Multibody Dynamics A - wb1310

Lecture 3, course 2014-2015

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Multibody Dynamics A
wb1310
(fall 2014, Q2)

Instructor: Arend L. Schwab

TU Delft

Delft University of Technology

Description: Multibody Dynamics A is an introductory course in applied dynamics of mechanical systems. The emphasis is on the usage of multibody dynamics software. We want you to learn enough about dynamics in 3D that you will be able to use a standard multibody dynamics software package correctly, appreciate the limitations, and say some sensible things about the model at hand.

In the course you will learn about the fundamentals of Multibody Dynamics: the description of the orientation of a rigid body in space, the Newton-Euler equations of motion for a 3D rigid body, how to add constraints to the equations of motion, and how to solve such a system of coupled equations. You will spend most of the time (80%) in doing the lab assignments. These assignment consists of a number of practical problems that have to be worked out with the software package ADAMS. Your findings are to be put down in a Lab Report.

Goal: By the end of the course you be able to make a complex model of realistic 3D mechanical system and draw some conclusions from the dynamical analysis.

Grading: The written exam is of the open book type and has the form of a questionnaire about the findings as written down in your lab report. The report serves as reference material for your exam. At the end of the exam the questionnaire together with the Lab Report are to be handed over, The final grading is 50% on the report and 50% on the written exam.

News

Hand-Outs
- The course Contents.
- The Laboratory Assignments.
- A short Introduction to ADAMS (1,169 KB).
- Tire and Road files for assignment#5: 16r26_new.tir, 18r38_new.tir, FlatRoad.rdf.

Office Hours
Instructor: Arend L. Schwab, a.l.schwab@tudelft.nl, Monday, 15-17 h., room F-0-010, phone: 015 278 2701.
TA: Sten Ponsioen, s.l.ponsioen@tudelft.nl, Monday, 13-17 h. IO-PC hall 3 (SHIFT).

Contents

Lecture	Topic	Assigment
1th-2nd	Introduction	1-Pendulum
1th-2nd	Newton-Euler eqn's of motion	2-Wheel
3rd	Modeling of Mechanical Systems	3-Crane
4th	Orientation of rigid body in space	4-Governer
5th	Coupled Differential And Algebraic Equations	5-Tractor/Bicycle
6th	Overview	5-Tractor/Bicycle

Accounting

Section	Hours
Lectures	7*2
Assignments (guided)	7*4
Assignments (free)	7*4
Class Prep	7*1
? **Written Exam!**	7
Total (3 ECTS)	84

Written exam: Thu 22 Jan 2015, 14-17 h.

Assignment 3

In order to examine fast and correct positioning of a container on an Automated Guided Vehicle, we study the model of an overhead container crane (gantry crane). Here we only consider the motion of the crab plus container, the hoisting motion will not be considered. The cables in which the container hangs, are modelled as compliant spring-damper elements. The container measures 8x8x40 [ft] at a total mass of 30 [metric tons] (dead weight plus load). You may assume a uniformly distributed mass for the calculation of the mass moment of inertia quantities. The vertical distance between the bottom of the crab and the top of the container is 25 [m]. The supporting cables are modelled by 4 cables which are mounted on the container in a purely vertically centered way, with a distance of 2 [m] in transverse and 6 [m] in longitudinal direction between them. Each individual cable has a stiffness of 3.0 10^6 [N/m] and a relative damping of 5 %. The driving motion of the crab is thought of as: first a constant acceleration, then a constant speed and finally a constant deceleration. The maximum speed is $v_{max} = 240$ [m/min] and the maximum ac(de)celeration is $a_{max} = 0.7$ [m/sec^2]. A crane expert told us that for the load to hang still after the crab's driving motion, we have to accelerate and decelerate in a multiple of the Period of Vibration T of the load oscillation.

1. Make a pencil-and-paper estimate of the Period of Vibration T of the load oscillation in the crab's driving motion.

2. Determine the Period of Vibration of the load oscillation in the crab's driving motion of your ADAMS model, for instance by means of an eigenfrequency analysis (Simulation Control → Linear).

