DNV·GL

PENDULUM DAMPER USER MANUAL

BLADED

Version: 4.9

DNV GL - Energy

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Bladed Pendulum Damper User Manual

Version 1.2

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1. Overview

Bladed provides the facility for users to model a pendulum-style damper.

This document describes the functionality available in Bladed 4.9.

Note that the ability to offset the damper from the attachment node (parameter *OffsetXYZ*) is only available in versions 4.9.0.23 and later.

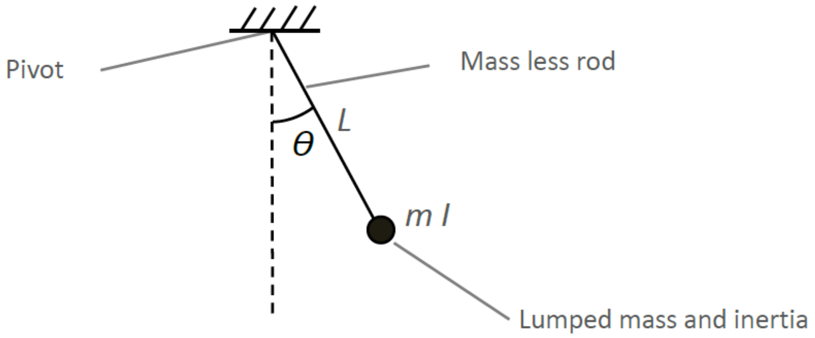
Note that the ability to add constant friction to the damper hinge (parameter *ConstantFriction*) is only available in versions 4.9.0.28 and later.

2. Description of Damper

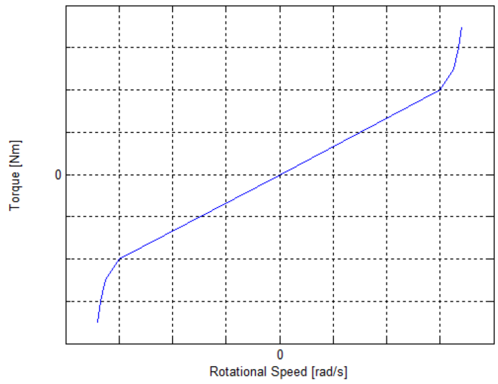
The damper is modelled within the Bladed multibody structural model, and its dynamics are integrated along with any other multibody component.

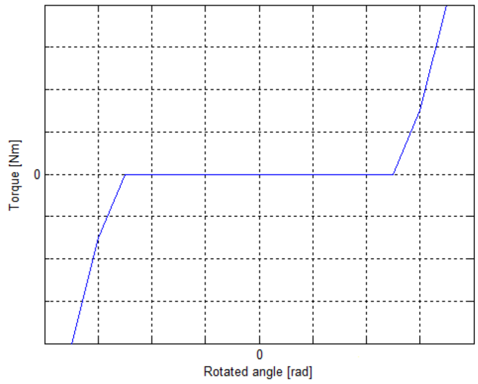
The pendulum damper rotates about an axis fixed relative to the component to which it has been attached. The attachment points currently supported are the nacelle, or any of the tower nodes. The damper hinge can be offset from an existing node using a rigid link. One or more dampers can be added to the model, or any node.

The pendulum damper is modelled as a simple arm, fixed at a pivot and with a lumped mass at the other end:



The pendulum damper equation of motion is non-linear, as the motion is not confined to small oscillations about the equilibrium position. In addition, non-linear pivot stiffness and damping values can be specified within a rotation angle and speed range using a look-up table, as illustrated below:





Damping (Torque vs. Speed)   Stiffness (Torque vs. Angle)

