Lecture - 23
Basics of propeller and maintenance

So for, we have studied different systems on a reciprocating engine. The reciprocating engine is incomplete without a propeller, the basic purpose of the propeller is to convert, the power being generated by the engine, into trust. So let us see, what a propeller is all about, what are the inspections? What are the maintenance? Required to be carried out on the propeller, of a reciprocating engine. So let us see, what a propeller is?

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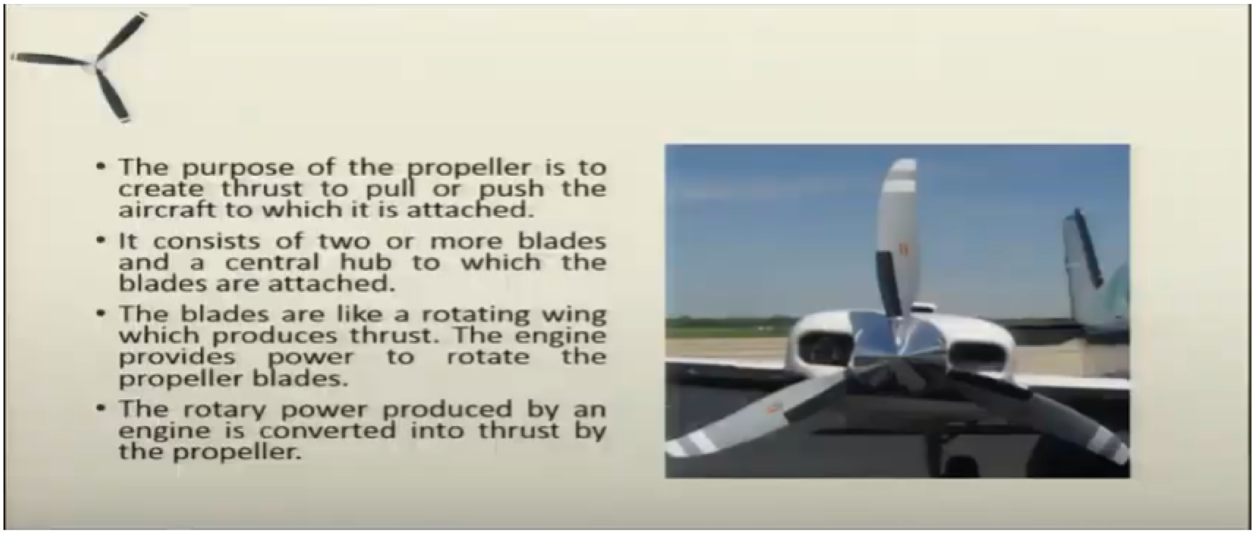

The purpose of the propeller is to create thrust, to pull or push the aircraft, to which it is attached. So, the engine is generating power and that power is converted into thrust, to pull or push the aircraft, to which it is attached. It consists of 2 or more blades and a central hub, to which the blades are attached. So, the propeller has got two or three blades and a central hub to which, the blades are attached. So you can see in the figure, there are three blades of a propeller and there is a central hub, to which the blades are attached. The blades are like a rotating wing, which produces thrust, so these blades, just like the wings of an aircraft, blades are also weak, wings but they are not fixed they are rotating away. The engine provides power to rotate the propeller blades. And the power to rotate the blades is coming from the engine. The rotary power produced by an engine is converted into thrust, by the propeller, as I said, just now that the power is being generated by the engine and that rotary power, produced by the engine is converted into thrust, by the propeller.

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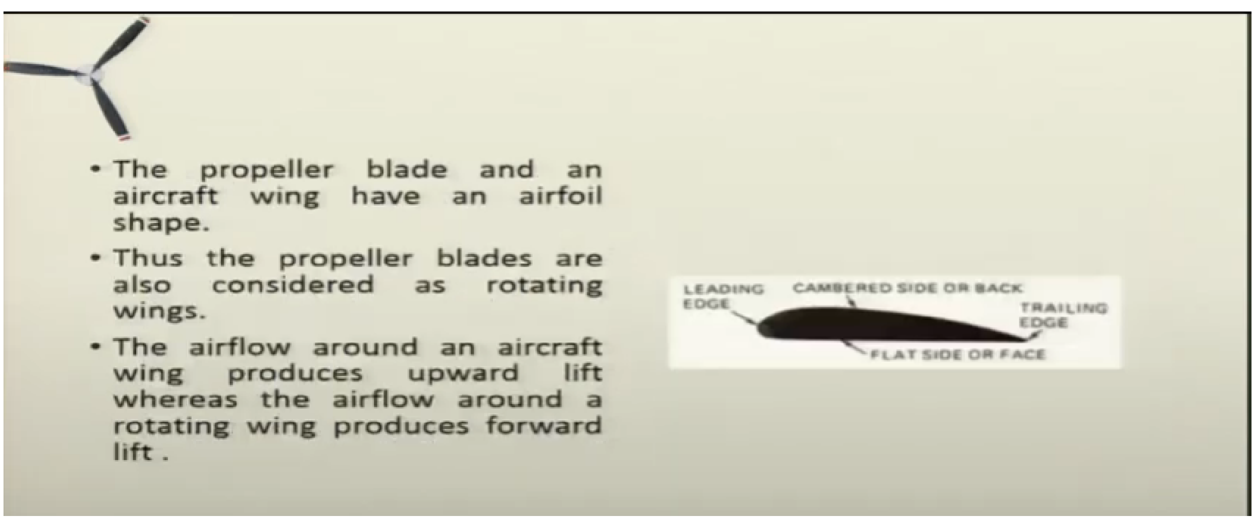

The propeller blade and an aircraft wing have an airfoil shape. Just like the wings of an aircraft, the wings have an airfoil shape; similarly the blades of the propeller also have an aerofoil shape. You can see in the figure, there is an airfoil shape shown, which has a leading edge, here you see this is your leading edge, then this is your trailing edge, the top is the cambered side or back and the bottom is the flat side or face. So, just like the aerofoil section of the wing, the blades are also having an airfoil section that is why, they are the blades are also called, ‘Wings’. But, they are rotating wings, thus the propeller blades are also considered as, rotating wing. The airflow around an aircraft wing produces upward lift, whereas the airflow around a rotating ring reduces, forward lift.

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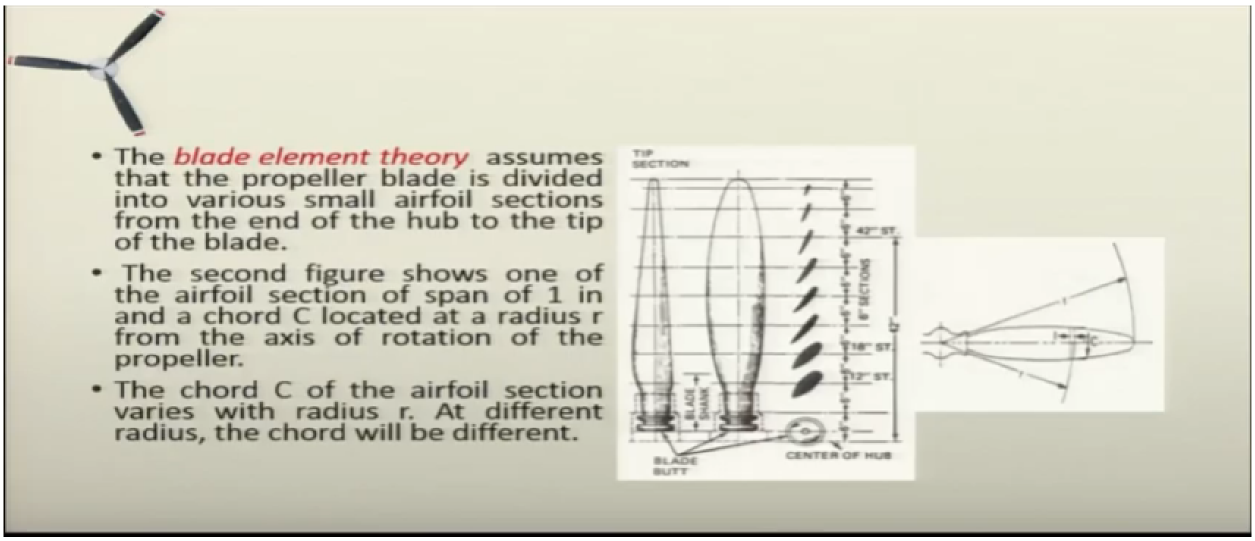

Now, there is a theory called the, ‘Blade Element Theory’. Which assumes that the propeller blade is divided into various small sections, various small airfoil sections from the end of the hub, to the tip of the blade. So here, in the figure you can see, this is one blade shown here, this is the end of the hub and this is the end of the blade that is the tip blade. And the entire blade is divided into various sections, you can see here; these are the various sections of the blade. And the blade element theory is assuming that, the air, the airfoil shape or the blade is divided into various airfoil sections, from the end, of the hub, to the tip. Here, in the second figure if you see, this shows one airfoil section. Now, one airfoil section is shown here, it is a span of 1 inch and a chord C, you can see the chord is C here, which is located at a radius R from the axis of rotation of the propeller. So, from the axis of rotation of the propeller, it is located at a distance R. The chord C of the airfoil section varies with radius R. So, depending on the radius R, the chord C will vary, if you see the blade here, you can see that the chord is different, at different radius R. So, at this point the chord will be different, at this point the chord will be different and at this point the chord will be different. The chord C of the airfoil section varies, with radius R; at different radius the chord will be different.

