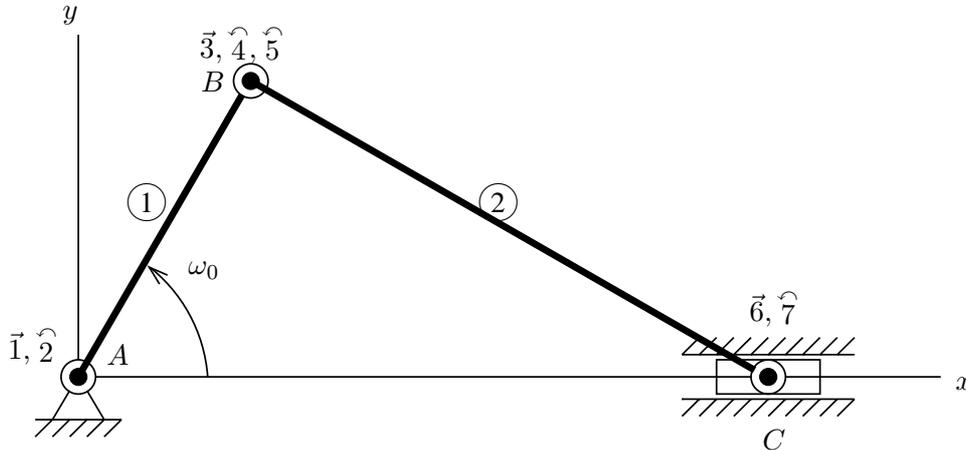


Exercise 2

Consider the planar slider crank mechanism of example 3.7.2 in the lecture notes. In this exercise we will make some SPACAR input files and run the example to study the behavior of a mechanism with flexibility. In the first problem the crank and the connecting rod are assumed to be rigid. In the initial



configuration, the crank and the connecting rod are horizontal. The crank length is 0.15 m, the length of the connecting rod is 0.30 m. For the dynamic analysis the following parameters are needed: The connecting rod has a mass per unit length of 0.22 kg/m. The mass of the sliding block or plunger C is given by $m_C = 0.033$ kg. The crank is driven at a constant angular velocity $\omega_0 = 150$ rad/s. The total simulation should comprise two crank rotations.

1. Create an input file for the rigid slider-crank mechanism (or try to understand the supplied sample). Run a simulation and check some computed quantities like the rotation angle in A , the position of block C , ...

In the next simulations we want to use this rigid manipulator as a reference, so we save some variables:

```
timea = time;
xa    = x;
xda   = xd;
xdda  = xdd;
lnpa  = lnp;
```

(You may other variables if you like).

2. Next we want to take bending flexibility of the connecting rod BC into account. For the third parameter of the ESTIFF keyword we take $EI_x = 13.5$ kg m². Create an input file for this flexible mechanism using 2 (flexible) beams for the connecting rod. Compare e.g. the horizontal position of the sliding block with the rigid case.
3. Redo the flexible simulation with less (=1) or more beam elements in the connecting rod. Note that the third parameter of the ESTIFF keyword equals EI_x/l^3 so its value has to be adjusted when the length of the elements changes. Compare the results with the rigid case as before. Note also the change in computing time. You can also look at the total number of time steps

SPACAR used internally for your simulation. This number is the `total` FE number on the last line in the `log` file.

You may get messages in the `log` file indicating `ERROR IN DRIVER, IFLAG= 4 of 6`. The first code (4) is a kind of warning that an internally defined maximum number of iterations (100) during one user defined time step has been exceeded. The result may still be OK, but to be sure, you can increase the number of time steps. The second code (6) indicates an error condition and occurs after 10 successive code (4) warnings in one user time step.

4. Finally, you can change the stiffness. Too high values will result in small vibrations at high frequencies and will ultimately lead to integrator errors. Too small values give clearly visible deformations during the visualization, but you may guess that at some stage the constitutive equations are no longer valid.