MAS416 - Modeling and Simulation of Mechatronic Systems

Introduction

This project is a part of the course MAS416 Modeling and Simulation at the University of Agder. The course is at Master level and is taken by students in Mechatronics and Renewable Energy. The project consists of the following parts:

- Create a dynamic model of an industrial robot from ABB using Simulink/Simscape. This robot has six degrees of freedom and contains a parallel linkage system. At the robot's wrist, an electric machining spindle is attached.
- Simulate the Simulink/Simscape model with an input of your own choice for each of the joints. The purpose of this simulation is to validate your model, for example that the gravity torque in each joint is reasonable.
- The tip of the spindle should follow a certain path, see Fig. 3, during the operation of interest. Make a program (use Matlab, Excel, or similar) that computes a reference position and a reference velocity for the tip of the robot for the entire operation. Save the references as time series in text files.
- In Simulink/Simscape make the tip of the spindle follow the prescribed path, see details under "Robot load case". Import the reference position and reference velocity from the previous mentioned text files. Record the six joint angles and joint velocities in text files.
- In Simulink/Simscape develop a model with geared servomotors as drivers for each axis. Use the joint angles and joint velocities from the previous step as reference.
- Optimize the design so that the robot costs as little as possible and moves as fast as possible through the prescribed path, see details under "Robot design".

The machine which is shown in Figs. 1 and 2.

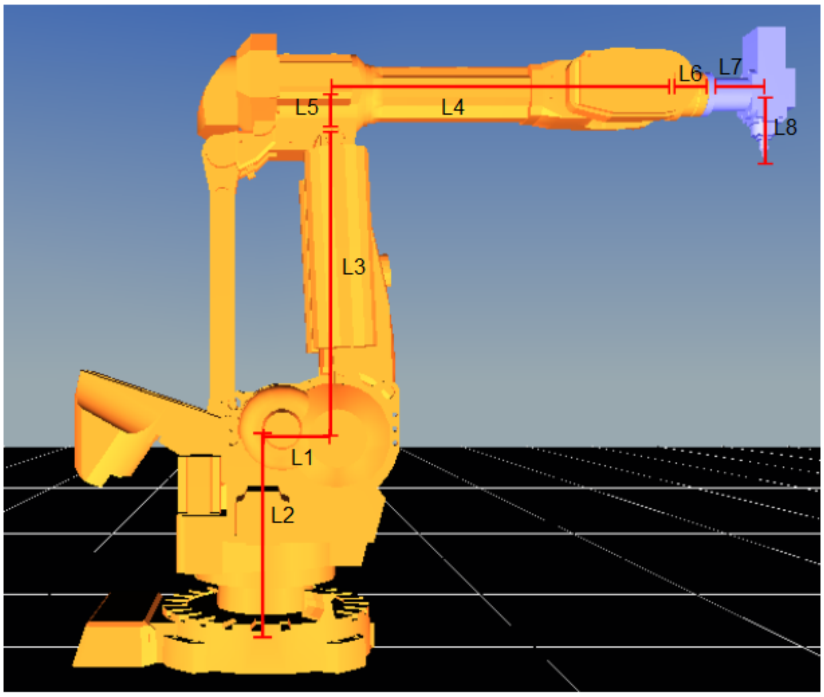


Figure 1 ABB-robot with some of the basic measurements = open loop kinematic parameters, $L_{1..8}$.

Simulink/Simscape modeling
In Simulink/Simscape it is recommended to design the model as a multibody dynamics model and then add components from rotational mechanics, power transmission and signals as needed.

The robot itself contains a single closed chain and when the tool point (point J in Fig. 2) is to be prescribed this must be done by introducing a second (virtual) closed chain.
There are six driven revolute joints, see Tab. 1.

Table 1 Actuated revolute joints.

Point	Axis	Reference body	Driven body
A	Reference z-axis	Frame	BLUE
B	Out-of-the-plane	BLUE	GREEN
B	Out-of-the-plane	BLUE	RED
G	Along GH-line	CYAN	GRAY
H	Out-of-the-plane	GRAY	BLACK
I	Along HI-line	BLACK	LIGHT BLUE

