**Supercharging of aircraft IC engines**

In this lecture, we will be talking about IC engine operations with specific reference to the aircraft engine. IC engines as you know used in all kinds of vehicles and many other operations. But when it comes to application in aircraft engines in basic power plant and power supplying unit, there are certain things that need to be done to satisfy the needs of aircraft engine and for the needs of the flying the aircraft. Now as you know an aircraft particularly flies or cruises at higher altitude quite often 5 km or even higher than that and as a result of which at that altitude the air density is very low and hence the air which is the working medium of this kind of engine is very thin. So the air supply into the engine is actually much lower in case of mass flow. And hence we need to do something about the fact that the air supply in mass flow is rather low. Now as we have seen in the earlier lectures, when the air mass flow supply is less or charge as we call it is less, the power production also goes down. So if the power production goes down in the aircraft engine, if it falls short of power, the propeller which produces thrust would not be able to produce the thrust that is required for aircraft to fly. And in such a case, aircraft would not be able to fly at all. In fact problems start much earlier, when the aircraft starts climbing from take off from let us say sea level altitude to higher altitude as the air become thinner and thinner the power supply goes down because of the fall in the mass flow. Now this is something which is typical of aircraft engine. This is not a problem with any other land based applications. And hence the aircraft engineers have to do something to ensure that this problem does not create a problem when the aircraft is flying. So the aircraft engine or IC engines used in aircraft do have slightly different configuration than the IC engines used in many or various land based operations. Let us take a look at some of these things that typically done in aircraft engines. We will also look at how aircraft engine or IC engine is operated under part load conditions. We don’t use an IC engine all the time at its full throttle or full load conditions quite often you don’t need so much of power. So you can operate under off design or what is also known as part load condition. Under this condition how do they operate and how do they produce power and what are their characteristics. These are few things that we will be looking up today as along with certain augmentation required for making this kind of IC engine useful for aircraft power plant. Let us take a look at some of these issues in today’s lecture. Now one of the things that we have seen is the density of the fresh charge which is going into the cylinder is an important issues. That determines the amount of mass flow that is going in. And at the end this mass flow determines the amount of torque that is produced by the engine. The other important parameter that affects the volumetric efficiency which we have defined earlier is the pressure and temperature of the outgoing burnt gas, and then of course there are engineering issues which are the design of the intake and exhaust valves or the manifolds and the timing of the opening and closing of intake and exhaust valves. Now these are the issues which have been engineered into the engines. So these are engineering issues and they need to be done properly to ensure that you have a good volumetric efficiency which means it should be as close to 100% as possible so that you are getting best out of engine size and shape. So volumetric efficiency essentially tells us how good you are making use of the engine given its shape and size already available. So these are the things that a designer in terms of engineering product has to be very careful about before the engine is made operational to achieve high efficiency during its actual operations. Now let us take a look at some of the things that we need to bother about. For example when the full throttle operation is going on as you can see in this diagram, the air is now compressed along this .okay. And as we have seen earlier quite often the process of ignition or burning of the fuel may be initiated little earlier. And if it is initiated much earlier this is how the graph would go, operation of combustion would be shown in the PV diagram. Which means it has been started before TDC, and hence the graph would go in a curved manner, instead of a straight line as we normally see in an ideal cycle. On the other hand the exhaust for example if it opens a little earlier the exhaust may have opened little earlier somewhere here and as a result of which you would have exhaust operation initiated earlier and this would take a curved path and hence the exhaust would be happening at a higher pressure than the intake operation. This as we know results in a certain amount of area that shows up over here and that area would actually would loss as for as power production is concerned. So the opening and closing of throttle is an important issue. Now under the part load condition similar things would be happening, the work done over here in part throttle is actually much less now than compared to full throttle operation. And in this situation if the opening or closing of the intake or exhaust occur much before the actual time of their opening and closing, then a good amount of work would actually be lost in the process of the differential between the exhaust operation and the intake operation. So that loop you see here is something that not available as the power output of the engine. This is again goes into the operation of the exhaust and intake and as a result that would not be available in terms of BHP. This is one of the issues that come up when the operation of the exhaust the ignition and the intake do not quite happen exactly ideally as we have seen in the ideal diagram. This actually shows the loop which we just talked about. In this as you can see here in the full throttle