For a propeller driven aircraft, thrust is produced by a propeller converting the shaft torque into propulsive force, and depends on the propeller efficiency [1]. However, propeller efficiency depends on the propeller angle of attack, consequently on the advance ratio given by

\[ J = \frac{V}{nD} \]

where \( V \) is the forward velocity of the aircraft, \( n \) is the rotational speed and \( D \) is the diameter of the propeller. Thus, for a constant RPM, propeller efficiency depends on the forward velocity of the aircraft as shown in Figure 1.

![Figure 1 Efficiency versus advance ratio for a fixed pitch propeller [2].](image)

If the propeller is a fixed pitch propeller, for a constant RPM, there is only one forward velocity where the efficiency reaches to a maximum. Consider the drawing given in Figure 2 where the forward velocity, blade angle, angle of attack, and rotational velocity relations are shown. If the blade angle is fixed, hence the propeller is fixed pitch, angle of attack will decrease as the forward velocity of aircraft increases. Although this will result in an efficiency increase initially, further velocity increase will bring the angle of attack to zero, and the propeller will not be able to generate thrust. In order to avoid this, variable pitch
or constant speed propellers are used. Figure 3 shows how the efficiency of a variable pitch propeller varies with the advance ratio.

Figure 2 Propeller blade angle [3].

Figure 3 Efficiency of a variable pitch propeller [2].
For a variable pitch propeller, the device called “propeller governor” changes the propeller pitch to a higher blade angle, as the forward velocity of the aircraft increases. Therefore, maximum efficiency is obtained for a wide range of forward velocities from take-off to cruise. In case of fixed pitch propellers, they are designed to provide optimum efficiency for only one flight phase, either climb or cruise, thus take-off performance is poor with the fixed pitch propellers.

References

