Università degli Studi di Padova – Dipartimento di Ingegneria Industriale

Corso di Laurea in Ingegneria Meccanica

Relazione per la prova finale «Analisi cinematica del deragliatore anteriore del gruppo Campagnolo Centaur»

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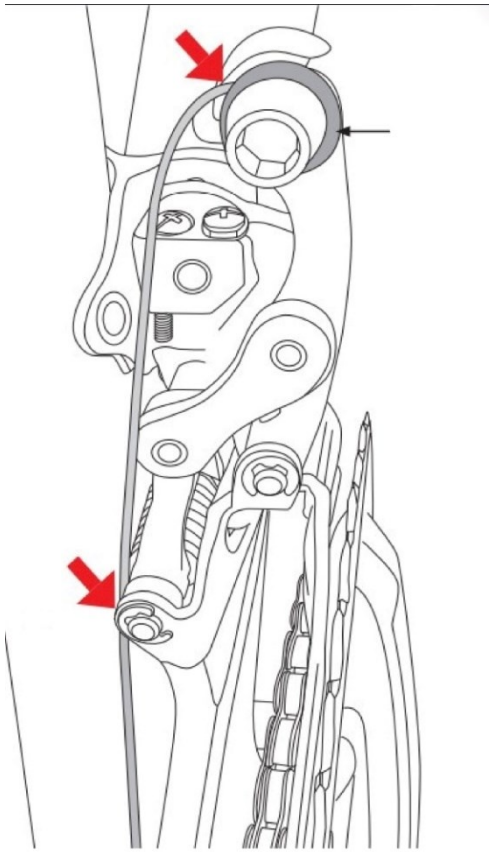
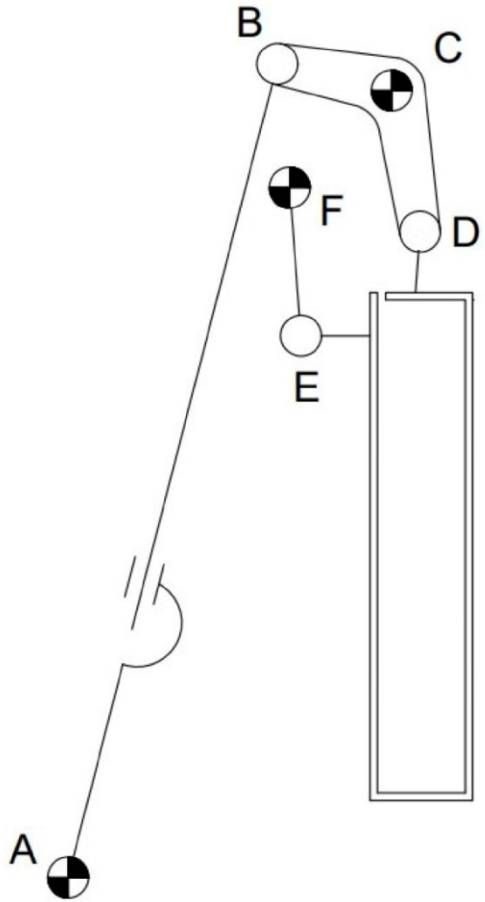
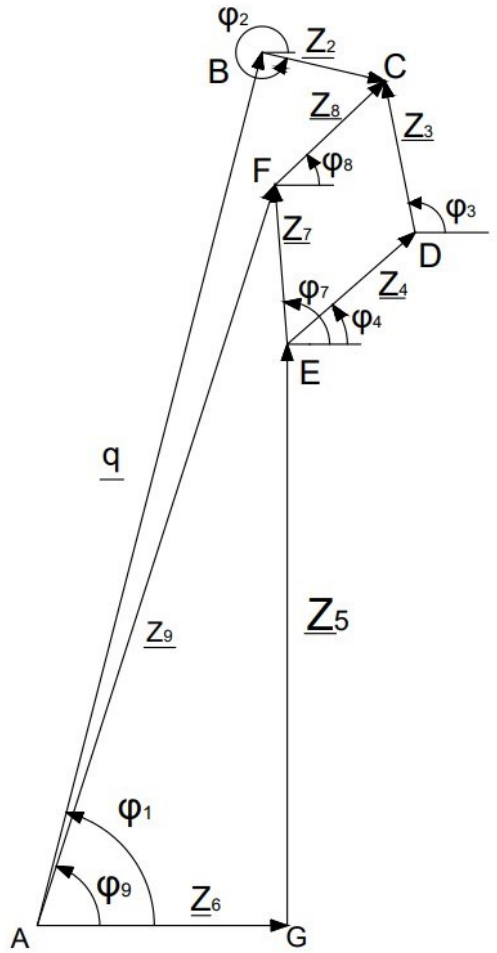
Padova, 26/09/2023

