ANDREWS' SQUEEZER MECHANISM

Figure 1 shows the planar, seven-link system known as Andrews' squeezer mechanism. A detailed description of the mechanism can be found in W. Schiehlen (ed.) *Multibody Systems Handbook*, Springer-Verlag, 1990. This system has a very small time scale and requires the use of integration step-sizes below 1 ms.

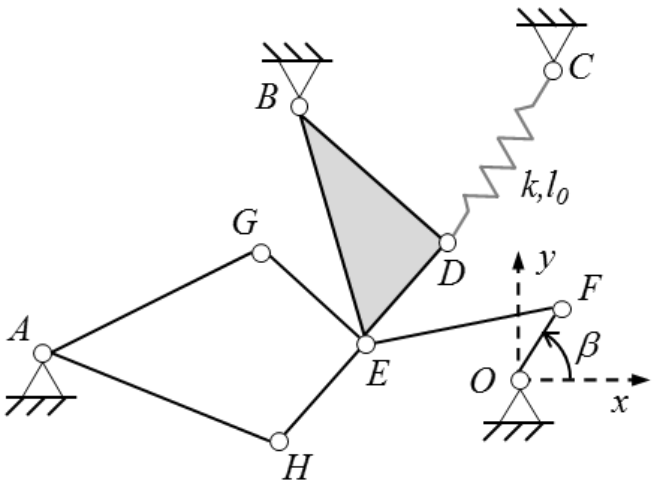

Figure 1: Andrews' squeezer mechanism

The coordinates of the different points in the local reference frames of the links are displayed in Table 1. For rods connecting two points, the *x* axis of the local frame is aligned with the rod. For link *E-B-D*, the local *y* axis is aligned with line *E-B*, pointing towards *B*. The origin of the local reference frame is the first point in the name of the link.

Link	**Point**	***x*** (m)	***y*** (m)
O-F	*O*	0.0	0.0
	F	0.007	0.0
E-F	*E*	0.0	0.0
	F	0.028	0.0
H-E	*H*	0.0	0.0
	E	0.02	0.0
G-E	*G*	0.0	0.0
	E	0.02	0.0

Link	**Point**	***x*** (m)	***y*** (m)
A-G	*A*	0.0	0.0
	G	0.04	0.0
A-H	*A*	0.0	0.0
	H	0.04	0.0
E-B-D	*E*	0.0	0.0
	B	0.0	0.035
	D	0.02	0.017

Table 1: Local coordinates of the points of the mechanism

The mass and inertia properties of the bodies of the mechanism are provided in Table 2. The position of the centre of mass of each link is expressed with respect to the origin of the local reference frame. The rotational inertia I_z of each body is expressed about its centre of mass. The global *x* and *y* coordinates of *A*, *B*, and *C* are shown in Table 3.

Link	mass (kg)	x_G (m)	y_G (m)	I_z (kg m^2)
O-F	0.04325	0.00092	0.0	$2.194 \cdot 10^{-6}$
E-F	0.00365	0.0165	0.0	$4.410 \cdot 10^{-7}$
H-E	0.00706	0.00579	0.0	$5.667 \cdot 10^{-7}$
G-E	0.00706	0.00579	0.0	$5.667 \cdot 10^{-7}$
A-G	0.07050	0.02308	0.00916	$1.169 \cdot 10^{-5}$
A-H	0.05498	0.01228	-0.00449	$1.912 \cdot 10^{-5}$
E-B-D	0.02373	0.01043	0.01626	$5.255 \cdot 10^{-6}$

Table 2: Mass and inertia properties of the links in the Andrew's squeezer mechanism

Point	x_G (m)	y_G (m)
A	-0.06934	-0.00227
B	-0.03635	0.03273
C	0.01400	0.07200

Table 3: Global *x* and *y* coordinates of points *A*, *B*, and *C*

A spring of stiffness k = 4530 N/m and natural length l_0 = 0.07785 m connects points *C* and *D*. A constant driving torque τ = 0.033 Nm acts on rod *O-F* during motion. The system moves without gravity effects from the initial position, in which β = -0.0620 rad. All the initial velocities are zero. The total simulation time is 0.05 s. Figure 2 shows the *x* and *y* coordinates of point *F* during motion.

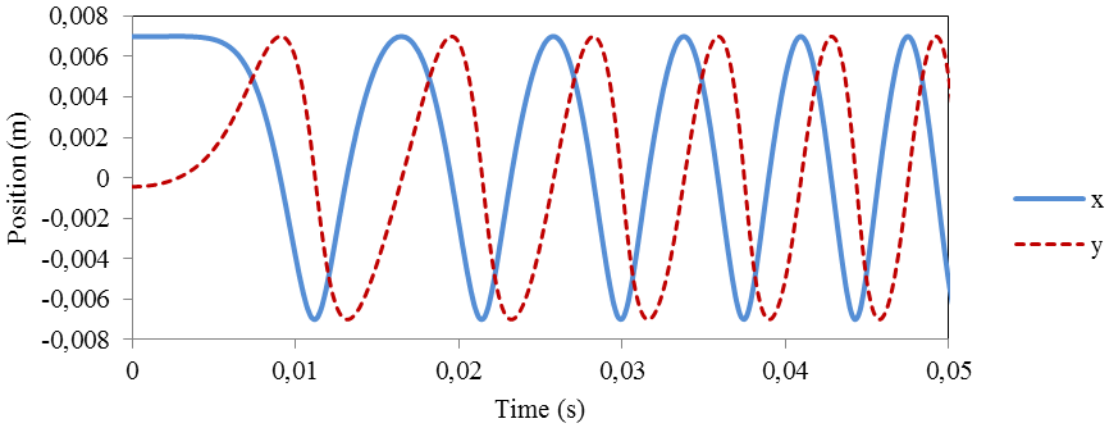

Figure 2: Time-history of the *x* and *y* coordinates of point *F*

Figure 3 shows the total energy balance of the system and the violations of the constraints at the position and velocity levels during the simulation. The constraints violation is the norm of the array of constraints at the corresponding level (configuration or velocities).

