leaner fuel mixtures became the norm. Subaru chose liquid-cooling for their EA series (flat) engine when it was introduced in 1966.

6.Liquid cooling system components:→

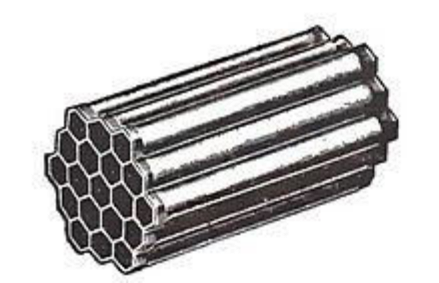
6.1.Radiator:-

Radiators are heat exchangers used for cooling internal combustion engines, mainly in automobiles but also in piston-engined aircraft, railway locomotives, motorcycles, stationary generating plant or any similar use of such an engine.

Internal combustion engines are often cooled by circulating a liquid called *engine coolant* through the engine block, where it is heated, then through a radiator where it loses heat to the atmosphere, and then returned to the engine. Engine coolant is usually water-based, but may also be oil. It is common to employ a water pump to force the engine coolant to circulate, and also for an axial fan to force air through the radiator.

6.1.1.Radiator construction:-

Automobile radiators are constructed of a pair of header tanks, linked by a core with many narrow passageways, giving a high surface area relative to volume. This core is usually made of stacked layers of metal sheet, pressed to form channels and soldered or brazed together. For many years radiators were made from brass or copper cores soldered to brass headers. Modern radiators have aluminum cores, and often save money and weight by using plastic headers. This construction is more prone to failure and less easily repaired than traditional materials.[12]



Fig—2--Honeycomb radiator tubes

An earlier construction method was the honeycomb radiator. Round tubes were swaged into hexagons at their ends, then stacked together and soldered. As they only touched at their ends, this formed what became in effect a solid water tank with many air tubes through it.[28]

Some vintage cars use radiator cores made from coiled tube, a less efficient but simpler construction.

6.1.2.DESIGN OF CONVENTIONAL RADIATOR

Considering a conventional car radiator having Height of 365 mm and Width is 610 mm and depth of radiator (L_{out}) is 22mm. The fin dimensions are: thickness of

fin(T_{hfin}) is 0.35, pitch of fin is 1.52 mm, and separation between two adjacent tubes is 8mm and the tube wall

thickness of 0.4 mm.

The corresponding value of $T_{H\ avg}$ (hot water average temperature) is 90^{O}CwithQ$_{d\ tubes}$as discharge rate fluid

which is 1.30 x 10-3 m3/sec, Q_{req}= 35596 W at maximum brake horse power of 37969 W, the wind

velocity which is mainly due to forward motion of vehicle is (Vair) 150 km/hr.

Rate of heat transfer over the surface of radiator is given by:[22]

Q= U x A x Ɵm

And Ɵm = $T_{H\ avg}$- $T_{C\ avg}$ = 90– 40 = 50^{O}C

UA= 1 / $R_{total,}$(total thermal resistance between water and air)

Where U is overall heat transfer coefficient between two fluids and Ɵm is AMTD (arithmetic mean temperature difference)

Rtotal = Rin + Rf, in + Rcond + Rout + Rf, out(1)[23]

Rin = 1/ ($h$in x A total,in)

$A_{total,in}$= .979416

Defining as nusselt number, K_{air} as thermal conductivity of air, Re as Reynolds number and Pr as Prandtl number

Re = (ρ x v x L_c) / μ

= .9937x10^4

Pr = (μ x c_p) / k

= 1.8936

= 3.66 + [(0.668 (D/W) x Re x Pr) / (1 + 0.04 ((D/W) x Re x Pr)$^{2/3}$]

= 6.3366

= (h_{in} x L_c) / k,Where Lc is characteristic length.

h_{in}= 2122.3 W/ m^2 K

Assuming R_{in} as convective resistance between the water & the inner surface of the tube, $R_{f,in}$ as fouling resistance that occurs on the internal surface of the tube, R_{cond} as resistance to conduction through tube wall, R_{out} as resistance between the air and the surface of the fins and the outer tube surface (it is due to both convection and conduction resistance to the fin) and R_f out as fouling resistance that occurs on the outer surface of the

tubes.[24]

R_{in}= 4.81 x 10^{-4} ^{0}C W^{-1}

Rf, in = R"f, in / Atotal in

= 1.021x 10^{-4} ^{O}C W^{-1}

Rf, out = R"f, out / Atotal out

= 3.3126x10^{-4} ^{O}CW^{-1}

We have $R''_{f,\ in}$ as fouling factor for inside, $R''_{f,\ out}$ as fouling factor for outside,

Rcond = th / [k tube x Atotal in]

= 0.0163x10^{-4} ^{O}CW^{-1}

Rout = 1 / (ηox out x Atotal,out)

