EasyDyn problem: lateral dynamics of a guided axle

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1 Description of the system

The *Guided Light Transit* (GLT, figure 1) vehicle is a so-called bi-modal vehicle which can ride in road mode as a classical bus or in guided mode by means of a guiding system based on a central rail.

Figure 1: GLT vehicle in guided mode (Bombardier Transport)

In the following, only the lateral motion of the guiding system is considered. The studied system (Figure 2) consists of an axle E undergoing only a translational motion (no yaw angle), two wheels and the guiding arm. The guiding arm is ended by a roller following the central rail. The plane of the roller is assumed to remain parallel to the arm.

The steering system is simplified and introduced only through the following kinematic constraints

$$\theta_G = A_G\,\theta \qquad \text{et} \qquad \theta_D = A_D\,\theta \tag{1}$$

where θ, θ_G et θ_D represent the rotation angles of, respectively, the arm , the left and the right wheels.

All necessary data are gathered in table 1.

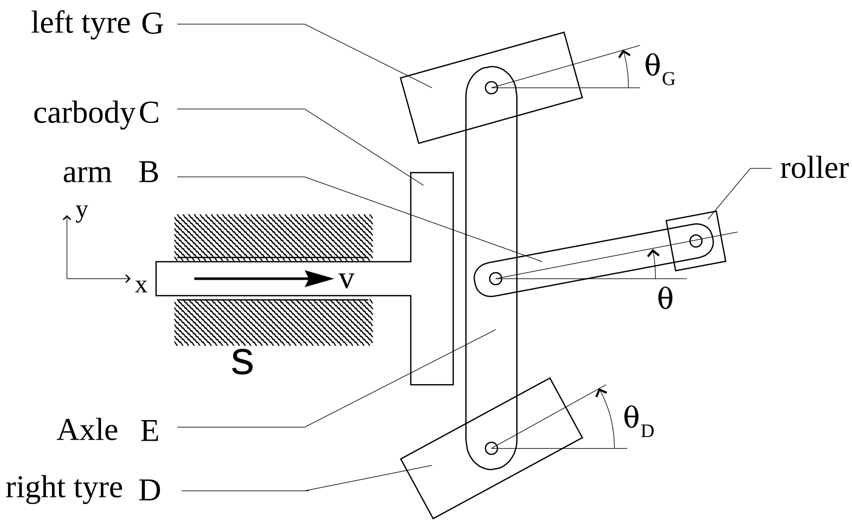


Figure 2: Layout of the model

Table 1: Characteristics of the system

m_E	axle mass	1200 kg
m_B	mass of the arm (with roller)	146 kg
m_G, m_D	mass of one wheel	136 kg
I_E	central moment of inertia of the axle	327 $kg.m^2$
I_B	central moment of inertia of the arm	3.05 $kg.m^2$
I_G, I_D	equatorial moment of inertia of a wheel	11.9 $kg.m^2$
C_s/F_z	cornering stiffness/ vertical force ratio	7.162
$C_{z,s}/F_z$	aligning moment coefficient/vertical force ratio	0,229 m
P_E	Load on the axle	12000 kg
d	arm length	0.6 m
L	track width	2 m
A	distance axle-center of mass of the arm	0.30 m
f_{22}	wheel-rail f_{22} coefficient (linear Kalker)	7,04 10^5
K	wheel-rail contact stiffness	5000 N/m
C	wheel-rail contact damping	500 Ns/m

2 Requested results

Perform the simulation of the axle, at a forward speed of 15 m/s, with an initial rotation velocity of the arm ($\dot{\theta}$) equal to 10 rad/s. The behaviour of the axle will be studied by combining two different values of the steering coefficient

$$A_G = A_D = 1.07 \qquad \text{or} \qquad A_G = A_D = 0.80$$

and two different models of the roller-rail link: a spring-damper (elastic model) or a wheel-rail contact.

The first model represents the behaviour of the system when a flange of the roller touches the rail. The second one assumes that the roller is inside the lateral clearance (no contact between rail and flanges).

3 Typical results

Figures 3 to 6 show the results obtained for the different study cases. Only case 3 (wheel-rail contact and AG=AD=0.8) is unstable.

