STIFF FLYBALL GOVERNOR

Figure 1 shows a flyball governor in which the coupler rods have been replaced with spring-damper elements. The system moves under gravity effects (9.81 m/s^2 along the negative direction of the z-axis). The stiffness and damping of the coupler rods have been adjusted to obtain a stiff system.

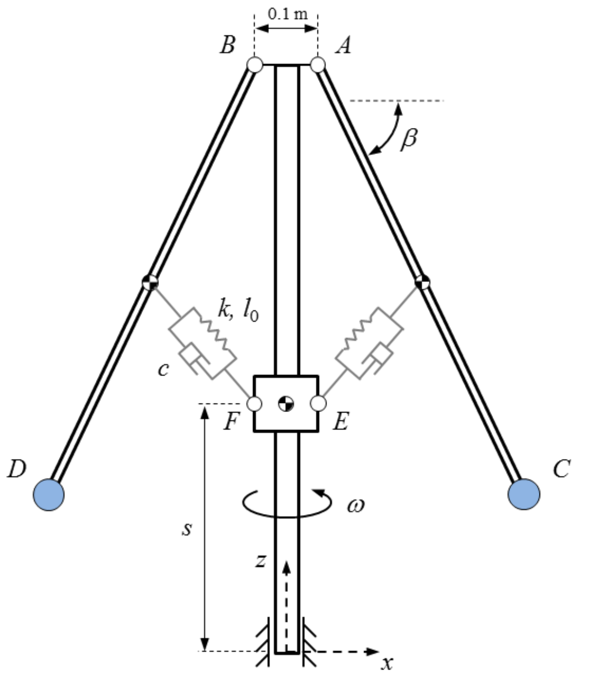

Figure 1: A flyball governor

Physical properties

Spring

$k = 8{\cdot}10^5$ N/m

$l_0 = 0.5$ m

Damper

$c = 4{\cdot}10^4$ Ns/m

Shaft dimensions: 1 m × 0.01 m × 0.01 m

Rod dimensions: 1 m × 0.01 m × 0.01 m

Slider dimensions: 0.1 m × 0.1 m × 0.1 m

The shaft, the rods, and the slider can be modelled as prismatic bodies with a uniformly distributed mass and density ρ = 3000 kg/m^3. Two 5 kg point masses are placed on points C and D. At time t = 0, both arms form an angle β = 30º with respect to the x-axis, s = 0.5 m, $\dot{\beta}$ = 0, $\dot{s}$ = 0. Initially, the shaft rotates about its axis with an angular velocity ω = 2π rad/s and is left to move freely under gravity effects afterwards.

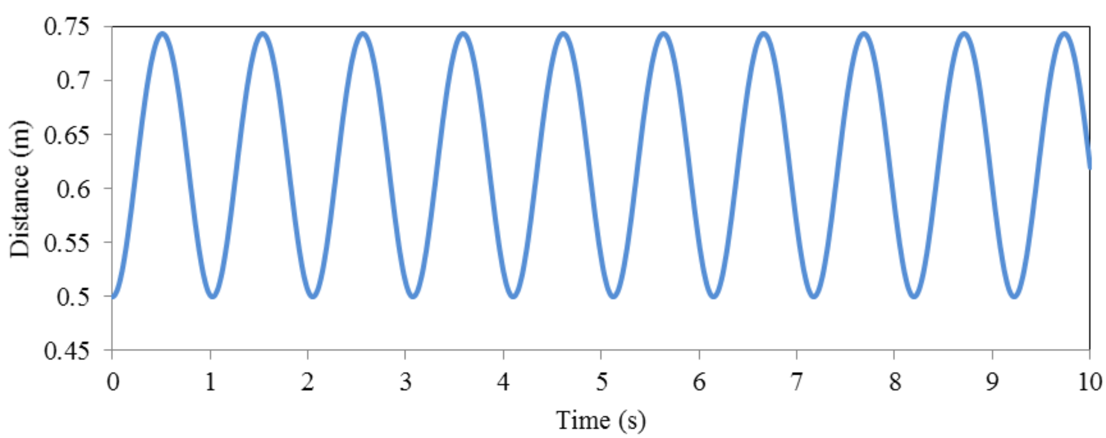

Figure 2: Time-history of the s coordinate

A reference solution for a 10 s simulation of the system motion was obtained using the ADAMS Solver using different formalisms with decreasing integrator tolerances and step-sizes, until convergence was achieved. This solution was verified with a custom code written in Fortran [1].

The time-history of the *s* coordinate during motion is shown in Fig. 2 and provided in the reference solution file. The first column in the file contains the timestamps t_i and the second one the reference value of the coordinate at each sampling time, $s_{ref}(t_i)$. The data were collected every 0.1 s starting at $t = 0$, yielding a total of $n = 101$ sampling points. The accuracy of a simulation is defined as the error with respect to the reference solution, evaluated as

$$e = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(e_i(t_i)\right)^2}$$

where e_i stands for the relative error at sampling point *i*, given by

$$e_i = \frac{|s(t_i) - s_{ref}(t_i)|}{|s_{ref}(t_i)|}$$

The maximum admissible error to consider the simulation correct is $e = 10^{-5}$.

References

[1] M. González, D. Dopico, U. Lugrís, and J. Cuadrado. A benchmarking system for MBS simulation software: Problem standardization and performance measurement. *Multibody System Dynamics*, 16(2), pp. 179-190. 2006.

Revision history

<u>2021 – January – 11th</u>
The initial conditions have been described in more detail. Thanks to Prof. Ned Nedialkov and Shahrooz Derakhshan for their valuable feedback.