condition if it happens nearly ideally, you have a very small loop over here. And as a result of which you can say that the power lost in the process of intake, exhaust is rather small. On the other hand what can happen is under part throttle condition, this loop would become very big. Now as it is as we have seen in the earlier diagram, the part throttle condition, the operational power available is actually on the lower side. And then if the power lost in the process of intake exhaust is in the higher order. This could happen due to the fact that the opening of the intake valve could be earlier or closing of the exhaust valve could be earlier. Now some of these issues affect the area of the loop that is shown over here, and if the area of the loop is higher that means more and more energy is wasted by the fact that the operation of the intake and exhaust valves are not happening properly. So some of those issues need to be taken care of the engineering aspect of the engine design and hence it shows up in the thermodynamic diagrams and as a result of which the engine power suffers. This is one of the issues that we were talking about that delayed ignition, what happens when you have a delayed ignition. We just saw what happens if we have an early ignition. Suppose you know this is what you would call normal ignition. Little earlier so that even when the compression process is being completed, the ignition is initiated. And as we have seen this goes along the path. Now suppose the ignition is delayed. As a result of delayed ignition, the ignition process is much later and then the path that it takes, it doesn’t take along this. It quickly goes into this path, and as result of which this huge area that you see, shaded area is a loss of work with relation to the indicated diagram or the ideal process one would have expected. So this loss of work is due to the fact that the ignition is delayed and not initiated at an appropriate time. So there is an exact time at which the ignition needs to be is initiated. If it is delayed is going to give a lot of loss work from the engine. So that is another issue that the ignition is to be timed exactly, otherwise large loss of work by the power stroke most likely to happen. Let us look at some of the issues again due to the late opening or poor design of exhaust valve. This happens when for example, this is your normal exhaust. Okay. Now suppose your late exhaust valve opening shows that its exhaust occurring around this. As a result of which this is the now exhaust path. Now this exhaust path as you can see well above the exhaust path over here and this is situation, that means this much of extra work needs to be done during the exhaust operation. Now this extra work now not be available as an output of the engine. This would be due to either late opening or poor design exhaust valve. There is a one small issue here that due to the late exhaust, the path that it takes actually creates slight bit of gain in work which is shown here. And rest of the work is actually due to the loss of work. So there is a very small gain in work, which is shown here. But the loss of work is of much higher order. And as result of which there is a large amount of loss of piston work and a very small amount of increase of intake work and very small amount of gain in exhaust work. So total loss is of much higher order and as a result of which total output of the engine could go down substantially. This is due to the fact that you have a late opening or poor design of exhaust valve operating within the engine. This may happen due to various reasons and some of those reason needs to be looked into either by the designer or by the operator during its functioning. The other issue is the poor intake design. We need to look at the fact that the intake operates ideally at a constant pressure and if the intake operates at a pressure much lower that what it is scheduled to, we get inlet intake loop that is now much bigger than it should have been ideally. Now this inlet loop takes away the work from the main engine in the process of pumping as it is shown here. And this intake pumping work now, extra intake pumping work now is not available as an engine output. So the poor intake design often also leads to or poor operation of their intake valve often leads to loss of work which would not be available to the engine BHP or engine output. So this is another issue which needs to be looked by the engineers who would design the engine. So the important performance parameters that we need to look into or the heat release per unit mass of air, this is the quality of the fuel that you are putting into the engine. So the choice of the fuel needs to be taken care of by the heat release capacity of the fuel. And the other is the quantity of the charge which is the mixture of air and fuel mixed in the carburettor per stroke of the engine. Now heat release per unit mass of air is decided by the chemical composition and the working air fuel ratio. Chemical composition is something which one needs to analyse before one makes a choice of the fuel and we have talked about the kind of fuel or aviation fuel that is normally used in these days, high octane ratio fuel. And that was chosen because of the chemical properties. The other is the working air fuel ratio, and as we have seen the working fuel air ratio actually can change from one operation point to other. This is something which the engine operators have some control over. The ideal fuel air ratio is what we call normally the stoichiometric ratio. But quite often the operation happens at a ration which is slightly different from ideal stoichiometric ratio. It could be slightly higher, or it could be slightly lower. And as long as it is within a certain zone of operation, safe zone of operation of fuel air ratio and as long as it operates in that ratio, the ignition process would continue to happen in a normal fashion. Now this is with reference to the heat release than all this will decide the heat release rate per unit mass of air as