DERAGLIATORE ANTERIORE GRUPPO CAMPAGNOLO CENTAUR

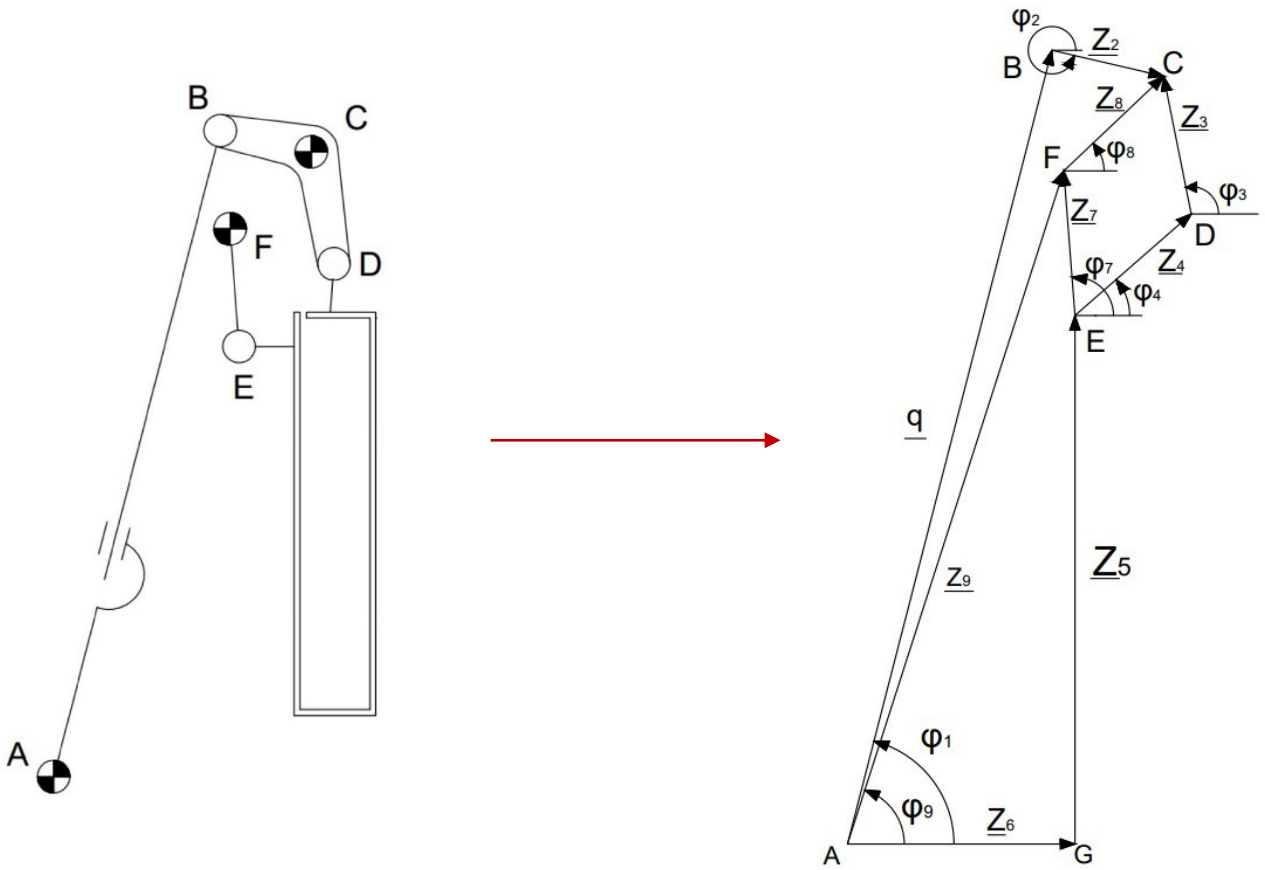






$$\text{n° gdl} = 3 \cdot (n-1) - 2R - 2P - 1C = 3 \cdot (6-1) - 2 \cdot 6 - 2 = 1$$

