Fundamentals of Aerospace Propulsion
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Lecture – 02

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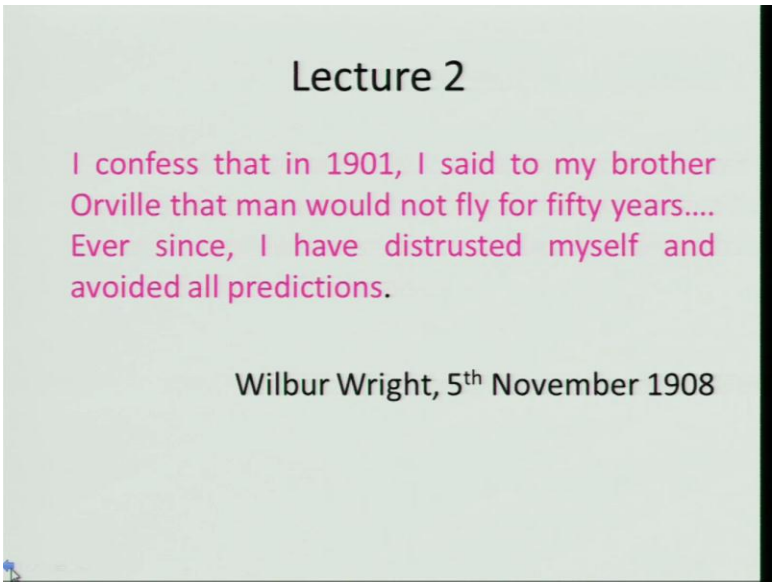

Let us start this lecture two before getting into this lecture two what we will do we will try to recall what we learnt in the last lecture in this course what we will be looking at aero thermal dynamics of the propulsion; that means, we will be looking at how to convert this energy into the thrust power. So, that is the basic idea between this in this course and subsequently in the last lecture we discuss about how the propulsion evolve in terms of history I ask a question why really we want to look at history it is important, because we need to learn the way they have the bluff the processes such that it will be useful for today to apply it such that our future will be better, and we will look at those things some portion.

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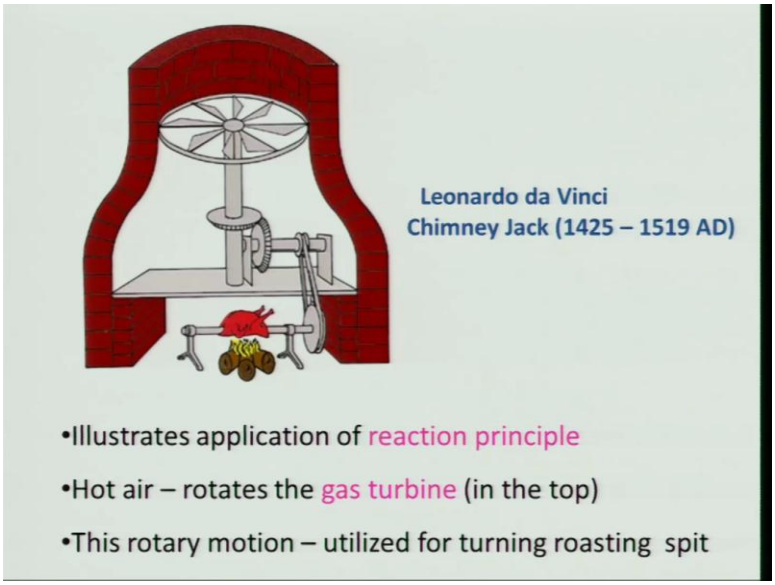

And let us look at Leonardo da Vinci really who device this chimney jack and if you look at this as the pictures, which is I have shown here, and this is you are a turbine, which will be rotating, and this turbine are the is connected to the this apt through a gear trends and also a leaver pulley, which is joined with this roasting peak and how does it work.

If we look at it basically burns this wood, which is being burnt to provide the heat to this roasting speed, what is that it is basically a place, which is being to be combed and this spate will be rotated now, and this burning of this what we call the this flesh or a meat the burning of this wood will be producing the gas, and this gas will be passing through this what we call the turbine, which will rotate it if we look at this is the first concept, which was being you know sketch by a Leonardo da Vinci who is not involve in the science activities; however, he was known as a greatest artist, and he illustrate this application of reaction principle right.

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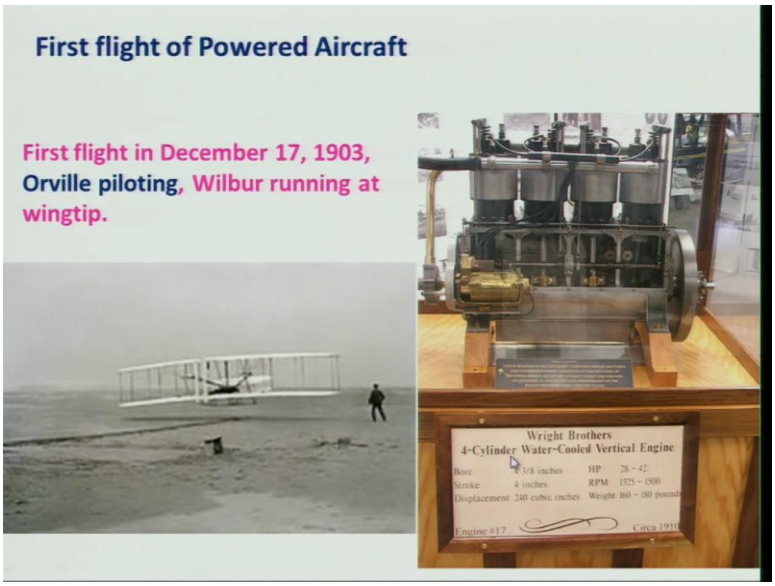

So, now we will be moving into the first flight of the aircraft and which had made a epoch in the history of aircraft propulsion. So, if we look at it was basically done by this right brothers in December 17, 1903 he flew the first flight, and if you look at his flight is pictures as shown here that this is the flight, which is here and it is having a propeller, which is not visible in this figure and orville pilot willing this flight, where as will where is standing here at the wingtip to look at how it is flying do you know how what is the duration of time it flew it was only for 112 seconds and it could cover 120 feet kind of things and after that it was ((Refer Time: 04:07)).

But; however, it may done history, but if you look at this two brothers who worked relentlessly with lot of failures if you remember that first slide I showed you that with frustration that for while told to his brother that man cannot fly for next fifty years, but they proved that yes it is possible. So, therefore, engineering per say it is being done with a lot of failures, but if you look at today's mindset that first failure make us to be depress.

So, that we will leave that and go somewhere else engineering cannot be done that way I must tell you, and those people who are developed the engines or any other kind of success they got all those thing with persistently fort and with a lot of failures. So, therefore, failure is the pillar of the success has been told and they used a what you call a inline engines, and which will be discussing about it, and it is basically a four cylinder

water cool vertical engines, and the figure is shown, and it is being done by design by a Charlie Taylor.

If you look at it is not a single men job to have an aircraft or any engineering product it is the group work, which is very essential and whenever you are working in a group, and you will acquire just with the people, and which is lacking in the present modern India that we become more secluded and single minded that one fetches engineering.

So, therefore, this is the quiet good lesson we should learn from this development, and it was really created a history. Now, this after this development the most of the aircraft is been propel by the propeller, and with the help of power plan known as IC engine.

