3D RIGID SLIDER-CRANK MECHANISM

Problem description

Figure 1 illustrates a spatial slider-crank mechanism[1], representing a four-body dynamic system. All links are rigid, subjected to gravity of magnitude 9.81 m/s^2 in the negative Z direction.

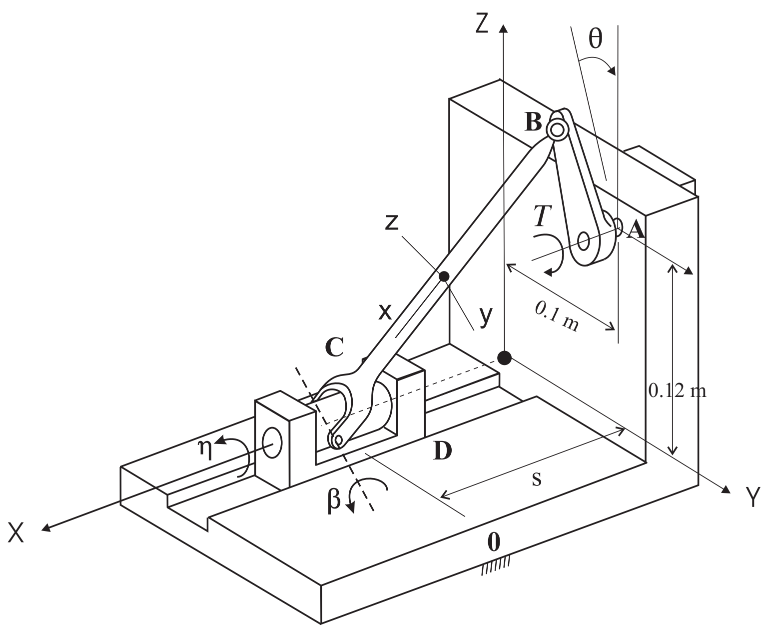

Figure 1: A spatial rigid slider-crank mechanism.

The mechanism consists of a crank AB of length 0.08 m, a connecting rod BC of length 0.3 m, and a sliding block. The crank, connected to the ground by revolute joint A, is driven from initial position $\theta = 0$ rad with initial angular speed of 6 rad/s. There is a spherical joint at B and a universal joint at C, with universal joint angles η and β defined in the figure. The block is constrained to the ground by a prismatic joint D with sliding displacement s.

Studying the forward dynamic response of the multibody system under the gravitational force, considering the above-mentioned initial conditions for the crank, is the main objective of this benchmark problem. Masses of the crank, connecting rod, and sliding block are respectively $m_{\mathrm{cr}} = 0.12$ kg, $m_{\mathrm{co}} = 0.5$ kg, and $m_{\mathrm{s}} = 2.0$ kg. Mass moments of inertia for

[1] Edward J. Haug, *Computer Aided Kinematics and Dynamics of Mechanical Systems.* Vol. 1, Boston: Allyn and Bacon, 1989, pp.396–401.

the three bodies are:

$$I_{\mathrm{cr}} = \begin{pmatrix} 0.0001 & 0 & 0 \\ 0 & 0.00001 & 0 \\ 0 & 0 & 0.0001 \end{pmatrix} \quad I_{\mathrm{co}} = \begin{pmatrix} 0.004 & 0 & 0 \\ 0 & 0.0004 & 0 \\ 0 & 0 & 0.004 \end{pmatrix}$$

$$I_{\mathrm{s}} = \begin{pmatrix} 0.0001 & 0 & 0 \\ 0 & 0.0001 & 0 \\ 0 & 0 & 0.0001 \end{pmatrix}$$

Joint-coordinate formulation is applied in the simulation model of the multibody system, considering the generalized coordinates as:

$$\mathbf{q} = \left\{\theta(t)\ \eta(t)\ \beta(t)\ s(t)\right\}^T$$

Four generalized coordinates coupled by three algebraic constraints leaves one degree of freedom for the mechanism, which can be simply perceived from the physics of the problem in this case. There is no friction in the joints.

Simulation results

MapleSim, a multi-domain modeling and simulation tool by Maplesoft, is used to simulate the 3D slider-crank mechanism. Graph-theoretic approach is used in MapleSim to introduce the topology of the system and formulate the system equations. A stiff DAEs solver is applied to acquire the simulation results.

Figure 2 shows the time history of the slider position and speed. Simulation results for

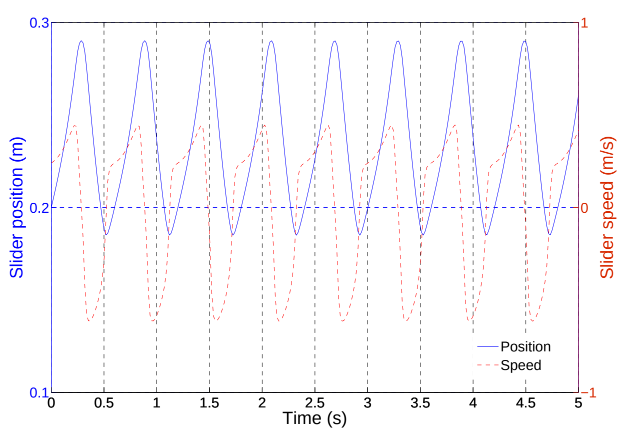

Figure 2: Time history of slider position and speed.

the crank angle are illustrated in Figure 3.

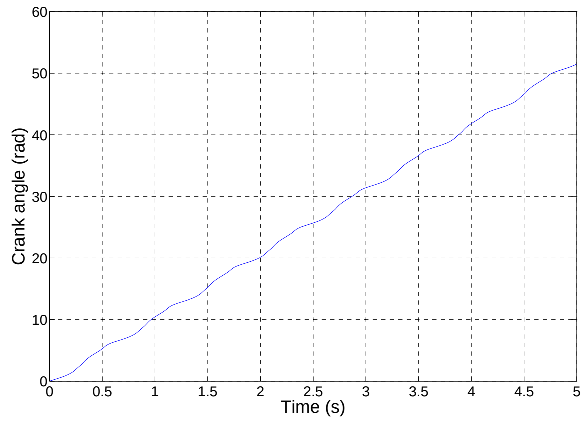

Figure 3: Time history of crank angle.

A text file from the simulation results data has been uploaded so that the user can regenerate the results for comparison purposes. The first column is time, the second one is the position data of the slider with respect to the global reference frame, and the third one is the crank angle data, starting from vertical position at which $\theta = 0$.

Table 1: Technical details for the problem, integrator, hardware, and software.

Integrator	Rosenbrock
Solver type	Stiff – variable time-step
Accuracy	xxx
Relative tolerance	1.10^{-4}
Absolute tolerance	1.10^{-4}
CPU time	250 ms
CPU/GPU	Intel(R) Core(TM2 Duo CPU E8400 3.00GHz 3.00 GHz)
Operating system	Windows7
Formulation procedure	Linear graph formulation
Dynamic equation	Symbolic, DAEs index-3
Programming language	MapleSim