ANALISI DEL MECCANISMO



MAGLIE DEL MECCANISMO

$$\underline{q} + \underline{z_2} - \underline{z_8} - \underline{z_9} = \underline{0}$$

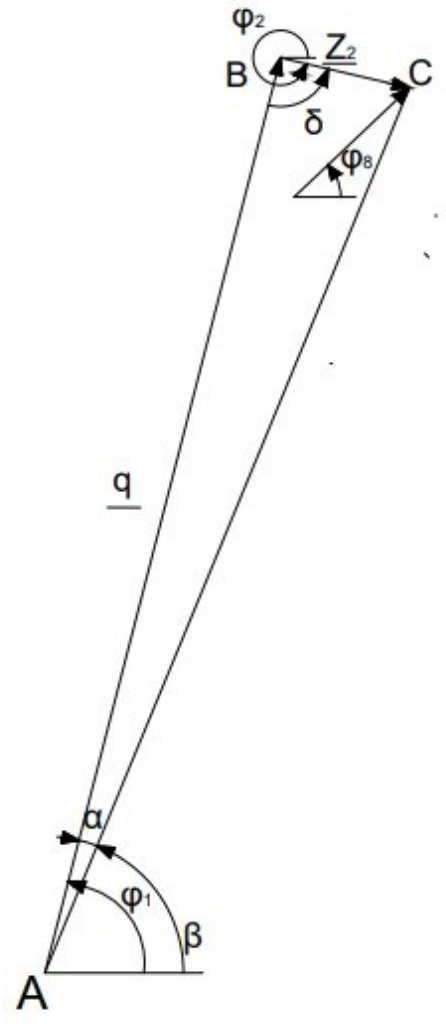
$$\underline{z_7} + \underline{z_8} - \underline{z_3} - \underline{z_4} = \underline{0}$$

$$\underline{z_9} - \underline{z_7} - \underline{z_5} - \underline{z_6} = \underline{0}$$

VARIABILI $q, \varphi_1, \varphi_2, \varphi_3, \varphi_4, \varphi_7, a_5, a_6$

LUNGHEZZE NOTE $a_2, a_3, a_4, a_7, a_8, L_{BD}$

ANALISI POSIZIONE



$$L_{AC} = \sqrt{{x_C}^2 + {y_C}^2} \quad [\mathrm{m}]$$

$$\alpha = \cos^{-1}\left(\frac{q^2 + {L_{AC}}^2 - {a_2}^2}{2qL_{AC}}\right) \quad [rad]$$

$$\beta = \sin^{-1}\left(\frac{y_C}{L_{AC}}\right) \quad [rad]$$

$$\varphi_1 = \alpha + \beta \quad [rad]$$

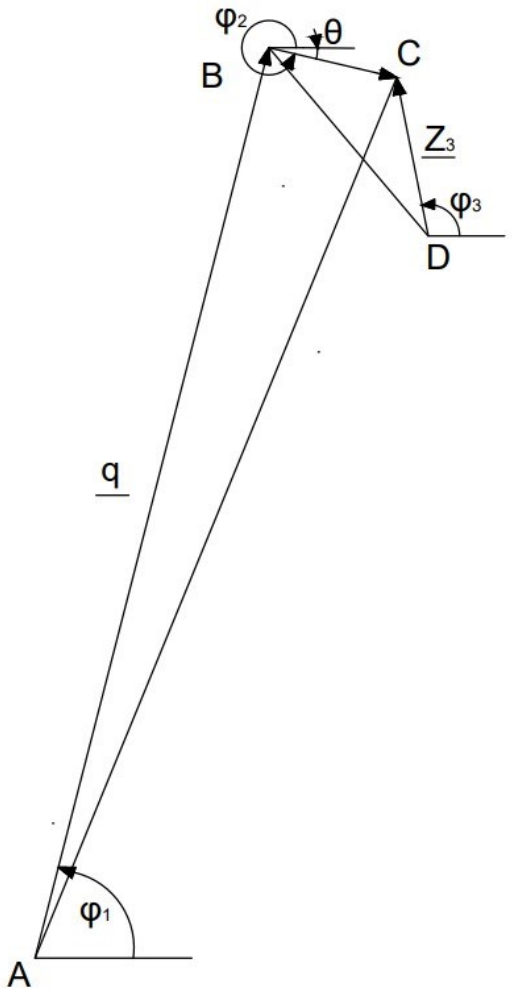
$$\delta = \cos^{-1}\left(\frac{q^2 + a_2^2 - {L_{AC}}^2}{2qa_2}\right) \quad [rad]$$