it is inducted into the cylinder. The other thing that we will decide that the amount of power that is coming out, the quantity of the charge. The thermodynamics always gives us the values in terms of power produced per unit mass flow. However the total power produced is always dependent on the mass flow that is going inside the cylinder or inside the engine as a whole. And hence the quantity of the charge that is going in decides the power that you would actually get. Now this is one of the issues that you would need to look into with specific reference to aircraft engines. Because in aircraft engine the quantity of charge that is going in, goes down with increase of altitude. As you go to higher and higher altitude, you would be using the same fuel. So its heat release rate probably remains of the same order, but the mass of the air is going down, and the quantity of the charge going down. So we need to look into these issues with specific reference to aircraft engine. In aircraft engine this issue of charge or mass of charge is taken care of or compensated for with the change of altitude by an additional unit called supercharger. This is basically a booster which is used before the chare air fuel mixture enters the cylinder. Now this cylinder is filled above the ambient pressure with help of the supercharger. Hence the density of the air is now higher than the ambient density. And hence the weight or mass of air that is introduced inside the cylinder per cycle is greater than in the supercharged case. So if you don’t have supercharging this mass of air that is going in would continuously goes down when you reach higher altitude, and it would continue to go down when you increase the altitude. So you need a supercharger to compensate the decrease of the ambient pressure and ambient density. And this is where the supercharger for aircraft engine comes into the picture. Now as you know the volume of operation would remain same for the same engine. So when you apply the volumetric efficiency, the net work done would be higher than that of naturally aspirated engine which means un supercharged engine. So you need supercharger to get more and more work done for the same engine as it goes to higher and higher altitude. Let us see how that actually happens. If you have supercharged engine, typically you would be using some kind of centrifugal blower to boost the density or the pressure that is going inside the cylinder and this boosting is done after the air and charge has been mixed and before it enters the main cylinder, before it is supplied to main cylinder. Now this is a separate unit, and the supercharger is a separate unit from the basic IC engine and as I said it is used specifically for aircraft engine. Now let us look at this diagram, we will see when you have un supercharged or what is often called naturally aspirated engine, you are basic indicated diagram would actually go along the dotted line. But as soon as you are applying supercharging, your basic intake now go down to higher pressure, and then your compression would take to a much higher pressure and hence your power stoke would be actually occurring at a higher pressure. So the mean effective pressure you are talked about would now be occurring at a much higher pressure, value of MEP would be much higher for this cycle compared to this dotted cycle which is a un supercharged engine. And as a result of which you can well imagine now that the power produced by the supercharged engine would be of much higher order. And this is exactly shown in this thermodynamic PV diagram, that the supercharger actually boosts the performance to a much higher level. How high it can be depends on the amount of supercharging that is available with engine. In all this time the fuel used is same and is introduced or injected into the cylinder in the same manner. So there is no change in the way the fuel is used or the kind of fuel is used only that the air charge as used as a working medium is supercharged or boosted in its pressure and density to a higher value and that allows us to pro more power and that may be available to aircraft power plant. Let us take a look at some of the issues that are related to, the effect of supercharging at sea level and at altitude. Now as I have mentioned you can use an engine both at full throttle or at part throttle depending on the amount of power that you actually make use of or you need to fly an aircraft in case of an aircraft engine. Now what happens is when you are at sea level, if you have un supercharged full throttle, your characteristics would move along this line and when you go to high altitude the un supercharged full throttle characteristics would continue to go down along this line with increase of altitude and a result of which your brake horse power would continue to go down. So when you are at sea level, at full throttle and supercharge as your manifold absolute pressure goes up, your power production goes up. Then as soon as you move at high altitude the aircraft starts climbing, and altitude is gained the power production continues to start going down and let us say at cruise your power production is somewhere over here and one has to very quickly figure out whether this power production is sufficient for flying the aircraft. In most cases this power production will probably found insufficient for flying the aircraft and that’s where the supercharger now comes in. If you have a supercharger, the supercharged power production would go along this line. It would go to a higher value and then if you move the altitude you could have high supercharging or low supercharging and it could move along this line along which you have constant manifold absolute pressure MAP, and then this is your still working at part throttle and then you can open up the throttle and go to full throttle because you need to conserve power, you need to get more power to get aircraft fly and with change altitude, your air is thinning down. So even with supercharging air will continue to thin down and as a result