

Exercise 3: Planar translator

The influence of different possibilities of actuator location and sensor location on the positioning of a rigid body in 2D space is subject of this exercise. Although SiSO-control is considered and the motion is intended to be translational in one direction and the body to move is rigid, the goal of the exercise is to experience that co-location control can be easily lost. Moreover, the goal is also to practise the use of rheonomic degrees of freedom for analyzes of disturbance rejection in this case.

The problem is adapted from the combination of a large and small stroke actuation. These are often applied in precision equipment (industrial printers, wafer stepper/scanners, telescopes, CD/DVD players etc.) in order to overcome an accuracy problem. The large stroke is usually established by linear motors with large forces and with loose accuracy tolerances and low bandwidth control, the small stroke is usually established by voice coil actuators (VCM's) with sharp accuracy tolerances and high bandwidth control.

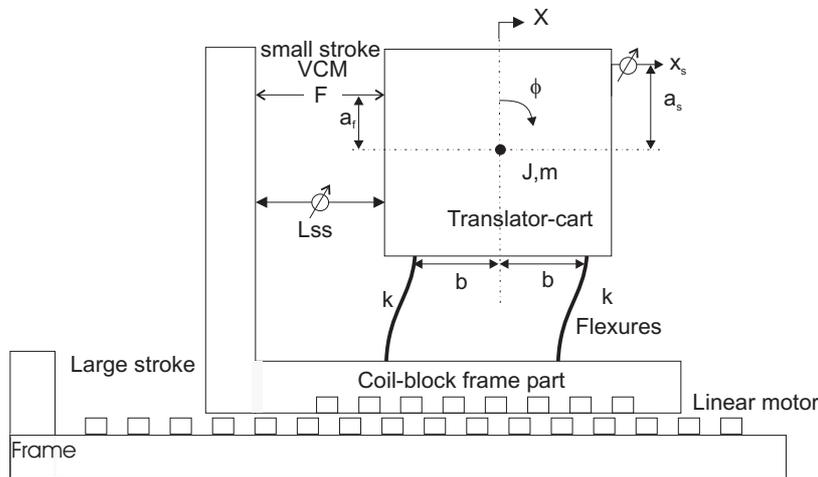


Figure 1: Large-stroke small-stroke manipulator

Figure 1 shows schematically the concept large-small stroke actuation combination. The sensor in a_s is an absolute position sensor. When the position of the cart is commanded to change, the small-stroke actuator moves the cart (master). The change is noticed by the sensor of the large-stroke (L_{ss}) and the linear motor moves the coil-block frame part (slave).

The best possibility is to actuate the cart in the c.o.m. However, this is not always possible due to constructive limitations. Other possibilities are actuation below the c.o.m and above the c.o.m. This accomplishes the excitation of parasitic modes. Also different locations of the sensor are possible. Moreover the sensor and actuator can be situated on opposite sites of the c.o.m. of the translator.

To analyzes these possibilities, the exercise is that a number of input-output transfer-function have to be obtained and evaluated.

The mass of the translator-cart is 1 kg it's inertia $J=0.00041 \text{ kgm}^2$. The flexures are leaf-springs with the properties as shown in table 1. The coil-block of the large-stroke actuator is initially considered as the fixed world.

E	$2.1 \cdot 10^{11}$	N/m ²
length	0.050	m
width	0.01	m
d (thickn.)	0.0002	m
ρ	7800	kg/m ³
Elem. mass	0.016	kg/m

Table 1: Leaf-spring dimensions

The c.o.m. of the translator-cart is assumed to be in the center. The cart has the following dimensions: $b = 0.02$ m. height $h = 0.06$ m.

1.

Construct a model in SPACAR using PLBEAM elements. Use as much rigid beams as necessary for modelling the cart. Use also beams to point the c.o.m. and the actuator and sensor position. Use two beams to model one leaf-spring (provides internal modes in the leaf-springs). Find out first how much degrees of freedom this model will have. (You can include a very small amount of internal damping in the leaf-springs for making nice bodeplots).

2.

Take as output the sensor- output x_s and an VCM-actuator force F as input. Position the actuator at $-b$ and $a_f = 1$ cm above the c.o.m. Position the sensor in $+b$ and $a_s = 1$ cm above the c.o.m.. Obtain the transfer-function using SPACAR. Evaluate (=describe what you see) this transfer-function by making a bodeplot and a pole-zero plot. It might be of use to use SPAVISUAL to show the mode-shapes. This tool is available after you complete the SPACAR analysis and then typing `spavisual('yourfilename',#)`¹ at the MATLAB command prompt. Add the next lines at the SPACAR input file by pressing the 'Add additional Dynamics commands' button in the userinterface and then select under `keywords` the following two items.

VIBREND 7.8540

ENLARGEFACTOR 0.05

3. (non-linearity)

Investigate the influence of gravity, causing pre-stress in the leaf-springs, on the transfer-function. Describe the phenomena you notice. Calculate from the first mode frequency an estimate of the stiffness in x-direction and compare this what is given initially. Investigate also the influence of the situation that the actuator delivers a static force of 0.2 N (in x-direction).

4. (non-colocated)

Remove the static actuator-force again. Now position the actuator in $-b$ and 1 cm below the c.o.m. ($a_f = -1$ cm). Obtain the transfer-function using SPACAR. Evaluate (=describe what you see) this transfer-function by making a bodeplot and a pole-zero plot. Notice especially the differences with Part 2.

¹where you replace the # by the number of the vibration mode you would like to visualise.

5. (non-colocated)

Same as part 4, but position the sensor in b and on top of the cart and the actuator in $-b$ and at the 3 cm below the c.o.m.

6. (Rheonomic DOF's)

Set actuator location en sensor location both in c.o.m. ($a_f = a_s = 0$, $b_a = -b$ and $b_s = b$). Investigate the amount of disturbance rejection the cart has with respect to a harmonic position error of the large-stroke actuator caused by cogging. The large-stroke actuator is travelling with a maximum velocity of 1 m/sec. The pitch of the magnets and coil-slots is 0.02 m. The small-stroke system is controlled by as well a position as a velocity feedback with gains respectively $k_p = 80000$ N/m and $k_v = 396$ Ns/m. (Tip: This feedback structure can be easily modeled using mechanical components)