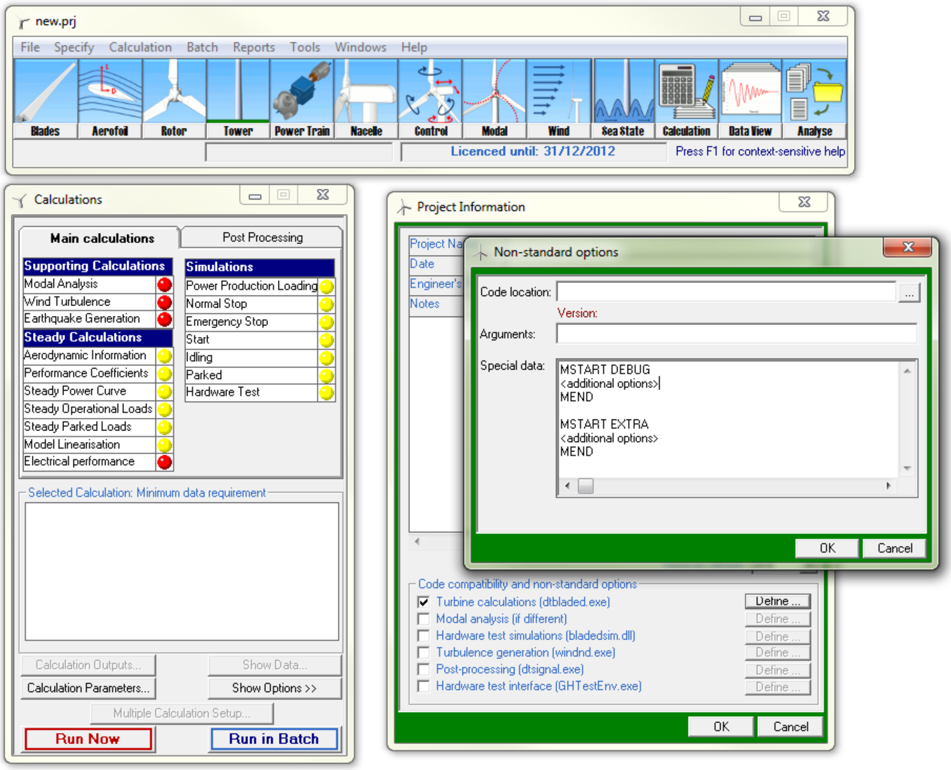
The pendulum damper is similar to the vibration damper feature that exists in the Bladed user interface and which is documented in the User Manual. The models differ in the following ways:

- The pendulum damper can apply forces and moments that act on the structure whereas the vibration damper can only apply forces in the horizontal plane.
- The vibration damper is a spring-mass-damper system whereas the pendulum damper is modelled as a pendulum.
- The vibration damper is available through the interface whereas the pendulum damper feature is only accessible as a “Project Info” option.

3. Defining the Damper

3.1 Project Info

The damper is defined through “Project Info”, which is a free-text field under the project’s properties. These can be defined by going to File → Project Info… and then ticking “Turbine calculations (dtbladed.exe) and then clicking “Define”:



All three boxes on this dialog are optional, so the “Special data” can be provided without specifying a new executable location or additional arguments.

3.2 Pendulum Damper Definition

The full definition of the pendulum dampers is shown in the following table.

Please also refer to the notes and the diagram below for clarification.

Keyword	Example Value	Description
MSTART	PENDULUMDAMPERS	*Module start*
NumPendulumDampers	1	*If more than one repeat the entire block below n times*[1]
Station	6	*For the nacelle, this should be "N" or "Nacelle".*[6] *For a tower station, this should be the number of the tower node, as seen in the Tower screen.*
Length	1.0	*The length of the pendulum arm in metres*
Direction	1.57	*The angle between the X-axis and the pendulum's swing axis, in radians*[2]
Mass	1000.0	*The mass of the pendulum's weight, in kg*
Inertia	1000.0	*The additional rotational inertia of the pendulum, in kg.m2*
Stiffness	0.0	*A constant stiffness for the hinge, in Nm/radian*
	or	
NumStiffnessPoints	2	*The number of points in the stiffness lookup table*
StiffnessAngles	-1.57 1.57	*The angles in the lookup table, in radians*[3]
StiffnessTorques	-1000.0 1000.0	*The stiffness torques to be applied at the above angles, in Nm*[4]
	and	
Damping	0.0	*A constant damping value for the hinge, in Nms/radian*
	or	
NumDampingPoints	2	*The number of points in the damping lookup table*
DampingVelocities	-1.57 1.57	*The velocities in the lookup table, in radians/s*[3]
DampingTorques	-500, 500	*The damping torques to be applied at the above angles, in Nm*[4]
	and	
InitialAngle	*1.57*	*Initial angle from vertical, in radians (optional: default=0.0)*[5]
OffsetXYZ	*2.0 0.1 1.0*	*Offset (in metres) of the damper hinge from the attachment node on the tower or yaw bearing.* *Offset is defined in the tower or yaw bearing coordinate system. All three components (x,y,z) must be specified. These systems are aligned with the global coordinate system when tower deflections and yaw angle are zero. See Figure 1.*
ConstantFriction	*1000*	*Constant friction torque applied to rotational hinge in Nm. (optional: default=0.0)*
	Additional dampers defined here	
MEND		*Module end*