the air mass flow going into the engine will continue to go down. But it will go down now at a much higher value than what we had seen in un supercharged case. And as a result of which this full throttle now allows you to produce more power than you can get for un supercharged engine. And if you are able to create high supercharging you can boost the power somewhere over here to even higher value at full throttle. So you can apply high supercharging, this was with low supercharging and you can go to even that means second booster for example, you can have two superchargers and you can go to even higher power production and take the power production somewhere over here at very high altitude if the need arises. So the combination of supercharging and use of low supercharging or high supercharging, which means you can have two superchargers allows you to create more power during the aircraft operation at high altitudes. In all these, what we have considered whether the engine is operating at constant rpm and they are operating at const fuel air ratio, those also can be varied. But we are not considered those variations in this particular diagram. And as a result of which as you can see now, the supercharger give immense amount of power boosting to the aircraft engine, starting at sea level, going at higher altitude you can produce more power either through single supercharger or through a double supercharging operation to get more power at high altitude operations. So the supercharging produces additional work that may be extracted from the exhaust gases by expanding them to atmosphere through a turbine. So the question now is how do you run the supercharger to produce this boosting of intake pressure and density. It is done by running in with the help of turbine and the question is how you run the turbine. The turbine is run by the exhaust gas that is coming out of the engine and that is fed into the turbine. Remember the exhaust gas that is coming out of the engine is still at a reasonable high temperature and at reasonable high pressure. So if you allow it to run through a turbine, it will produce certain amount of power and this power then can be used to run the supercharger or booster which as I have mentioned earlier is basically centrifugal compressor and hence the power supply to the supercharger can be done with the help of turbine which is done by the help of the exhaust gas that is coming out. The aircraft, when it goes to higher altitude, increases the pressure and this allows the manifold pressure to be either held to design value close to the design value for which the engine was designed for or something very near to that value and as a result of which you continue to get good amount of power that the engine is originally designed for. So many of the superchargers are often called turbo superchargers, and this supercharger plus turbine configuration, the rpm of this can be varied by adjusting the turbine discharge nozzle to produce pressure ratio of the turbine so that the turbine power production can be varied to run the supercharger. So the whole turbine supercharger combination also be controlled separately by controlling the turbine discharge nozzle so that the pressure ratio produced by the supercharger can also be varied depending on the need of the engine at that particular altitude. So the turbo supercharger has control systems of its own independent of the engine control and as a result of which the amount of supercharging that you do to boost the engine can also be varied depending on the need of the aircraft when it is flying. The supercharger delivery pressure is given by supercharger pressure ratio and this is the pressure at the turbo supercharger exit divided by the ram pressure outside of the air scoop. This arrangement can maintain a constant engine BHP or almost constant engine BHP from sea level to very high altitude. So the engine continues to give nearly its design power production and this operating altitude is determined by the maximum allowable rpm of the supercharger. So which means the aircraft engine can now operate at higher and higher altitude because of the supercharging that is available and the final altitude at which it can operate, the aircraft can fly is now determined by the supercharging capacity and the maximum available supercharger turbine combine. So not only the power as boosted now you can fly the aircraft at even high altitude which has an advantage as we know, that higher the altitude at which you fly the aircraft lesser is the drag experienced by the aircraft and lesser is the power actually required to fly the aircraft and if you required less power to fly the aircraft your continuous fuel consumption is also going to be low. So all those gains can be actually factored into the aircraft mission or aircraft flight schedule if you have a supercharger. So for a supercharged aircraft can fly at a higher altitude to effect the net gains that come from flying at a high altitude and this is something that typical of aircraft engine normally not necessary in most of the land based operation. So the aircraft engines typically have superchargers, which are designed to operate at high altitude. It is normally not necessary when it is cruising at low altitude or when it is taking off, it is necessary flying at higher altitude and as I mentioned to at what altitude an aircraft can fly would actually determined by the capacity of the supercharger. So the supercharger is designed separately to fit into the aircraft engine and fit into the need of the aircraft and take the aircraft to higher altitudes. Let us look at what happens if you have a supercharger and what happens to the PV diagram of the cycle. You have a supercharger which again is some kind of aero thermodynamic unit. Hence it needs to have certain amount of thermodynamic basics of its own for its to be included in the engine configuration. So if you look at this you will find that the basic engine which operates, let us say at AB which is the intake to the compression system