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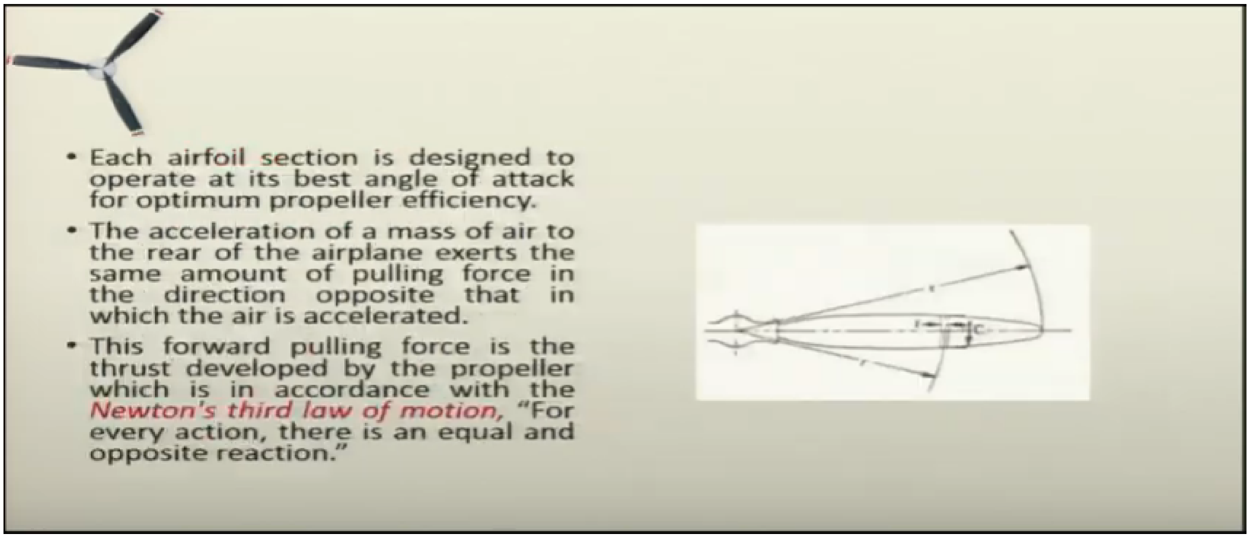

Each airfoil section is designed, to operate at its best angle of attack, for optimum propeller efficiency. Now, just now we said that, this blade element theory, this assumes that, the propeller is divided into various sections. And each section is designed to operate at its best angle of attack, so that when all the sections combined together, they operate at the best angle of attack and provide best propeller efficiency, they provide optimum propeller efficiency. The acceleration of a mass of air, to the rear of the airplane, exerts the same amount of pulling force in the direction opposite that, in which the air is accelerated. Now, the mass of air is being accelerated, to the rear of the aircraft and that mass of air, will provide a pulling force, in the direction opposite that, in which the air is accelerated. The forward pulling force is the crust, developed by the propeller. Now, this forward force, this forward pulling force is the first developed by the propeller, which is in accordance with the Newton's, third law of motion, which states that for every action there is an equal and opposite reaction, in this case also the mass of air is being accelerated, rearwards and in reaction to it, there is a forward pulling force, acting which is the first developed by the propeller.

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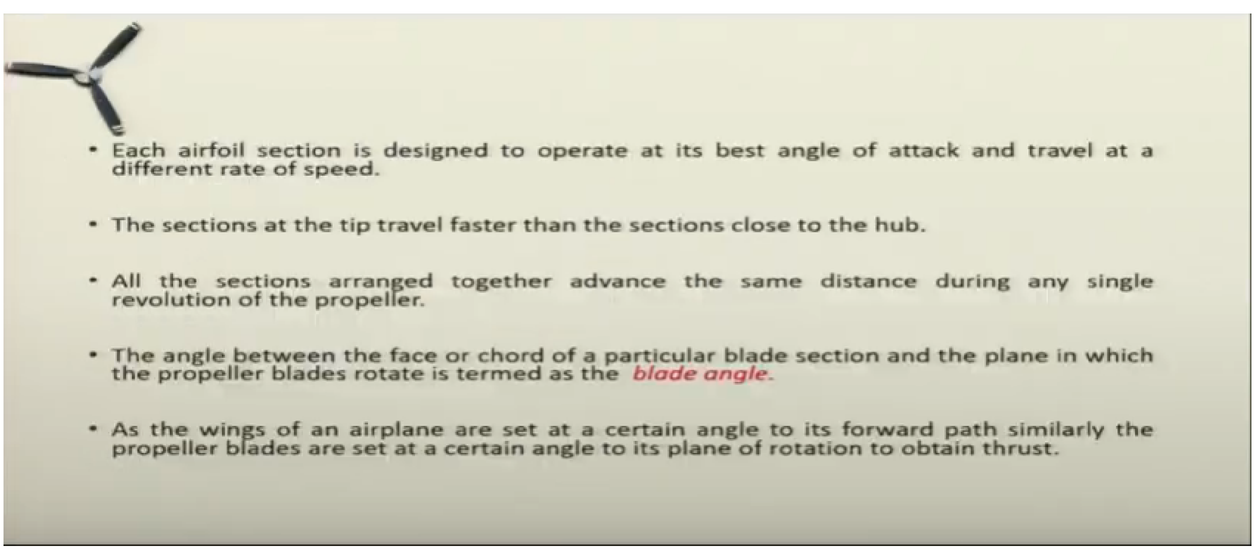

Each airfoil section is designed to operate, at its best angle of attack and travel at a different rate of speed. We have just now seen that, each aerofoil section is designed to operate at its best angle of attack. And operates at different rate of speed. The sections and the tip travel faster, than the sections close to the hub. Now, the sections which are at the tip of the blade, they travel faster, as compared to the sections, which are close to the hub. All the sections arranged together, advance the same distance during any single revolution of the problem. So now, when all the sections are combined together, together they advance the same distance during, one revolution of the popular. So, this blade is divided into various sections, the sections near the tip, they are traveling faster than the sections close to the hub. But, the distance advanced will be same during any single revolution of the propeller, when all the sections are assumed to be arranged together. The angle between the face or called of a, 'Particular Blade Section'. And the plane in which the propeller blades rotate is termed, as the blade angle. Now, this is very important blade angle, it is the angle between the face or chord of the particular blade section and the plane in which the propeller blades rotate, this is termed as the blade angle. As the wings of an airplane are set at a certain angle, to its forward path, similarly the propeller blades are set at a certain angle, to its plane of rotation to obtain thrust. We have read that, these blades are like rotating wings, as the blades, as the wings of the aircraft are set at a certain angle, to its forward part similarly these blades the rotating wings are also set, at a certain angle to its plane of rotation to obtain thrust.

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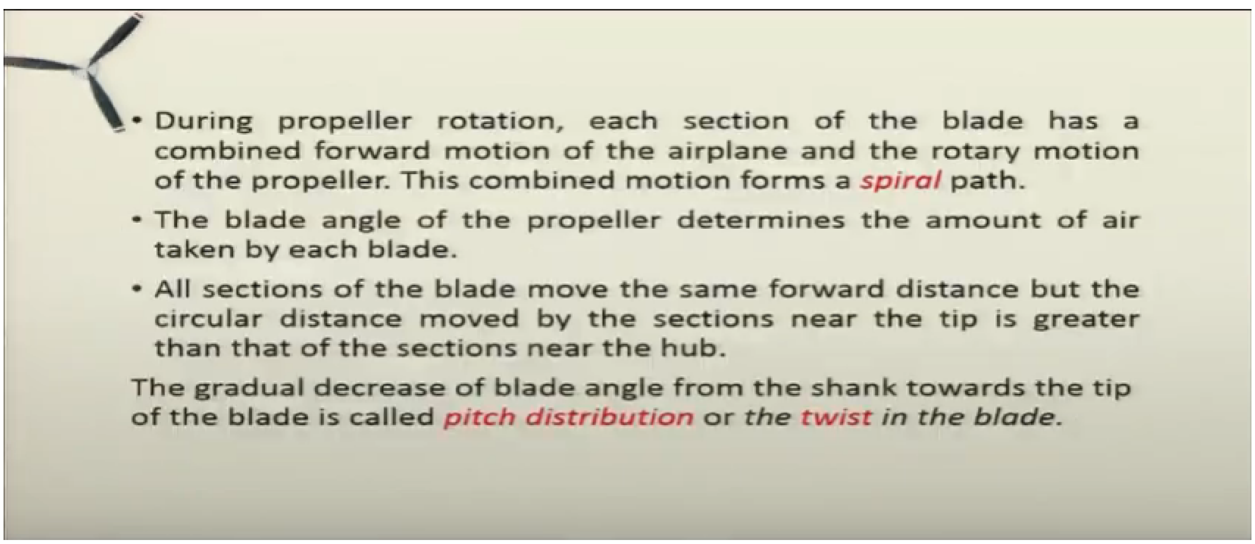

During propeller rotation, each section of the blade has a combined, forward motion of the airplane and rotary motion of the propeller. This combined motion forms a spiral path. Now, each section of the plate, during rotation has a forward movement, as well as, a rotary movement. This forward movement, as well as, the rotary movement, combined together gives a spiral path, it forms a spiral path. The blade angle of the propeller determines the amount of air taken by each blade. Now, the amount of air which is taken by each blade; will depend on the blade angle. All sections of the blade moved the same forward distance, but the circular distance moved by the sections, near the tip is greater than the sections near the hub. The sections which are close to the tip, they travel faster compared to the sections near the hub. The distance moved by the sections near the tip, rather the circular distance moved by the sections near the tip is, greater than that of the sections near the hub. So, the sections near the tip, they are moving, a greater circular distance, as compared to the sections near the hub. Whereas all the sections of the body, they move the same forward distance. So, see same forward distance is being moved by all the sections, but the circular distance is more for the sections near the tip and less for the sections near the hub. The gradual decrease of the blade angle from the shank, towards the tip of the blade is called, ‘Pitch Distribution’ or the, ‘Twist’, in the blade. Now, we have seen that, there is a blade angle, the gradual decrease of blade angle, from the shank towards the tip is termed as, the twist in the blade or it is called the, ‘Pitch Distribution’ of the blade.

