

Bladed aerodynamics geometry assumptions up to v4.7

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Author: Phil Bradstock

Checked: Will Collier

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Updated document title and included reference to later Bladed versions

1 OVERVIEW

This document describes some assumptions made in the aerodynamics calculation in Bladed 4.3-4.7. Note that this information does **not** apply to the new aerodynamics implementation, which is used in Bladed 4.8 and later versions (and is also available in beta in Bladed 4.7).

Basic rotor geometric is described in section 2.

The velocities incident to the blade aerodynamic sections must be determined, allowing calculation of the section lift, drag and pitching moment. This is described in section 3.

These calculated loads must be applied to the Bladed structural model in order to determine the structural response and calculate loads. This process is described in section 4.

2 ROTOR GEOMETRY DEFINITIONS

A blade and rotor definition is illustrated in Figure 2-1, viewed from the side.

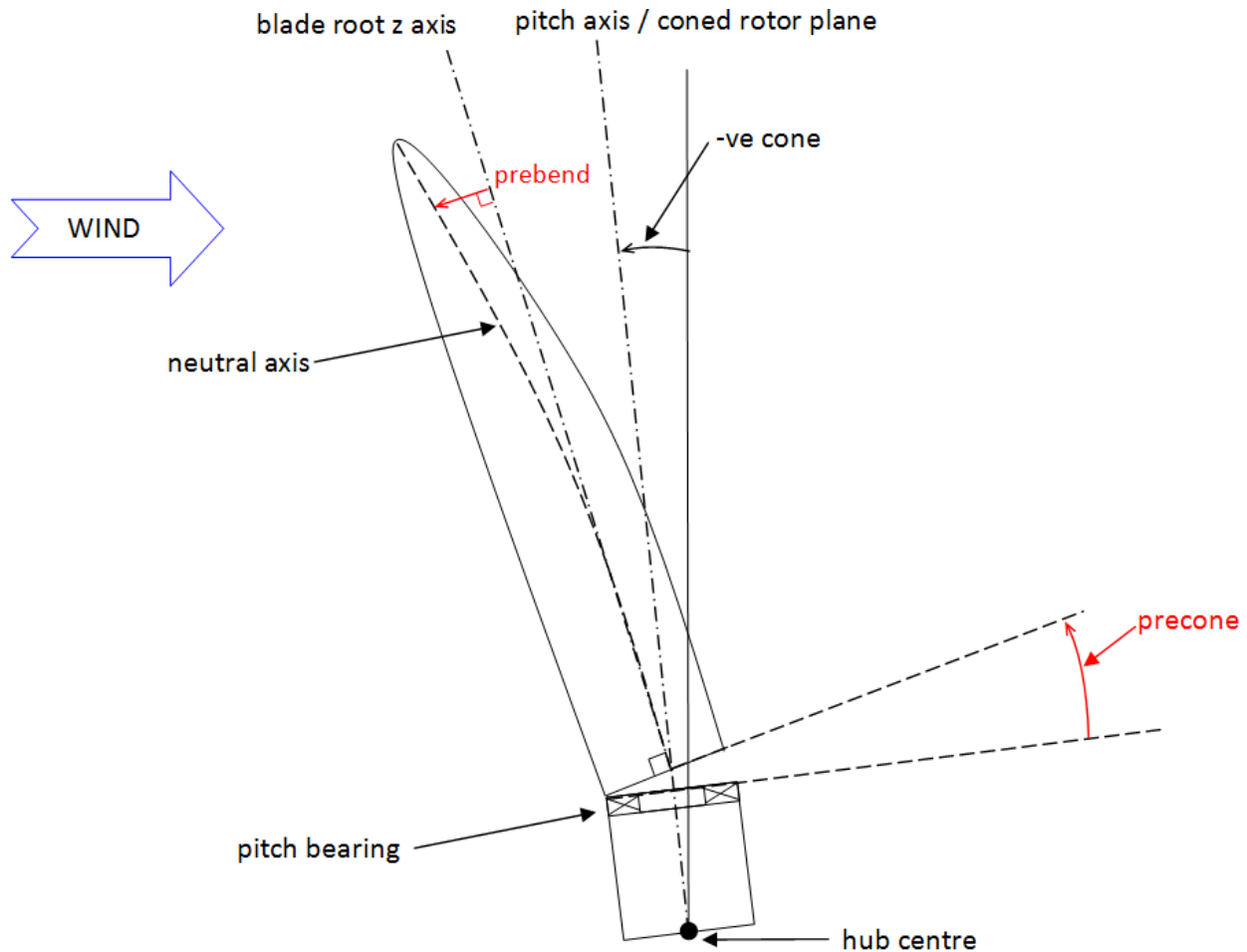


Figure 2-1: Rotor geometry definitions

The following key terms are defined:

- **Prebend:** An offset of the blade neutral axis from the blade root z axis. Note that the term **sweep** is used for a similar offset in the orthogonal direction. These offsets also cause a rotation of the blade neutral axis relative to the pitch axis.
- **Pre-cone:** A blade mounting rotation in between the pitch bearing and blade root. Note that the term **pre-sweep** is used for a similar offset in the orthogonal direction.
- **Coned rotor plane:** The cone-shaped plane that is swept through by the pitch axis as the rotor rotates.

3 RELATIVE WIND VELOCITY

To calculate the aerodynamic forces generated along the blade, it is necessary to determine the velocity of the wind *relative* to the blade section velocity. Calculation of the wind velocity and the blade velocity are described in this section.

The relative velocity is calculated at each blade station according to:

$$\text{Relative wind velocity} = \text{Wind velocity} - \text{Blade station velocity}$$

This equation is performed by calculating the wind and blade velocities in the "in coned rotor plane" and "out of coned rotor plane" directions. These directions are illustrated in Figure 3-1. Ideally this relative velocity calculation would be done in the local neutral axis frame, but this is not the always the case in the Bladed aerodynamics, as explained in this section.

