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UNIVERSITÀ DI PAVIA
Dipartimento di
Ingegneria Industriale
e dell'Informazione

Automated Mechanical System Design

Motion curve planning 02

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Develop an test motion curve modules

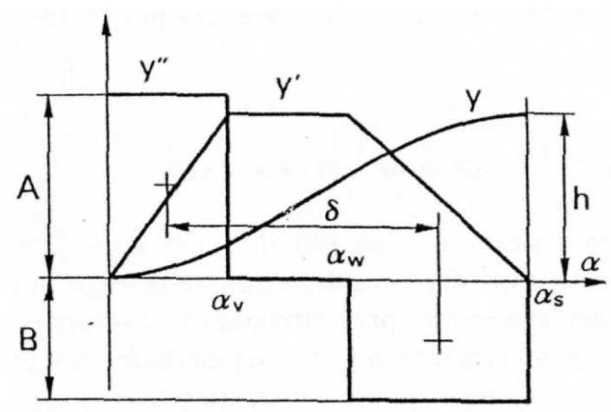
Develop Matlab functions and scripts in order to collect and test the following motion curve modules:

- Cubic curve
- Cycloidal curve
- Asymmetric trapezoidal speed profile (s-shape)
- Modified trapezoidal (acceleration) curve (seven parameters)

Develop an test motion curve modules

From first propriety of the acceleration diagram

$$\frac{A}{B} = \frac{\alpha_s - \alpha_w}{\alpha_v}$$



While, from the second propriety of the acceleration diagram

$$\begin{cases} y'_{max}\delta = h = A\alpha_v\delta \\ \delta = \dfrac{\alpha_s}{2} - \dfrac{\alpha_v}{2} + \dfrac{\alpha_w}{2} \end{cases}$$

From the previous equations it is possible to evaluate the values of the maximum acceleration

$$\begin{cases} A = \dfrac{2h}{\alpha_v(\alpha_s - \alpha_v + \alpha_w)} \\ B = \dfrac{2h}{(\alpha_s - \alpha_w)(\alpha_s - \alpha_v + \alpha_w)} \end{cases}$$

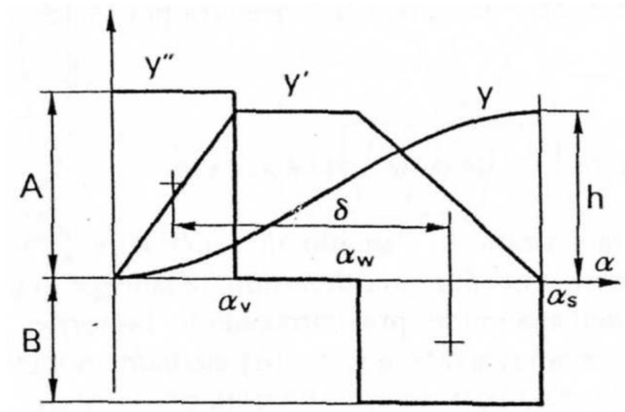
Develop an test motion curve modules

It is possible, integrating the acceleration diagram, to define the motion curve in terms of velocity and displacement

$$0 < \alpha < \alpha_v \qquad \begin{cases} y'' = A \\ y' = A\alpha \\ y = \frac{1}{2}A\alpha^2 \end{cases}$$

$$\alpha_v < \alpha < \alpha_w \qquad \begin{cases} y'' = 0 \\ y' = A\alpha_v \\ y = A\alpha_v\left(\alpha - \frac{\alpha_v}{2}\right) \end{cases}$$

$$\alpha_w < \alpha < \alpha_s \qquad \begin{cases} y'' = -B \\ y' = A\alpha_v - B(\alpha - \alpha_w) \\ y = A\alpha_v\left(\alpha - \frac{\alpha_v}{2}\right) - \frac{B}{2}(\alpha - \alpha_w)^2 \end{cases}$$



Develop an test motion curve modules

Regarding the “Modified trapezoidal (acceleration) curve” (seven parameters) please referred to kiro website:

- Modified Trapezoidal Trajectory_eng.pdf
- Modified Trapezoidal Trajectory_ita.pdf