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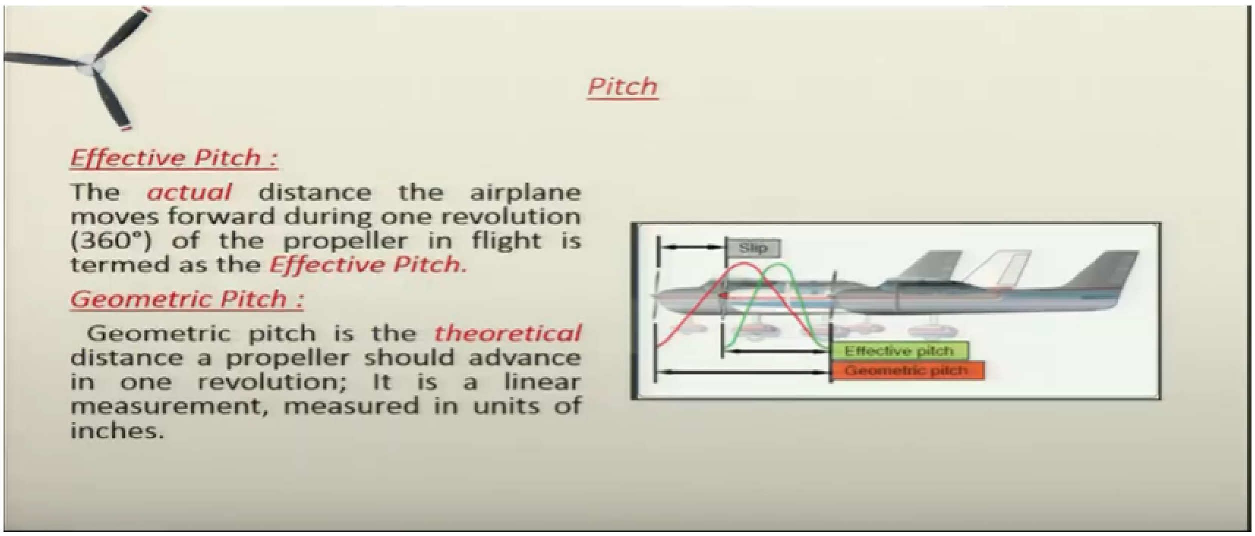

Now, let us see what is pitch? One is effective pitch and another is geometric pitch. Effective pitch is the actual distance, the airplane moves forward during one revolution of the propeller in flight. So, the actual distance moved by the airplane, forward during one revolution of the propeller in flight is termed, as the effective pitch. So, it is the actual distance moved. Geometric pitch is the theoretical distance; a propeller should advance in one revolution. So, geometric pitch is the theoretical distance, a propeller should advance in one revolution, it is a linear measurement, measured in units of inches.

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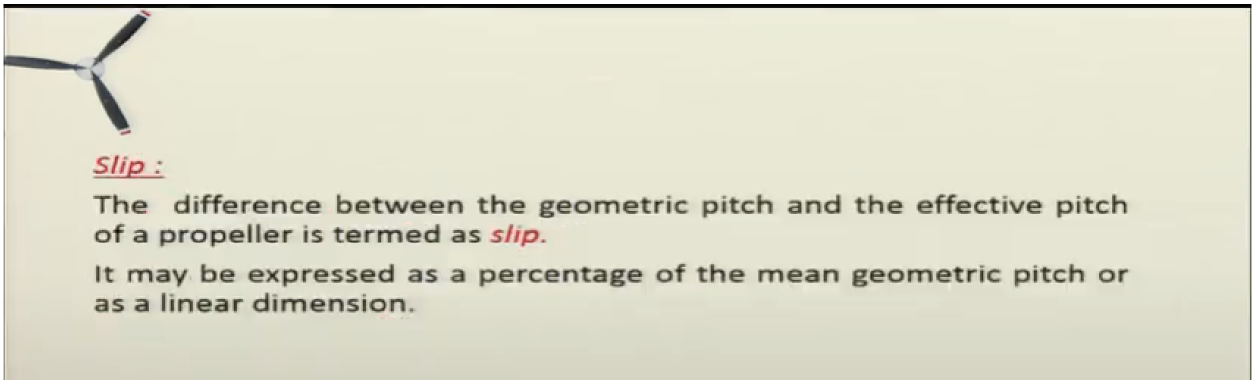

Now, slip what a slip? The difference between the geometric pitch and the effective pitch, of a propeller is termed as slip. So, we have seen in our earlier slide that geometric pitch is the theoretical distance, whereas the effective pitch is the actual distance. So, the difference between the geometric pitch and the effective pitch is termed, as the slip. It may be expressed, as a percentage of the mean geometric pitch or as, a linear dimension. It may be expressed in percentage of the mean geometric pitch.

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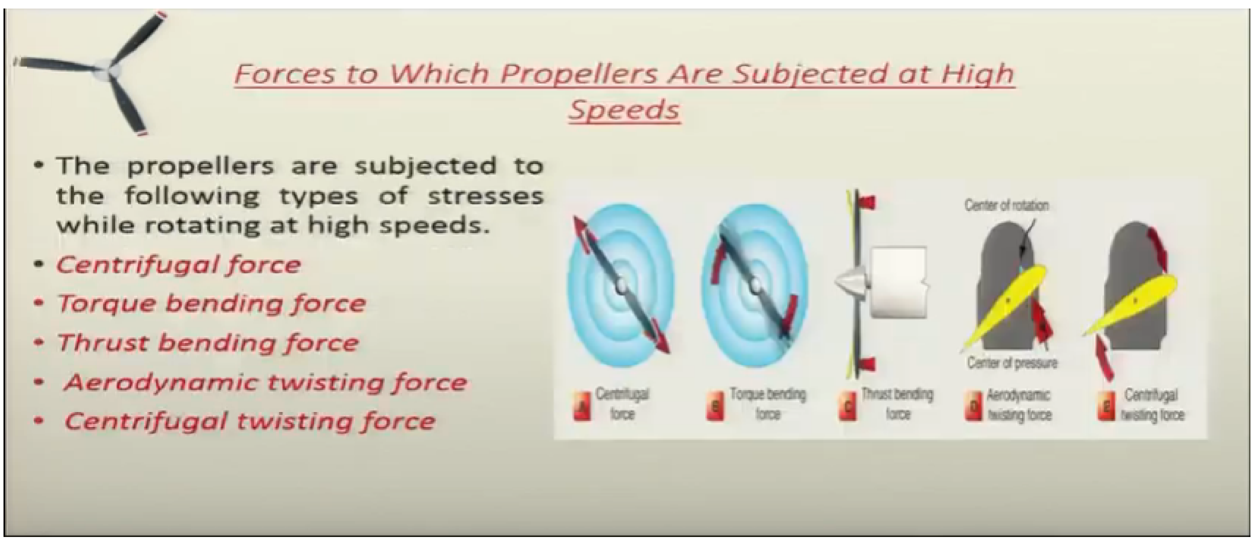

Forces to which propellers are subjected at high speeds. Now, since the propeller is rotating at a very high speed, it is subjected to various forces. Let us see, what are the different forces to which it is subjected, the propellers are subjected to the following types of stresses, while rotating at high speeds. One is the centrifugal force here in the figure, you can see this is your centrifugal force, then you have the torque bending force, this is figure B, you can see this is your talk binding force, then you have the first binding force, figure C this is your first binding force, then D is your aerodynamic twisting force, here you see this is your aerodynamic twisting force and next is your centrifugal twisting force. And the figure E you can see, the centrifugal twisting force. So, the various forces centrifugal force, torque bending force, thrust bending force, aerodynamic twisting force and said it, centrifugal twisting force. So, various forces acting on the propeller blade.