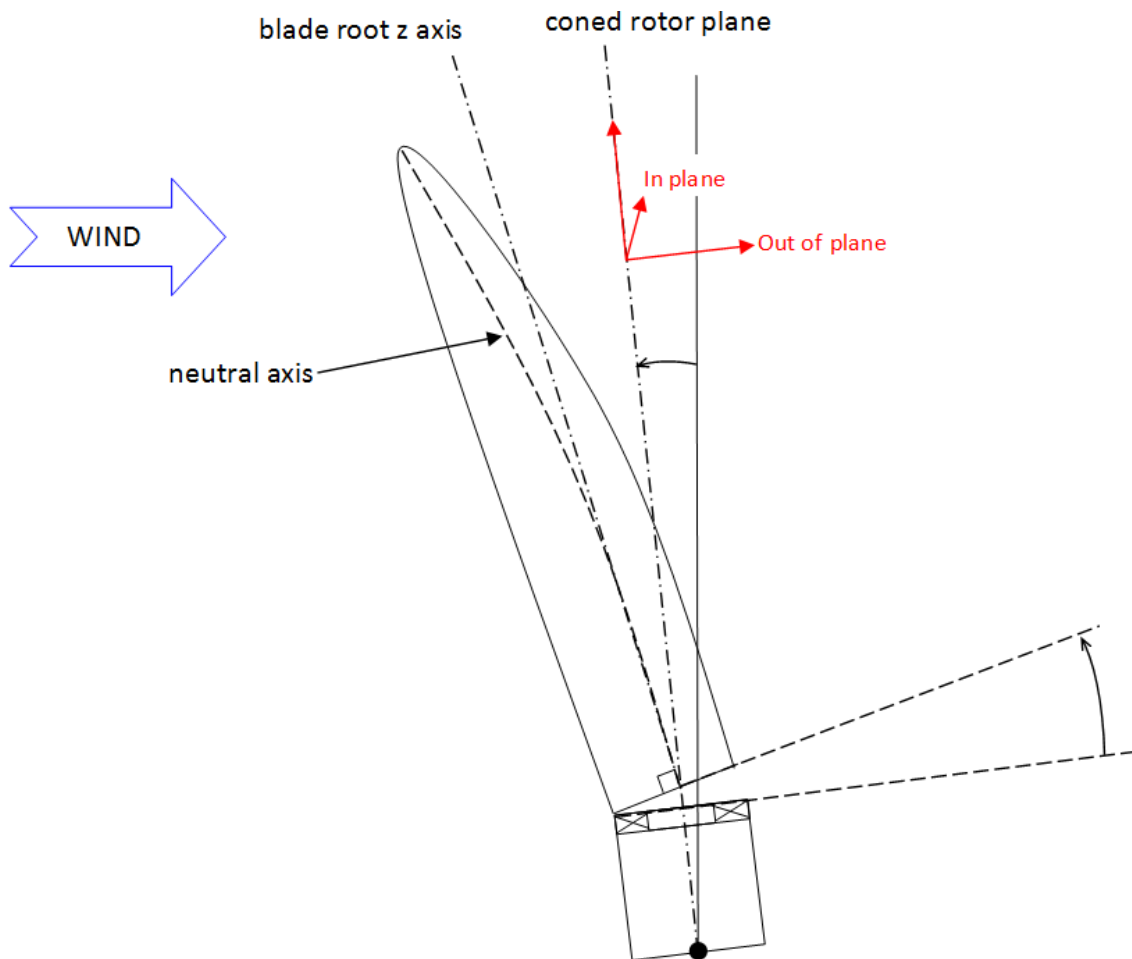


Figure 3-1: Illustration of "in plane" and "out of plane" directions

3.1 Wind Velocities

The wind velocity in global coordinates is taken from the wind file at the true position of the **elastic** axis. The effect of cone, pre-cone, pre-sweep, pre-bend, sweep and blade deflection on *position* of the elastic axis in the wind field are all taken into account. This global wind velocity includes the effect of upflow and wind direction.

A transformation (rotation) into the coned rotor plane is performed to calculate the in-plane and out-of-plane velocities at each blade station, accounting for:

- Azimuth
- Yaw misalignment
- Tilt
- Cone angle
- Teeter angle

The calculated wind velocities in the coned rotor plane are denoted u_{ip} and u_{oop} . Note that change in blade section orientation due to **pre-cone** and **pre-sweep** at the blade root, and **sweep** and **pre-bend** within the blade geometry are not included in this transformation.

3.2 Blade Velocities

The blade velocities are obtained from the structural model at the **elastic** axis. These velocities are expressed in the coned rotor plane coordinate system for comparison with the wind velocity.

The blade velocities are taken from the structural dynamics at the **neutral (elastic)** axis, but are then transformed to the **aerodynamic** axis by the following equations (assuming clockwise rotor):

$$v_{oop}^a = v_{oop}^e - c \left(y_{cs} - \frac{1}{4} \right) \dot{\beta} \cos \beta$$
$$v_{ip}^a = v_{ip}^e + c \left(y_{cs} - \frac{1}{4} \right) \dot{\beta} \cos \beta$$

Where β is the pitch + twist + torsional deflection, c is the chord length, y_{cs} is the shear centre offset along the chord and the superscripts a and e represent the aerodynamic and elastic axes respectively.

3.3 Relative Velocities

The relative velocities in the coned rotor plane at each blade station are then calculated as

$$v_{op,rel} = u_{oop} - v_{oop}^a$$
$$v_{ip,rel} = u_{ip} - v_{ip}^a$$

4 APPLIED LOADS

Once the generated aerodynamic forces have been calculated, these forces must be applied to the structural model, in order to determine the structural response and loads.