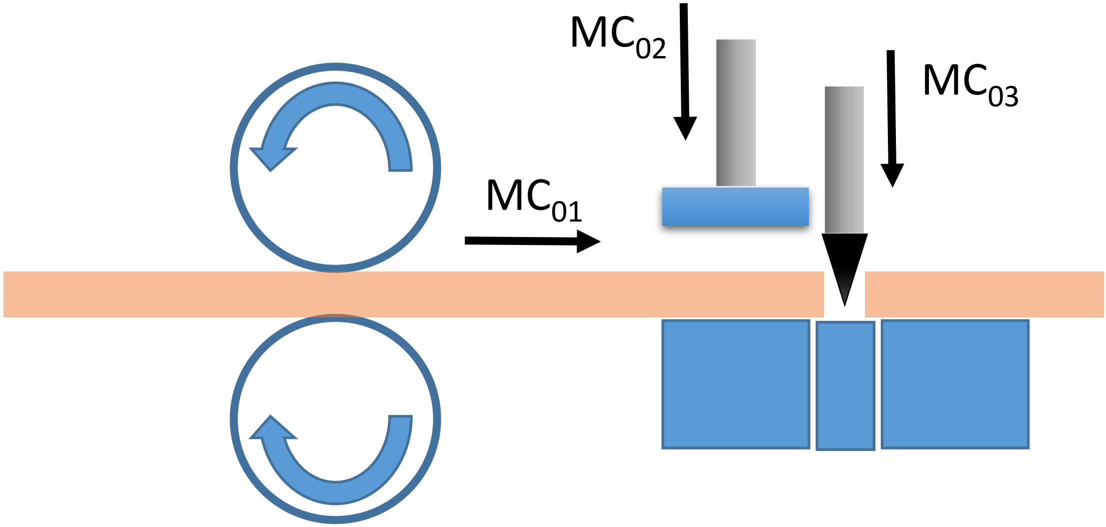
Note:

Use this profile in order to develop the project for the exam.

Timing diagram for a cutting machine

Design the timing diagram for a functional group of a cutting machine made up of three mechanism:

- Feeding group → motion curve MC_{01}
- Pressing group → motion curve MC_{02}
- Cutting group → motion curve MC_{03}



Rise for each curve:

