

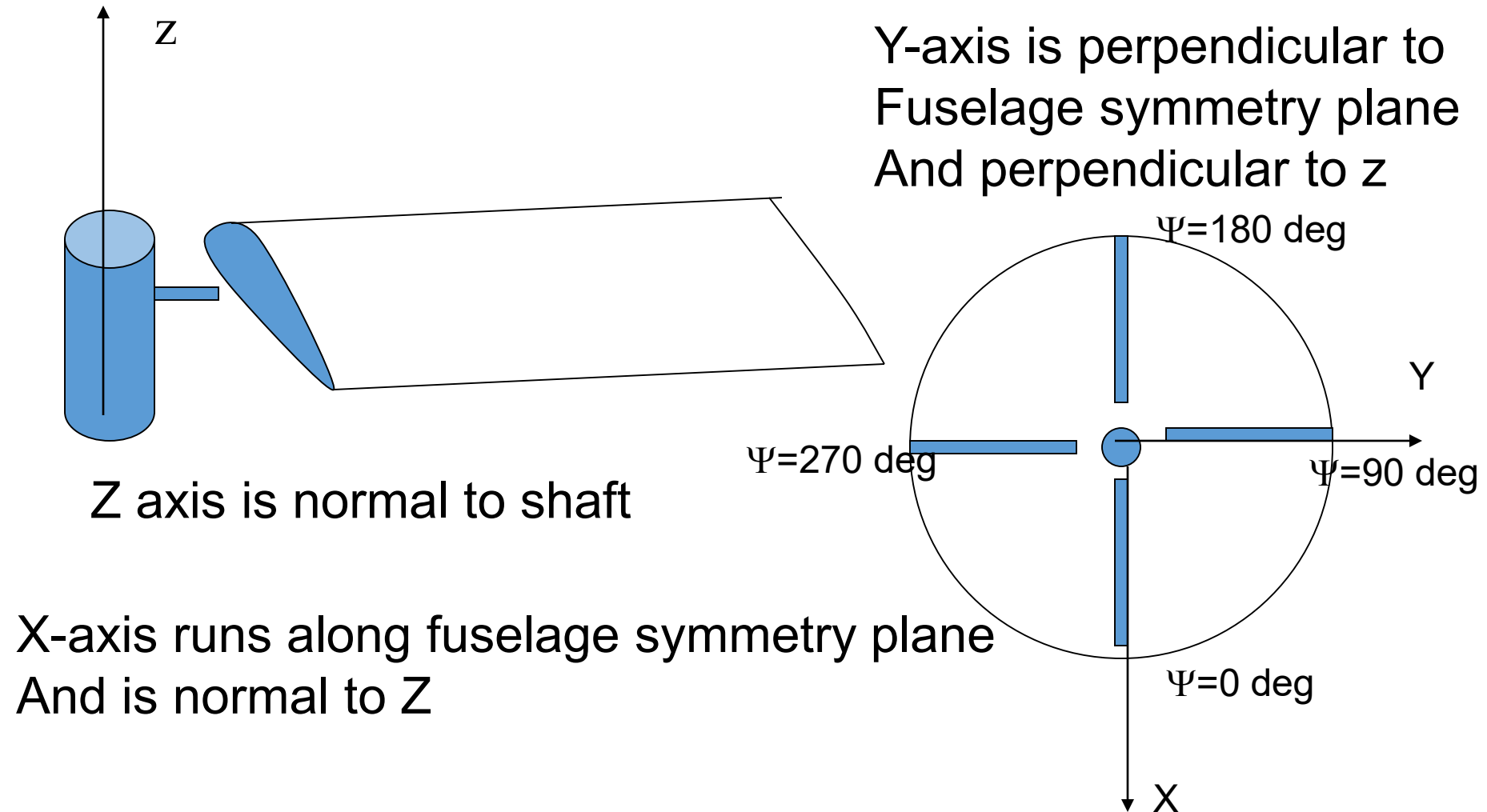
Forward Flight

Rotor Coordinate Systems

Coordinate Systems

- Before we start defining the blade motion, and the blade angular positions, it is necessary to define what is the coordinate system to use.
- Unfortunately, there are many possible coordinate systems. No unique choice.