$$\varphi_2 = \pi + \varphi_1 + \delta \quad [rad]$$

$$x_B = q\cos\varphi_1 \quad [m]$$

$$y_B = q\sin\varphi_1 \quad [m]$$

ANALISI POSIZIONE



$$\theta = 360 - \varphi_2 \quad [rad]$$

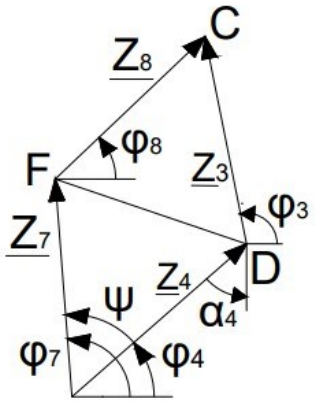
$$\varphi_3 = \pi - \cos^{-1}\left(\frac{a_3^2 + L_{BD}^2 - a_2^2}{2a_3 L_{BD}}\right) - \left(\cos^{-1}\left(\frac{a_2^2 + L_{BD}^2 - a_3^2}{2a_2 L_{BD}}\right) + \theta\right) \quad [rad]$$

$$x_D = q\cos\varphi_1 + a_2\cos\varphi_2 - a_3\cos\varphi_3 \quad [m]$$

$$y_D = q\sin\varphi_1 + a_2\sin\varphi_2 - a_3\sin\varphi_3 \quad [m]$$

$$L_{FD} = \sqrt{(x_F - x_D)^2 + (y_F - y_D)^2} \quad [m]$$

$$\psi = \cos^{-1}\left(\frac{a_7^2 + a_4^2 - {L_{FD}}^2}{2a_7 a_4}\right) \quad [rad]$$

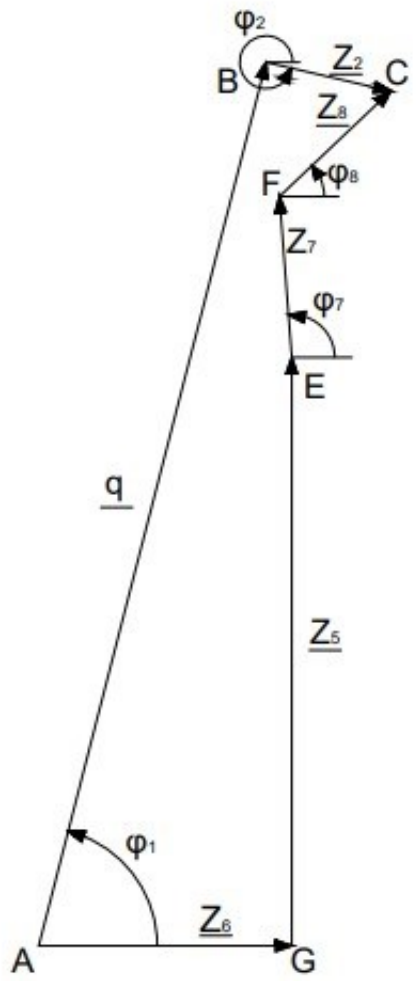


$$\alpha_4 = \pi - \cos^{-1}\left(\frac{L_{FD}^2 + a_4^2 - a_7^2}{2L_{FD}a_4}\right) - \cos^{-1}\left(\frac{L_{FD}^2 + a_3^2 - a_8^2}{2L_{FD}a_3}\right) - \cos^{-1}\left(\frac{x_D - x_C}{a_3}\right) \quad [rad]$$

