<u>“Constant Speed” Propeller Control</u>

Overview:

An aircraft engine is designed to operate over a relatively small range of revolutions per minute (RPM). This is because propellers are limited by rotational speed. Most aircraft engines are “direct drive”. Direct drive means the propeller is connected directly to the engine crankshaft.

The rotational speed of an aircraft propeller is limited by blade tip speed. Aircraft propellers typically operate with the blade tip speed approaching the speed of sound at maximum power. As the tip speed of a propeller begins to exceed the speed of sound, noise increases greatly and efficiency (thrust) falls away. Typically this limits aircraft engines that drive the propeller directly from the end of the crankshaft to around 2700 - 3000 RPM. For engine speeds (RPM) above this range, either a gearbox is fitted (Rotax, Lycoming “GO” series etc) or the propeller diameter is reduced (Jabiru aircraft engines and other small aircraft engines). Fitting a gearbox can add to complexity. Reducing propeller diameter limits the amount of thrust that can be produced and is only suited to smaller engines (typically less than 130 HP).

With a typical fixed pitch propeller, the engine RPM is selected with the throttle. The RPM will only remain constant when the airspeed and air density remain constant. This limitation means that a fixed pitch propeller can really only be designed for “climb” or “cruise” or somewhere in between. With a fixed pitch propeller, engine RPM’s need to be controlled by the throttle as in flight conditions change.

One way aircraft manufacturers overcome the limitations of a fixed pitch propeller is to fit a device called a “Constant Speed Propeller” or CSU. With a CSU, the blades of the propeller can be rotated through a range that allows a lesser pitch for high power settings and a coarser pitch for cruise power settings. Blade angle change is made using oil from the engine pumped through a special pump often called a governor. The governor is a part of a CSU.

During flight, the speed-sensitive governor of the propeller automatically controls the blade angle as required to maintain a constant RPM from the engine.

Three factors tend to vary the RPM of the engine during operation. These factors are **power, airspeed, and air density.** If the RPM is to remain constant, the blade angle must vary directly with power, directly with airspeed, and inversely with air density. The governor provides the means by which the propeller can adjust itself automatically to varying power and flight conditions while converting engine power to thrust.

Fundamental Forces: Three fundamental forces are used to control blade angle. These forces are:

1. Centrifugal twisting moment, centrifugal force acting on a rotating blade which tends at all times to move the blade into **low pitch.**
2. Oil at engine pressure on the outboard piston side, which supplements the centrifugal twisting moment toward **low pitch.**
3. Propeller Governor oil on the inboard piston side, which balances the first two forces and move the blades toward **high pitch**

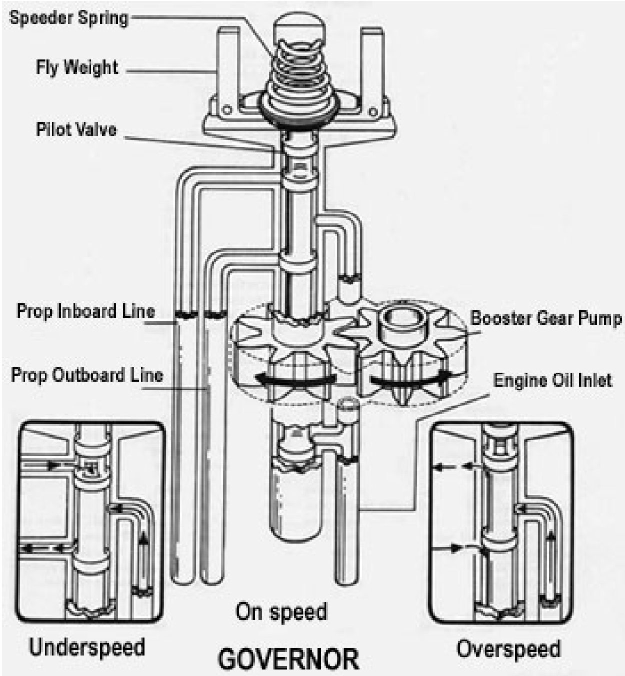
Constant Speed: If an engine driven governor is used, the propeller will operate as a CSU. The propeller and engine speed will be maintained constant at any RPM setting within the operating range of the propeller.

Governor Operation: The Governor supplies and controls the flow of oil to and from the propeller. The engine driven governor receives oil from the engine lubricating system and boost its pressure to that required to operate the pitch-changing mechanism. It consists essentially of:

1. A gear pump to increase the pressure of the engine oil to the pressure required for propeller operation.
2. A relief valve system which regulates the operating pressure in the governor.
3. A pilot valve actuated by flyweights which control the flow of oil through the governor
4. The speeder spring provides a mean by which the initial load on the pilot valve can be changed through the rack and pulley arrangement which controlled by pilot.

The governor maintains the required balance between all three control forces by metering to, or drain from, the inboard side of the propeller piston to maintain the propeller blade angle for constant speed operation.

The governor operates by means of flyweights which control the position of a pilot valve. When the propeller RPM is below that for which the governor is set through the speeder spring by pilot, the governor flyweight moves inward due to less centrifugal force acting on flyweight than on the compression of speeder spring. If the propeller RPM is higher than setting, the flyweight will move outward due to the flyweight having more centrifugal force than compression of speeder spring. During the flyweight moving inward or outward, the pilot valve will move and direct engine oil pressure to the propeller cylinder through the engine propeller shaft.



Flight Operation: This is just only guide line for understanding . The engine or aircraft manufacturers' operating manual should be consulted for each particular aircraft.