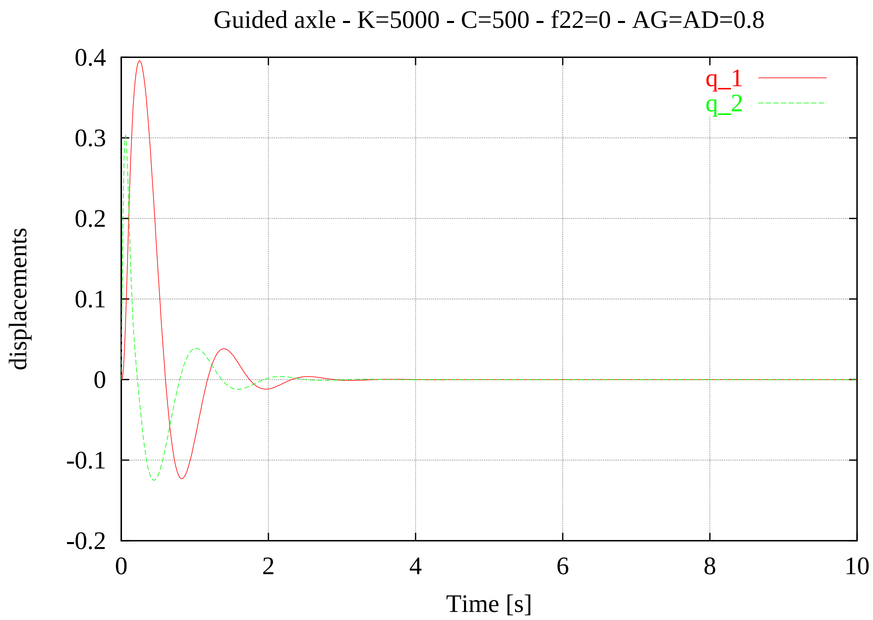


Figure 3: Case 1: spring-damper and AG=AD=0.8

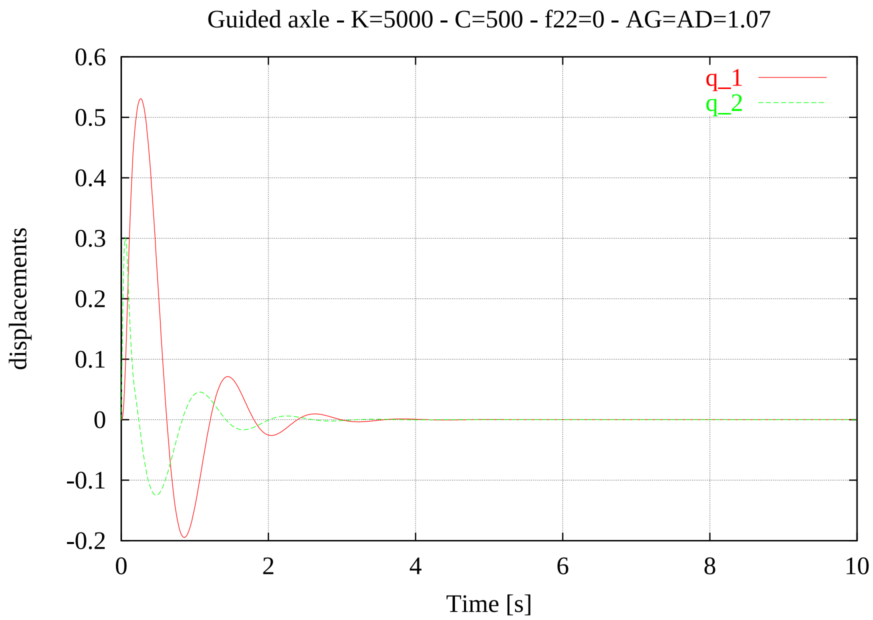


Figure 4: Case 2: spring-damper and AG=AD=1.07