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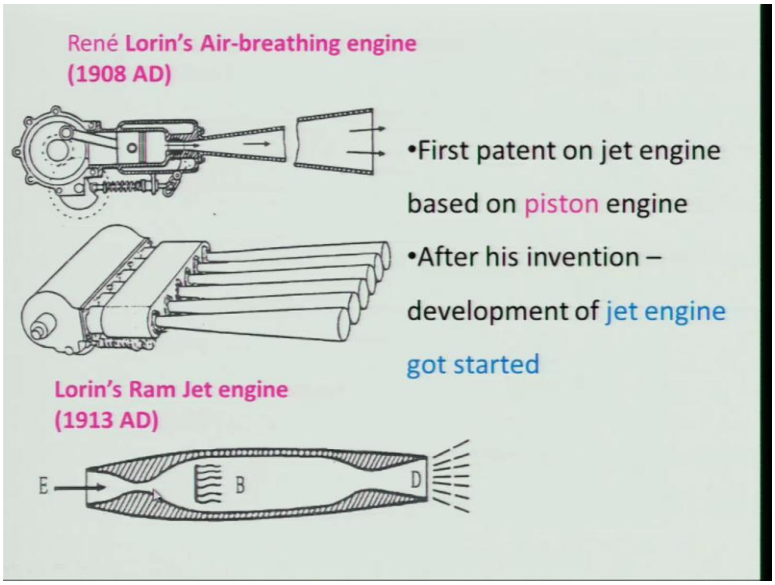

And of course, the air breathing engine concept was given by a genius I call it Rene Lorin and who gave a concept taking from the piston engine I will show you a figure here, and in this case this engine is basically connected with a with a nozzle, which is you can call it as convergent divergent nozzle, and this is the cross sectional view.

And this is the number of nozzles, which are connected to a inline engine, if you look at this is basically inline engine, and he gave this concept of piston engine converting piston engine to air breathing; that means, is basically a concept of jet engine you can call and of course, the piston engine is an air breathing engine, because it takes the air and use what you call for burning the fuel.

So, it is an air breathing engine; however, the jet engine concept was given by Rene Lorin in 1908, and he gave another beautiful concept in 1913 AD, and which is the ram jet engine that we use today for the missile applications, and if you look at this is having a what to call a diffuser right or air intake which of course, work in a supersonic flight and it is having a combustion chamber and a nozzle. So, if we look at it is not having any rotary components or any complicated components it is mere duct which you give the thrust.

So, if you look at these are the concept, which was given by lauren and he is a known to be a great innovators. So, what is important for engineering is innovation, and person should be creative in nature, but unfortunately today we are not that creative, because of fact that we are working quiet hard, and always busy in something or other, but the man in a nature is creating I always say that man is a creative creature by nature unfortunately, modern educational system and the societal society is not allowing us to go back to our own nature and develop, and work for others.

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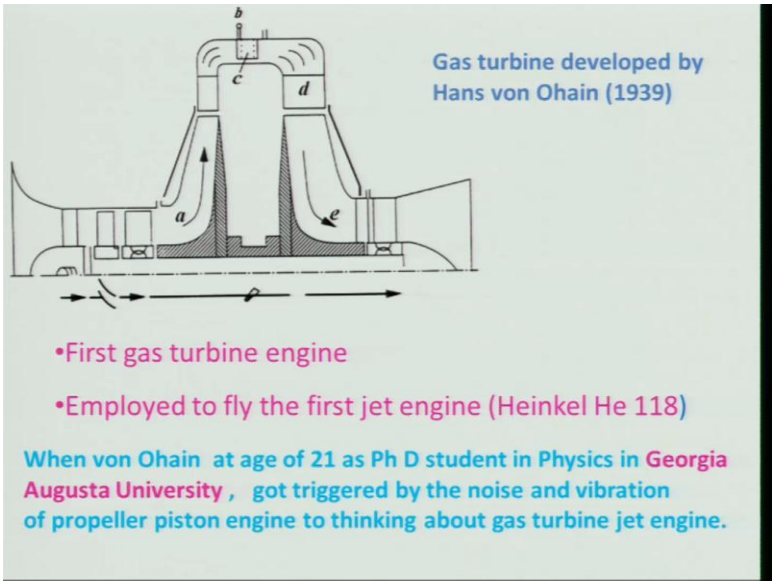

So, coming back to that I will tell you that this after that subsequently 1939, there is a person German Hans von Ohain would develop the gas turbine engine, but most of you will be telling me that it is the whittle sir whittle who develop the gas turbine engine, but it is actually the Von ohain who when he was a student in a Ph D student in the Georgia Augusta university at the age of twenty one and enroll as a Ph D program in physics he

was never a engineer, and he got annoyed by the noise, and vibration created by the propeller piston engine in his lab.

And then he thought about why not have a engine, which will be smooth enough and it would not cause any noise or vibration at the same time it will give you a large amount of power as compare to its own weight, and that he that idea was lingering in his mind for quiet sometime till he finished his speech he did not run away from the Ph D program he finished his ph D, and then he requested his professor, Professor. Paul to write a recommendation to another person whose name is Heinkel.

Heinkel is a basically proprietor of a aircraft engines, and then introduce Heinkel was very encouraging, but at the same time he is a business man he was a business man and he was reluctant to take of this thing he convince as a young person, and worked hard with a lot of constraint, and came up with a engine which cross section I has shown here it is having a air intake, and then there is a radial compressor there is a combustion chamber, and it is the having a turbine right, and he flew that in 1939 as a first air craft to be found by the gas turbine jet engine.

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So, if you look at and this is the first engine ever engine was wing flown by the turbojet power in which hydrogen as a fuel is being use today people are contemplating to use the hydrogen as a aviation fuel for aircraft, because of engine pollution are the problems being faced by across the globe and he was the first person, but you he was never

consider as a inventory of gas turbine engine, because of fact that the German last the war in the second world war.

So, therefore, you was, but fortunately and I am also very delighted that in 1991 he was consider or was accepted by the world wide as a in an inventor of the gas co-inventor of the gas turbine look at the fate we always think, I did not get this, I did not get that, but here he waited.

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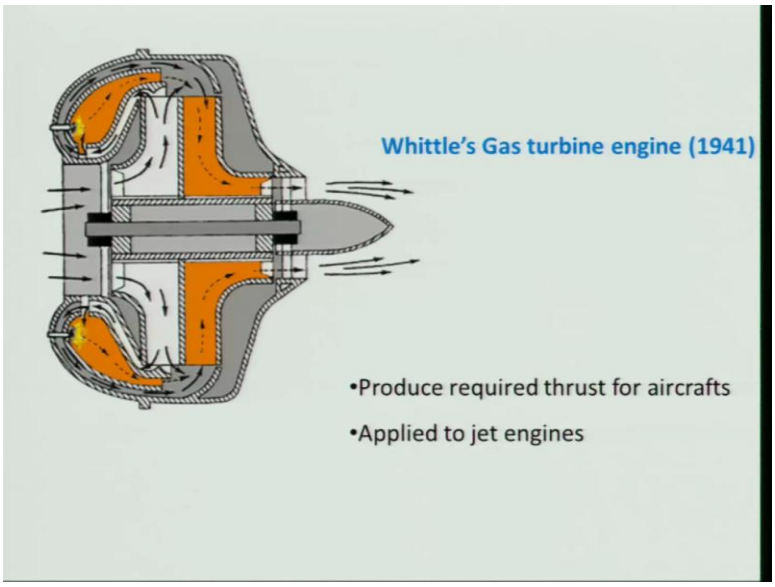

Of course, he was alive at that time and he could manage to be known as co-inventor of the gas turbine which was due, but he was not given, because they last a war and of course, at the parallely to for winning the war before that there was a first world war during the second world war the British is, where trying hard to have a engine, and the sir whittle developed a engine, which I have shown here.