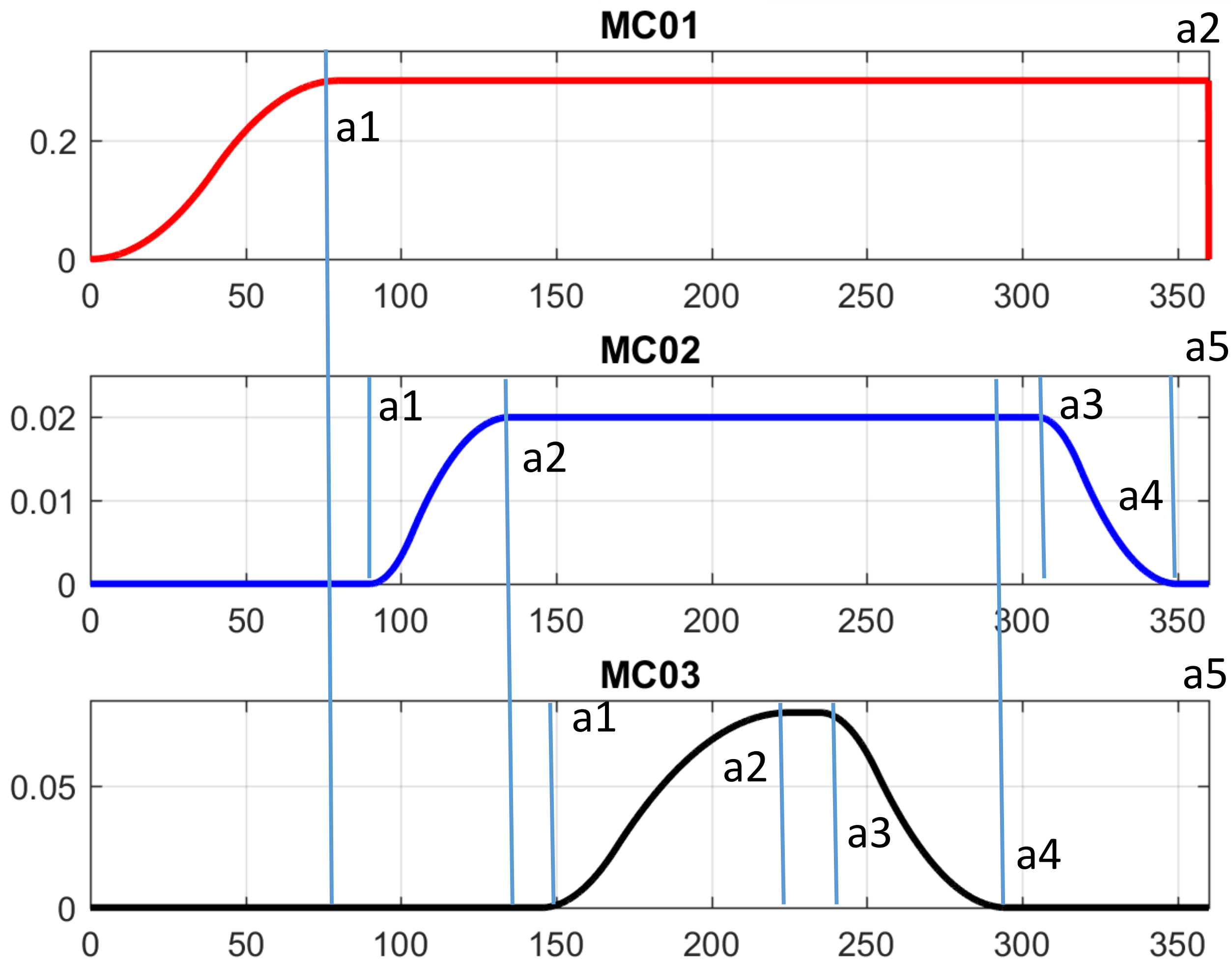
- h_{01} = 300mm
- h_{02} = 20 mm
- h_{03} = 80 mm

Timing diagram for a cutting machine

MC_{01}:
a1=80; a2=360;

MC_{02}
a1=90; a2=135;
a3=305; a4=350;
a5=360;

MC_{03}
a1=145; a2=225;
a3=235; a4=295;
a5=360;



Timing diagram for a cutting machine

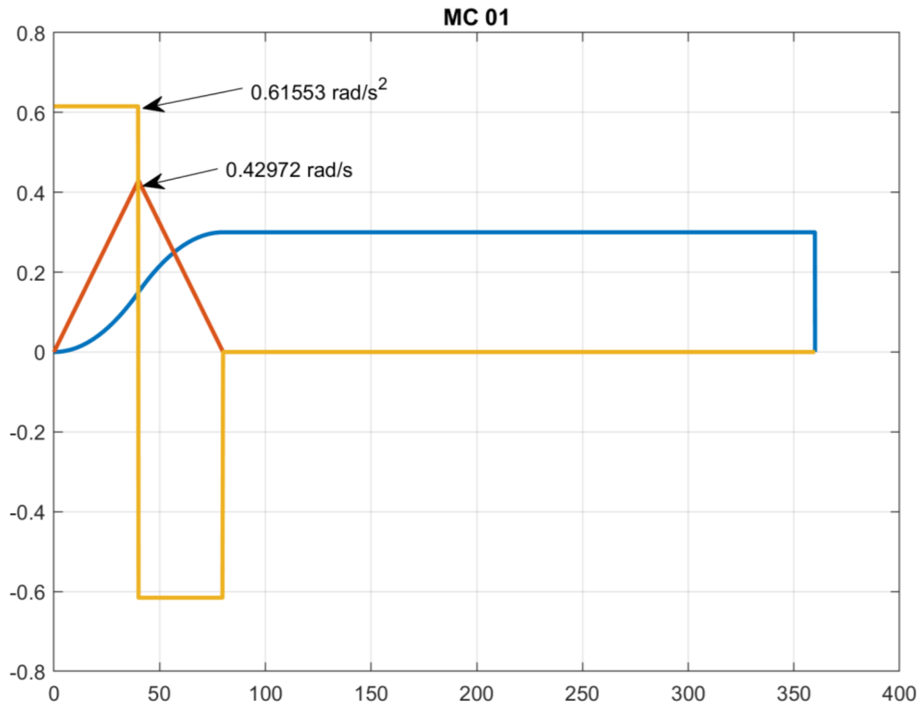
Using the motion curve module that you developed, calculate:

- Maximum geometrical acceleration and speed values for each movement
- If the machine cut 200 pieces per minute, what is the maximum acceleration value of each movement?

Timing diagram for a cutting machine

200 pieces per minute → 200 rpm of the master shaft

$$\begin{cases} \dfrac{200}{60} = 3.33 \text{ turns per second} \\ \dfrac{60}{200} = 0.3 \text{ sec. for each turn/product} \\ \omega = \dfrac{200 \cdot 2\pi}{60} = 20.944 \text{ rad/s} \end{cases}$$

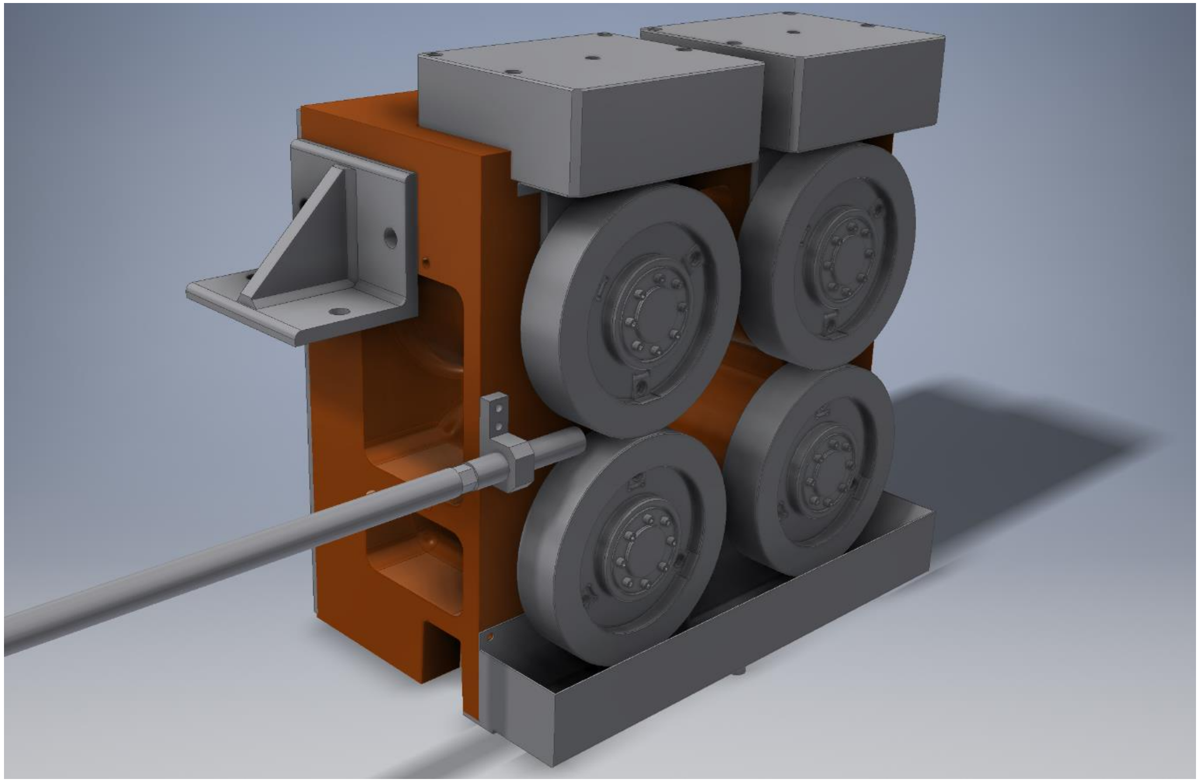


$$\begin{cases} \dot{y} = y'\omega = 0.43 \cdot 20.94 = 9m/s \\ \ddot{y} = y''\omega^2 = 0.61 \cdot 20.94^2 = 270m/s^2 \end{cases}$$

$$\ddot{y}_{max} = c_a \frac{h}{t_a^2} = 4\frac{0.3}{(0.3\frac{80}{360})^2} = 270 \text{ m/s}^2$$