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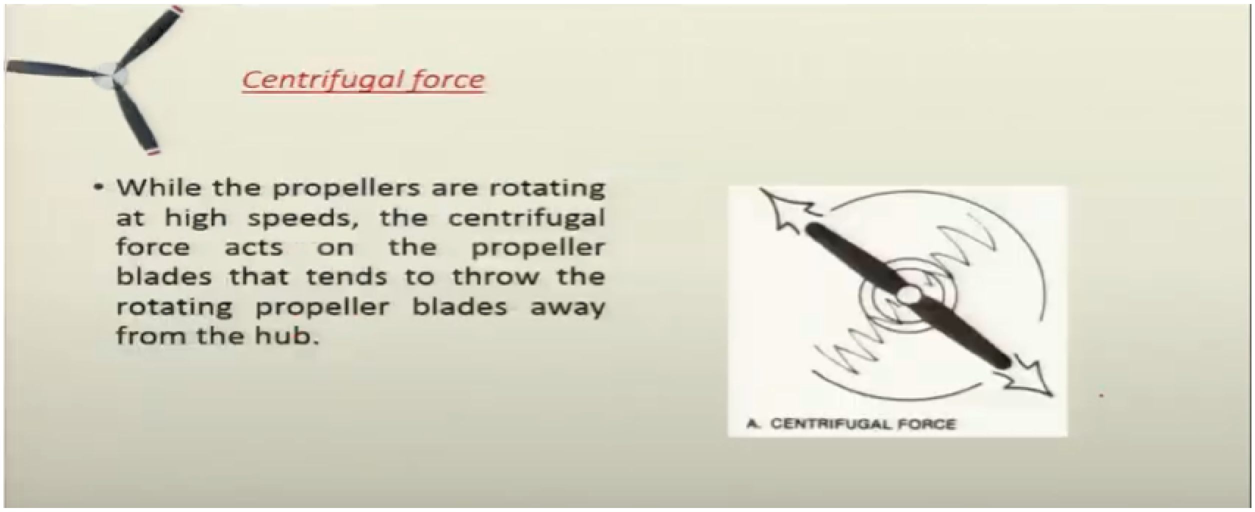

Centrifugal force let us see, what a centrifugal force? While the propellers are rotating at high speeds, the centrifugal force acts on the propeller blades that tends to throw the rotating propeller blades, away from the hub. So, the centrifugal force since the propellers are rotating at a very high speed, the centrifugal force will be acting on the propeller blades and this centrifugal force will tend to throw the problem blades away from the hub. So, in the figure here, you can see the centrifugal force acting on the blades and it tends to throw the blades away from the hub.

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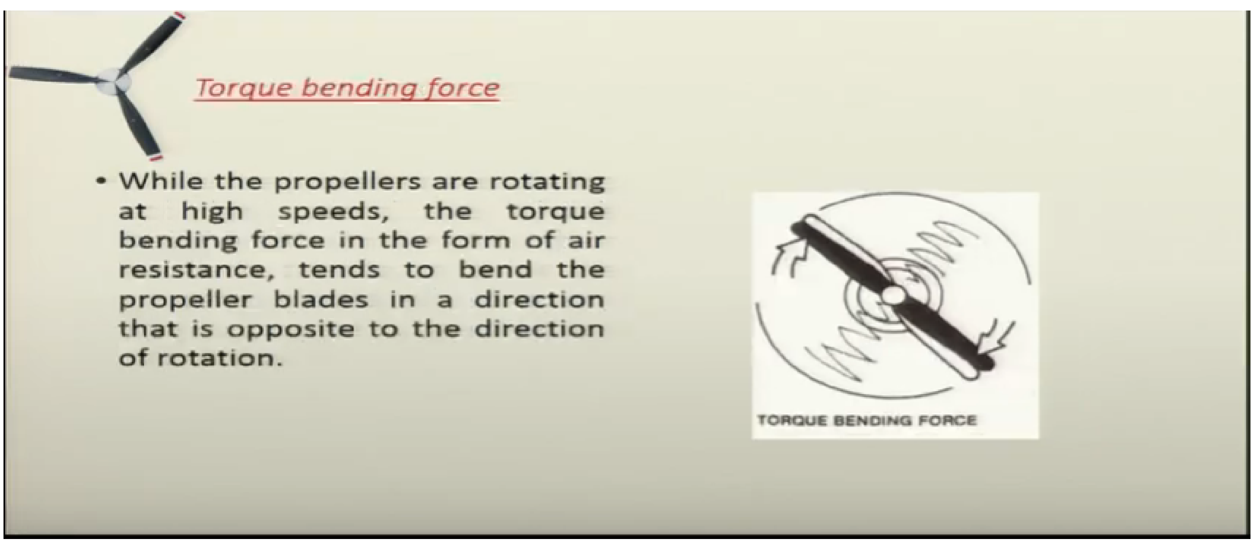

Next is your torque bending force? While the propellers are rotating at high speeds, the talk bending force is the form of air resistance, which tends to bend the propeller blades, in a direction that is opposite to the direction of rotation. So, this call bending force will tend to bend the blades in the direction, opposite to the direction of rotation and it is in the form of air resistance. So, while the propellers are rotating at high speeds, the stall bending force will tend to bend the problem it's in a direction, opposite to the direction of rotation.

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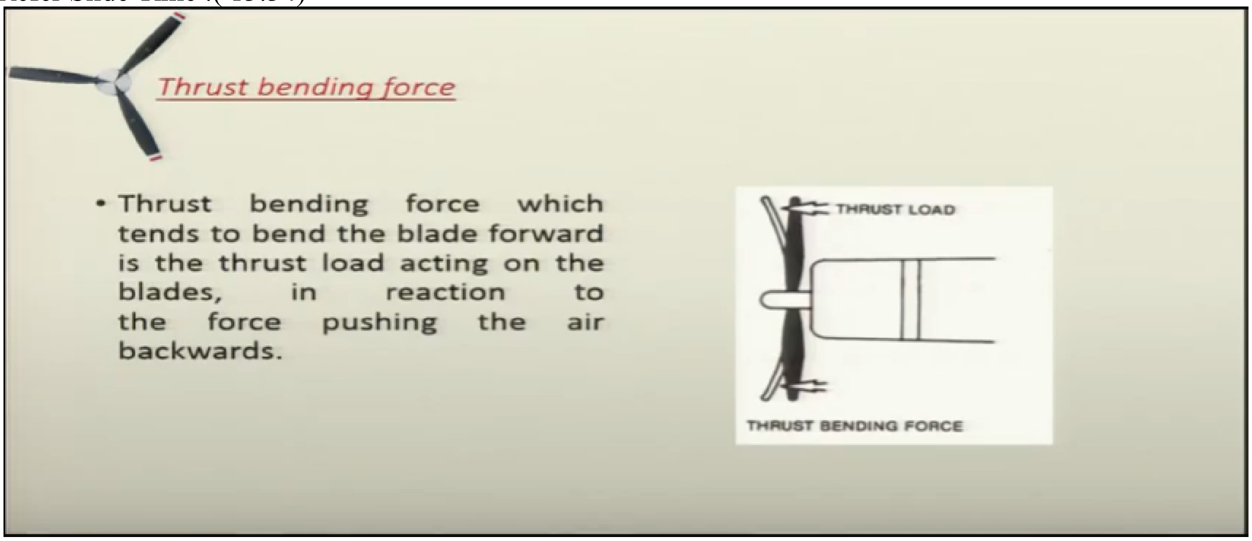

Next is your thrust bending force. First bending force which tends to bend the blade forward is the thrust load, acting on the blades. We all know that, the thrust is acting in the forward direction and because of these thrust loads, the blade, it will tend to Bank the blade forward, in reaction to the forces pushing the air backwards. So thrust bending force, they are they tend to bend the blades, forward in reaction to the force, pushing the air backwards.

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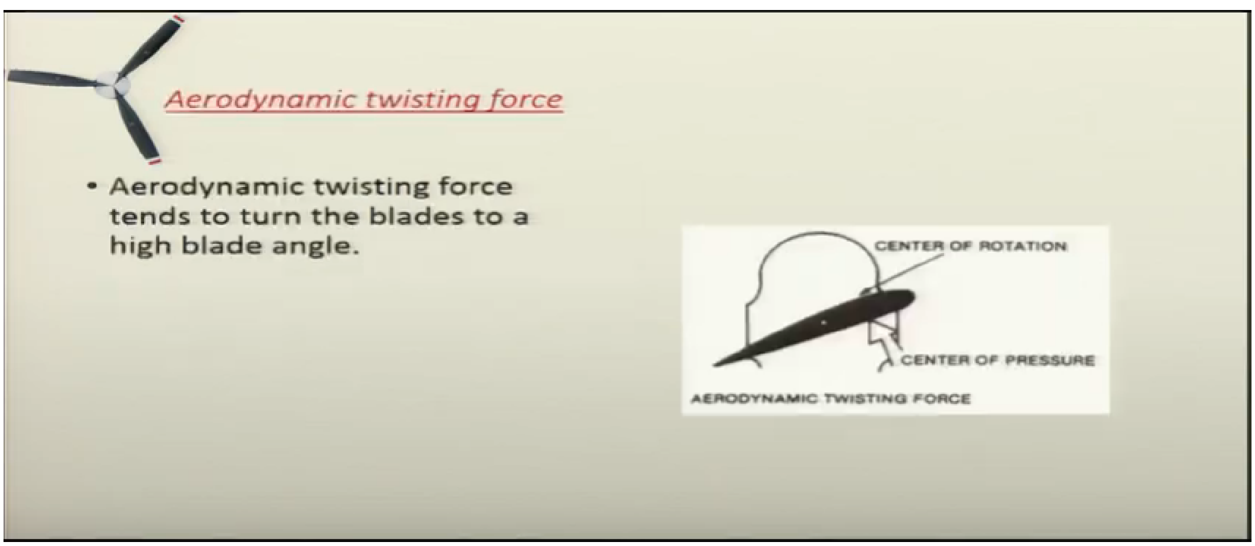

Next is aerodynamic twisting force. We tend to turn the blades to a high blade angle. So, this aerodynamic twisting force will tend to turn the blade, to a higher blade angle.