Notes:

1 More than one damper can be added to a single station.
2 If the direction is 0.0, the axis will lie along the X-axis. If the direction is other than 0.0, the axis will be rotated around the Z-axis using the right-hand rule.
3 The look-up tables are expected to pass through 0:0, and to fill the lower-left and upper-right quadrants of a graph – i.e. positive angles result in positive torques and vice versa. This represents a retarding torque, opposing the motion or velocity. If these criteria are not met, warnings will be reported, but the simulation will continue using these values.
4 Note that the values for stiffness and damping look-up tables are torques, and therefore do not match the units of the singles, constant values that can be specified.
5 Pendulum angles are measured about the pendulum's axis, using the right-hand rule.
6 When attaching to the nacelle, the rotation axis of the damper is defined relative to the nacelle's X-axis, even if there is an initial yaw angle.

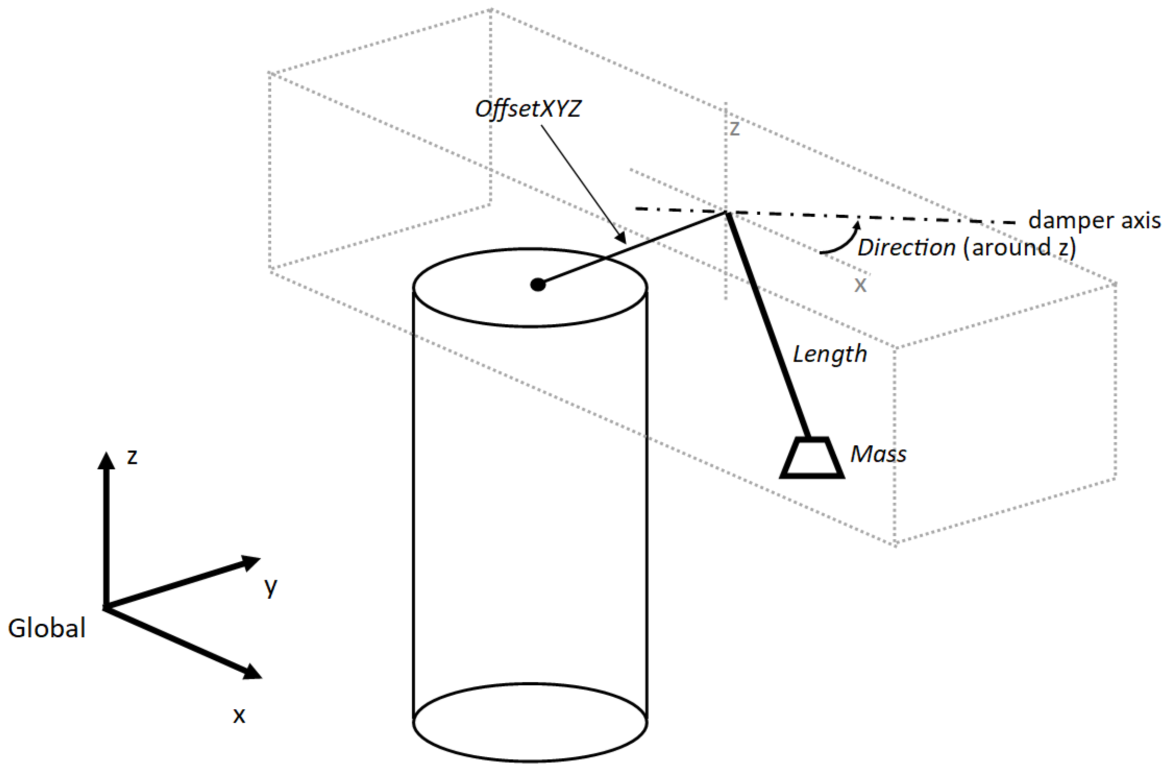


Figure 1: Diagram to show relationship between the attachment node, OffsetXYZ and Direction

4. Logging

Logging groups will be created for each pendulum damper specified. Each group will have the following series:

- Hinge angle, measured about the hinge access (see note 5 above).
- Rotational velocity.
- Reaction forces between the hinge and the structure.
- Reaction moments between the hinge and the structure.
- Stiffness torques being applied.
- Damping torques being applied.