Aerodynamic loads are calculated at the blade stations, and then applied as *distributed* loads along the whole blade element, assuming a linear variation in load.

Generally, the loads are applied in the coned rotor coordinate system. An exception to this is when accounting for pre-cone and pre-sweep as discussed below.

4.1 Blade sweep and pre-bend

Sweep and **pre-bend** within the blade definition do not change the orientation in which the aerodynamic loads are applied to the structural model, as illustrated in Figure 4-1. This is equivalent to assuming that the aerofoil axes are parallel to the blade root axes Z direction.

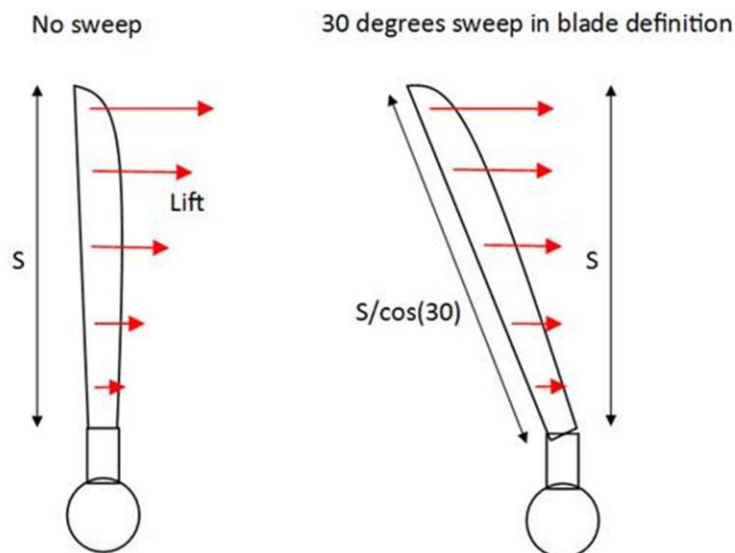
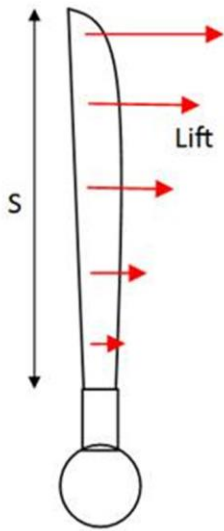


Figure 4-1: Effect of sweep or pre-bend when applying aerodynamic forces

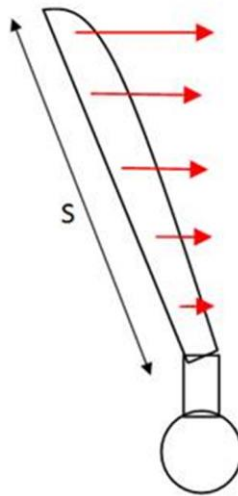
4.2 Pre-cone and pre-sweep

In older versions of Bladed (4.3 and earlier), the effect of **pre-cone** and **pre-sweep** are not included when calculating the orientation in which to apply the aerodynamic loads. This changed in a later version of 4.4, where the aerodynamic loads are now applied in the **blade root axes** rather than in the coned rotor plane. This is illustrated in Figure 4-2.

No sweep



Pre-sweep (Bladed 4.4.0.114)



Pre-sweep (Bladed 4.4.0.115)

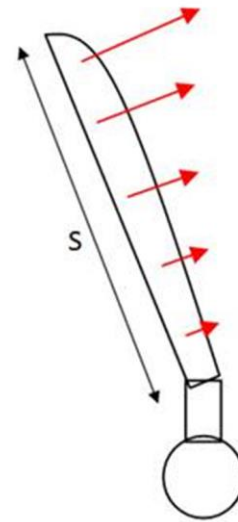


Figure 4-2: Effect of pre-sweep or pre-cone when applying aerodynamic forces