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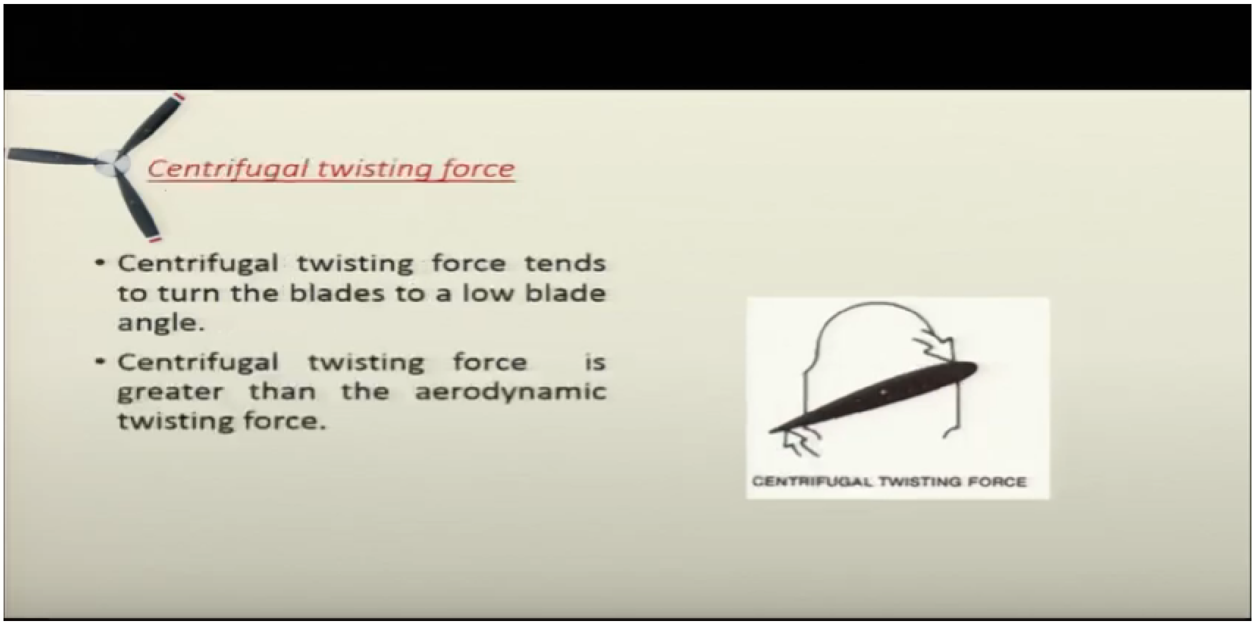

The centrifugal twisting force, this tends to turn the blades to a low blade angle. So we have seen, the aerodynamic twisting force, tends to turn the blades to a high blade angle, whereas the centrifugal twisting force tends to turn the blades to a lower blade angle. And this centrifugal twisting force is greater than, the aerodynamic twisting force. So, on a popular you have, more centrifugal twisting force, as compared to aerodynamic twisting force and this, the centrifugal twisting force will tend to move the blades, to a lower blade angle.

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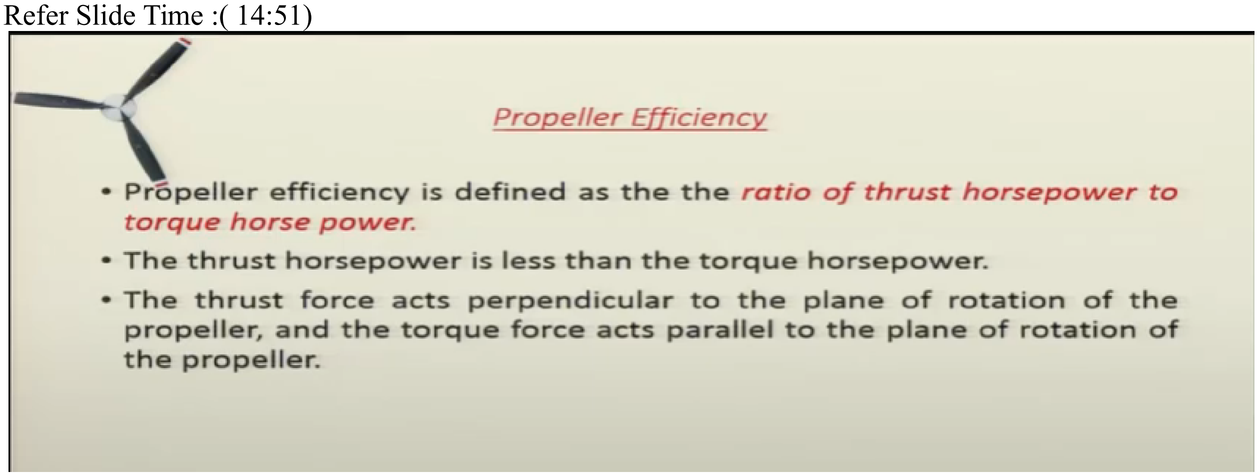

Now, next is propeller efficiency. Now, what is popular efficiency? It is defined as the ratio of first horsepower to torque horsepower. Now, propeller efficiency it is defined as, the ratio of thrust horsepower to torque horsepower. The thrust horsepower is less than the torque horsepower, the thrust force acts perpendicular to the plane of rotation of the propeller and a torque force acts, parallel to the plane of rotation of the propeller. We all know that, the thrust force is acting perpendicular to the plane of rotation, whereas the torque force is acting parallel to the plane of rotation. And propeller efficiency is the ratio of thrust horsepower to tour horsepower and first horsepower is less than the, torque horsepower.

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The cockpit propeller control is blue in color; it has generally located on the central pedestal to the right of the throttle. So, inside the cockpit, you have a cockpit propeller control, which is blue in color and the help of this problem control, you can vary the blade angle of the propeller, you can move the blade, from a high angle to a low angle. The full forward position, of the cockpit of propeller control is the fine pitch or the full increase rpm. So, in case if the propeller control is in the full forward position, then it is this in the fine pitch position or will increase rpm or you can say, a low blade angle and the full F position of the cockpit propeller control is the coast pitch or the decrease rpm or higher blade angle.

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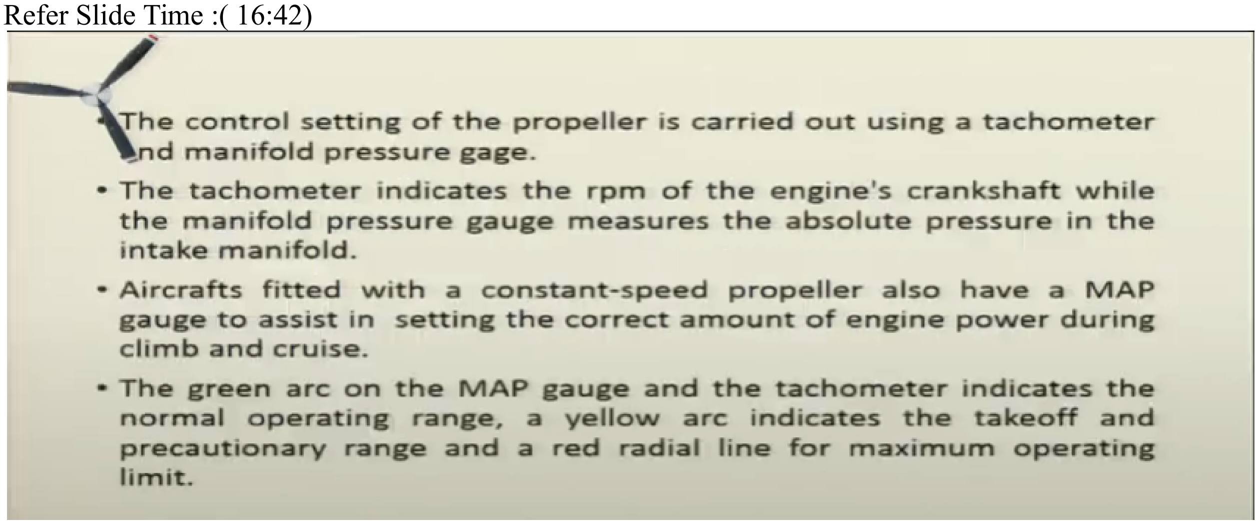