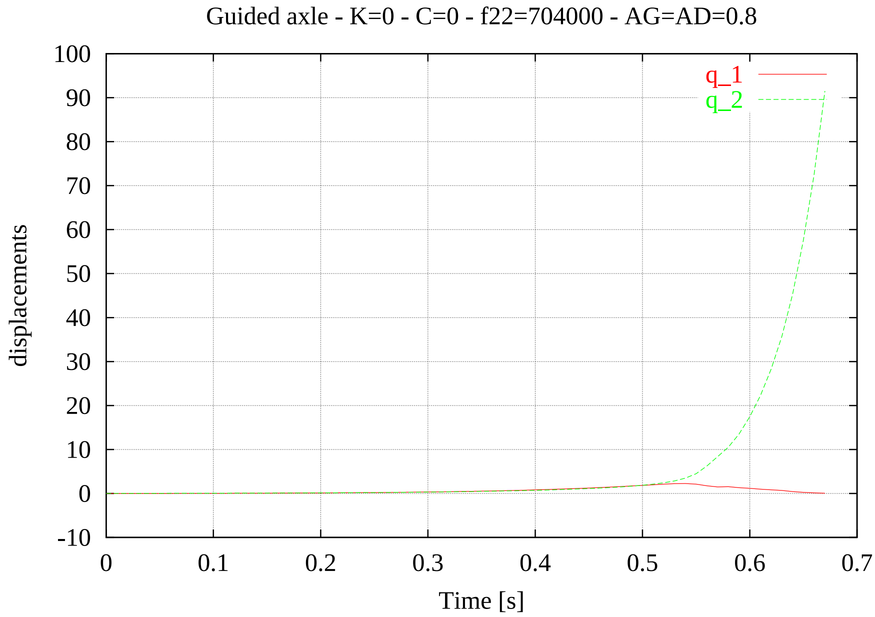


Figure 5: Case 3: wheel-rail Kalker contact and AG=AD=0.8

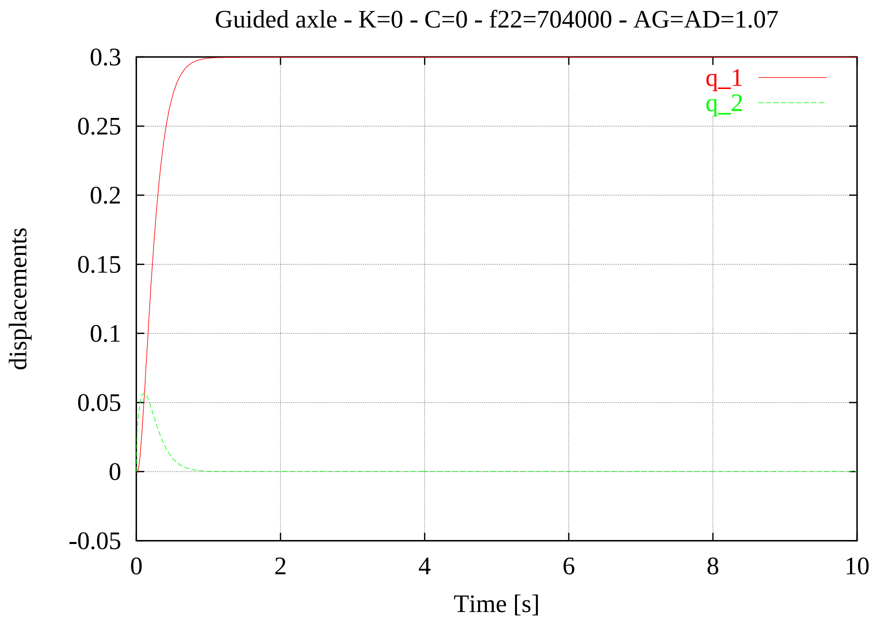
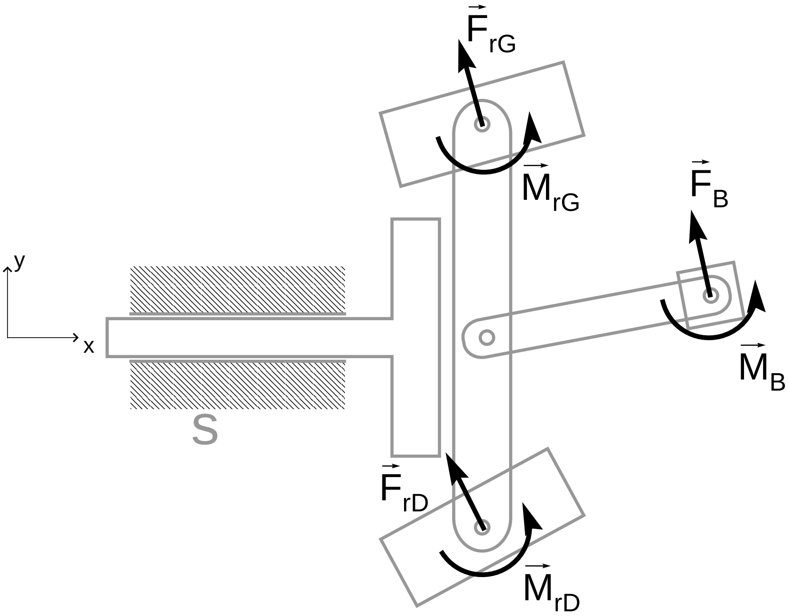