$$\varphi_4 = \frac{\pi}{2} - \alpha_4 \quad [\text{rad}]$$

$$\varphi_7 = \varphi_4 + \psi \quad [rad]$$

ANALISI POSIZIONE



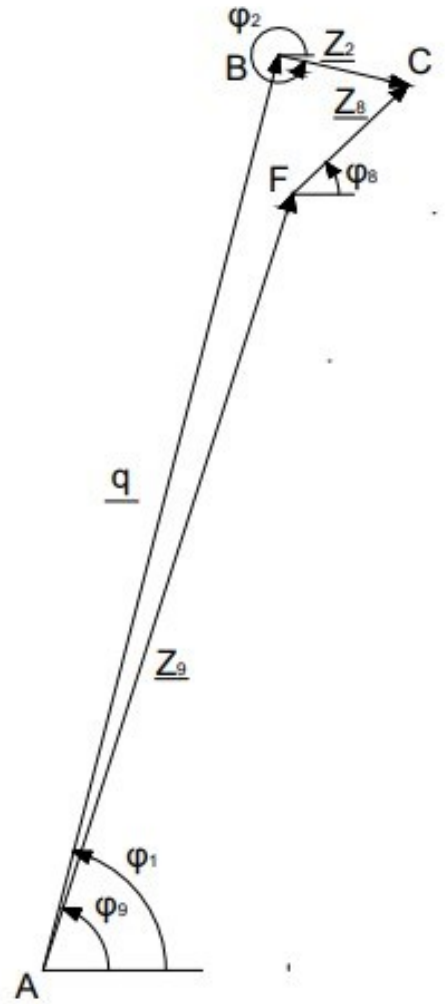
$$\underline{q} + \underline{z_2} - \underline{z_8} - \underline{z_7} - \underline{z_5} - \underline{z_6} = \underline{0}$$

$$q\begin{Bmatrix}\cos\varphi_1\\ \sin\varphi_1\end{Bmatrix} + a_2\begin{Bmatrix}\cos\varphi_2\\ \sin\varphi_2\end{Bmatrix} - \begin{Bmatrix}x_C - x_F\\ y_C - y_F\end{Bmatrix} - a_7\begin{Bmatrix}\cos\varphi_7\\ \sin\varphi_7\end{Bmatrix} - a_5\begin{Bmatrix}0\\1\end{Bmatrix} - a_6\begin{Bmatrix}1\\0\end{Bmatrix} = \begin{Bmatrix}0\\0\end{Bmatrix}$$

$$a_6 = qcos\varphi_1 + a_2cos\varphi_2 - (x_C - x_F) - a_7cos\varphi_7 \quad [\mathrm{m}]$$

$$a_5 = qsin\varphi_1 + a_2sin\varphi_2 - (y_C - y_F) - a_7sin\varphi_7 \quad [m]$$

ANALISI DI VELOCITÀ E ACCELERAZIONE 1^a MAGLIA



$$\dot{q}\begin{Bmatrix}\cos\varphi_1\\ \sin\varphi_1\end{Bmatrix} + q\begin{Bmatrix}-\sin\varphi_1\\ \cos\varphi_1\end{Bmatrix}\dot{\varphi}_1 + a_2\begin{Bmatrix}-\sin\varphi_2\\ \cos\varphi_2\end{Bmatrix}\dot{\varphi}_2 = \begin{Bmatrix}0\\ 0\end{Bmatrix}$$

$$\begin{bmatrix}-qsin\varphi_1 & -a_2sin\varphi_2\\ qcos\varphi_1 & a_2cos\varphi_2\end{bmatrix}\begin{Bmatrix}\dot{\varphi}_1\\ \dot{\varphi}_2\end{Bmatrix} = -\begin{Bmatrix}cos\varphi_1\\ \sin\varphi_1\end{Bmatrix}\dot{q}$$

$$\begin{Bmatrix}\dot{\varphi}_1\\ \dot{\varphi}_2\end{Bmatrix} = \frac{1}{a_2qsin\,(\varphi_2-\varphi_1)}\begin{bmatrix}a_2cos\varphi_2 & a_2sin\varphi_2\\ -qcos\varphi_1 & -qsin\varphi_1\end{bmatrix}\begin{Bmatrix}cos\varphi_1\\ \sin\varphi_1\end{Bmatrix}\dot{q}$$

$$w_{\varphi_1} = -\frac{\cos(\varphi_1-\varphi_2)}{qsin(\varphi_2-\varphi_1)} \qquad [m^{-1}]$$