Now, the instruments which are helpful in case of propellers are the tachometer and the manifold pressure gauge, the control setting of the propeller is carried out using these gauges, the tachometer and the manifold pressure gauge, the tachometer indicates the rpm of the engines crankshaft or the propeller, while the manifold pressure gauge, measures the absolute pressure in the intake manifold. So, the two gauges tachometer is giving you the rpm, whereas the manifold pressure gage is giving you the absolute pressure in the intake manifold. A curved fitted with a constant speed propeller; also have a manifold pressure gage, to assist in setting the correct amount of engine power, during climb and cruise. So, the correct amount of power can be set, using manifold pressure gage and aircrafts fitted with a constant speed propeller, will have a manifold pressure gage. All the gauges, you have the green arc, the yellow arc and the red, red line. The green arc is for the normal operating range, the yellow arc indicates the

precautionary range and the red line is the maximum operating limit. So, in case of all the instruments probably, in most of the instruments you will see that, the gauges have the colored markings; Green is for normal operating range, yellow is precautionary range and red is your maximum limit.
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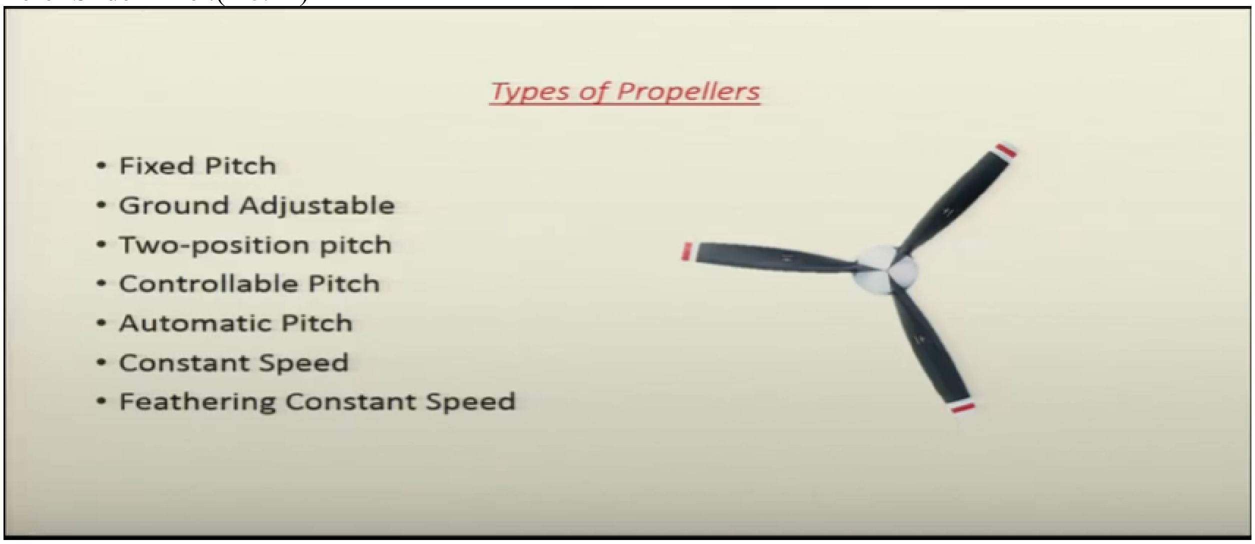

Now, coming to the types of propellers, there are various types of propellers, some of them are fixed pitch propellers, ground adjustable propellers, two position pitch propellers, controllable pitch propellers, automatic pitch, constant speed, feathering constant speed. So, number of types of propellers, let us see them, one by one.
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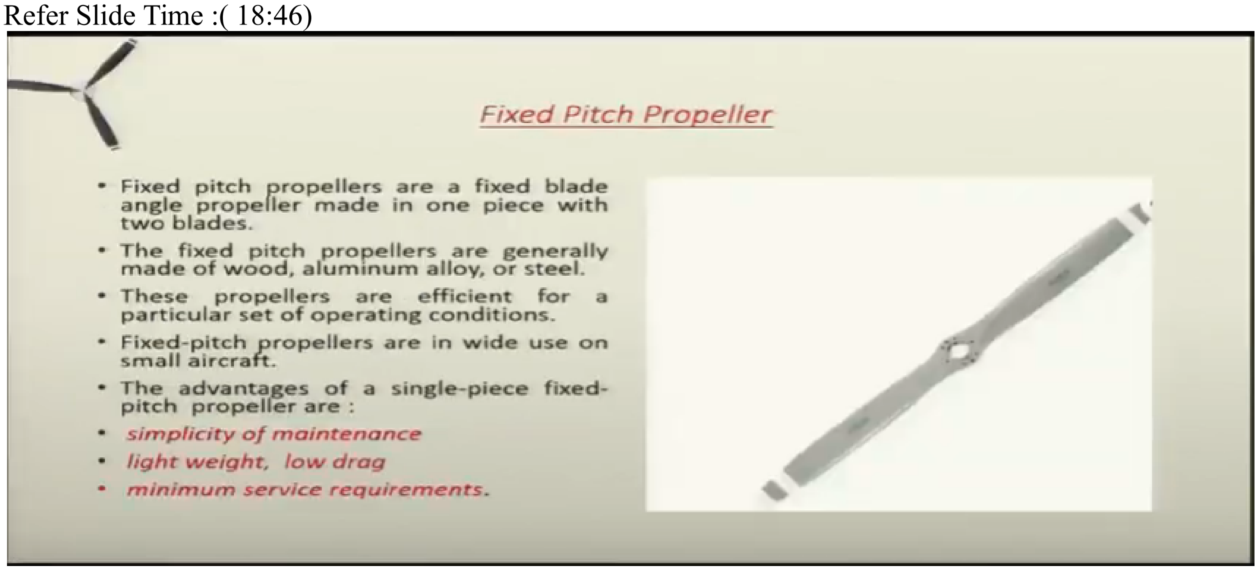

Coming to the fixed pitch propeller. So, the fixed-pitch propellers, they are fixed blade angle propellers and they are made in one piece and have two blades. So, the blade angle is fixed in this case, they are made in one piece and have two blades, they are generally made of wood aluminum alloy or steel. So, the fixed wedge propellers, they are made of wood aluminum of steel, they are of one-piece construction with two blades and have, a fixed blade angle. These propellers are efficient for a particular set of operating conditions. So, they are efficient in one set of operating conditions only. Fixed-pitch propellers are in wide use on small aircrafts, so on small aircrafts fixed-pitch propellers have been, widely used the

advantages of single piece, fixed-pitch propellers are simplicity of maintenance, they are very simple, in maintaining, they are very light in weight, they offer very low drag and have minimum service requirements. So, very simple and construction very simple and maintenance and very few service requirements, this is this type of propeller; fixed-pitch propeller is widely used on small aircrafts.
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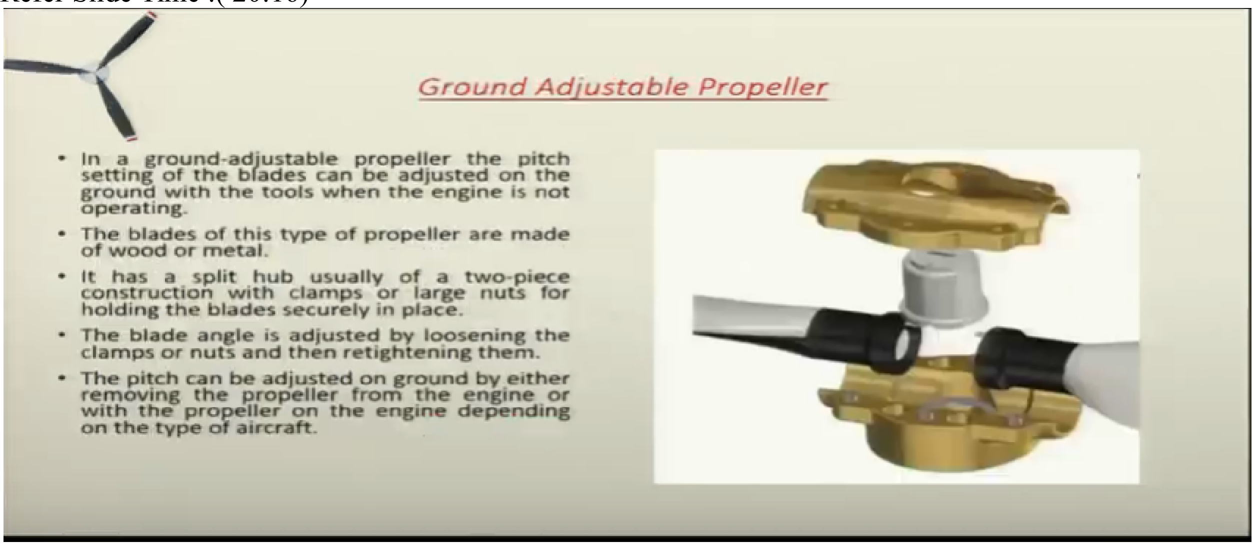