and the comp line is B C as we have seen normally in most of the cycles that we have looked at and the work required to do those compression process is then given by ABCD. And that is the area that the compression work that needs to be done in the compression process of the engine. Now this source of this work is the turbine. Now this turbine is supplying power to compression process that has been supercharged. Now the turbine work, it extract work from the outgoing burnt gas that has been exhausted from the main engine and the turbine work can also be represented in the same PV diagram and let us say that the turbine work is represented by ZYXW or you know, this particular area and as we can see now that this work done by the turbine then needs to be equal to this work that is needed from the intake. So as long as this work done by the turbine as represented by the PV diagram here is equal to this work shown by ABCD. We have combination of turbine and compressor that can do this supercharging job and aid the engine in operating at high altitude. So this is the supercharging PV diagram separate from the engine PV diagram as we have seen before and this need to have compiled to the laws to thermodynamics as you have done in detail earlier. So supercharging operation by itself has to conform to basic laws of thermodynamics as you have done before in the earlier lectures. The exhaust gas which enters the turbine along the line let us say WX, then expands along the XY line. So this is how the turbine operates. So the intake starts from AB and then goes up to CD. The exhaust starts from W, and then it enters to WX. It expands along the line XY, and does the work. That is the working of the turbine and working of the compression from B to C working of the turbine in this PV diagram is from X to Y and then pushes out the work of the gas along YZ line. If the turbine is used only to drive the compressor, the areas as I mentioned the areas ABCD and the areas AWXYZ must be equal. If the turbine work fall short then the turbo compressor combination would slow down. If the turbine produces more work, then the turbo compressor combination would speed up to higher speeds whether that is required or whether that is warranted or allowed is to be decided by the engine operator. So if the turbine work is excessive, the turbine discharge nozzle may be throttled raising the line YZ until the area YXWXYZ is again equal to that one way of reducing the turbine work if it comes out to be doing more work as I mentioned earlier you have the discharge nozzle to control the amount of work that has been done by the turbine which runs the compressor which is the supercharger. So that the turbine and the supercharger work are equal to each other, no more and no less. This is how the supercharger actually functions and that is what shown here thermodynamically in the PV diagram. If we look at the way it is shown, you have a supercharger over here before the flow actually gets into the cylinder as I mentioned it is normally done after the carburettor where the air and fuel is mixed in the correct proportion or the wanted proportion for that particular operation and then the fuel air mixture, which we call as charge is supercharged. One of the possible supercharging is in the order of 6:1 ratio at high altitude. That is the kind of supercharging you probably need. And then boost the density before it is fed into the cylinder. Now what happens is the power output or the brake horse power can be now be shown with the altitude. It is expected that all the time go down. But the un-supercharged power goes down along this line and the supercharged power goes along the upper line and in between there is a line which is actually used for the purpose of supercharging itself and as a result of which one can say the net output is given along this line. So supercharger nearly restores the power output of the engine and typically double supercharging or what is often known as high supercharging is used essentially only for the climb operation of the aircraft. It may not be necessary actually during the cruise operation of the aircraft. It is necessary for the climb operation where you have to take the aircraft from low altitude to high altitude, along with its passengers, cargo and you need excess power overcome the drag of the aircraft. The differential between the thrust produced by the engine or power plant and drag experienced by the aircraft takes the aircraft to higher altitude through the climb operation. So during the climbing the thrust produced by the engine or power plant has to be more than that of the drag experienced by the aircraft. Now this differential produces the climb operation. So during the climb you need that excess power to produce excess thrust and hence during the climb operation one may use double supercharger or high supercharging. Once you reach the cruise operation, you don’t need the high operation, high supercharging anymore and you need only as much power as the aircraft experiencing as thrust because cruising, the thrust is equal to drag for straight and level flight. So during the cruise operation, you need to produce only as much thrust as experienced by the aircraft as drag and extra thrust is not required anymore. Hence during that operation, the second supercharger can be switched off and aircraft can operate only with the single supercharger or what we can call may be low supercharger. So that is how the supercharger is used for various aircraft operation during the climb and later on during the cruise flight of the aircraft. So let us sum up and say that you can have single stage supercharger which is good enough for the aircraft to fly at high altitude. You may have two stage supercharger which allows additional boosting during the climb operation or you can have variable speed supercharger where the supercharger speed can be varied to high or medium and as we were discussing just now that you may need to do at high speed supercharging to get high supercharging during climb and