In this engine, if you look at this is your what you call the centrifugal compressor and this goes into a combustion chamber, which have sun this is known as a reverse combustion chamber or a reverse combustor, and which was a quiet compact in that, and then it will be expended in a turbine, which is a radial turbine or centrifugal turbine of course, the nozzle it will be expanded and you will get the thrust.

So, if you look at this reverse combustor is coming of well again after null and; however, lot of work has to be done on that to have a compact micro combustors, which I would not be discussing about it; however, if some of you where interested you can look at it.

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So, this is the development of the gas turbine engine what we could see and of course, in India we are having a ambitious program of this air craft engines and also the space craft engine, and we could manage to develop a light come at air craft in 2001, and which is basically smallest light weight multi role come at aircraft in the world, which dimensions are given, and a length is 13.2 meter, height is 4.4 meter and span of course, the 8.2 meter.

So, if you look at it can cover a mac number 1.6 to 1.8 it is a technology fly by wire and of course, the gravity limit is 9 plus 9 g two minus 3.5 g, and keep in mind at we are here to get a engine of our own, and this light come at air craft being propel or being powered by the general electric F404 and GE-IN20 engines, and you must be aware that we are having a such a establishment known as gas turbine such as establishment g t r e, which is instrumental in developing engine.

Unfortunately, we are not very successful in spite of lot of money being spent I wish some of you will contribute for the development, and it is a important to have such kind of engine not only for having a comeback come at aircraft or, but it is also required for

civilian aircrafts and other applications. So, we need to augment our technical know how is, and knowledge to develop certain things which will be useful.

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So, beside this we are having a plan vertical ambitious programs of launching vehicles one of them, which I am showing here is GSLV which all of you will be aware this is geo synchronous satellite launch vehicle, which was developed in 18 April 2001.

There are several versions, which have come up till now, because already 11 years or over by this time, and which will be if you look at it is having a four stop end motors, and which is having a booster rocket engines, and they will be first stage and second stage, which will be discussing little later on, but just to give a brief idea I am just talking about it.

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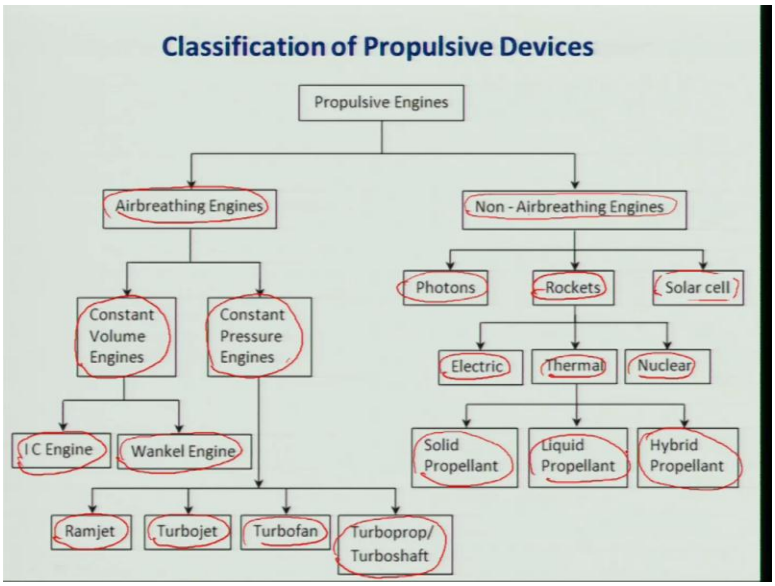

Now, having come to this brief history of the propulsion let us look at how we can classify a propulsive device. As I mention earlier that propulsive device can be broadly classified into two, one is air breathing engines and other is non air breathing engines.

Air breathing engines means is basically the which will breath the air this is the air breathing engine; that means, it will be taking air as an oxidizer and you can use as a fuel like your piston engine, gas turbine engine and other place, but how ever this can be restricted into the what you call in the atmosphere only, but when you want to go beyond atmosphere naturally you do not get the air, because the atmosphere would not be there, and air is not there means oxidizer or oxygen would not be available.

So, therefore, we will have to look at a another class of engine for aerospace application that is the non air breathing engines means it will be caring not only the fuel, but also the oxidizer. So, this air breathing engines can be broadly divided into two categories, one is your constant volume engines, and what is the example of constant volume engine like your piston engines right it is it can be spark ignition engine, it can be what you call comparison ignition engine or the dwell engine.

There are several other varieties like stalling engines, and then your brighton engines can be used brighton cycle, can be use in the piston as I told, but it is not being use; however, there is a another class of engine, which is known as constant pressure engine what is the

meaning of constant pressure engine during this combustion process pressure will be remaining constant right.

How that possible that is a matter of you know discussion, we will do that whenever we will get into that now let us look at how this constant volume engine can be divided into the IC engine that is a internal combustion engine, that is the another class of engine, which you call it as a external combustion engine how of a propulsion we do not use it.

Internal combustion means the combustion will be taking place inside the engine itself, and there is a another very compact engine, which I will be a discussing little bit is known as wankel engine, which is not being used very much; however, it as a potential to be used for several aerospace applications particularly, air breathing engine class.

Whereas, the constant pressure engines is divided in to the ramjet engine, which will be discussing to some extent very briefly it will later on and turbojet engines, turbofan engines, and turboprop, and turbo-shaft engines.

So, all these things will be discussing as we go along let us look at how we can classify this non air breathing engines, and it is can be divided into three, one is photon engines photons; that means, photons you know light particles, and which is basically will be collected in the outer space and can be use, but this is not in a very vertical develop stage rather I would say that it is very infancy stage.

And there is a solar cell, which is similar to that that of photon, but; however, it will be having a panel which will be collecting the photon from the sun, and then converting into the various forms of energy whether it is a what you call solar cell or it can be any other thermal kind of things, what we will be interested in basically the rockets engines and this rocket engines will be divided again into electrical and thermal, and nuclear; that means, electrical energy will be use in the electrical rocket engines.

Which I will not be discussing, but; however, we each will be using the what we call is a thermal engine, which will be main focus of our discussion of these course that is we will be discussing about solid propellant engines and liquid propellant engines, and hybrid propellant; that means, combination of solid and liquid, which will be discussing and towards the end of this course we will be discussing about this more; however, for the completeness sake we will be now looking at some of this concepts little bit further.