Feeding group layout

Study the feeding group, shown in the figure, and determine the torque required by the motor to follow the designed motion curve when the production is <u>100 pieces/minutes</u>.



Import in inventor the file:

P6-16-00-ASSIEME GENERALE.STEP

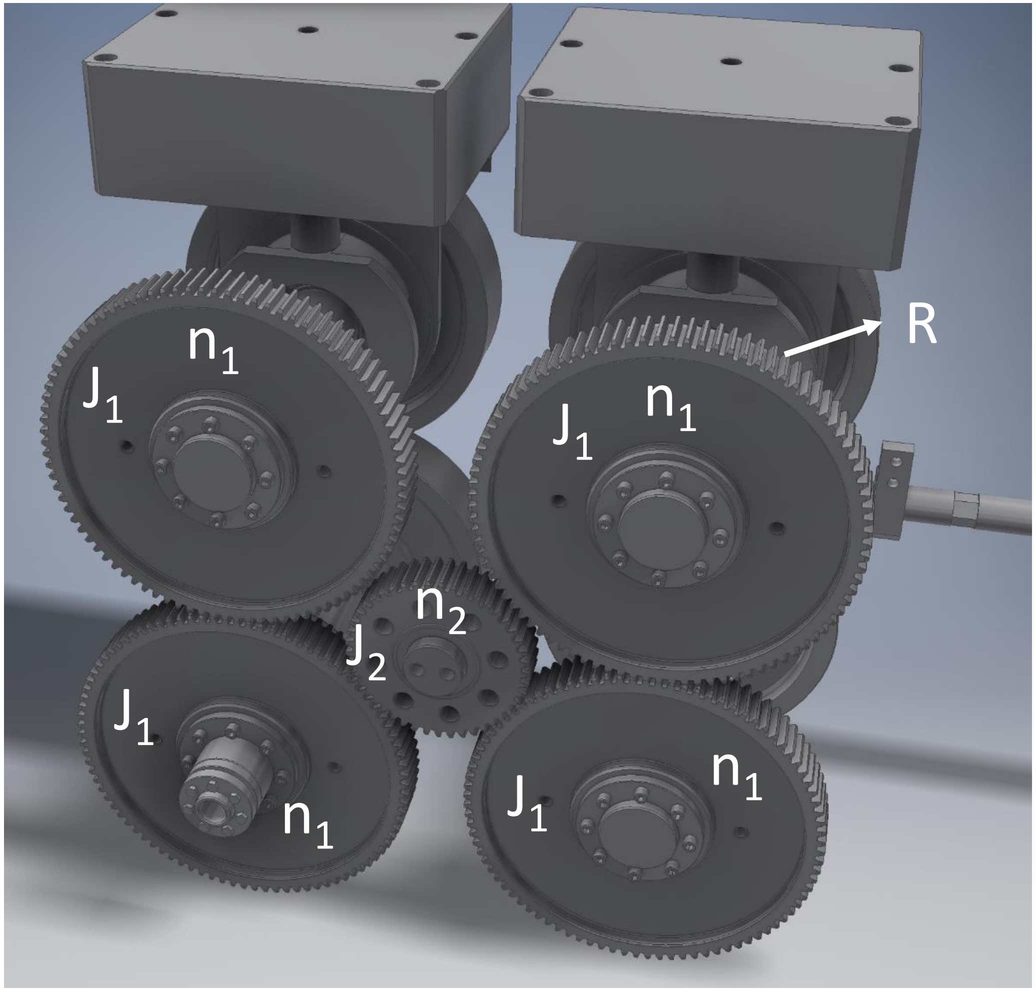
All the components are steel made.