$A_{total\ out}$ = 6.037528 m^2

η_o $= 1 - [(A_{s\ fin\ tot} / A_{tot})(1-\eta_{fin})]$

$\eta_{fin} = .983$

$\eta_o = .985$

Let V is velocity of air flow, ν kinematic viscosity of

air, $A_{s\ fin\ total}$ is total fin surface area, $A_{s\ unfin\ is}$total un-finned surface area

$$\mathbf{Re = (\rho \times v \times L_{out}) / \mu}$$

$= 5.4 \times 10^4$

$$\mathbf{Pr = (\mu \times c_p) / k_{air}}$$

$= .7046$

$$\mathbf{= 0.036 \times (Re)^{4/5} \times (Pr)^{1/3}}$$

$= 195.67$

$$\mathbf{= (\quad _{out} \times L_{out}) / k_{air}}$$

$h_{out} = 241\ W/m^2K$

$R_{out} = 6.977 \times 10^{-4}\ {}^{O}C\ W^{-1}$

$$\mathbf{R_{total} = 16.13693 \times 10^{-4}\ {}^{O}CW^{-1}}$$

$$\mathbf{U A = 1 / R_{total}}$$

$= .6197 \times 10^{-3}\ W/\ {}^{O}C$

Therefore, the rate of heat transfer for the radiator is **Q**

= **30984 W** over total fin surface area of 5.2096 m^2 and total un-finned surface area of 0.827928 m^2.
And the difference in heat rate, $\mathbf{\Delta Q = Q_{req} - Q_{act} = 4612W}$

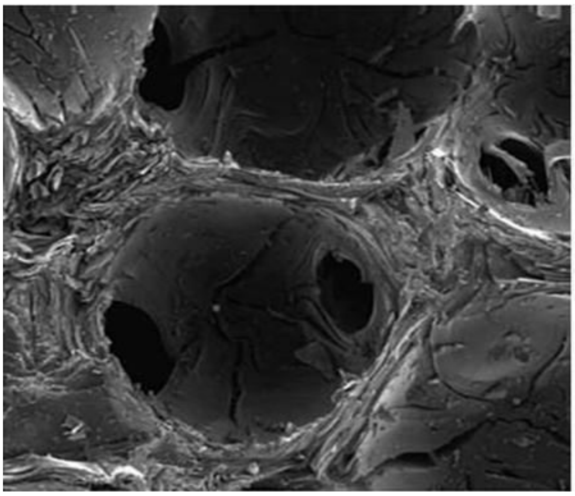


Fig 2 Scanning electron micrograph of the Carbon foam surface of asingle pore

6.1.2.1.USING CARBON FOAM: Fin Material [25]

Air–water heat exchangers are commonly employed in high output internal combustion engine cooling. The resistance to convective heat transfer on the air side of the heat exchanger dominates in the design of these heat exchangers. Large numbers of metal fins are used to provide additional surface area on the air side of the heat exchanger to lower the total convective thermal resistance. These fins are generally made of aluminum having ($k_{aluminum}$) of 160 - 250 W/m-K. Instead of this

Porous carbon-foamwith effective (stagnant) conductivity in the range 40–180 [W/m-K] dueto the very high specific conductivity of the carbonmaterial (k

900–1700 [W/m-K]) depending on theporosity which is normally between 0.7 and 0.9 using the current foaming process can be used to replace the aluminum fins in finned tube radiators.

The unique thermodynamic properties of the foam would serve to reduce the thermal resistance of a heat exchanger. As porous carbon foam has an open, interconnected internal structure.

Porosity = 70 %

D_{void} = 350 x 10^{-6} m

β = 9000 m^2/m^3

α = 0.653

pfin = 2 x 10^{-3} m

thfin = 0.7 x 10^{-3} m

Nfins row = 304

Rout = Rout eff

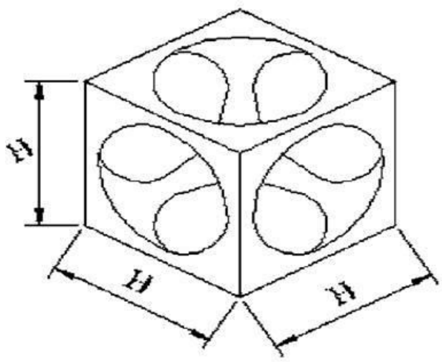


Fig 3 Unit cube geometry of carbon foam

Where β is the interior surface area to volume ratio of

the foam and$D_{void}$is the void diameter of the foam.H is the dimension of the unit cube.

Now, $(1/R_{out\ eff}) = (1/R_{out\ red}) + (1/R_{out\ voids})$

Rout void =1 / ($h$out, voidx As,fin,void)

$Re = (V \times D_{void}) / \nu$

$= 859.42$

$Pr = (\mu \times c_p) / k$

$= .7046$

$= 1.064 \times (Re)^{.59} \times (Pr)^{1/3}$

$= 50.9813$

$= (h_{out\ void} \times D_{void}) / k$

$h_{out\ void} = 3947.40$

As fin void = β x Vol.fin total

$= 12.47\ m^2$

Rout void =1 / ($h$out,void x As,fin,void)

$= .20312 \times 10^{-4\,o}CW^{-1}$

Rout red = 1/(ηo red x $h$out x Atotal out red)

Atotal,out red = As,fin,total + As,unfin – As front void $A_{s,fin,total} = 5.2096\ m^2$