then settle down to medium supercharging for medium to low supercharging during its cruise operation of the aircraft. Most of the superchargers are centrifugal flow blowers or compressor or often compression ratio as we mentioned, 3, 4, 5 or 6. And this kind of machine is being used for superchargers right from the beginning. However it is possible that if you need low supercharging you can probably use axial flow compressor into a three stage can produce sufficient pressure rise inside the supercharging facility to boost the performance of the aircraft. So you can have number of choices in the choice of the supercharger depending on the size of the engine, depending on the kind of aircraft power scheduling that you need to do and of course depending on the altitude finally you expect the engine to be used for aircraft thrust making device. So these are the various choices that engine designer has in choice of the supercharger and as you can see, here a number of choices for making a choice for supercharging of aircraft engine. One of the choices that typically an engine designer would have is turbo supercharger and one of the possibilities is that one can use turbo supercharger with what is also known as intercooler. Now in this diagram the arrangement is shown, you have the engine, we are showing let us say two cylinders. You have the basic engine which of course runs the propeller, which is we know produces the thrust. And this is the carburettor which of course combines the fuel and air and produces the charge. That goes inside the cylinders and then you have normally gear box which runs the supercharger which is of course which we know normally centrifugal compressor. Now what can be done, as the supercharger is operating, and the supercharger runs with the help of turbine, this turbine runs from the gas that is coming out of the exhaust pipe. So instead of gas going straight away out of the atmosphere the exhaust pipe takes to the turbine and runs the turbine and then from the turbine it goes out through a small nozzle which I have mentioned can have a variable geometry capacity or variable throttle capacity to control the operation of the turbine and through the operation of the turbine control you can have control of the supercharger operation. So this how the turbine supercharger combination is brought to a certain amount of control through the outlet control of the turbine, now what can be done is you see from the supercharger the air is coming into the supercharger, let us say the mass fuel and then it is being fed into the pipe through which it goes to the carburettor and then through the carburettor, it is fed into the cylinder. Now on the path of its going into the carburettor the air can be further cooled with the help of ambient atmospheric air which is at high altitude, quite cool. So this cool air can now be used to cool the supercharged air because in the process of supercharging if you have a compression the air actually get heated up. So along with the rise in pressure, the thermodynamics tells us very clearly that through the supercharging process the pressure is gone up, the temperature is also gone up. So from the thermodynamics, we know that if the temperature is gone up the performance of the engine would actually suffer little. The higher the temperature of the intake air, lower would be the performance. As a result of which in fact lower will be the density of the air coming. So one of the ways of further boosting, the engine performance is by cooling and this is often calling an inter cooler. That is a cooler which is an intermediate between the supercharger and the carburettor. And this intermediate cooling simply called intercooler and this intercooler cools the air. The air, you remember is still compressed to high pressure compensating for higher altitude, now its cooled, it is just passed through intercooler and gets cooled. And this now compressed but cooled air is now fed into the carburettor and then the fuel air mixture is created which then goes inside the cylinder. And as a result of which we have a kind of double boosting of engine performance, first it is cooled by the supercharger and then it is boosted by cooling the air and all these concepts as you know comes from the basic understanding of the thermodynamics of the engine. So you need to always refer back to basic thermodynamics to understand why these things are done and of course finally they have to be engineered into the engine configuration so that they operate properly during the actual functioning. So intercooler is a possibility that has been used sometimes to boost the engine performance little more if the engine is operating at very high altitudes. So intercooler is an additional method by which turbo supercharger can be further compensated for its heating that occurs through the turbo supercharger unit. So these are some of the combinations through which the aircraft engine often gets operation boosted or augmented in its flight during the climb, during high altitude flight and some of these as I mentioned are typical of aircraft engine, they do not normally happen or necessary during the land bases operation. So you probably won’t see them in most of the land based engine or land based vehicles. Sometimes you may have heard or used in the raising engine where of course for raising purposes this kind of boosters are used to augment the power for the raising engines. In the next class we will look at all the things we have done with reference to the various aircraft engine and try to solve some problems using the basic thermodynamic and basic engineering parameters that we have defined and see whether these things can be put together in solving of realistic problems and I will also bring few problems for you to solve yourself and this is what we will be doing in the next class. so it will be some kind of tutorial we will indulge in, little be tough problem solving using the basic thermodynamic cycles and aircraft engine parameters that we have discussed in the earlier class.