The driving torque increases the total energy of the system, such as

$$E - E_0 = \tau(\beta - \beta_0)$$

where E is the mechanical energy at a given time, E_0 is the mechanical energy of the system at time t = 0, and the energy introduced in the system by the driving torque is $\tau(\beta - \beta_0)$, with β_0 the value of angle β at time t = 0. The total energy balance ΔU is defined as

$$\Delta U = T + V - E_0 - \tau(\beta - \beta_0)$$

where T is the kinetic energy and V is the potential energy. The value of ΔU should remain zero during motion. The error of the simulation will be considered as the maximum drift of ΔU from its theoretical null value.

The objective of this benchmark problem is to carry out the simulation of the motion in the minimum CPU time, while keeping the maximum drift of balance ΔU away from the 0 reference value below 10^{-5} J.

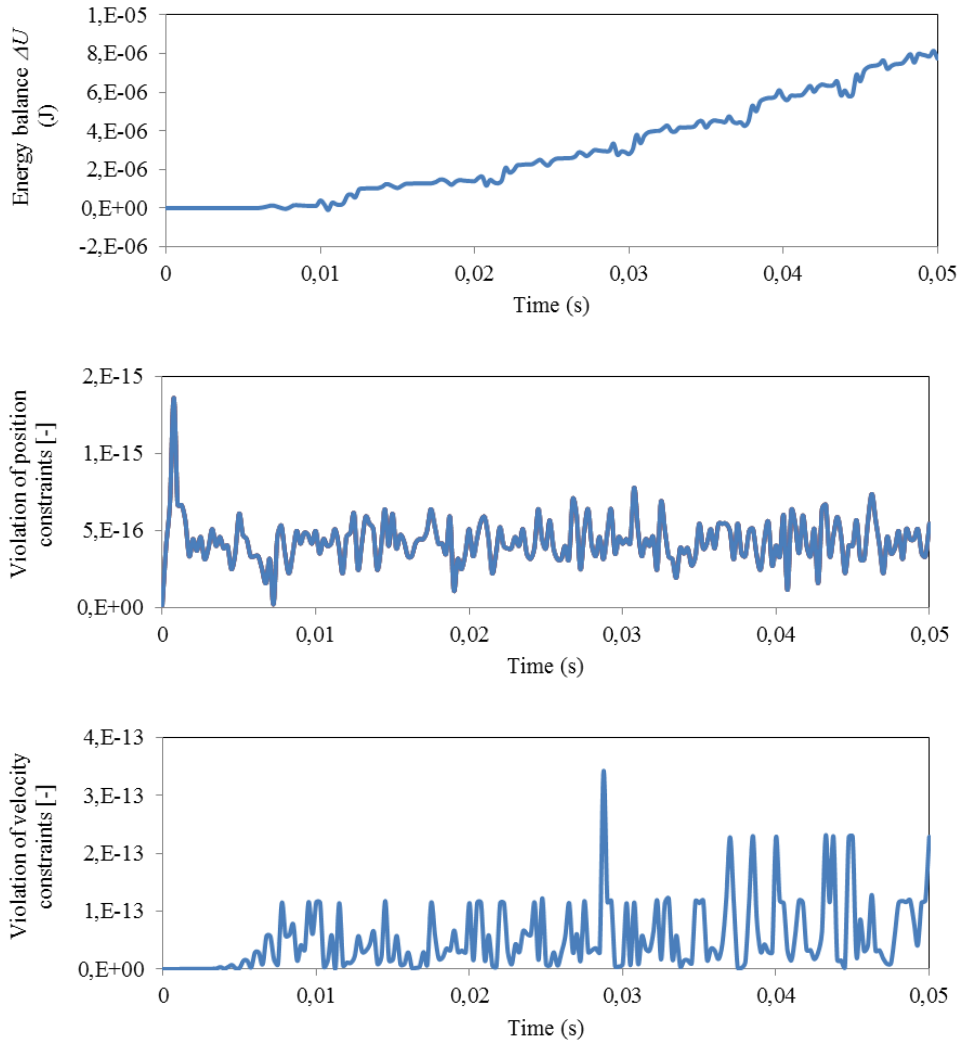

Figure 3: Time-history of the energy balance ΔU of the mechanism and the violation of constraints at the configuration and velocity levels

A reference text file with the results is available, for comparison purposes. The file is composed of eight columns. The first one represents the simulation timestamp, from 0 to 0.05 s. The second and third columns contain the x and y coordinates of point F during motion. The fourth and fifth ones contain the kinetic and potential energy of the system. The sixth column includes the energy introduced by the driving torque in the system since the beginning of the motion. The last two ones represent the constraints violation at the configuration and velocity levels.

Revision history

2016 – April – 18th
Table 1 corrected: *y* coordinate of point *H* in link *AH* changed from 0.04 m to 0.0 m.