Figure 6: Case 4: wheel-rail Kalker conbtact and AG=AD=1.07

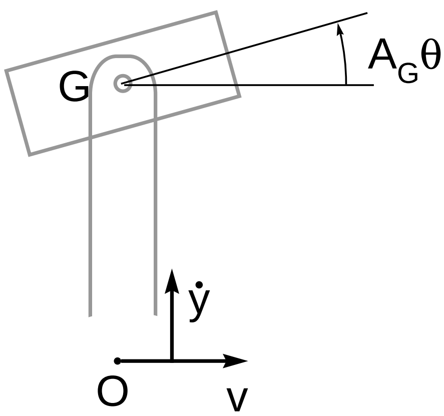
A Models of the roller-rail connection



Conventional direction of forces

$\vec{F}_{r,G}$ and $\vec{F}_{r,D}$ on left and right wheels $\perp$ to the plane of the wheels.
$\vec{F}_B$ on the arm (from the rail) $\perp$ to the arm.
$\vec{M}_{r,G}$, $\vec{M}_{r,D}$ and $\vec{M}_B$ anti-clockwise.

A.1 Tyre efforts



$$F_G = -\overbrace{C_s}^{\text{cornering stiffness}} \underbrace{\alpha_G}_{\text{slip angle}}$$

$$F_G = -C_s\left(\frac{\dot{y}}{v} - A_G\theta\right)$$

$$M_G = C_{z,s}\,\alpha_G$$
$$M_G = C_{z,s}\left(\frac{\dot{y}}{v} - A_G\theta\right)$$

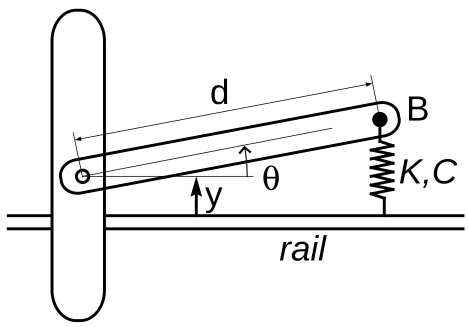
The model is identical for the right wheel.

A.2 Efforts from the rail to the arm

Two models are considered

1. an elastic model with a spring and a damper to define the roller-rail connection;
2. a wheel-rail Kalker contact.

CASE 1 : elastic model



$$F_B = -K(y + d\,\sin\theta) - C(\dot{y} + \dot{\theta}\,d\,\cos\theta)$$

$$M_B = 0$$

CASE 2 : Kalker model

$\vec{v}_B = \vec{v}_O + \vec{\omega} \wedge \vec{OB}$
$\vec{v}_B = \dot{x}\,\vec{u}_x + \dot{y}\,\vec{u}_y + \dot{\theta}\,d\,\vec{u}_t$

$\Rightarrow$ lateral (along $\vec{u}_t$) component of roller velocity :
$\dot{y}\,\cos\theta - \dot{x}\,\sin\theta + \dot{\theta}\,d$

$\Rightarrow F_B = -\frac{f_{22}}{v}(\dot{y}\cos\theta - \dot{x}\,\sin\theta + \dot{\theta}\,d)$
or, after linearization, $F_B = -f_{22}(\frac{\dot{y}+\dot{\theta}\,d}{v} - \theta)$.