$A_{s,unfin} = .827928\ m^2$

As front void = As,fin,total x α

$= 3.40186\ m^2$

$A_{total,out\ red} = 2.635668\ m^2$

$\eta_{o\ red} = .86$

$R_{out\ red} = 18.3060 \times 10^{-4\,o}CW^{-1}$

1/Rout eff= 1/Rout red + 1/Rout,void

$R_{out\ eff}$= .20077 x 10^{-4} $^{O}C\ W^{-1}$

R_{total} = 9.3607 x 10^{-4} $^{O}C\ W^{-1}$ from equation of R_{total} UA = 1/ R_{total}

= 1068.296

Therefore, rate of heat transfer from this design Q = U x A x Θ_m

= **53414 W**

Which is much greater than the required value Q_{req}= 35596 W. Hence, the existing radiator can be made smaller in size by 203 mm (33 %) in width. That's means there is an extra availability of 1630 cm^3 space in engine compartment.[26][27]

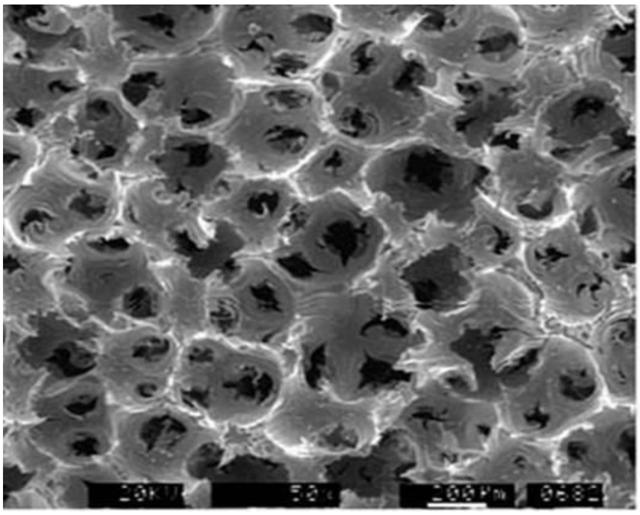


Fig 4 Scanning electron micrograph of the carbon foam surface

6.1.2.2.USING NANOFLUID: Coolant[29]

Fluid design considering thermal and viscous properties is a critical aspect of cooling system optimization for a variety of applications. Nano-fluids, a two-phase mixtures composed of very fine particles in suspension in a continuous and saturated liquids (water, ethylene glycol, engine oil), may constitute a very interesting alternative for advanced cooling system. It may be possible that important heat transfer enhancement may be achieved while using Nano-fluids compared to the use of conventional fluids.

Considering heat performance of water based Nano-fluids, Al_2O_3 with 47 nm particle-sizes, in a conventional car radiator based upon the constraint defined earlier.

k =.76 W/m k

$\mu = 4.596 \times 10^{-3}$ N-s/m^2 $\nu = 4.23 \times 10^{-6}$ m^2/s Cp $= 1.456 \times 10^3$
J/kg K
There is increase in kinematic viscosity of water after other compounds are mixed as described above

$Re = (v \times Lc) / \nu = .076583 \times 10^4$

$Pr = (\mu \times c_p) / k = 9.0429$

$$= 3.66 + [\ (0.668\ (D/W) \times Re \times Pr) / (1 + 0.04\ (\ (D/W) \times Re \times Pr)^{2/3}]$$

= 15.5573

As V_{water} is 1.55 m/s, Lc = 4Ac / P is 2.09 mm (characteristic length) thus Lc / W is 3.42 mm.

$= (h_{in} \times L_c) / k$

$h_{in} = 5657.2$ W/m^2 K

$R_{in} = 1.8048 \times 10^{-4}\ {}^oCW^{-1}$

Replacing the value of R_{in} in equation of R_{total} $R_{total} = 1.313073 \times 10^{-3}\ {}^o\ CW^{-1}$

$UA = 1 / R_{total}$

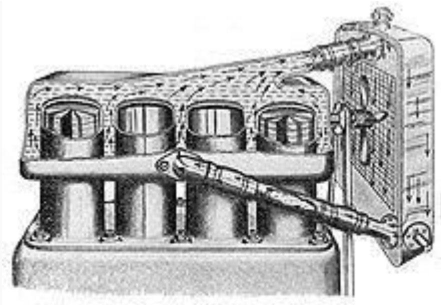
$= 761.572$ W/^{o}C

There, rate of heat transfer for this design Q= U x A x Θm

= 38078.6 W

This rate of heat transfer is greater than the Q_{req} (35596 W). Hence the radiator can work efficiently even when air temperature is higher as in warm summer days.

6.2.Coolant pump:-



Fig—5--Thermosyphon cooling system of 1937, without circulating pump

Radiators first used downward vertical flow, driven solely by a thermosyphon effect. Coolant is heated in the engine, becomes less dense, and so rises. As the radiator cools the fluid, the coolant becomes denser and falls. This effect is sufficient for low-power stationary engines, but inadequate for all but the earliest automobiles. All automobiles for many years have used centrifugal pumps to circulate the engine coolant because natural circulation has very low flow rates.[13]

6.3.Heater:-

A system of valves or baffles, or both, is usually incorporated to simultaneously operate a small radiator inside the vehicle. This small radiator, and the associated blower fan, is called the heater core, and serves to warm the cabin interior. Like the radiator, the heater core acts by removing heat from the engine. For this reason, automotive technicians often advise operators to turn ***on*** the heater and set it to high if the engine is overheating, to assist the main radiator.[14]

6.3.1.Temperature control:-

Waterflow control:-

Fig—6--Car engine thermostat

The engine temperature on modern cars is primarily controlled by a wax-pellet type of thermostat, a valve which opens once the engine has reached its optimum operating temperature.