Feeding group layout

Calculate:

- the equivalent J of all the actuated axes
- the inverse dynamic problem writing a simple Matlab script
- plot the values of speed and torque on a Cartesian plan where rpm is on the abscissa axis and torque on the ordinate one.

Feeding group layout



Input data:

n_1=90 teeth

n_2=45 teeth

The resistance force is:
F_r=500 N

Mass & geometrical analysis:

J_1=0,284 kg m^2

J_2=0,007 kg m^2

R=0.134 m

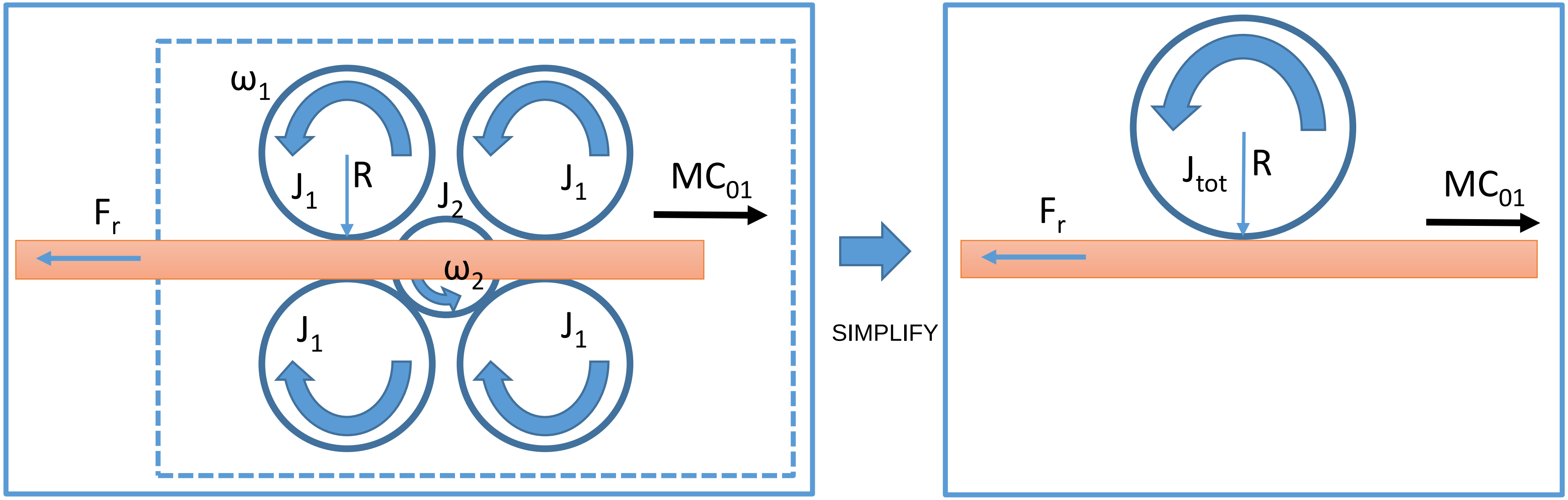
Feeding group layout

Calculate the equivalent J of all the actuated axes

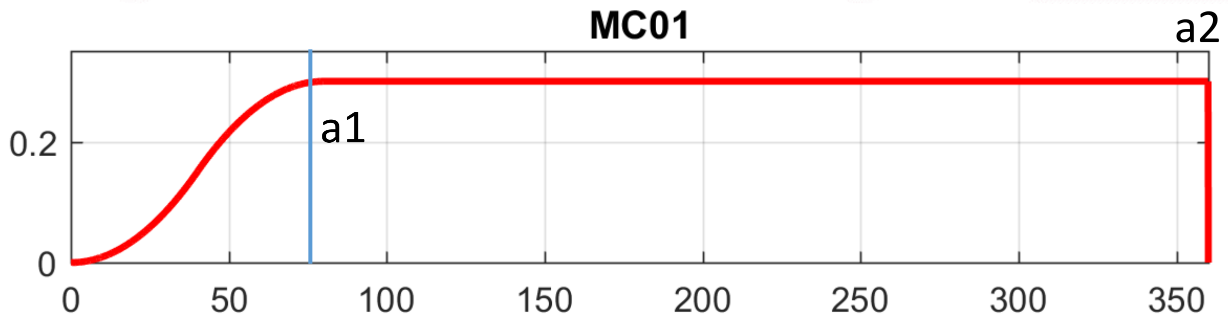
$$\omega_1 \tau_g = \omega_2 \rightarrow \boxed{\tau_g = \frac{\omega_2}{\omega_1} = \frac{n_1}{n_2} = \frac{90}{45} = 2}$$

