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VALIDATION OF THE POINT-MASS MODELLING APPROACH FOR FIBRES IN THE INVERTED PENDULUM MODEL

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Abstract: *Fibres, cables and wires can play an important role in design of many machines. One of interesting applications is replacing the chosen rigid elements of a manipulator or a mechanism with fibres. The main advantage of this design is achievement of a lower moving inertia, which can lead to a higher mechanism speed and lower production costs. A chosen inverted pendulum attached to a frame by two fibres serves as a typical testing system for the investigation of the fibres properties influence on the system dynamic response. Motion of the pendulum of this nonlinear system is investigated using the* ***alaska*** *simulation tool. The sophisticated point-mass fibre model is validated on the basis of the results obtained using a massless fibre model. In addition, the equation of motion based on the massless approach is studied in terms of solution existence and its uniqueness.*

Keywords: ***Inverted pendulum, fibres, multibody modelling, vibration.***

1. Introduction

Inverted pendulum, which is attached and driven by two fibres and affected by a gravitation force, was chosen as an example of the investigation of fibres' behaviour. The motion of this simplified representation of a typical cable manipulator is investigated using the **alaska** simulation tool (the influence of some parameters of this system has already been investigated – e.g. Polach et al., 2012). The sophisticated point-mass fibre model is validated on the basis of the results obtained using a massless fibre model.

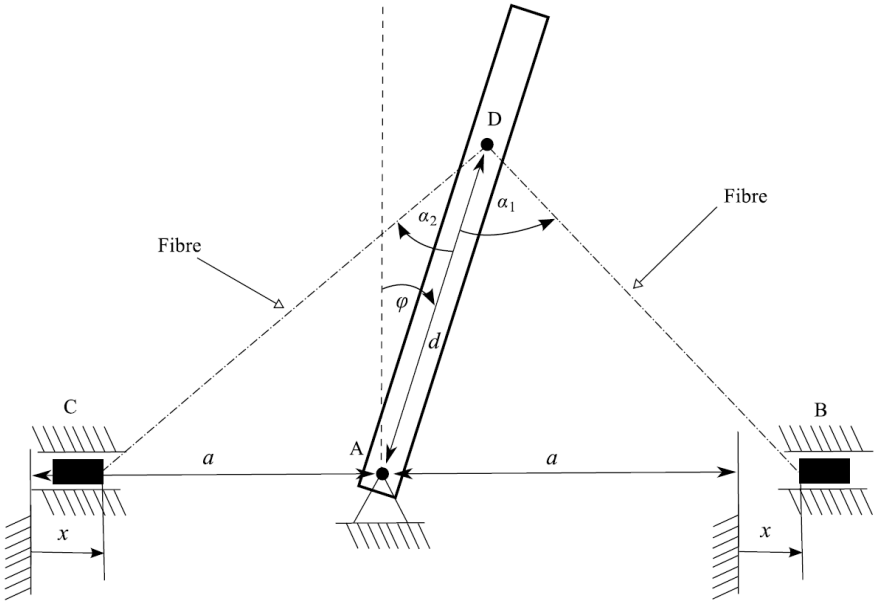

Fig. 1: Inverted pendulum actuated by the fibres.

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2. Inverted pendulum

The massless model of the inverted pendulum system is shown in Fig. 1. The used model of the fibre based on the point-mass model is geometrically identical. Each fibre is discretized using 10 point masses. The stiffness and the damping between the masses are determined in order to keep the global properties of the massless fibre model (e.g. Polach & Hajžman, 2011c).

The system kinematics can be described by angle φ (one degree of freedom) and prescribed kinematic excitation $x(t) = x_0 \cdot \sin(2 \cdot \pi \cdot f \cdot t)$, where x_0 is the chosen amplitude of motion, f is the excitation frequency and t is time. Excitation in points designated B and C (see Fig. 1) is considered to be symmetrical and of the same amplitude x_0.

3. Numerical simulations

The kinematic excitation amplitude x_0 = 0.02 m was chosen. Excitation frequency f was considered in the range from 0.1 Hz to 200 Hz. In the case of the point-mass fibre model very low mass of fibre was considered: mass of one fibre is 0.1 grams. To compare: mass of the so far lightest considered (carbon) real fibre was 3.846 grams. Extreme values of pendulum angle φ are given in Fig. 2.

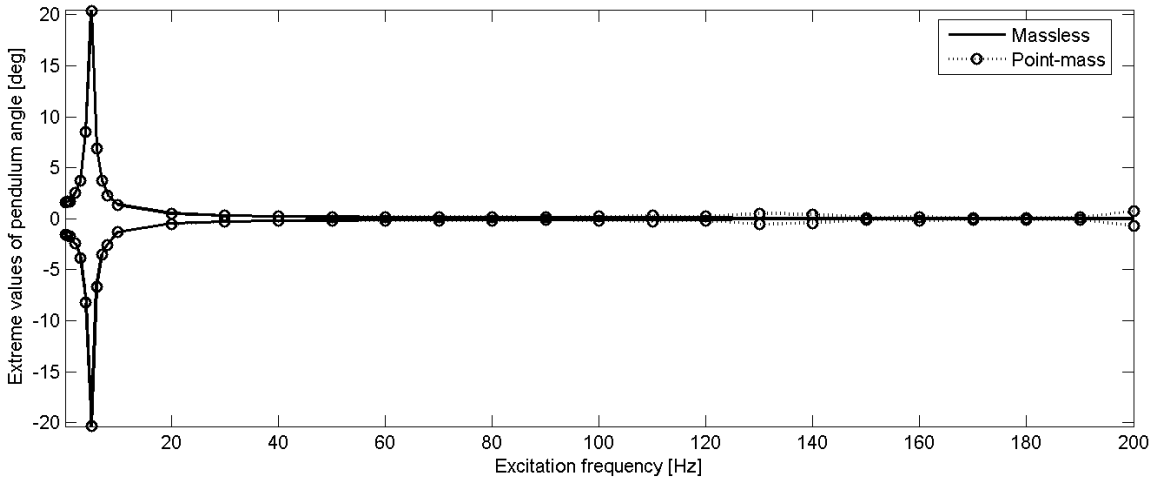

Fig. 2: Extreme values of time histories of pendulum angle in dependence on the excitation frequency.

4. Conclusions

The approach to the cable modelling based on the point-mass representations for the investigation of the motion of the inverted pendulum was validated on the basis of the results obtained using the massless fibre model. It was proved that point-mass fibre model is well applicable up to the excitation frequency of approx. 50 Hz (which is generally sufficient for the control of the considered cable-based manipulators). At higher excitation frequencies partly vibration of individual point masses and partly probably also influence of numerical errors at solving equations of motion show up in the results of simulations. They are caused by considering almost massless fibres in the point-mass fibre model.

Experimental verification of the cable dynamics within the manipulator systems and research aimed at measuring the material properties of selected fibres are considered important steps in further research.

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