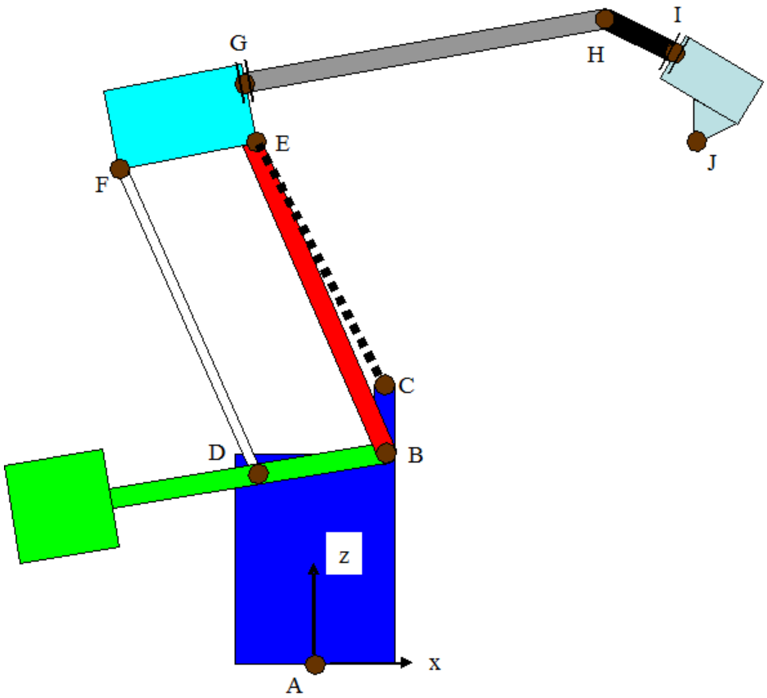


Figure 2 Simplified kinematic model of ABB-robot. The right hand reference coordinate system is shown in point A.

The machine has the following open loop kinematic parameters (all units in mm):

$$L_{1..8} = [240 \quad 800 \quad 1050 \quad 1175 \quad 225 \quad 200 \quad 235 \quad 248]\ mm$$

The links BE and HI are limited in motion.
The rotation of the link BE is limited to $\pm 80°$ relative to vertical and the rotation of the link HI is limited to $\pm 90°$ relative to the centre line from G to H.
Between point C and E a single spring is suspended. The undeformed length and stiffness of the undamped spring are 750 mm and 100 kN/m, respectively.

The kinematic and inertia data (inertia data relative to mass center and local coordinate system) of the different bodies are given in Appendix A. Any other geometry data can be chosen freely but should reflect the approximate dimensions of the robot.

Robot load case

The point J must start from rest in point P1, pass through points P2..P6, and finish in point P7 where it should come to rest. The coordinates of the seven points are listed in Tab. 2. During the entire period of operation the tool (Body IJ) should translate, i.e., L7 must remain horizontal (+/- 0.2º) and L8 must remain vertical (+/- 0.2º), and the tool must not rotate around the L8-axis (+/- 0.2º), see Fig. 1.

Table 2 Coordinates of path points relative to reference coordinate system (NOT YET FINISHED).

Point	**x [mm]**	**y [mm]**	**z [mm]**
P1			
P2			
P3			
P4			
P5			
P6			
P7			

Point J must start exactly at P1 and it must pass P2..P6 within a distance of 3 mm and come to rest at P7 within a distance of 1 mm.

Robot design

The six actuated revolute joints are all driven by geared servomotors. You can choose any of three different servomotors for each of the six axes. The three different servomotors should all have a mass moment of inertia J = 0.002 kgm^2 and the motor torque constant that can be any of the three values:

Motor torque constant	0.5 Nm/A	1.0 Nm/A	1.5 Nm/A
Motor dimensionless cost	1	1.25	1.5

The gearboxes are to be modeled as ideal with one of the following four gear ratios:

Gearbox ratio	20	50	100	200
Gearbox dimensionless cost	1	1.25	1.5	2.5

Design the robot (choose servomotors and gearboxes) and prescribe the motion P1-P2-….-P7 so that the total cost of the servomotors and gearboxes are minimized and the total time P1-P2-…-P7 is minimized.

Grading

The project grade accounts for 40% of the grade in MAS416.