$$\frac{1}{2} J_2 \omega_2^2 = \frac{1}{2} J^* \omega_1^2 \rightarrow \boxed{J^* = J_2 \left(\frac{\omega_2}{\omega_1}\right)^2 = 4J_2}$$

$$J_{tot} = 4J_1 + 4J_2$$



Feeding group



MC_{01}:

a1=80; a2=360;

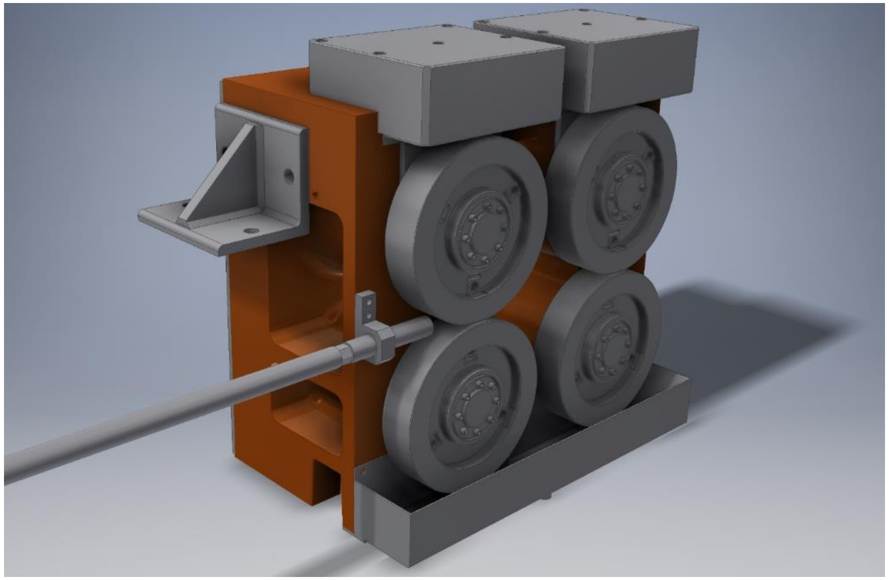
Production

→ 100 pieces per minute

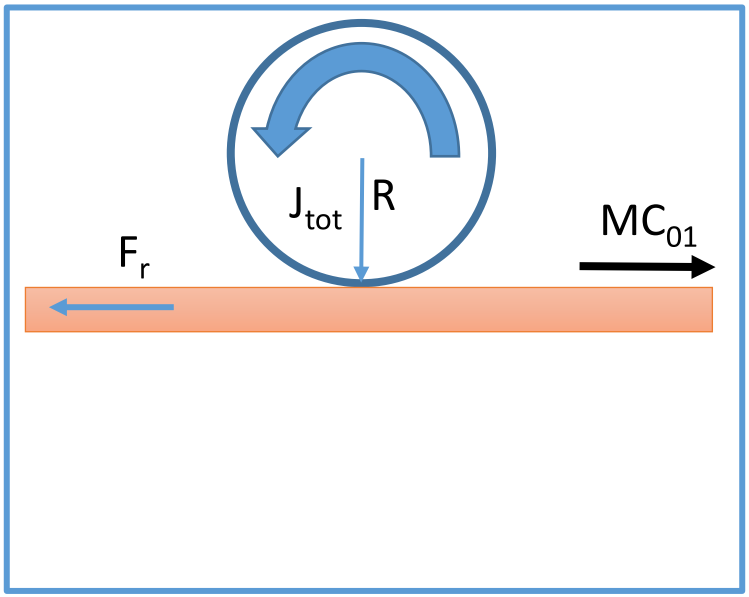
→ $t_c = t_{a2} = 60/100 = 0.6$ s

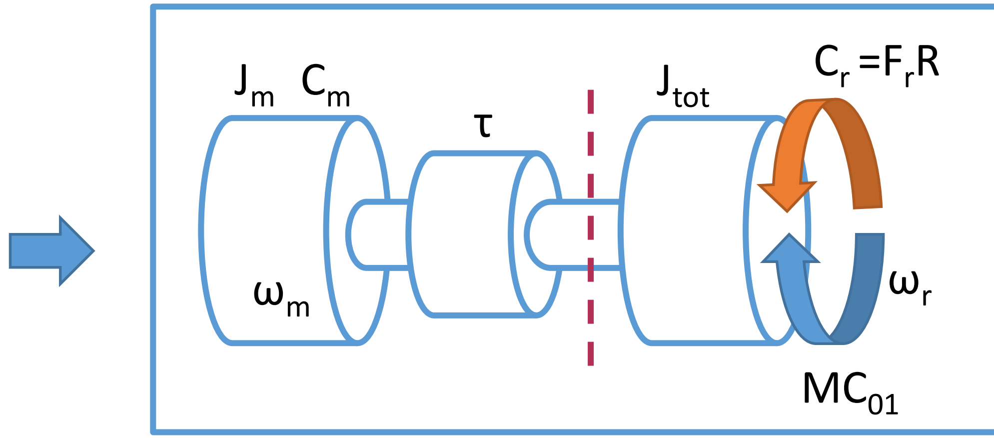
→$t_{a1} = 0.6*(80/360) = 0.133$ s

→ω=100*2*pi/60



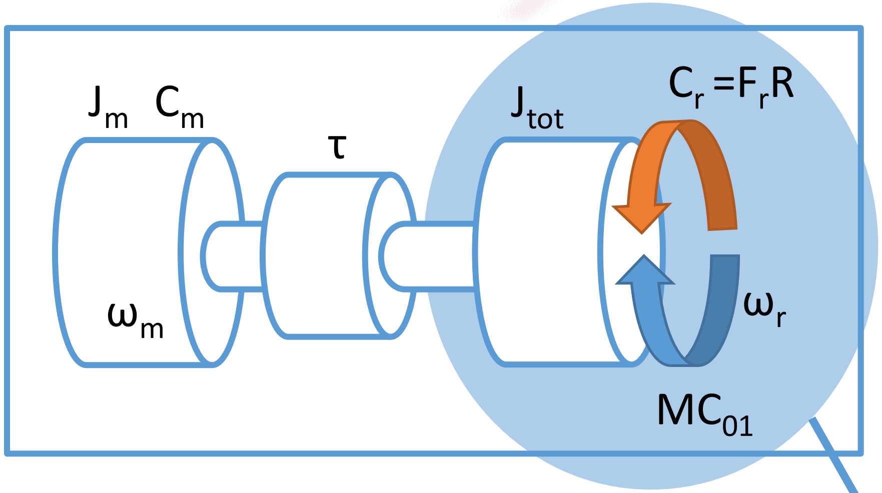
Feeding group layout





$$\begin{cases} J_{\text{tot}} = 4J_1 + 4J_2 \\ C_r = F_r R = 500 \cdot 0.134 = 67 Nm \\ \omega_r = \dfrac{v}{R} \end{cases}$$

Feeding group



$$C_m\omega_m - J_m\dot{\omega}_m\omega_m = C_r\omega_r + J_{tot}\dot{\omega}_r\omega_r$$

$$\frac{C_m}{\tau} - \frac{J_m}{\tau^2}\dot{\omega}_r = C_r + J_{tot}\dot{\omega}_r$$

$$C_m = \frac{J_m}{\tau}\dot{\omega}_r + \tau(C_r + J_{tot}\dot{\omega}_r) = \frac{J_m}{\tau}\dot{\omega}_r + \tau C_r^*$$

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Thank you for your attention