Hub Plane



Tip Path Plane

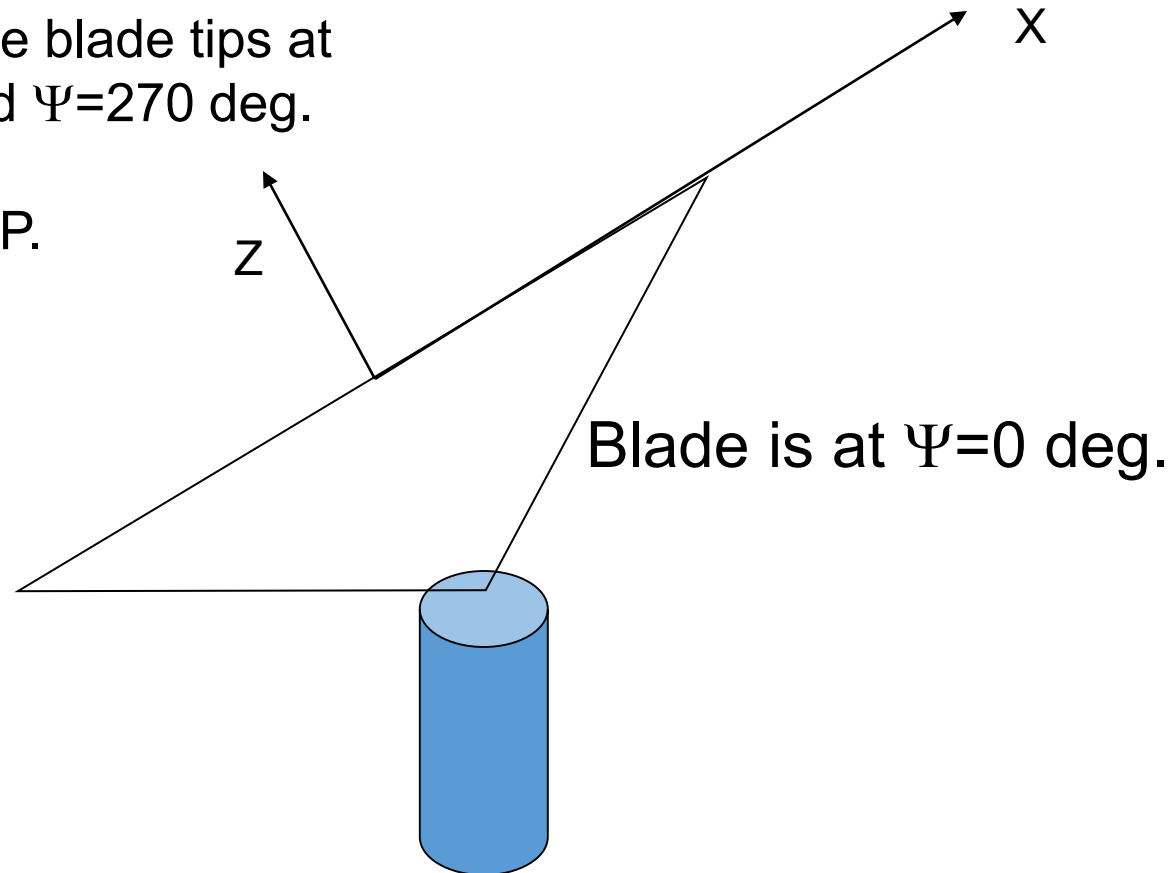
This plane is defined by two straight lines.

The first connects the blade tips at azimuth angle $\Psi=0$ and $\Psi=180$ deg.