When the engine is cold, the thermostat is closed except for a small bypass flow so that the thermostat experiences changes to the coolant temperature as the engine warms up. Engine coolant is directed by the thermostat to the inlet of the circulating pump and is returned directly to the engine, bypassing the radiator. Directing water to circulate only through the engine allows the temperature to reach optimum operating temperature as quickly as possible whilst avoiding localised "hot spots." Once the coolant reaches the thermostat's activation temperature, it opens, allowing water to flow through the radiator to prevent the temperature rising higher.[15][16]

Once at optimum temperature, the thermostat controls the flow of engine coolant to the radiator so that the engine continues to operate at optimum temperature. Under peak load conditions, such as driving slowly up a steep hill whilst heavily laden on a hot day, the thermostat will be approaching fully open because the engine will be producing near to maximum power while the velocity of air flow across the radiator is low. (The velocity of air flow across the radiator has a major effect on its ability to dissipate heat.) Conversely, when cruising fast downhill on a motorway on a cold night on a light throttle, the thermostat will be nearly closed because the engine is producing little power, and the radiator is able to dissipate much more heat than the engine is producing. Allowing too much flow of coolant to the radiator would result in the engine being over cooled and operating at lower than optimum temperature, resulting in decreased fuel efficiency and increased exhaust emissions. Furthermore, engine durability, reliability, and longevity are sometimes compromised, if any components (such as the crankshaft bearings) are engineered to take thermal expansion into account to fit together with the correct clearances. Another side effect of over-cooling is reduced performance of the cabin heater, though in typical cases it still blows air at a considerably higher temperature than ambient.[17]

The thermostat is therefore constantly moving throughout its range, responding to changes in vehicle operating load, speed and external temperature, to keep the engine at its optimum operating temperature.

On vintage cars you may find a bellows type thermostat, which has a corrugated bellows containing a volatile liquid such as alcohol or acetone. These types of thermostats do not work well at cooling system pressures above about 7 psi. Modern motor vehicles typically run at around 15 psi, which precludes the use of the bellows type thermostat. On direct air-cooled engines this is not a concern for the bellows thermostat that controls a flap valve in the air passages.[18]

6.4.Airflow control:-

Other factors influence the temperature of the engine, including radiator size and the type of radiator fan. The size of the radiator (and thus its cooling capacity) is chosen such that it can keep the engine at the design temperature under the most extreme conditions a vehicle is likely to encounter (such as climbing a mountain whilst fully loaded on a hot day).

Airflow speed through a radiator is a major influence on the heat it loses. Vehicle speed affects this, in rough proportion to the engine effort, thus giving crude self-regulatory feedback. Where an additional cooling fan is driven by the engine, this also tracks engine speed similarly.

Engine-driven fans are often regulated by a viscous-drive clutch from the drivebelt, which slips and reduces the fan speed at low temperatures. This improves fuel efficiency by not wasting power on driving the fan unnecessarily. On modern vehicles, further regulation of cooling rate is provided by either variable speed or cycling radiator fans. Electric fans are controlled by a thermostatic switch or the engine control unit. Electric fans also have the advantage of giving good airflow and cooling at low engine revs or when stationary, such as in slow-moving traffic.

Before the development of viscous-drive and electric fans, engines were fitted with simple fixed fans that drew air through the radiator at all times. Vehicles whose design required the installation of a large radiator to cope with heavy work at high temperatures, such as commercial vehicles and tractors would often run cool in cold weather under light loads, even with the presence of a thermostat, as the large radiator and fixed fan caused a rapid and significant drop in coolant temperature as soon as the thermostat opened. This problem can be solved by fitting a **radiator blind** (or **radiator shroud**) to the radiator that can be adjusted to partially or fully block the airflow through the radiator. At its simplest the blind is a roll of material such as canvas or rubber that is unfurled along the length of the radiator to cover the desired portion. Some older vehicles, like the World War I-era S.E.5 and SPAD S.XIIIsingle-engined fighters, have a series of shutters that can be adjusted from the driver's or pilot's seat to provide a degree of control. Some modern cars have a series of shutters that are automatically opened and closed by the engine control unit to provide a balance of cooling and aerodynamics as needed.[20]

6.4.1.Coolant pressure:-

Because the thermal efficiency of internal combustion engines increases with internal temperature, the coolant is kept at higher-than-atmospheric pressure to increase its boiling point. A calibrated pressure-relief valve is usually incorporated in the radiator's fill cap. This pressure varies between models, but typically ranges from 4 to 30 psi (30 to 200 kPa).[21]

As the coolant expands with increasing temperature, its pressure in the closed system must increase. Ultimately, the pressure relief valve opens, and excess fluid is dumped into an overflow container. Fluid overflow ceases when the thermostat modulates the rate of cooling to keep the temperature of the coolant at optimum. When the engine coolant cools and contracts (as conditions change or when the engine is switched off), the fluid is returned to the radiator through additional valving in the cap.