3. Simulate the motion of the container assuming a total displacement in the driving direction of the crab of 60 [m]. Check the statement of the crane expert, is he right? Plot the speed of the crab and the speed of the container in the crab's driving direction as a function of the *displacement* of the crab in the driving direction.

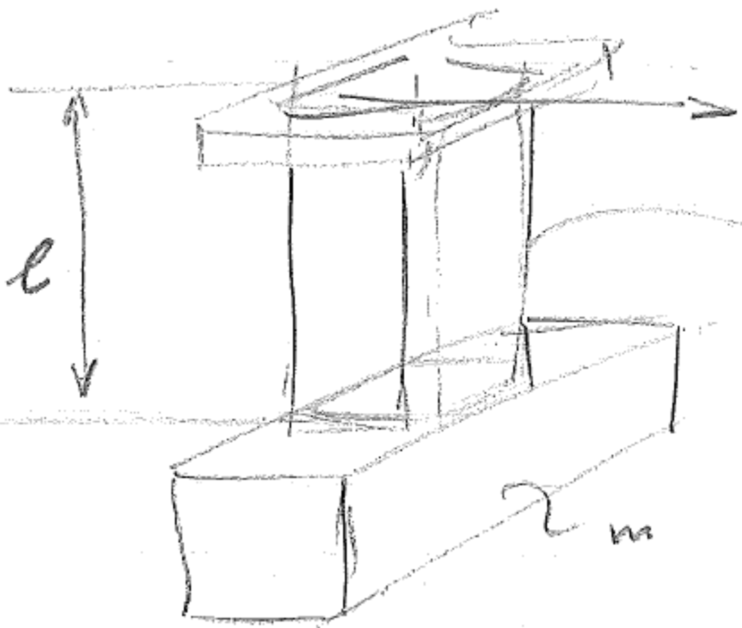
   The crab motion can generated by using a Translational Joint Motion. First create such a joint with a random value, after which the function F(time)= can be modified in the Function Builder. By summation of a number of STEP functions you may obtain the desired motion.

4. As a rule, the container will be loaded asymmetrically and we are wondering what the effect of this will be on the container's positioning on the A.G.V. Assume the centre of mass to be 20 % = $(1.6, 1.6, 8.0)$ [ft] off from the geometrical centre (keep the mass moments of inertia at the centre of mass as is). Change the model and simulate the same driving motion. Plot the container's angular rotation around its vertical axle as a function of time and compare this result with the symmetrical situation. Is there a significant difference such that positioning of the container on the AGV will give trouble? Explain!


EUROMAX
EUROMAX
COSCO
COSCO OCEANIA
HONG KONG

Assignment 3

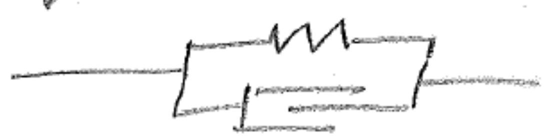
De containerkraan



Welke kant op bewegen?

veer-demper element

$k = 3 \cdot 10^6$ N/m

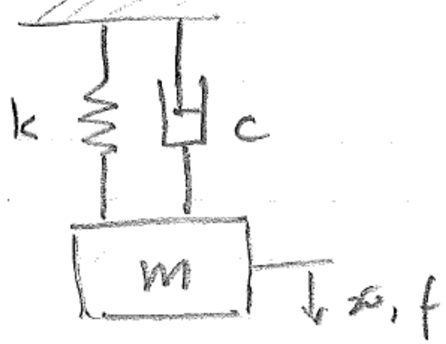


c ?

Materiaal Demping ± 5 % (van Dat?)