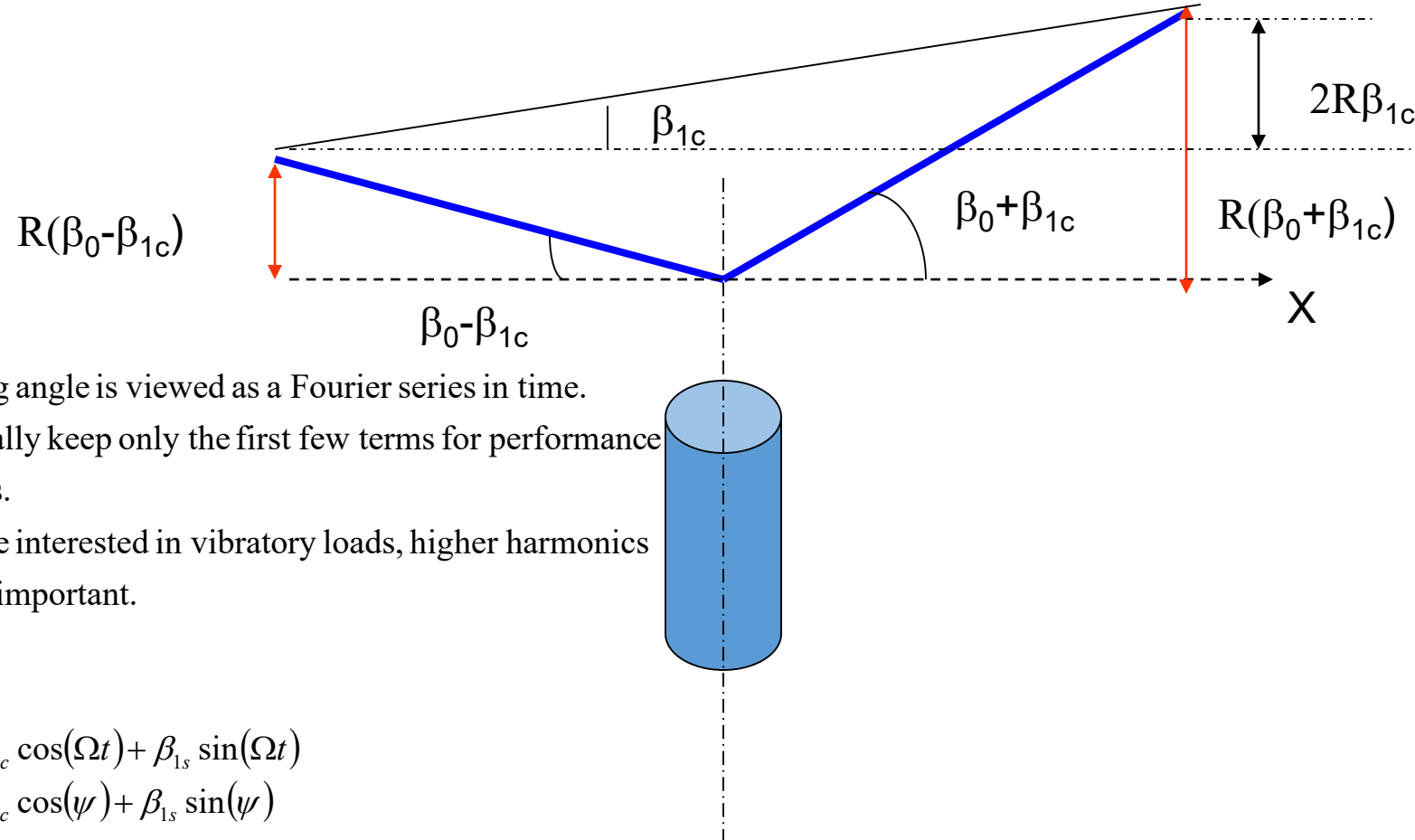
The second connects the blade tips at azimuth angle $\Psi=90$ and $\Psi=270$ deg.

Z is perpendicular to TPP.

In TPP, the blade
Does not appear to be
Flapping..