Next is ground adjustable propellers. In a ground adjustable propeller, the pitch setting of the blades can be adjusted on the ground. So, we have seen that in a fixed pitch propeller, there was only one blade setting, it had a fixed blade angle, the blade angle could not be altered. But, in case of ground adjustable propellers, the blade angle can be adjusted. But, only on ground with the help of tools, when the engine is not operating. The blades of this type of propeller are made of either wood or metal, it has a split hub. Usually of a two-piece construction, so you can see here in the figure, the hub is split into two and clamps or large nuts are used for holding the blades, securely in place. So, the clamps or the hold-down nuts, will hold the blades in place, the hub is split in two parts, the blade angle is adjusted by loosening the clamps or nuts and then, retightening them. So, the clamps or the nuts have to be loosened and then, the blade angle adjusted and then, they are again retightening. The pitch can be adjusted on ground, by either removing the propeller from the engine or with the propeller on the engine depending on the type of aircraft. So, in case of ground adjustable propellers, the pitch for adjusting the pitch, either you have to remove the propeller from the aircraft or the pitch setting can be adjusted with the propeller, on the engine, it all depends on the type of aircraft, type of propeller, being used. So, in case of fixed which propellers the blade angle was constant, it was we could not adjust the blade angle, it had a fixed blade angle, whereas in case of a ground adjustable popular. The pitch or the blade angle can be adjusted on the ground, with engine not operating, either propeller fitted on the aircraft or you have to remove the propeller from the aircraft and then adjust it.
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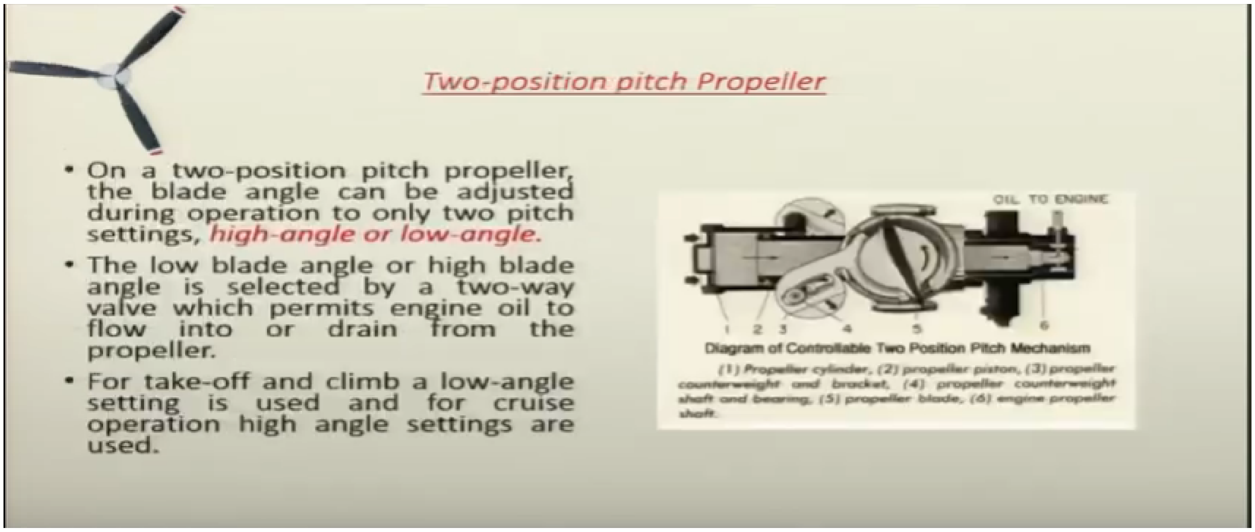

Next is a two position pitch propeller. On a two position pitch propeller, the blade angle can be adjusted, during operation - only to pitch settings. We have seen in case of ground adjustable propeller, the pitch setting could be adjusted only on the ground, when the engine is not operating. But, in case of a two position pitch propeller, you can adjust the pitch, during operation but only 2 pitch settings are possible, a high angle or a low angle. But, this is possible during operation, the low blade angle or the high blade angle is selected by a two-way wall, which permits engine oil to flow into or drain from the propeller. So, this is possible the high blade angle or low blade angle, by selecting a two-way wall, which permits the ancient oil to flow, into the propeller or drain from the propeller. So, a two-way wall makes it possible, for takeoff and climb a lower angle setting is used, because weather look, low angle we get maximum rpm. So, for takeoff incline a low angle setting is used and for cruise operation, high angle settings are used. So, in case of a two-position bit popular, only 2 position, 2 pitch settings are possible but during operation of the engine.

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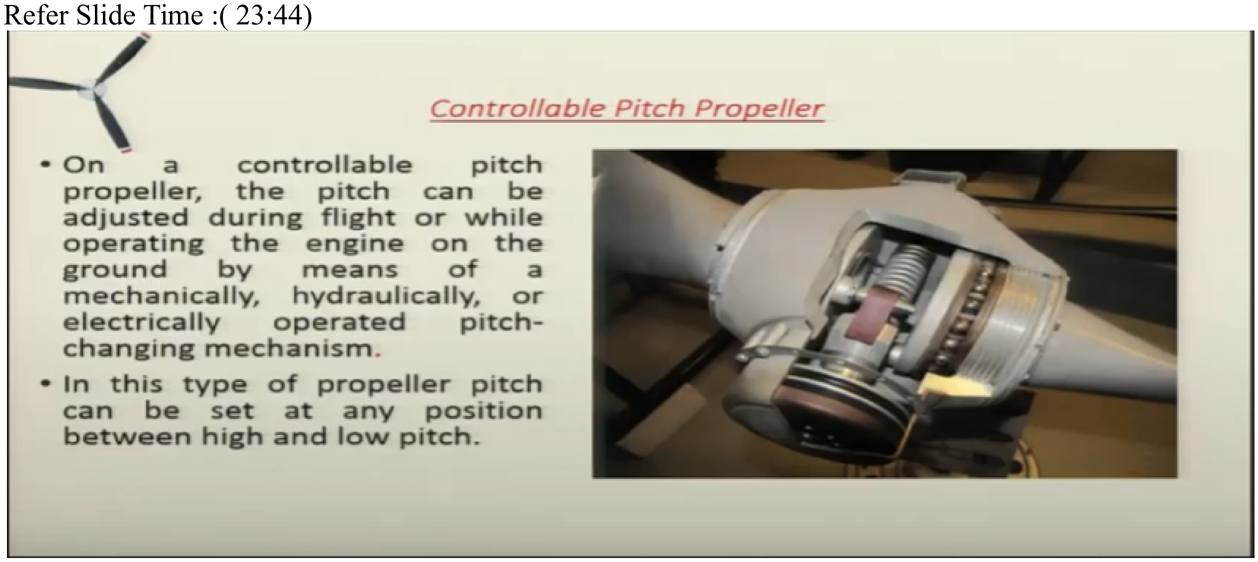

Next is your controllable pitch propeller. On a controllable pitch propeller, the pitch can be adjusted during flight or while operating the engine on the ground, by means of mechanically, hydraulically or electrically operated by changing mechanism. So, in this type of propeller controllable pitch propeller, you can adjust the pitch of the propeller, while the engine in an operation, either on ground or in air by means of the pitch changing mechanism, which may be hydraulic, mechanical or electrically operated. In this type of propeller which can be set at any position, between high and low pitch. So, this type of propeller has the advantage, of setting the pitch, between the high and low pitch, at any position. But, in case of 2 pitch setting, we were able to select the pitch setting, at only to positions, the low pitch and the high pitch. In this case any position is possible, between high and low pinch.

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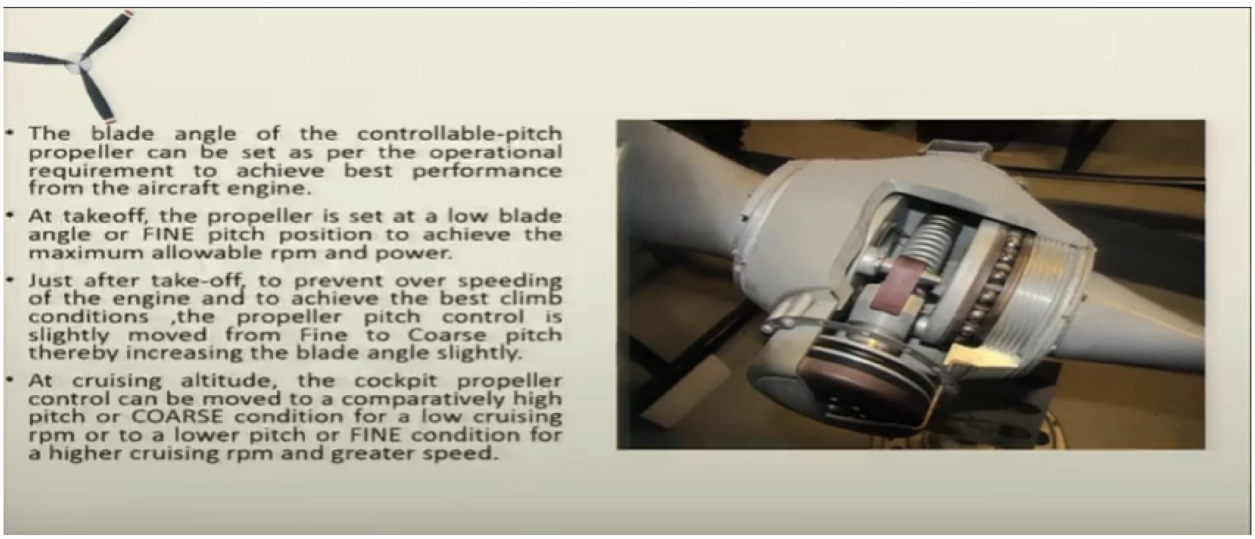

The blade angle of the controllable pitch propeller can be set, as per the operational requirement, to achieve best performance from the aircraft engine. Now, this provision of setting, the pitch at any position between the low and high position, makes it possible to achieve best performance, from the aircraft engine. At takeoff the propellers is set at a low blade angle or fine pitch position, to achieve the maximum allowable, allowable rpm and power. As I have just now told that, during takeoff, we need maximum power, we need maximum rpm. So, during takeoff, the propeller blade angle is set, at a local low angle or we call it a fine pitch position, so that maximum rpm and power is attained. Just after takeoff to prevent over speeding of the engine and to achieve the best climb conditions, the propeller pitch control is slightly moved from fine to coarse pitch, thereby increasing the blade angle slightly. So, just after takeoff, we need to move the propeller control from fine pitch position, to the coarse pitch position that is from low blade angle to high blade angle. So, as to prevent over speeding of the engine and this is only possible. Because, of this propeller where, you have the provision to adjust the pitch setting, at anywhere in-between the low pitch or the high pitch. At cruising altitude, the cockpit propeller control can be moved, to a comparatively high pitch or coarse pitch, for a low closing rpm or to a lower pitch or fine condition, for higher cruising rpm and greater speed. So, you see that in the cruising altitude in the twos condition also, you can adjust the cockpit popular control and set the pitch setting, as per your requirement, for more rpm or forgetting less rpm, the pitch setting can be adjusted accordingly. So, this is only possible because, we have the provision to adjust the pitch, anywhere in between the two extreme positions. So, if you compare it, with the fixed pitch or the ground adjustable was popular, you can see that, the controllable level pitch propeller is has got various advantages it has got more flexibility and we it helps us, to achieve best performance from the aircraft engine.