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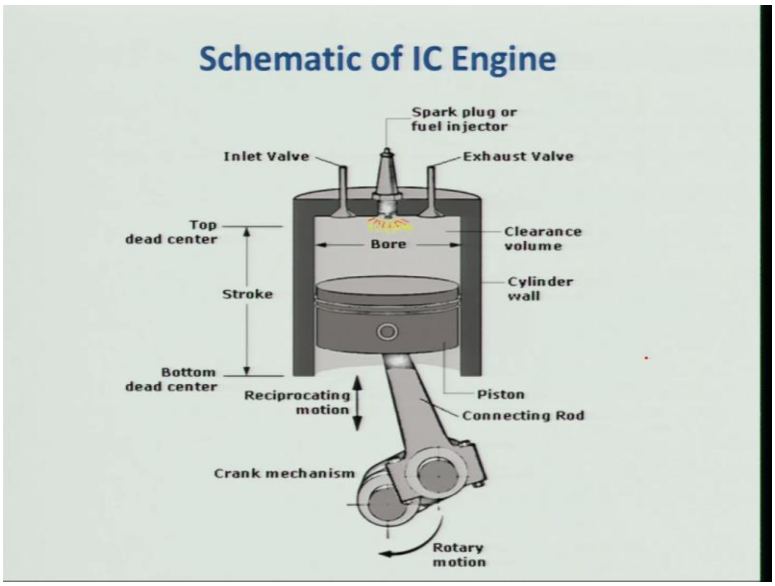

And let us look at a schematic of ice engines we know that, I have taken a cross external view it is having various components one is of course, the piston and other is your connecting rod, and there is a crank shaft. In this case, the piston and the crank shaft it will be help to convert the translation motion into the rotary motion, and in this case there is a inlet valve through which whenever it will be open through which the air will be entering into it, and we can have a fuel, which is mix together or it can be injected directly.

In this case, it is basically mixed before and coming and ah. When it will be compress again as the piston will move from the bottom date center to the top date center at the end of compression there will be ignition with the help of spark plug, and then the combustion will be taking place, which will be pushing the piston, and thus the power will be generated, and that is known as power stroke during which the piston will move from top to the bottom date center.

And then when the piston will move from the bottom date center to the top date center the combustible are the what we call the exhaust gases will be going out through this valve, and that complete the cycle of course, this is known as the force stroke engines.

But; however, there is a two stroke engines, which is being coming up again it can be utilize in future, and unfortunately I would not be covering in this course the piston engines as such although a large number of aircraft even today, if you look at the number

wise are being power by the piston engines, and in our flight lab we are having seven aircrafts, which are been propel by the piston engine.

Therefore, I would ask you people to look at it and learn yourself and may be some of you can write a term paper on piston aero piston engines, which is different than the auto mobile.

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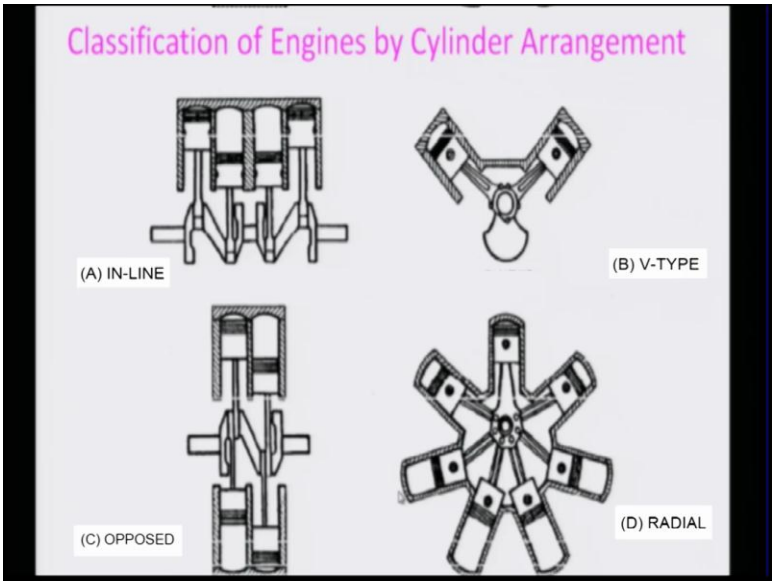

Based on the cylinder and piston arrangement we can classify the engines into four, but of course, you can have more, but here as shown the four type, one is inline engine, if you can look at there are several piston cylinders are connected to a same crank shaft, but with different phases phase angles such that it can move randomly or move in a continuous manner without much fluctuation in the power label on the load on the crank shaft.

And the another kind is the v-type, and which is a is piston and the crank shaft being connected through this to the shaft in such a way that it will cancel each other along this what we call horizontal force. So, that balance will be better and there is a another oppose piston arrangement, which is shown here that both of this pistons like or opposing to each other.

For example, this is at the top date center, this is are the bottom date center kind of things both the vertical it can be vertical, and it can also be horizontal the basic idea is that the

shaft should run smoothly, and without this thing, but this is not really being very much use aircraft engine; however, in line and v-types are being used and. So, also the radial in the radial the piston and cylinder are being arrange along the radius that the it will be the power will be transfer to the shaft in a very smooth manner without much fluctuation, and the load under the ((Refer Time: 25:15)). So, we will be a discussing a little more in the next slide that is inline and radial, which are being use very much for the aircraft engines.

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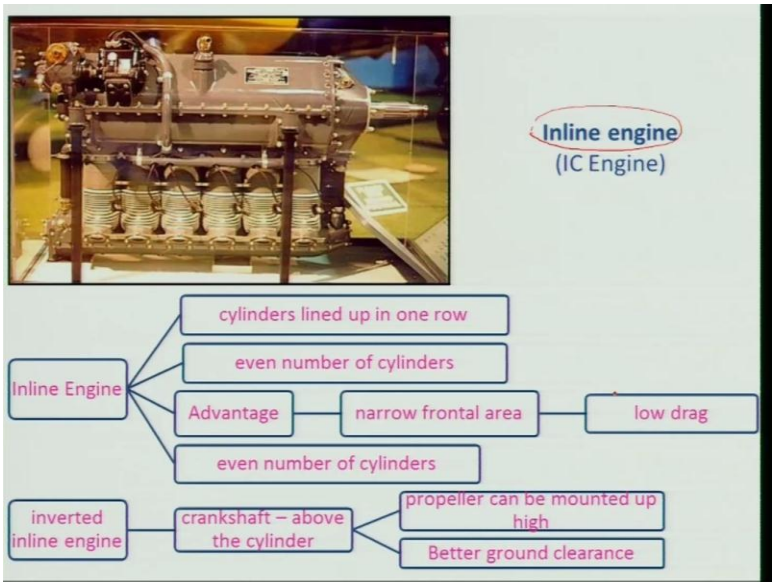

So, under this category I will show you two engines, one is inline engine as I told that it is being use by the right brothers, and which is having a cylinder these are the cylinders, which is lined up in one row, and if you look at generally piston on the top, but here in this case pistons are in the bottom and this is the crank shaft, which is having a shaft.

Which is shown here and to which the propeller will be mounted, and this is been done, because a propeller can be mounted easily and better ground clearance you can have, because the propeller size is higher. So, you can test it well and put it. So, therefore, this kind of engine, which is being use and it is having a narrow frontal area, and lower drag can be therefore, it is being use in the engines.