Tip Path Plane



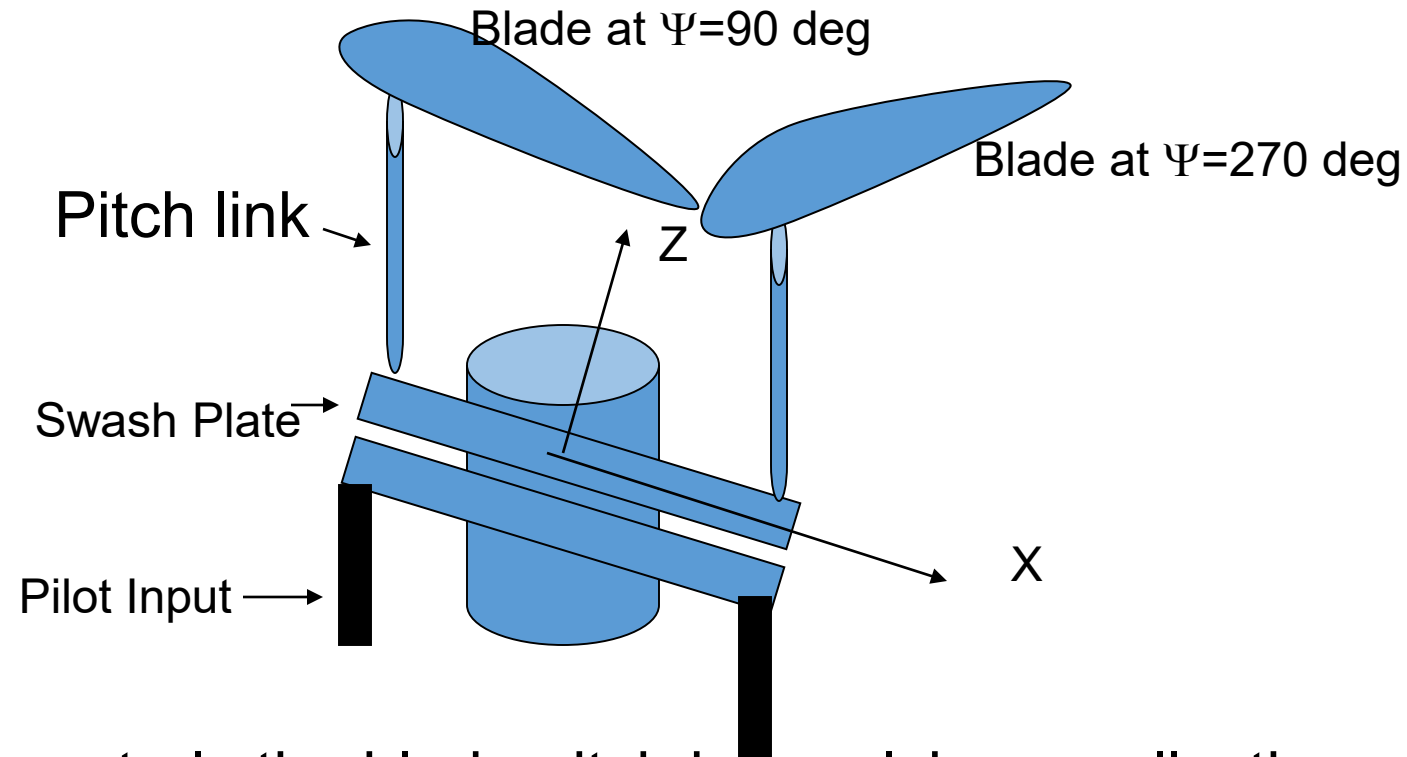
Flapping angle is viewed as a Fourier series in time.

We usually keep only the first few terms for performance analyses.

If we are interested in vibratory loads, higher harmonics are also important.

$$\begin{aligned}\beta &\cong \beta_0 + \beta_{1c} \cos(\Omega t) + \beta_{1s} \sin(\Omega t) \\ &= \beta_0 + \beta_{1c} \cos(\psi) + \beta_{1s} \sin(\psi)\end{aligned}$$

No-Feathering Plane (NFP)



The pilot controls the blade pitch by applying a collective control (all blades pitch up or down by the same amount), or by a cyclic control (which involves tilting the swash-plate). Some of the pitch links move up, while others move down. The airfoils connected pitch up or down).

Differences between Various Systems

- For an observer sitting on the tip path plane, the blade tips appear to be touching the plane all the time. There is no flapping motion in this coordinate system.
- For an observer sitting on the swash plate, the pitch links will appear to be stationary. There is no vertical up or down motion of the pitch links, and no pitching motion of the blades either.
- In the shaft plane, the blades will appear to pitch and flap, both.
- One can use any one of these coordinate systems for blade element theory. Some coordinate systems are easier to work with. For example, in the TPP we can set the flapping motion to zero.