6.4.2.Engine coolant:-

Before World War II, engine coolant was usually plain water. Antifreeze was used solely to control freezing, and this was often only done in cold weather.

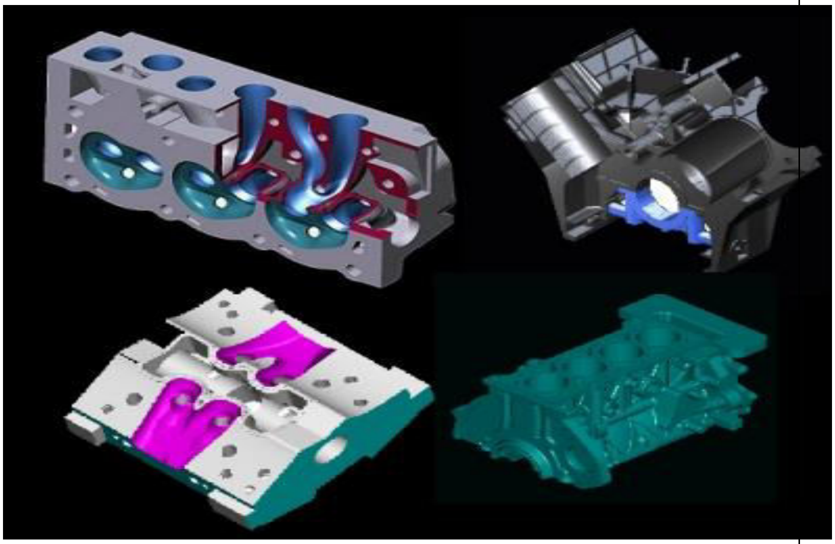
Development in high-performance aircraft engines required improved coolants with higher boiling points, leading to the adoption of glycol or water-glycol mixtures. These led to the adoption of glycols for their antifreeze properties.

Since the development of aluminium or mixed-metal engines, corrosion inhibition has become even more important than antifreeze, and in all regions and seasons.

6.5.Water Jackets:-

Designed to keep engine block and cylinder head cool.Open spaces between the outside of cylinder and inside of cylinder block and head.

When engine is running at normal operating temperature, the coolant is forced through the water jackets in the engine block, through the head gasket, into the head, and back to the radiator.



fig—7 water jackets

6.6.Cooling fan:-

Like the thermostat, the cooling fan has to be controlled so that it allows the engine to maintain a constant temperature

Front-wheel drive cars have **electric fans** because the engine is usually mounted transversely, meaning the output of the engine points toward the side of the car. The fans are controlled either with a thermostatic switch or

. **fig-8 cooling fans**

by the engine computer, and they turn on when the temperature of the coolant goes above a set point. They turn back off when the temperature drops below the point. [18]

6.7.Coolant recovery system [needs and working procedure]:-

The coolant recovery system is an important part of a vehicle's cooling system. Low-profile crossflow radiators do not have top tanks like older top fill radiators, so a separate recovery tank mounted somewhere under the hood serves as both a coolant reservoir and expansion/recovery tank.

As engine coolant heats up, it expands. In older top fill radiators, an inch or two of dead air space in the top of the radiator provided the necessary room for expansion. If the coolant got too hot, it would force its way past the spring-loaded radiator cap to relieve pressure, and any coolant that escaped would flow through a discharge tube into a recovery tank.

With modern coolant recovery systems, the radiator cap is no longer on top of the radiator, and the radiator has no upper tank to allow for expansion. So the radiator is connected to an external reservoir that serves as both an expansion tank and coolant recovery tank.

6.7.1.Coolant Recovery Tank:-

The coolant recovery tank is typically a white molded plastic tank. It might be mounted near the radiator, on an inner fender or against the firewall. The plastic tank is translucent so you can see the fluid level inside. The tank has markings on the side that tell you when the coolant level is low.

Fig—9—coolant recovery tank

The coolant level inside the tank should be maintained so that it does not exceed the highest marking when the engine is at normal operating temperature. The highest level is often marked HOT FULL.

A lower COLD or ADD mark may be on the tank indicating the lowest level the coolant should be at when the engine is cold. If the coolant level inside the tank is lower than the COLD or ADD mark when the engine is cold, coolant needs to be added to the reservoir to bring the level up above the mark.[19]

7.Advantages and Disadvantages of liquid Cooling System:→

7.1.Advantages:-

(a) Uniform cooling of cylinder, cylinder head and valves.
(b) Specific fuel consumption of engine improves by using water cooling system.
(c) If we employ water cooling system, then engine need not be provided at the front end of moving vehicle.
(d) Engine is less noisy as compared with air cooled engines, as it has water for damping noise.