We bedoelen relatieve demping $\beta = 0.05$

?



$$m\ddot{x} + c\dot{x} + k x = f$$

$$\ddot{x} + \frac{c}{m}\dot{x} + \frac{k}{m}x = 0 \quad \text{gevd.}$$

$$\ddot{x} + 2\beta\omega_0\dot{x} + \omega_0^2 x = 0$$

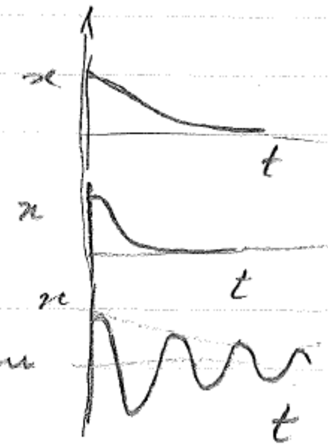
$$\omega_0 = \sqrt{\frac{k}{m}} \quad \text{eigenfreq}$$

$$\beta = \frac{c}{2m\omega_0} \quad \text{relatieve demping}$$

$\beta > 1$ Overgedempt Overdamped

$\beta = 1$ Kritisch gedempt Critical Damped

$\beta < 1$ Ondergedempt Under Damped / Oscilerend Afnem



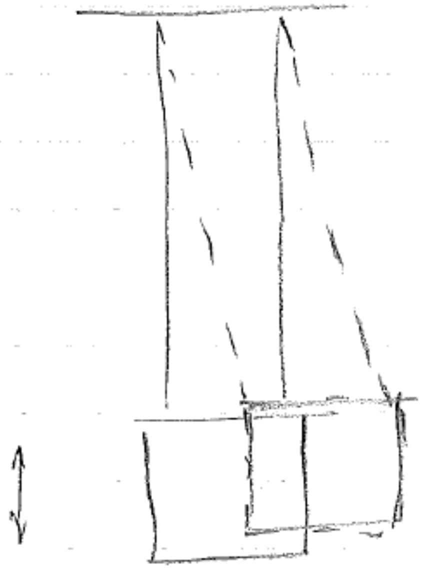
Zie Merven & Kraay H 8

$$\omega_n = \sqrt{1-\beta^2}\,\omega_0 \qquad x = x_0 e^{-\beta\omega_0 t}\cdot\cos(\omega_n t + \varphi_0)$$

Welke ω_0 er zijn er zo veel ?

Hoe en langst deze demper zal op negeve afweg zeten sterken Waaien

Wat is de langste ?



$m = \sout{30\,000}\ 32500$ kg $\quad k = 4 * 3 \cdot 10^6$

$\beta = 0.05 \quad c = 0.1 \cdot \sout{30\,000}\ 32500 \sqrt{\dfrac{4 \cdot 3 \cdot 10^6}{\sout{30\,000}\ 32500}}$

$c = 0.1 \sqrt{4 \cdot 3 \cdot 10^6 \cdot \sout{3 \cdot 10^4}\ 3.25 \cdot 10^4} \cong 0.1 \cdot 2 \cdot 3.1 \cdot 10^5 = 6.2 \cdot 10^4$

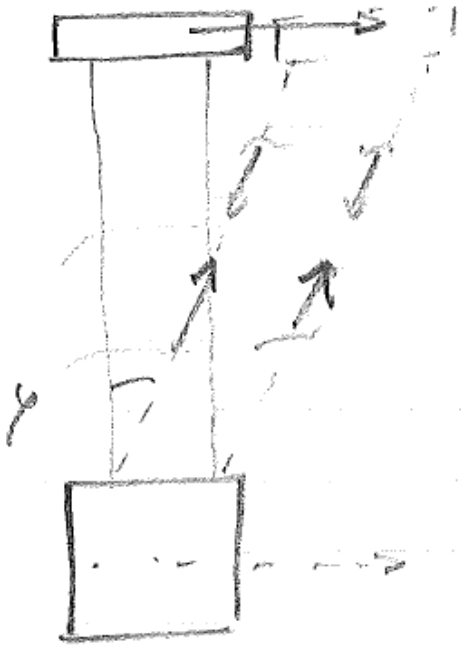
1 veer $\dfrac{c}{4} = 1.6 \cdot 10^4$ [Ns/m]

Wat is de T van de luchtslingering?