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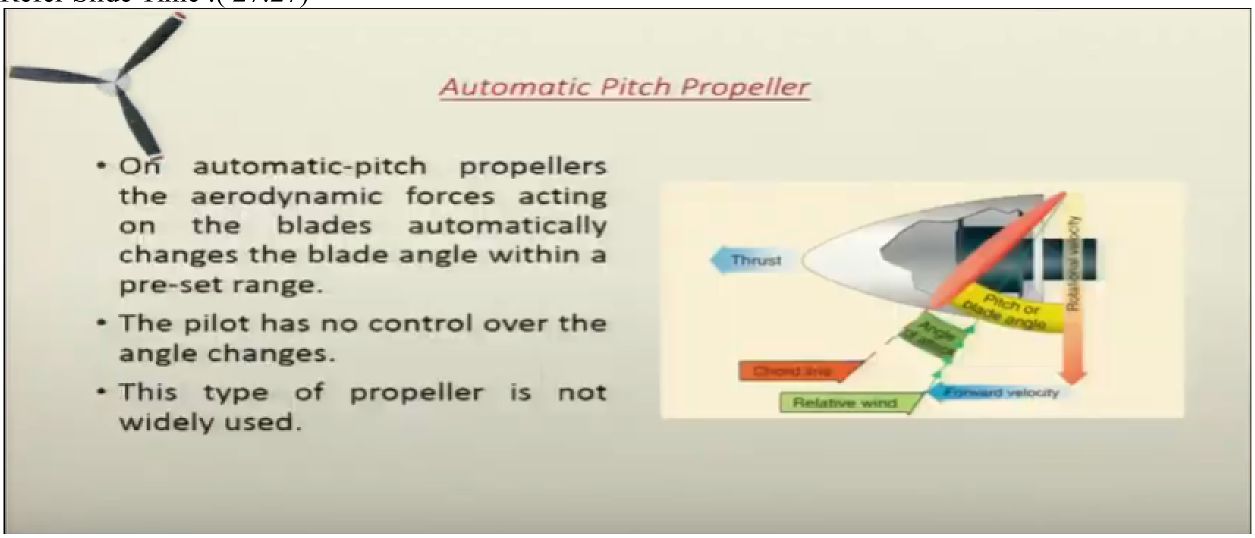

Next is your automatic pitch propeller. Now, this automatic switch propeller is not very popular, it is not being used, not being widely used I will say; that it is because the automatic page propeller aerodynamic forces, acting on the blades will automatically change the blade angle, within a preset range. So now, in this automatic pitch propeller, the pilot is not supposed to do anything, the aerodynamic forces will automatically change the blade angle, within a preset range. So, the pilot has no control, over the angle changes. But, this propeller is not being widely used on the aircraft's.

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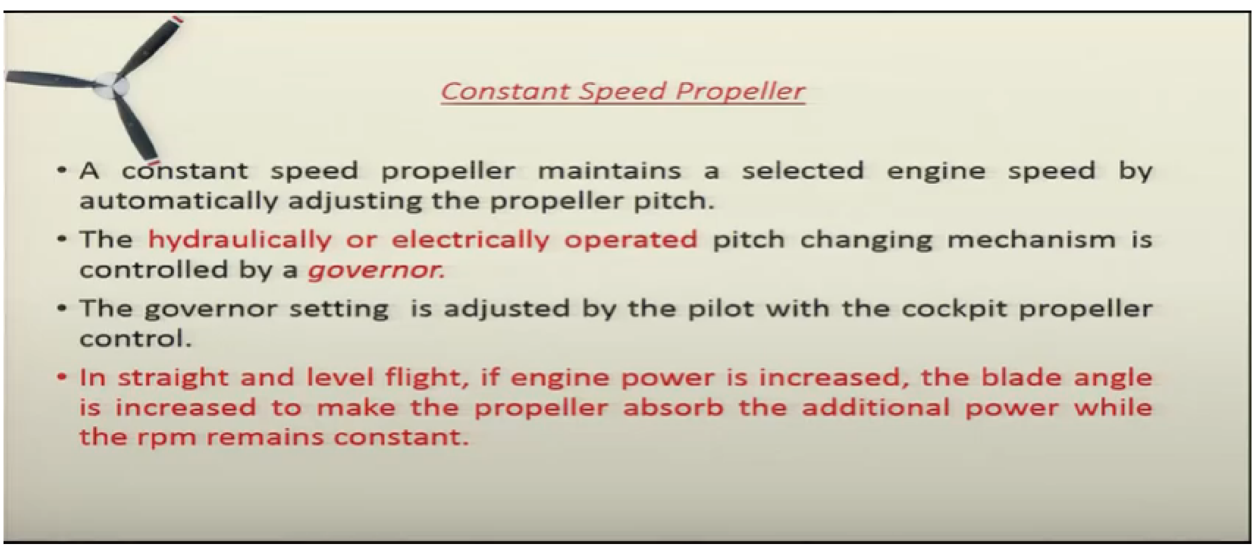

One of the most popular. Propeller used on the aircrafts, on reciprocating engine aircrafts is a constant speed propeller. A constant speed propeller maintains a selected engine speed, by automatically adjusting the propeller pitch. So, this type of propeller, the constant speed propeller, will automatically adjust the pitch, the propeller pitch, in order to maintain a selected engine speed. As the name suggests that it, maintains a constant speed and this propeller, will vary the pitch will automatically adjust the pitch, to maintain the constant speed. The hydraulically or electrically operated by changing mechanism is controlled by a governor. So there is a device called, ‘Governor’. Which will control, the pitch changing mechanism and this pitch changing mechanism, may be hydraulically operated or electrically operated. The governor setting is adjusted by the cockpit with the cockpit propeller control. So, in the cockpit you have, the cockpit propeller control, with that cockpit propeller control, the pilot will adjust the governor setting, in straight and level flight, if the engine power is increased. The blade angle is increased, to make the propeller absorb, the additional power while the rpm remains constant. So, you have seen in straight and level flight, in case the engine power is increased, the blade angle will increase, to make the propeller absorb the additional power, while the rpm will remain constant.

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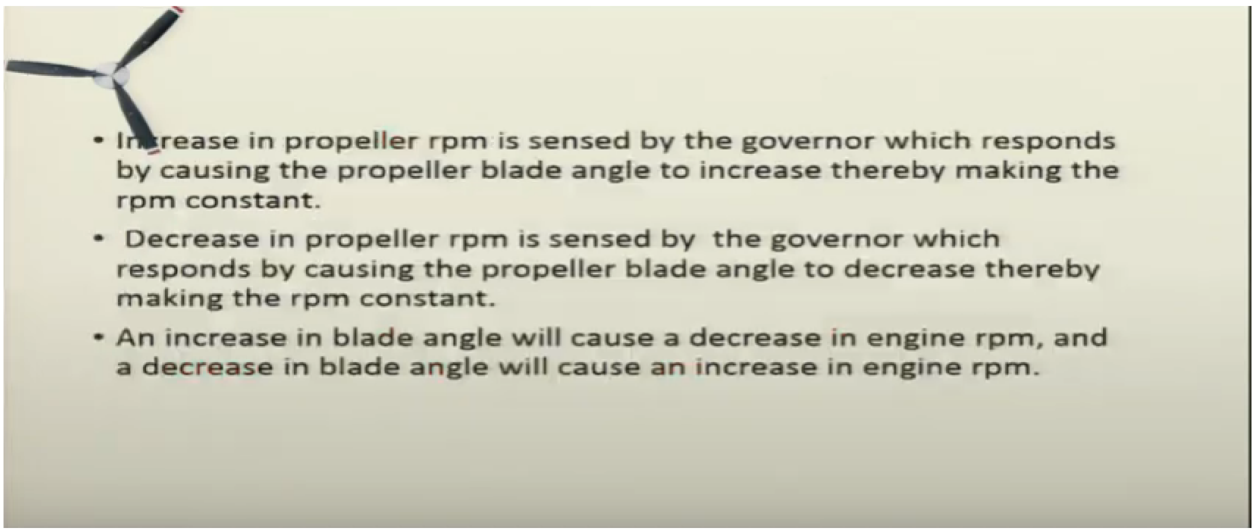

Increase in propeller rpm is sensed by the governor. So, any increase in rpm, so during operation if your propeller rpm increases. So, any increase in rpm will be sensed by the governor. And this governor will respond, by causing the propeller blade angle to increase, thereby making the rpm constant. So now, your rpm has increased, the purpose of the governor, the function of the governor, will be to bring this rpm down. So that the constant speed is maintained. So, in order to do so, the governor will first sense the rpm the increase in rpm, it will respond by increasing the blade angle, so that once the propeller blade angle is increased, it that means, more load is created on the blades, the rpm will decrease and finally the rpm the speed will be constant. Similarly, in case if there is a decrease in propeller rpm, again it will be sensed by the governor, which will cause the propeller blade, to blade angle to decrease, thereby making the rpm constant. Now, when you decrease the blade angle, the load acting on the propeller will decrease, the rpm of the propeller will increase and thus, again we will have a constant speed. An increase in blade angle will cause, a decrease in our engine rpm and a decrease in blade angle, will cause an increase in engine rpm.