7.2.Disadvantages:-

(a) It depends upon the supply of water.
(b) The water pump which circulates water absorbs considerable power.
(c) If the water cooling system fails then it will result in severe damage of engine.
(d) The water cooling system is costlier as it has more number of parts. Also it requires more maintenance and care for its parts

8.Air-cooled Engine:-

An air-cooled engine is simpler to design then the water cooled engine because the heat is transferred from the cylinder and head directly to the air. There is no need for water jackets, hoses, water pump, radiator, etc. But, the engine design uses many fins on the cylinder and head for effective heat transfer to the surrounding air. The amount of heat transfer that occurs between two mediums (in this case the metal of the engine and air) depends on three factors : (i) the temperature difference (AT) between them, («) the heat transfer area in contact between them, and (Hi) the heat transfer coefficient. The heat transfer coefficient between metal to water is about 100 times better than metal to air. Therefore, either the metal to air surface area or the temperature difference (AT) or a combination of the two should be 100 times larger in an air-cooled engine to obtain the same amount of heat transfer. The fins increase the contact area between the two mediums. Additionally, the cylinder and heat temperature in an air-cooled engine is about twice that of a comparable water-cooled engine. Therefore, more and larger fins are provided in the critical areas of the combustion chamber and exhaust valve/port areas to prevent occurrence of abnormal combustion. Because of the higher upper-cylinder temperatures, more heat goes through the piston and cylinder to oil. All automotive air-cooled engines use oil coolers to assist removal of excess heat. Most

air-cooled engines use a higher viscosity oil to compensate for these higher temperatures.
The high power demand is the weak point of an air-cooled engine. If this causes too high a temperature in the combustion chamber, pre-ignition and/or detonation occur, with possible damage of the engine in a short time period. Combustion chamber temperature in an air-cooled engine is normally controlled by maintaining the compression pressure low, the ignition timing slightly retarded, and/or the air-fuel ratio rich relative to a water-cooled engine. Nowadays nearly all of the high power motorcycle engines have changed over to water cooling. This has provided better combustion chamber temperature control, and has allowed an increase in the power output and reduction in exhaust emissions. In addition, the more even cylinder temperatures have reduced localised hot spots so that piston and cylinder destruction and scuffing have been minimised.

8.1.Air-cooling System Components:-

When the vehicle is normally operated at a speed sufficient to provide enough air movement to transfer heat, the entire cooling system is merely the fins on the air-cooled engine. Many motor cycles are examples of this. But, improved streamlining usually requires a smaller frontal area which demands narrower engines. In this case cylinders have to be placed behind each other, and this requires duct work (cowling) to insure enough air flow to the rear cylinders of the engine. The shape of the cowling (Fig. 12.43) guides the forced convection current around all the cylinders and provides a direct exist after the air has extracted and absorbed the heat from the engine.
Some engine configurations, such as flat four-cylinder engines, employ baffles to improve

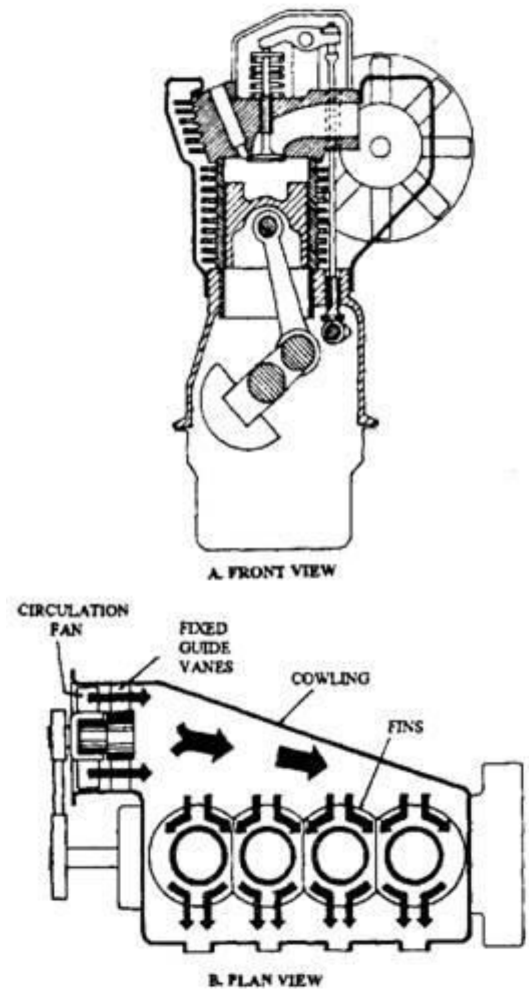
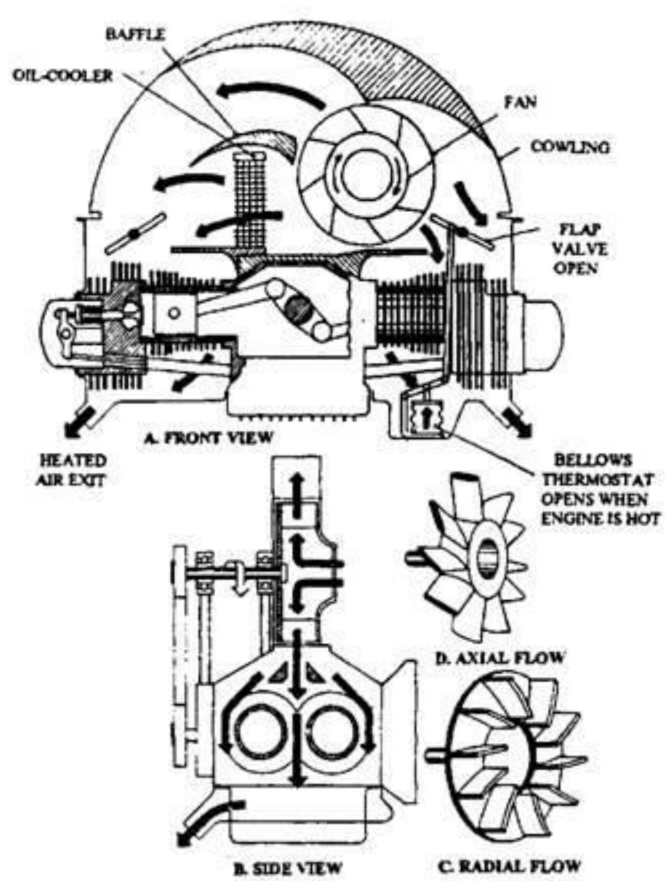