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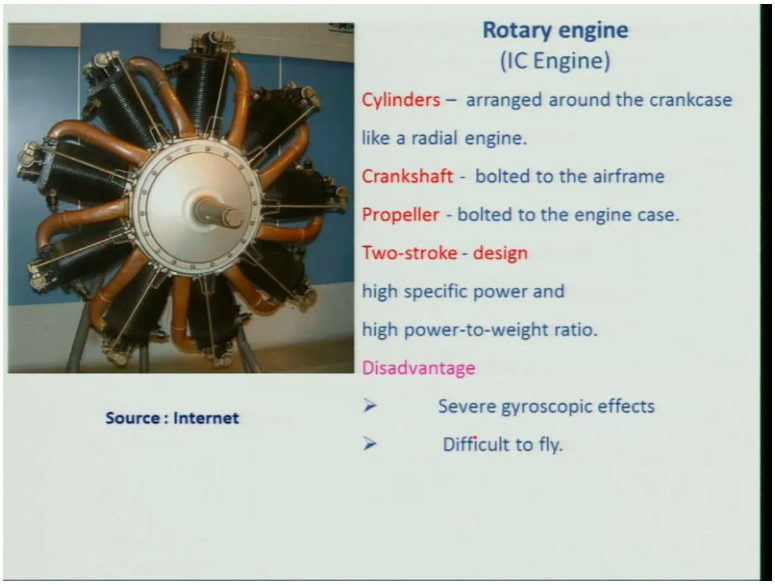

And of course, there are several re-engines, which is together having use and there is another engine which you can see in our flight lab, which is being kept as a model I guess it is a rotary engine; that means, the cylinder these are the cylinders, which are being mounted along with the thing and as result it will be well balance right.

The balancing is the big problem in the IC engine you might be our those people who are studied the mechanical engineering will be knowing that. So, it is a cylinder arrange around the crank case like a radial engine and it is a bolt the propeller bolted to the engine like this is the place, where it will bolted and it is a generally two stroked design.

As I told that engine can be four stroke and two stroke, it is having higher specific power and high power to weight ratio of course, there are several disadvantages that severe gyroscopic effect and difficult to fly, because it is little bit heavy in nature right. So, it is not being used now a days; however, it was being used earlier this.

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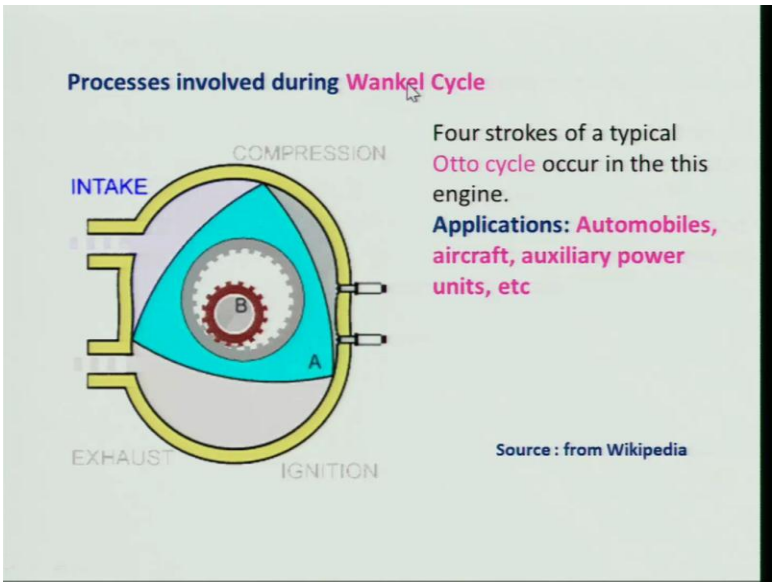

So, I will be discussing about wankel engine I am very much fascinated by this engine, because it is quiet compact, it works on a basically four stroke of a typical auto cycle in this engine, you can look at in this animation that air is coming over this known as air intake it will be compress, and then once it compress then the ignition the combustion take place over here, and then it will be expanded and it will be going to the adjust.

So, this is a quiet compact engine and of course, lot of people lots of research groups across the globe are working and in India N A L that is national aeronautical laboratory is working on this engine for a quiet sometime, and I was told it is in operational mode at this movement.

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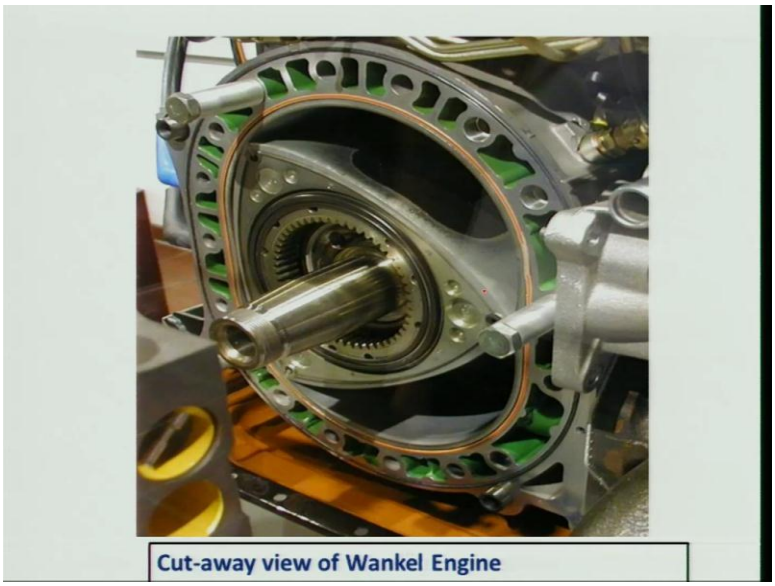

This wankel engine can be use not only for the aircraft, but also for the what to call auto mobile and auxiliary power units and other thing. So, I will just show you a cut away view of the wankel engine it looks to be quiet simple as compare to that, but it is a quiet compact other that at the center.

And if you look at this the epileptic gears and this is the chamber, where the combustion, and then you know air will be coming inside, and then it will be reacted somewhere here igniters and it will be going out. So, this engines is a quiet promising one according to me, but unfortunately it has not been use in real situation I hope, and wish that it will be worked may be some of you will be looking at it, if you were having interest in engine like this.

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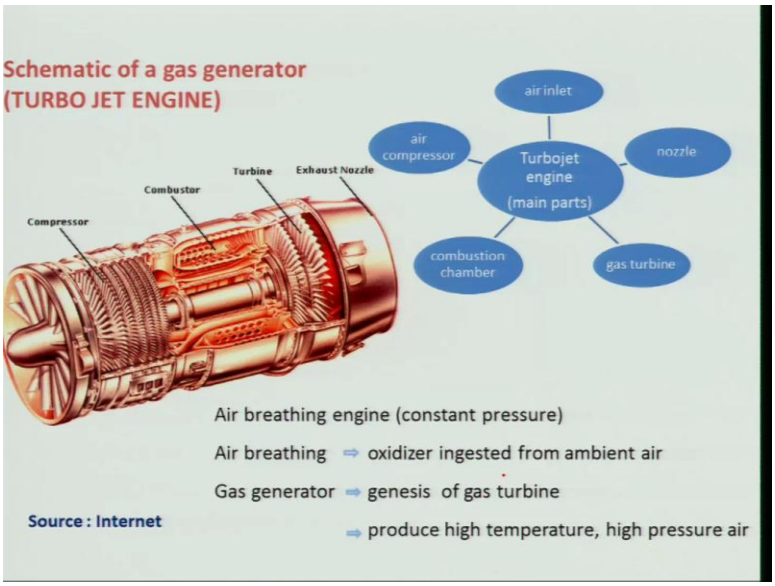

So, let us look at a gas turbine engine that basically it is a gas generator, which has shown here, this having a compression is having a combustion chamber, and this is having a turbine, and this constitute the gas generators and whenever the gas generator is connected with a nozzle and at air intake, which is not shown in this figure is consider as an aero gas turbine engine or turbo jet engine right.

