Orientation of blade local element frame relative to the blade root coordinates

Contents

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1 OVERVIEW

This document describes how the local element frame is orientated relative to the blade root.

The local element frame is closely related to the blade principal axes frame orientation. The relationship between these coordinate systems is described.

2 LOCAL ELEMENT FRAME ORIENTATION

Consider a blade element with an inboard node A and further outboard node B, as shown in Figure 1. The difference in coordinates between point A and B are expressed in the "root axes" coordinates as r_x, r_y and r_z, which correspond to the difference in the variables "Neutral axis (x)", "Neutral axis (y)" and "Distance along blade root Z axis" respectively.

To fully define the local element coordinate system, two of the three vectors that form the coordinate basis are calculated by Bladed from the user inputs. The element coordinate system is defined as shown in red in the diagram below. The element x direction vector is known based on the difference in positions of nodes A and B.

The local element z direction needs to be calculated to fully define the local element coordinate system for the structural model.

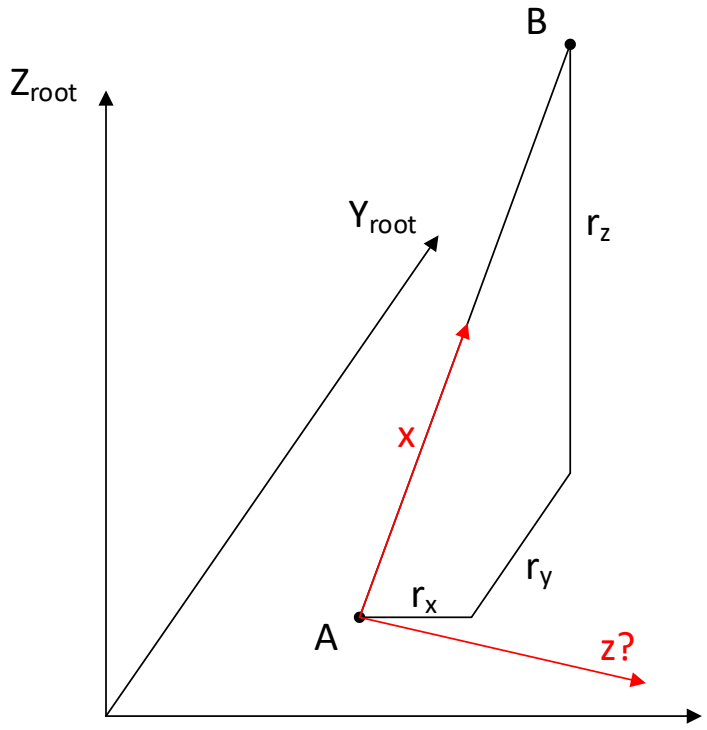

Figure 1: Definition of the blade local element x direction

2.1 Three rotations to define the local element z direction

The element local z direction vector is calculated by applying 3 successive rotations to the local element z axis. The 3 rotations are about the blade root axes X, Y and Z directions.

The element local z axis is assumed initially to be aligned with X_{root} direction.

2.1.1 Rotation due to "principal axis orientation"

The first rotation is a rotation about an axis parallel to the Z_{root} axis. The angle of rotation is the "principal axis orientation" as specified in the blade screen. This is illustrated in Figure 2.

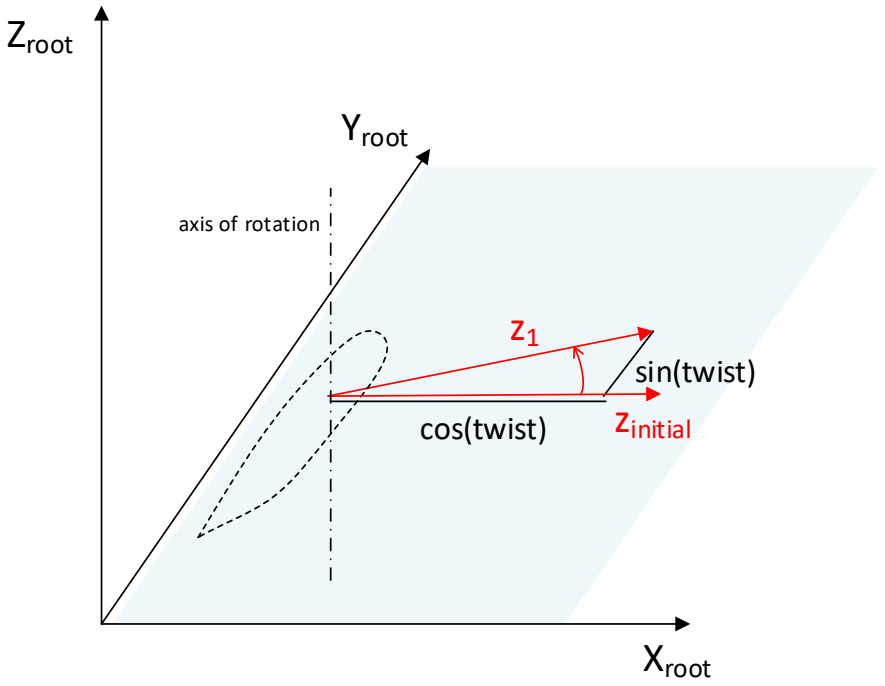

Figure 2: Rotation of local element z direction due to "principal axis orientation"

2.1.2 Rotation due to prebend

Next, the vector z_1 is rotated by the prebend angle, by rotating about an axis parallel to the Y_{root} axis, as illustrated in Figure 3.