Takeoff : Place the governor control in the full forward position . This position is setting the propeller blades to low pitch angle Engine RPM will increase until it reaches the takeoff RPM for which the governor has been set. From this setting, the RPM will be held constant by the governor, which means that full power is available during takeoff and climb.

Cruising: Once the cruising RPM has been set, it will be held constant by the governor. All changes in attitude of the aircraft, altitude, and the engine power can be made without affecting the RPM as long as the blades do not contact the pitch limit stop.

Power Descent: As the airspeed increases during descent, the governor will move the propeller blades to a higher pitch in order to hold the RPM at the desired value.

Approach and Landing: Set the governor to its maximum cruising RPM position during approach. During landing, the governor control should be set in the high RPM position and this moves the blades to full low pitch angle.

When an aircraft engine is fitted with a constant CSU and engine RPM remains constant over a wide range of throttle settings some sort of device needs to be fitted so that the pilot can accurately determine precisely how much throttle needs to be applied to achieve replicable power settings over a range of different altitudes and air densities. The most common device to determine throttle settings is a manifold pressure gauge.

Manifold Pressure Gauge: A manifold pressure gauge is a simple device that measures air pressure inside the aircraft engines manifold. This presents to the pilot a means of adjusting throttle settings while the engine RPM remains constant. When the aircraft engine is stopped the manifold pressure gauge simply measures outside air pressure. This provides a reference that the gauge is indeed working correctly. Pressure is displayed in “inches of mercury” or hg. At sea level this is approximately 29”. As soon as the aircraft engine is started pressure inside the engine manifold falls due to airflow restriction via the throttle butterfly and vacuum generated by the engine pistons sucking in air. As the throttle opens, pressure inside the manifold tends to increase in a linear fashion until, at full throttle it is only just below that of the outside air.

In Flight Operation of a CSU: To avoid overloading the engine the following acronym should be remembered:

To Reduce Power: Throttle back followed by pitch (RPM) back.
To Increase Power: Pitch (RPM) up then throttle up.

"Throttle back, pitch back"
"Pitch up, throttle up"

In flight this equates to taking off with full throttle and with the propeller pitch control to full fine (all the way in). When a power reduction is needed, say for a cruise climb, first the throttle is reduced to a given manifold pressure setting THEN propeller pitch is reduced by winding the constant speed controller out to achieve a desired RPM.

When cruise altitude is attained a further power reduction would be achieved by further reduction of the throttle to another manifold pressure setting followed by further reducing propeller pitch by winding out the CSU controller further to achieve desired RPM.

If power needs to be increased again, say to again initiate a climb, first RPM would be increased by winding in the CSU control then throttle would be opened to achieve a given manifold pressure setting.

At the top of climb again it would be "Throttle Back" followed by "Pitch Back".

Remember: Air density falls as altitude is gained. Therefore as an aircraft climbs, manifold pressure will reduce if the throttle remains in a constant position. As the aircraft climbs manifold pressure should be kept constant by monitoring the manifold pressure gauge and increasing the throttle as required. Eventually "full throttle height" will be reached when the throttle is wide open but pressure continues to fall. To maintain manifold pressure after full throttle height is reached requires either a turbo charger or a supercharger or both. (Turbo or supercharging increases engine power by increasing manifold pressure).

Conversely, of you begin a descent from altitude, manifold pressure will need to be reduced as the aircraft descends into more dense air.

Typical Power Settings: (Note: For correct settings refer to aircraft flight manual or aircraft engine operation guide).

Take off: Full fine and full throttle. This is 100% engine power.
Cruise climb: Reduce throttle to 25" manifold pressure then reduce pitch (RPM) to 2500. This is often referred to as 25/25 and usually equates to around 75% of maximum engine power.
High power cruise: 25/25 (75%)
Medium power cruise: 23/23 (65%)
Economy cruise: 20/23 (55%)
Loiter power for observation etc: 15/20

Or any other combination as per the aircraft engine operation handbook.

Other variations: Running "oversquare" is often not recommended. Oversquare would be having manifold pressure exceed RPM eg 25 hg manifold pressure and say 2400 RPM (25/24). In reality oversquare operations can often achieve high degrees of fuel efficiency but need to be done carefully in accordance with engine manufacturer guidelines.

One example of "oversquare" that is commonly used however is to simply reduce engine RPM slightly after takeoff while keeping the throttle full open. This is often done in noise sensitive areas to reduce propeller noise while still maintaining a high power setting (around 90%) Typically this could be by simply reducing engine RPM to 2500 while keeping the throttle full open.

Pre Flight Inspection: As part of a pre flight inspection a CSU propeller should be checked for oil and or grease leaks. Typically these will first become evident if a thin greasy film appears on the propeller blades or aircraft window.

Pre Take Off Check: Prior to the first take off of the day a CSU should be cycled 2 – 3 times. Cycling the unit will mix cold oil inside the governor into the engine and ensure smooth operation when the CSU is first adjusted. Cycling the CSU will also indicate that the unit is working correctly.

To cycle a CSU, typically the engine is first warmed, then after a magneto check, and with the engine still at magneto check speed the CSU control is pulled smoothly out to its full extent. As soon as the engine note changes the CSU control should be smoothly returned back to the full in position.

Extending Aircraft Glide Range: In the event of an engine failure the propeller control should be moved to the full coarse position (all the way out). Provided the engine is still turning over this mill move the blade pitch to full coarse. This will reduce propeller drag and extend the glide range noticeably. This can be simulated during simulated engine failure however it should be noted that the propeller control should be moved back to the fine (full in) position BEFORE reapplying power.