So, as I told you this is a air breathing engine and the combustion takes place in this place, which is at constant pressure right, that is why it is known as constant pressure engine. And as I told you what will be happening here when air will enter in to the air intake there will be increasing in pressure, because the kinetic energy is converted in to pressure energy, and then it will be further compress in the compressor and there is a combustion chamber, where the heat being added and the it will be expanded in a turbine and it is expanded further in the nozzle to produce the thrust.

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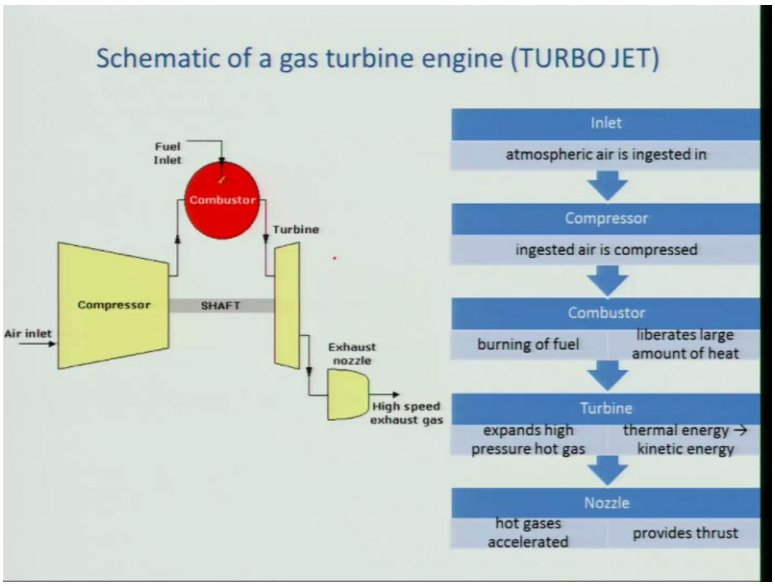

So, if we look at as shown this schematic diagram here, there I have showed you a cross sectional view, which is air will be entering into compressor and this is the combustion chamber, and the turbine keep in mind. The turbine will be producing power, which is just mean to run the compression it would not be giving you any thrust and of course, the thrust will be obtain by the by expanding the gas in the exhaust nozzle. So, that is a basically what you call the turbo jet engine.

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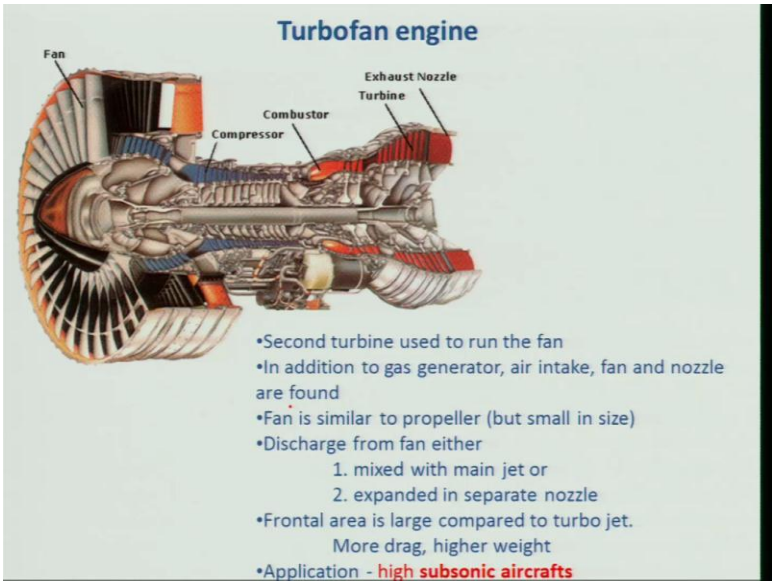

And there is a another class of engine which will be discussing, but let us look at a cross sectional view, which is similar to that of the turbo jet engine; however, it is having little difference that is apart from the core engine or the gas generate it is having a big fan and also a nozzle right. And this we can also nozzle when it is expanded the gas going through the fan it can produce also some thrust, and beside this there is a nozzle exhaust nozzle in the core engine, which will be producing the thrust.

So, total thrust by the engine can be obtained by both the fan nozzle and the exits nozzle, and there might be a situation, where both the fan stream and the core stream mix together, and then can be expanded. There is a various varieties of this turbo fan engines with their and keep in mind that it is being use very much for high subsonic aircrafts; however, it keeps a lot of drag as well as compare to the turbo jet engines.

So, what are the advantages and the what to call disadvantages will be discussing little later, but keep in mind that it is a heavier than the turbo jet engine its having more duct; however, it is being used in the your passenger aircraft or civil aircraft like Boeing kind of class.

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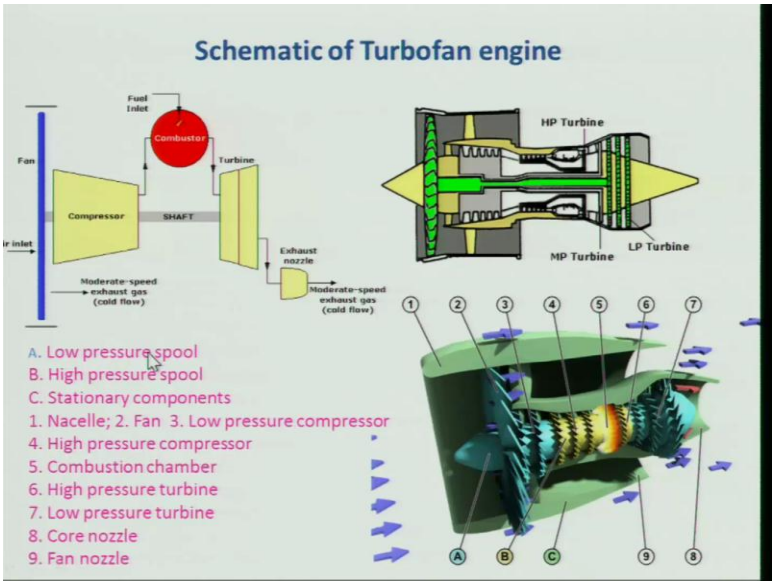

So, let us look at now, a schematic I have just shown you and I have already discuss about this thing you just look at any machine what really happens, in this case it is having a two spool engines, what is the meaning of this two spool engine, one is low

pressure spool; that means, that is a shaft, which is will be the low pressure like low pressure turbine, which will be here you know will be connected to the air fan right.

And where are the high pressure turbine which will be somewhere located here will be connected to the compressor, and then this is having a two concentrating shaft, which will be rotating; that means, two r p m are being used unlike in a turbo jet engine, where the r p m will be one or the shaft will be one, because of fact that the blade what you call the fan will be rotating at a lowest speed that is the important.

So, beside this of course, this is a two separate nozzle, which I have shown here, one is core nozzle other is fan nozzle. So, now, we will look at the turbo what you call shaft engines.

