Belt drive simulation

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Table 1: Main parameters for the belt drive.

Parameter	Value	Units	Description
r	0.09995	m	pulley radius
d	0.1π	m	distance between two pulleys
h_b	0.0001	m	belt height
w_b	0.08	m	belt width
$\bar{l}_b$	0.38π	m	stress-free belt length
l_b	0.4π	m	initial, deformed belt length
ε_{ref}	-0.05	-	added reference axial strain of the belt
u_0	0.	m	horizontal displacement (used only in original model [1])
EA	8000	N m	axial stiffness
EI	$\frac{4}{3} \cdot 10^{-3}$	$\mathrm{N\,m^2}$	bending stiffness
ρ	1036	$\mathrm{kg/m^3}$	beam density
dEA	1	$\mathrm{N/ms^2}$	strain proportional damping
ω_{P1}	12	rad $\mathrm{s^{-1}}$	angular velocity of driving pulley
d_{P2}	2	Nm/s	angular velocity proportional damping at pulley P_2
t_0	0.05	s	driving start time
t_1	0.60	s	driving end time
$t_{\tau 0}$	1.0	s	torque τ_{P2} raised at pulley P_2
$t_{\tau 1}$	1.5	s	torque τ_{P2} at pulley P_2 reaches nominal value
I_p	0.25	$\mathrm{kg\,m^{-2}}$	moment of inertia of pulleys
g	9.81	$\mathrm{m\,s^{-2}}$	gravity

1 Methods

A brief description of cable element, normal and tangential contact model will be added here.

2 Description of numerical example

The belt drive has two pulleys P_1 and P_2 with identical radius and inertia, see the geometrical setup in Figure 1. This numerical example is similar to the one developed in [1] with some modifications which attempt to eliminate the vibrations in the beginning of the simulation and allow the system to reach the steady state. The angular velocity of pulley P_1 is prescribed by means of an algebraic constraint, while some resistance torque over time is added to pulley P_2, see the description hereafter. The belt is modelled as Bernoulli-Euler beam with bending stiffness

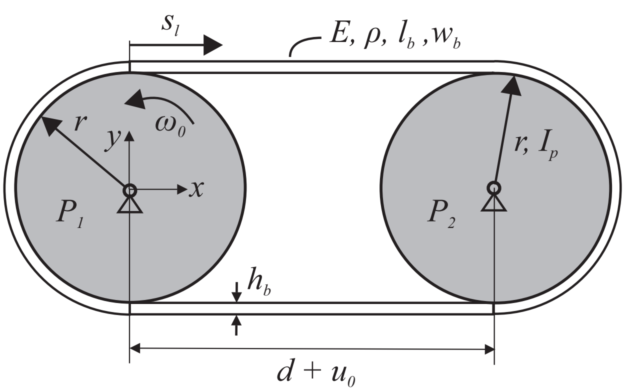

Figure 1: Belt drive with two pulleys, displaced from initial position by u_0.

EI, axial stiffness EA, rectangular cross section with height h_b and width w_b, as well as stretch proportional damping, density, and further parameters given in Table 1. A constant acceleration is prescribed to pulley P_1 between t_0 and t_1:

$$\omega_{P1}(t) = \begin{cases} 0\,\frac{\mathrm{rad}}{\mathrm{s}}, & \text{if} \quad t < t_0 \\ \omega_{P1} \frac{t - t_0}{t_0 - t_1} & \text{if} \quad t_0 < t < t_1 \\ 12 & \text{else} \,. \end{cases} \tag{1}$$

Table 2: Parameters for ObjectANCFCable2D

Parameter	Value
physicsMassPerLength	ρA
physicsBendingStiffness	EI
physicsAxialStiffness	EA
physicsBendingDamping	dEI
physicsAxialDamping	dEA
physicsReferenceAxialStrain	ε_{ref}
physicsReferenceCurvature	0
useReducedOrderIntegration	2
strainIsRelativeToReference	False
visualization	(to be added...)

A torque proportional to the angular velocity is applied to the pulley P_2 which represents damping of rotational motion:

$$\tau_{P2}(t) = \begin{cases} 0\,\mathrm{Nm}, & \text{if} \quad t < 1 \\ 25\,(0.5 - 0.5 \cdot \cos(2(t-1)\pi))\,\mathrm{Nm} & \text{if} \quad 1 < t < 1.5 \\ 25\,\mathrm{Nm} & \text{else}\,. \end{cases} \tag{2}$$

As compared to [1], we use a much smaller belt height h_b in order to exclude bending effects, a higher pre-tension (due to pre-stretch), while keeping the axial stiffness EA the same. Furthermore, the bending stiffness is lowered by a factor of 50, which reduces bending effects, as it would lead to significant deviations from an analytical solution otherwise. The support of pulley P_1 is not displaced during the first 0.05 s of the simulation, but the pre-stretch ε_{ref} is applied before running a static computation, which defines a static equilibrium for the dynamic simulation hereafter. The contact stiffness, as shown later by the nominal simulation parameters, has been increased by a factor of 40 and a tangential stiffness (bristle) model has been included in order to retrieve highly accurate contact behavior.

3 Description of code

For simulating the system we are using the multibody dynamics code Exudyn [2]. For the ANCF beam elements modeling the belt we are using ObjectANCFCable2D, see the documentation of Exudyn[1], theDoc. Parameters used for ObjectANCFCable2D are defined in Table 2.

For modeling the pulley we are using ...

For the parameter variation ...

4 Instructions for running the example

References

[1] A. Pechstein and J. Gerstmayr, "A Lagrange-Eulerian formulation of an axially moving beam based on the absolute nodal coordinate formulation," *Multibody System Dynamics*, vol. 30, no. 3, pp. 343–358, 2013.

[2] J. Gerstmayr, "Exudyn – A C++ based Python package for flexible multibody systems," in *the proceedings of the 6th Joint International Conference on Multibody System Dynamics and the 10th Asian Conference on Multibody System Dynamics*, (New Delhi, India), 2022, submitted.

[1] EXUDYN V1.3.86.dev1; https://github.com/jgerstmayr/EXUDYN