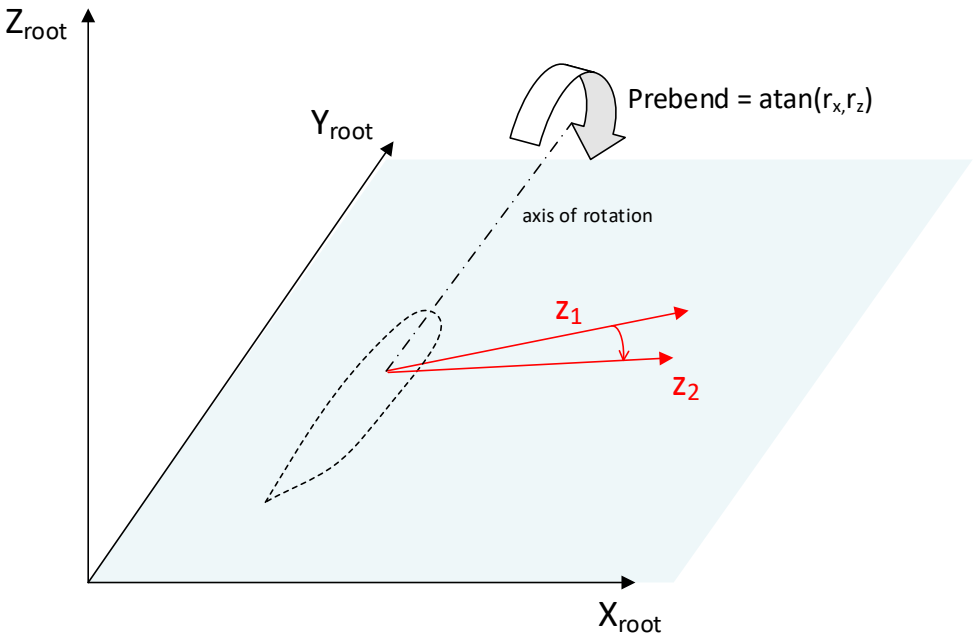

Figure 3: Rotation of blade local element z axis by prebend angle

2.1.3 Rotation due to sweep

Finally, the vector z_1 is rotated by the sweep angle, by rotating about an axis parallel to the X_{root} axis, as illustrated in Figure 4.

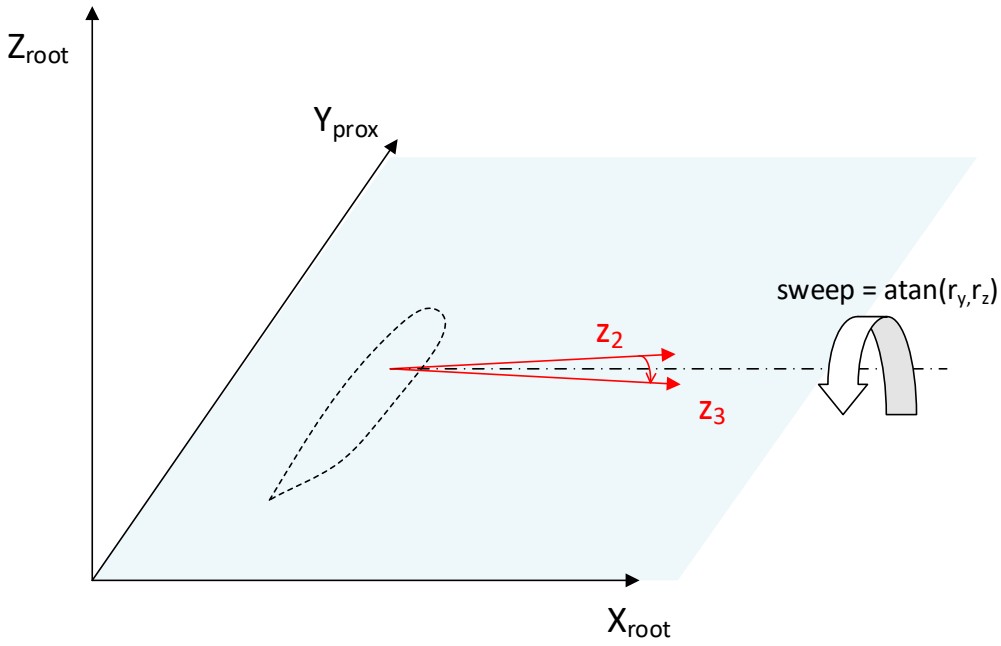

Figure 4: Rotation of blade local element z axis by sweep angle

3 PRINCIPAL AXIS FRAME ORIENTATION

The previous section defined the blade local element frame. However, the "principal axis" frame is used for load output in Bladed. The principal axis orientation is calculated by taking the average orientation of the two blade elements at the node where the elements join. This is illustrated in Figure 5. The two adjoining local element frames are shown in green and red. The principal axes output frame is shown in blue.

Note that the element local coordinate system has its x direction along the element, unlike the "principal axes" coordinate system which has z along the element axis.

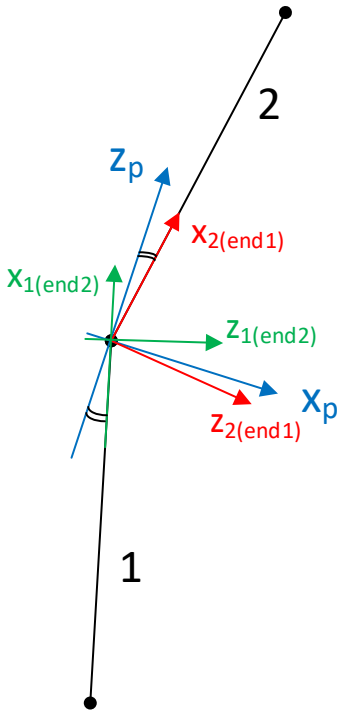

Figure 5: Principal axes and local element axes orientations