Denk alvast zelf even over na

Wellicht kan ADAMS je wel antwoord geven

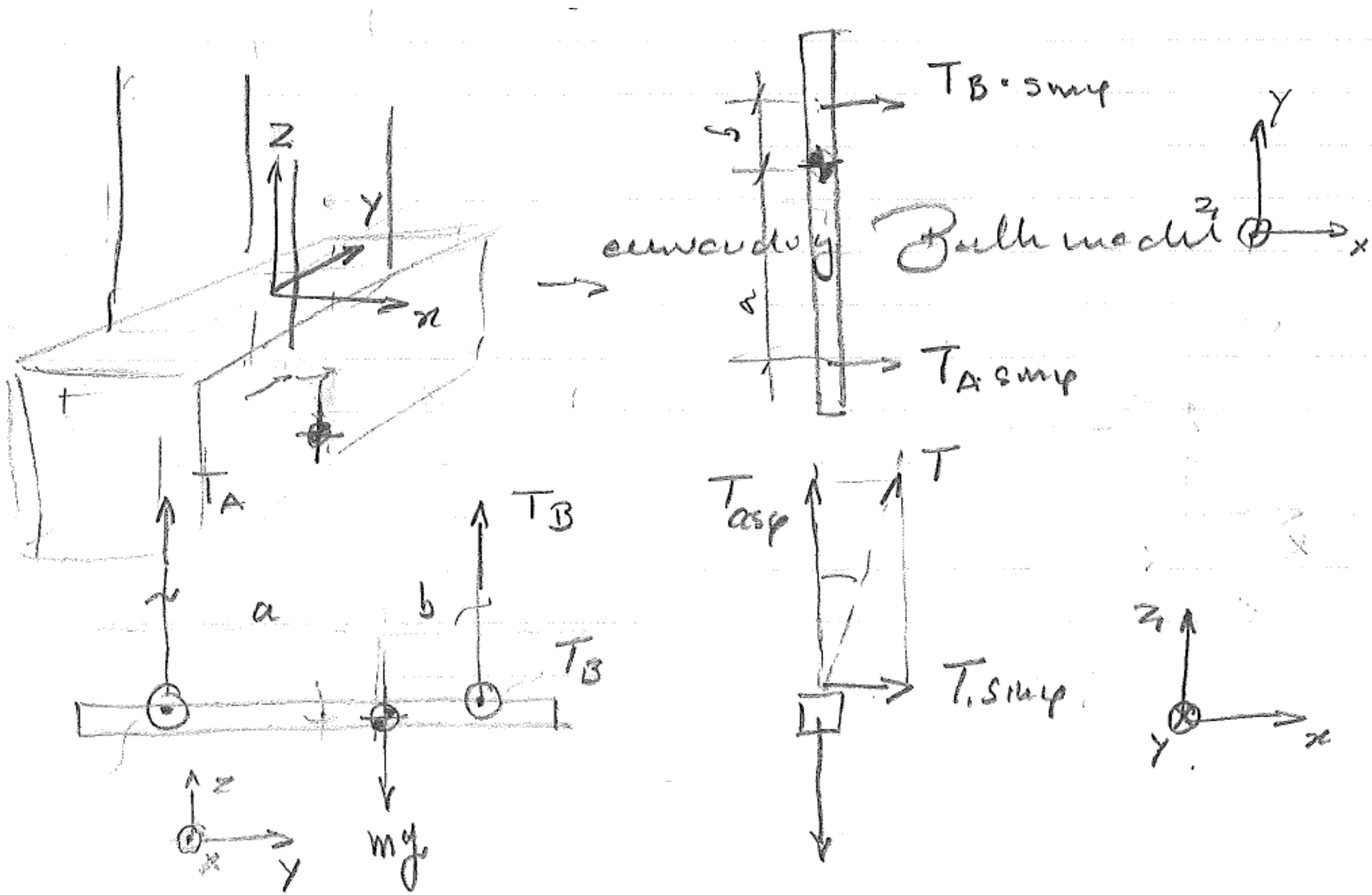
Waarom gaat de Container Bewegen?