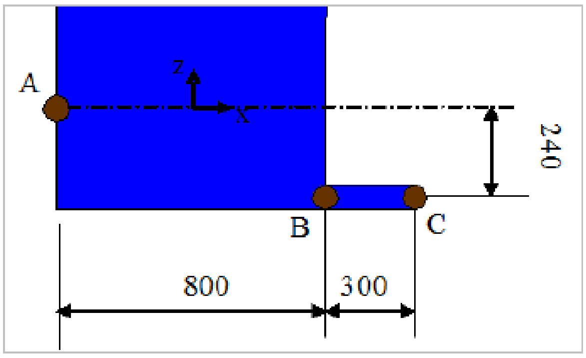
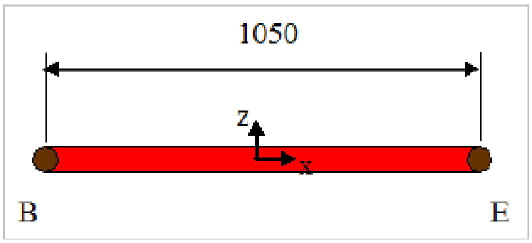
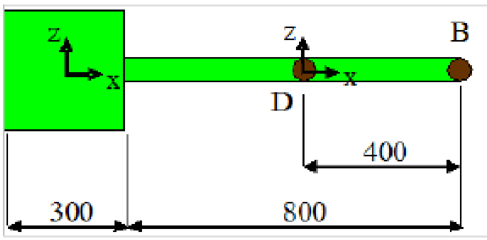
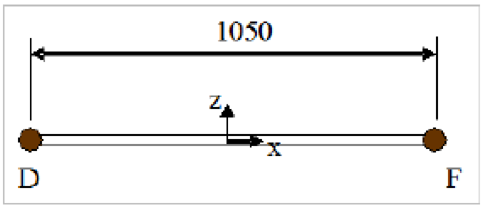
Evaluation

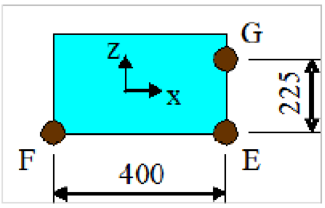
The project is evaluated via the handed-in report, see also the sensor guidance.

Special considerations

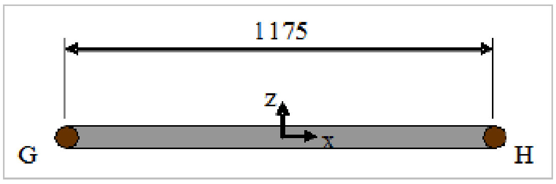
Normally, the project must be carried out with either 3 or 4 participants. Alternatively, the project can be carried out individually, i.e., 1 participant. In that case the project is fundamentally the same, however, the task is reduced, so that no minimization of cost and total time is expected.

Appendix A
All coordinate systems shown on the different bodies are local coordinate systems positioned in the mass center of the individual bodies.

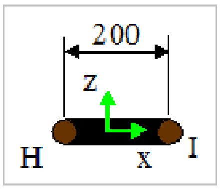
		$m = 750\ kg$ $I_x = 50\ kg \cdot m^2$ $I_y = 50\ kg \cdot m^2$ $I_z = 50\ kg \cdot m^2$
		$m = 250\ kg$ $I_x = 1\ kg \cdot m^2$ $I_y = 20\ kg \cdot m^2$ $I_z = 20\ kg \cdot m^2$
	$m = 150\ kg$ $I_x = 0.5\ kg \cdot m^2$ $I_y = 8\ kg \cdot m^2$ $I_z = 8\ kg \cdot m^2$	$m = 500\ kg$ $I_x = 10\ kg \cdot m^2$ $I_y = 10\ kg \cdot m^2$ $I_z = 10\ kg \cdot m^2$
		$m = 50\ kg$ $I_x = 0.2\ kg \cdot m^2$ $I_y = 1\ kg \cdot m^2$ $I_z = 1\ kg \cdot m^2$



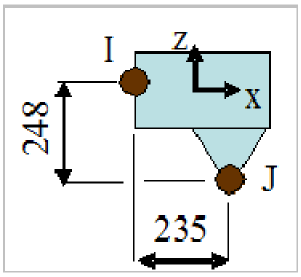
$$m = 150\,kg$$
$$I_x = 2\,kg \cdot m^2$$
$$I_y = 3\,kg \cdot m^2$$
$$I_z = 2\,kg \cdot m^2$$



$$m = 200\,kg$$
$$I_x = 1\,kg \cdot m^2$$
$$I_y = 18\,kg \cdot m^2$$
$$I_z = 18\,kg \cdot m^2$$



$$m = 100\,kg$$
$$I_x = 0.5\,kg \cdot m^2$$
$$I_y = 2\,kg \cdot m^2$$
$$I_z = 2\,kg \cdot m^2$$



$$m = 50\,kg$$
$$I_x = 1\,kg \cdot m^2$$
$$I_y = 1\,kg \cdot m^2$$
$$I_z = 1\,kg \cdot m^2$$