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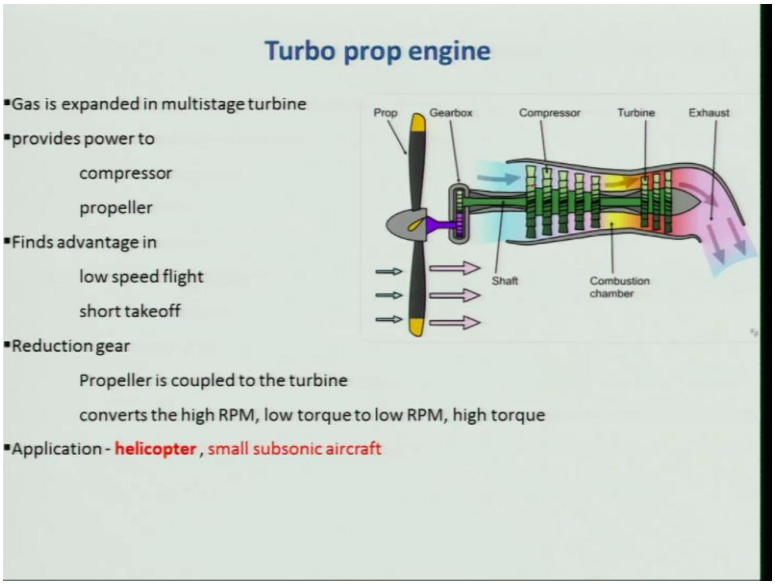

And turbo shaft engine, if you look at it is having the similar what you call core engines except that it is connected to a popular through a gear box, and this gear box is quite heavy as compare to the you know like your other engine components, because why it will be heavy, if you look at your ice engine or automobile engines you do not have a very heavy gear box.

Why this air craft engine will be have r p m not only has to be reduce, but also the power label will be much high. So, but how ever this kind of engines which used find application low speed flights, and shorted take off and also what you call like a vertical

take of kind things it can do, and it is use in helicopters and small subsonic air craft engines.

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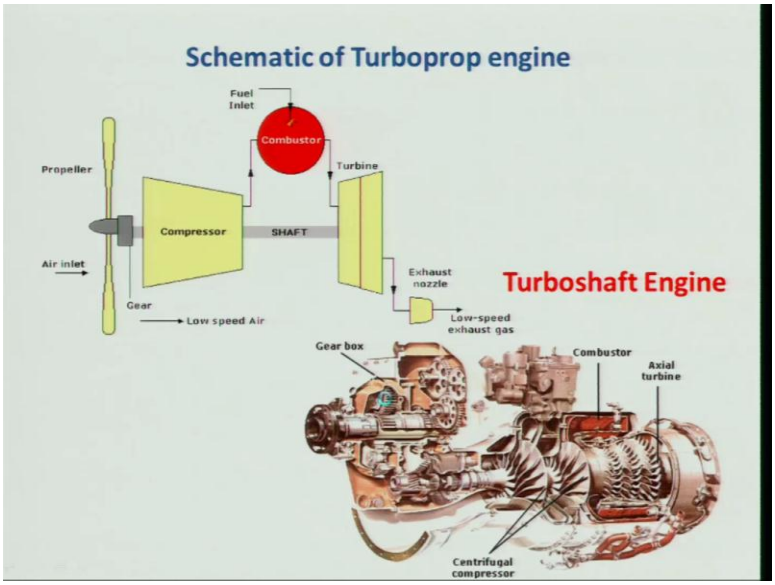

And the schematic I have shown here, it is having a propeller its having a gear box compressor and combustion chamber it is having a turbine, which will be one will be like high pressure connected to the compressor, where is the low pressure will be connected to the propeller through the gear box.

And of course, you may get some times the stress to the nozzle, but there is a turbo shaft engine which will be you know only you know when the power will be available in the turbo shaft and no thrust being obtain in the exits nozzle as such and it is having several application.

As I told you particularly for the vertical takeoff and sort take off and landing it is being used very much.

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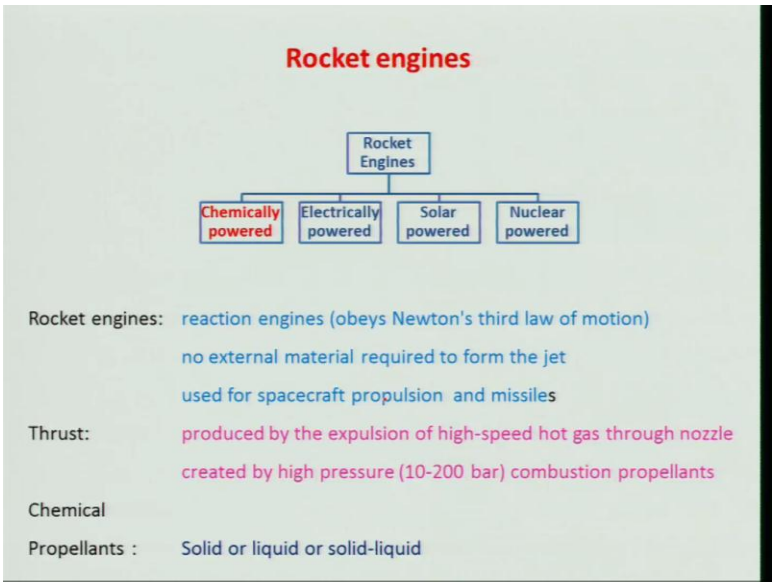

So, let us look at the rocket engines as I told that rocket engines is basically the reaction engines, which obeys the Newton's third law of motion, and in this case no external material is really required to form the jet, what do you mean by this external material, basically you need not to take any air form that must be you are going beyond the atmosphere then you need to carry both the fuel, and oxidizes such that it will be independent of atmosphere.

And if you look at the performance of air with in engine will be depend on the condition and of the atmosphere through which it will be passing through, where as it is independent of that is the beauty of this rocket engines and it is as I mention earlier it is use for space craft propulsion and missiles.

And there is a lot of development; however, it is, but if look at this pain a large amount of our budget for the defense in the name of von, which is a quite, a beat and it is not only in this country, but occur the glow we spend lot of money, and lot of resources, lot of man powers for winning a war and, which is in future.

So, therefore, it is very important to look at that we should not only be a part of this colossal vests of resources and see that how it can be utilize for the elevation of poverty, and other things. So, that our country and other places can be live peacefully. So, I must tell you that all though I teach this subject, but however, I feel that it must not be use and abuse by this the war mongering people to have a war.

So; however, there is several civilian application which can be done and, which must be use that thing I must ask, because all of you that has you people are the next generation are the leaders of this country technically man power particularly. And you should see that we should not really look at in this aspect rather use that how we can use further other man driven applications without spoiling the atmosphere that is the very important.

So, if you look at this produce the expulsion high speed hot gas through a nozzle this is the basic principle, which gives you thrust in case of everything engines particularly class of your turbo jet turbo fan, and to turbo prop and also the rocket engines, where as your IC engine best or the pistol engine best is basically through the propels.

And here we use the propels, which are basically chemicals and as we are talking about the chemical powered engines and the solid liquid or solid liquid engine, what we call it as a hybrid rocket engines, and we will be discussing little bit about electrical power engines now, and solar power engines and nuclear power engines. And I just want to give a parts I view of this thing although this course is focus to on the chemical rocket engines and the gas turbine engines.

But; however, I just want to give a view. So, that you can get a whole view, but we will be concentrating on the two aspect, one is the rocket engine other is the gas turbine engines.