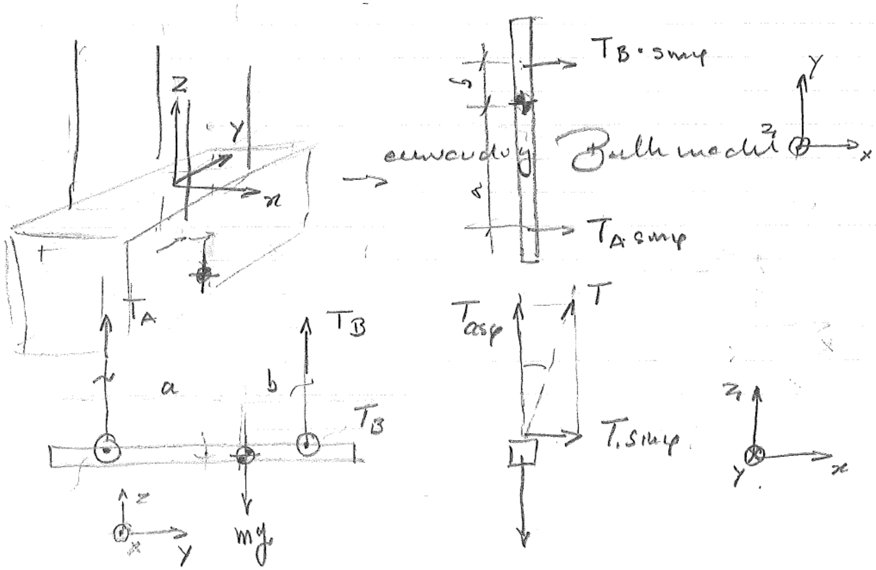


f ? geen !

$f = f_{wacht} * \sin\varphi$

Slotvraag Zal de Caulenne bij A-sym belasting geen Slingering ?


z
y
x
T_A
T_B
a
b
mg
T_B · sinφ
T_A · sinφ
T
T cosφ
T sinφ



Massa middelpunt

$$\Sigma F_x = m\ddot{x} \qquad T_A \cdot \sin\varphi + T_B \cdot \sin\varphi = m\ddot{x}$$

$$\Sigma F_y = m\ddot{y} \qquad 0 = m\ddot{y}$$

$$\Sigma F_z = m\ddot{z} \qquad T_A \cdot \cos\varphi + T_B \cdot \cos\varphi - mg = m\ddot{z}$$

$$\Sigma M_x = J_{xx} \cdot \dot{\omega}_x \qquad -T_A \cos\varphi \cdot a + T_B \cos\varphi \cdot b = I_{xx}\dot{\omega}_x$$

$$\Sigma M_y = J_{yy}\,\dot{\omega}_y \qquad 0 = I_{yy}\dot{\omega}_y$$

$$\Sigma M_z = J_{zz} \cdot \dot{\omega}_z \qquad T_A \sin\varphi \cdot a - T_B \cdot \sin\varphi \cdot b = I_{zz}\dot{\omega}_z$$

8 Onbekenden 6 Vergelijkingen?

2 Verbindingsvoorwaarden $\ell_{1,2} = \text{constant} \rightarrow \ddot{z} = 0$, $\dot{\omega}_x = 0$

$$T_A + T_B = \frac{mg}{\cos\varphi} \qquad -T_A \cos\varphi \cdot a + T_B \cos\varphi\, b = 0$$

$$T_B = \frac{a}{b} T_A$$

$$\left(1 + \frac{a}{b}\right) T_A = \frac{mg}{\cos\varphi} \qquad T_A = \frac{b}{a+b} \cdot \frac{mg}{\cos\varphi}$$

$$T_B = \frac{a}{a+b} \cdot \frac{mg}{\cos\varphi}$$

$$\ddot{x} = g \cdot \tan\varphi \qquad \varphi \ll \qquad \ddot{x} \approx g \cdot \varphi$$

$$\ddot{y} = 0$$

$$\dot{\omega}_y = 0$$

$$\dot{\omega}_z \overset{?}{=} 0 \qquad \ell$$