Fig. 10 Air-cooling system for an in-line four-cylinder engine.

the air distribution between cylinders and to direct additional air to critical components such as the oil-cooler (Fig. 8).

A fan or blower is installed in air-cooled engines, with little or slow movement of air, to sufficiently improve air flow past the fins. Most engines that use blower fans also use shrouds or ducts to insure the flow of cooling air past the fins. Two classes of fan used with air-cooled engines are the radial flow type (Fig. 8.A), where the air is flung outwards by centrifugal force, and the axial flow type , where the air is pushed along parallel to the axis of the fan spindle. The radial-flow fan is more compact for a given output but tends to be noisy. The axial-flow fan is more consistent, reliable and delivers large quantities of air. Hence, the former is used with small engines, while the latter is preferred for heavy-duty high output engines.

The amount of blower air circulating between the cowling and the cylinders may be regulated by a throttle ring located on the inlet side of the fan. The function of this ring is to vary the effective inlet-passage exposed area of the fan to suit the operating conditions of the



<u>Fig. 11. Air-cooling system for a horizontally opposed four-cylinder engine.</u>

engine (Fig. 10). This can be automatically achieved by incorporating a thermostat in a hot working region of the engine so that it senses the temperature change. When the engine is cold,

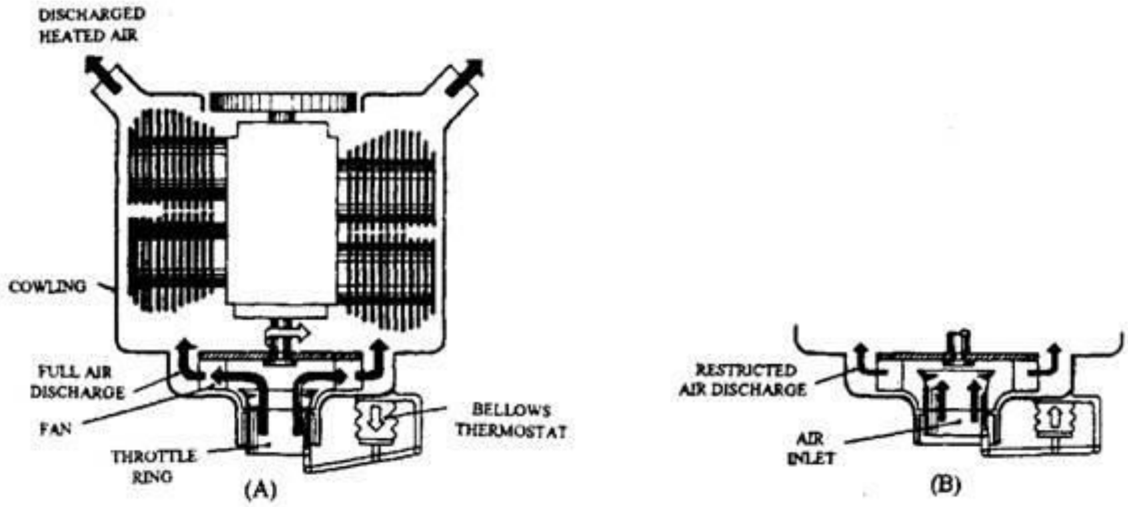


Fig. 12. Air-cooled engine with fan discharge control. A. Thermostat opens throttle ring. B. Thermostat closes throttle ring.

the thermostat actuates either a linkage or a hydraulic servo connected to the throttle ring to restrict the air-flow to the fan. When the engine is hot, the restriction is removed, thus permitting more air to circulate. The thermostat provides the same benefits as those used on water-cooled engines and should always be in good condition.

8.1.1.Baffles:-

Engine baffles have a critical role in ensuring that the engine is correctly cooled. Engine baffles and cowls are designed to provide an air seal between the top and bottom of the engine. This air seal ensures that the cooling air is correctly directed through the engine, oil cooler and engine compartment to guarantee the proper cooling of the engine.

Just as a leak in the radiator in your car can cause your car engine to overheat, leaks in engine baffles can cause your aircraft engine to overheat.

Poorly fitting or maintained engine baffles can result in the cooling air going around instead of through the engine.

Leaks can cause uneven cooling of the engine. One or more cylinders may be operating at substantially higher temperatures than the other cylinders.

A multi-channel Cylinder Head Temperature gauge is the best way to verify that all cylinders are operating at similar temperatures. For continuous operation the Cylinder Head Temperatures should be kept below 400°F and preferably below 380°F.