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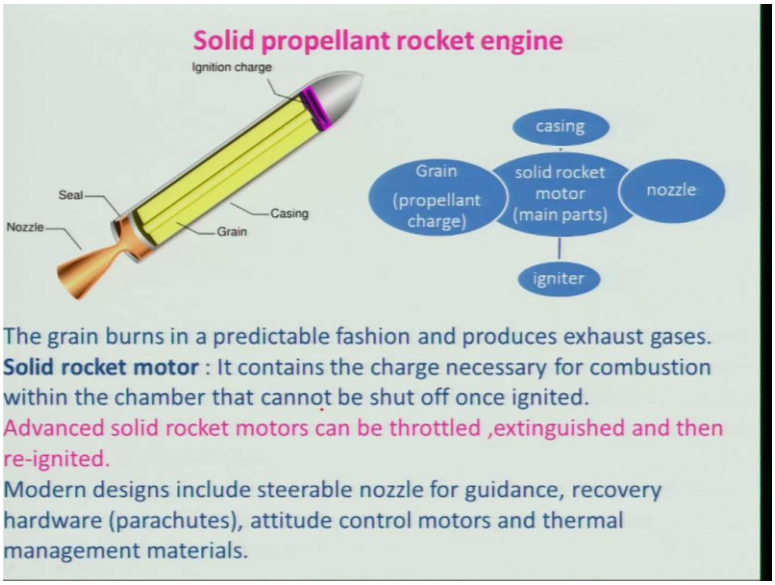

And in this course we will be look at the whatever the fundamentals are required to dell in to the aero space propulsion particularly in the aspect of the gas turbine and rocket engines. So, let us look at solid propellant rocket engines, which is basically consist of a casing and it is having a grain, and it is having a nozzle, and if we look at this is a constituent and is having a ignited as well.

So, if we look at it is the grain which burns in a predictable fashion and produces the exits gas, and we will be talking about how this grain design is required and other things towards the lateral part of this course. And that is the cracks of the solid propellant engine solid propellant rocket engines and this can be the problem with this solid problem rocket engine is that once it is ignited, you cannot really put it half; however, in modern times there are several ways and vince are putting it of and where you can extinguish the combustion throttled, and reignited it all those things can be incorporated rather had been incorporated in modern.

So, modern design includes steer able nozzle for guidance recovery like hardware and attitude control motors, and thermal management of materials and other things.

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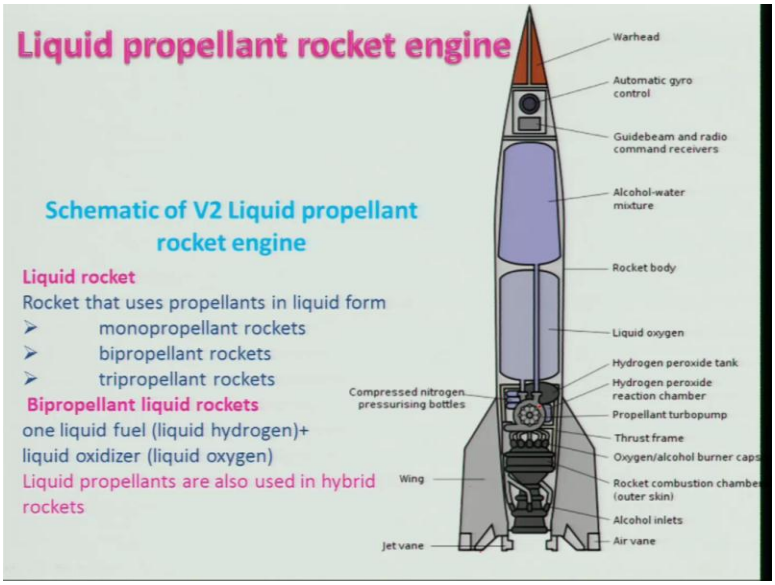

And let us look at a liquid propellant rocket engines in place of solid propellant, which is quiet heavy, and then also it will function as long as the propellant is there. And it is having limitation you cannot tuttle as I told you that, where are the liquid propellant is

having like a specific impulse higher specific impulse, which will be discussing little later on defining it what it is.

And if you look at the liquid rocket engine can have a mono propellant mono, propellant means the single propellant which will be containing both act as the both oxidizers and fuel, and bi propellant, where you know like one is oxidizer other is propel, other is a fuel and tri propellant, which is really being use, but; however, the three combination can be use.

The example of bi propellant is the one is the liquid fuel that is a liquid hydrogen, which is been use and liquid oxidizer like a liquid oxygen is being used as a propellant. And I will just show you a schematic of the V2 liquid propellant rocket engine, which has created a habeck during the Second World War, which was being what to call develop by Germans.

And it was the first ballistic missile, which was used in the entire world in 1942 kind of things, and it has you know like for producing this 12,000 people died just to produce this several, because of under the nozzle, where as it has created lot of havoc in the England. So, this engine if you look at shown here, which is having a war head and this of course, the gyro is there automatic gyro guidance, and control.

It is based on the alcohol and water mixtures right and alcohol is, now does not being of course, the liquid oxygen everything use it is a quiet compact engines, and it produces a thrust, and it is having a wing and jet advance to control this engines, if you look at your engine is this much I mean this is a very small compact it is having a large amount of fuel and oxidizer.

So, all. So, and which is subsequently this a V2 rocket engine is being captured and taken to USA, England and Russia they have further developed this engine whatever, engine we see the father of those engines is basically piso V2 rocket liquid propellant rocket engine design.

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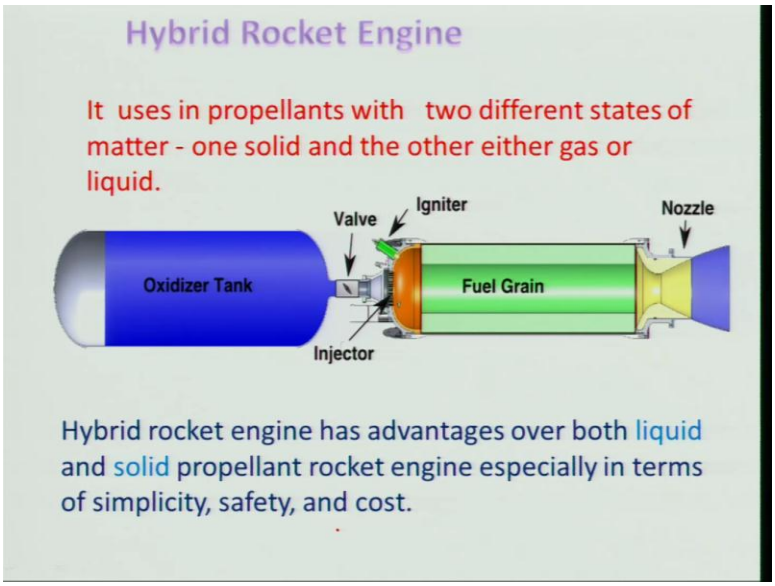

So, let us look at a hybrid engine, where the both solid fuel like grain is being use and oxidizer, and it is having abuse, because it is having several advantages over both the solid and the liquid propellant engines. So, either one solid or are even the gas or the liquid can be combine to it.

It is not the only the liquid and solid it can be combine, and hybrid rocket engine as advantages our both liquid and solid propellant rocket engine especially in terms of simplicity safety and cost. So, with this I will stop over, and if you are having any doubt you can ask me a question.