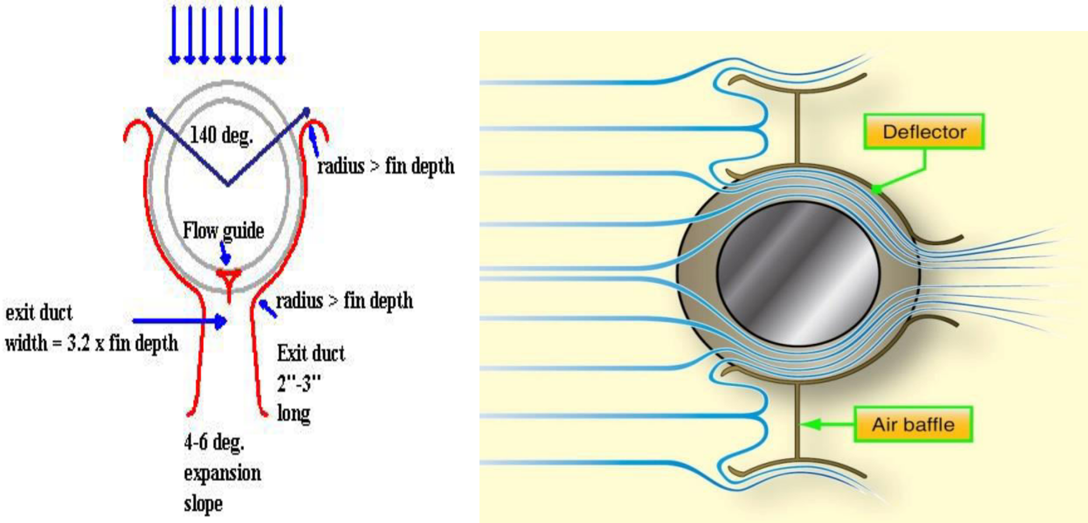
High cylinder head temperatures can cause:

- Faster wear rates of top end engine components, in particular exhaust valves and valve guides.
- Cylinder head cracks.
- Oxidised engine oil and glazed cylinder bores.

Things to look for when inspecting and refitting baffles include:-

- Ensure all baffles are correctly fastened to the engine.
- Make sure no baffles are missing. Pay particular attention to small baffles that need to be fitted around oil coolers, engine mounts, inter-cylinder baffles, etc.
- Seal excessive gaps where baffles are attached to the engine with a suitable flexible sealant. Check that large gaps are not left around the inter-cylinder baffles.
- Check the baffle rubbers have not become worn or torn.
- Check that when the cowls are fitted the baffle rubbers form a good seal. (Dust tracks on the inside of the cowl can indicate where leaks are occurring.)
- Check that the cooling air pressure in flight is not folding baffle rubbers back and dislodging them from their correct position.

Keeping your engine baffles in good condition will benefit your engine and save you money in the long run.



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Fig—13—baffle air flow in air cooling system

8.2.Advantages of Air Cooling;-

The major advantages of air cooling are simplicity, light weight and relatively low cost. There is no requirement for water jackets, water pump, hoses, radiator, or coolant. Cylinder head and cylinder castings are less complicated as there is no water jacketing. Since there is no liquid coolant, the problems caused by boiling, freezing, or corrosion are absent. In most cases the only service and maintenance required is to remove airborne debris from the fins, and to keep the blower drive belt, thermostat and damper doors in working condition.
Many air-cooled engines offer better cylinder bore and ring life. Piston, rings and cylinder warm-up occurs much faster because there is less material and liquid mass to warm up. Since the fins do not start transferring heat until they get hot and there is a large AT available, the parts and the oil that is next to them come into normal operating temperature fairly fast.[20]

8.3.Disadvantages:-

(a) It depends upon the supply of water.

(b) The water pump which circulates water absorbs considerable power.

(c) If the water cooling system fails then it will result in severe damage of engine.

s(d) The water cooling system is costlier as it has more number of parts. Also it requires more maintenance and care for its parts.

9.Future aspects of engine cooling :-

The Turbo-Cooling system (TCS) is a system for reducing engine charge air temperature to below ambient levels. Thermodynamically it is an air-cycle cooling system, which provide the charge air cooling function for a turbocharged gasoline or diesel engine. Charge air temperatures as low as -10 degC can be achieved & the cooling effects extend down to low engine speeds & loads. The benefits are primarily those of extending the knock limit & reducing over-fuelling requirements in highly boosted engines. The market for such engines is increasing rapidly, along with progressive increases in specific power. For diesel engines the main benefits are recued engine-out NOX emissions plus the increased potential for operating with a 'low temperature'combustionsystem.

Fig—14- turbo cooling system

The core of the TCS is a turbo-expander. WDL have developed a prototype, based on an automotive turbocharger. The exhaust turbine wheel & housing have been replaced with a dedicated 'cold air' turbine & matching housing, with a rig-tested

efficiency of more than 85%. The system operate by 'over-boosting' the charge air from the standard compressor/CAC , then cooling with an intercooler, followed by expansion though the new turbine. This results in significant charge air temperature reduction & the power from the turbine drives the compressor of the turbo-expander. The complete system of turbo-expander, intercooler, ducting & controller is compact & cost effective. It is an additive technology which does not require any base engine changes, although an increase in compression ratio shows benefits in drive-cycle economy.[18]

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