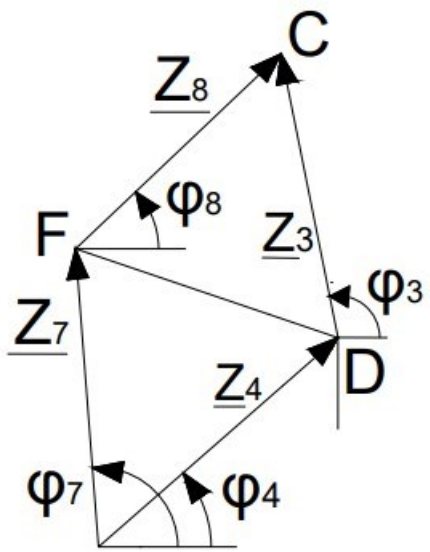
$$w_{\varphi_2} = \frac{1}{a_2sin(\varphi_2-\varphi_1)} \qquad [m^{-1}]$$

$$\begin{bmatrix}-qsin\varphi_1 & -a_2sin\varphi_2\\ qcos\varphi_1 & a_2cos\varphi_2\end{bmatrix}\begin{Bmatrix}\ddot{\varphi}_1\\ \ddot{\varphi}_2\end{Bmatrix} + \begin{Bmatrix}cos\varphi_1\\ \sin\varphi_1\end{Bmatrix}\ddot{q} + \begin{Bmatrix}-2w_{\varphi_1}\sin\varphi_1 - qw_{\varphi_1}^2\cos\varphi_1 - a_2\,w_{\varphi_2}^2cos\varphi_2\\ 2w_{\varphi_1}\cos\varphi_1 - qw_{\varphi_1}^2\sin\varphi_1 - a_2\,w_{\varphi_2}^2sin\varphi_2\end{Bmatrix}\{\dot{q}^2\} = \begin{Bmatrix}0\\ 0\end{Bmatrix}$$

$$\frac{dw_{\varphi_1}}{dq} = -\frac{2w_{\varphi_1}\sin(\varphi_2-\varphi_1) - \mathrm{q}w_{\varphi_1}^2\cos(\varphi_1-\varphi_2) - a_2w_{\varphi_2}^2}{qsin(\varphi_2-\varphi_1)} \qquad [m^{-2}]$$

$$\frac{dw_{\varphi_2}}{dq} = -\frac{q\,w_{\varphi_1}^2 + \mathrm{a}_2w_{\varphi_2}^2\cos(\varphi_1-\varphi_2)}{a_2sin(\varphi_2-\varphi_1)} \qquad [m^{-2}]$$

ANALISI DI VELOCITÀ E ACCELERAZIONE 2^a MAGLIA



$$a_7\begin{Bmatrix}-\sin\varphi_7\\ \cos\varphi_7\end{Bmatrix}\dot{\varphi}_7 - a_3\begin{Bmatrix}-\sin\varphi_3\\ \cos\varphi_3\end{Bmatrix}\dot{\varphi}_3 - a_4\begin{Bmatrix}-\sin\varphi_4\\ \cos\varphi_4\end{Bmatrix}\dot{\varphi}_4 = \begin{Bmatrix}0\\0\end{Bmatrix} \longrightarrow \varphi_3 = \dot{w}_{\varphi_2}\cdot\dot{q}$$

$$\begin{bmatrix}-a_7 sin\varphi_7 & a_4 sin\varphi_4\\ a_7 cos\varphi_7 & -a_4 cos\varphi_4\end{bmatrix}\begin{Bmatrix}\dot{\varphi}_7\\ \dot{\varphi}_4\end{Bmatrix} = \begin{Bmatrix}-a_3 w_{\varphi_2} sin\varphi_3\\ a_3 w_{\varphi_2}\cos\varphi_3\end{Bmatrix}\dot{q}$$

$$\begin{Bmatrix}\dot{\varphi}_7\\ \dot{\varphi}_4\end{Bmatrix} = \frac{1}{a_7 a_4 sin\,(\varphi_7-\varphi_4)}\begin{bmatrix}a_4 cos\varphi_4 & a_4 sin\varphi_4\\ a_7 cos\varphi_7 & a_7 sin\varphi_7\end{bmatrix}\begin{Bmatrix}-a_3 w_{\varphi_2} sin\varphi_3\\ a_3 w_{\varphi_2}\cos\varphi_3\end{Bmatrix}\dot{q}$$

$$w_{\varphi_7} = -\frac{a_3 w_{\varphi_2}\sin(\varphi_4-\varphi_3)}{a_7 sin(\varphi_7-\varphi_4)} \qquad [m^{-1}]$$

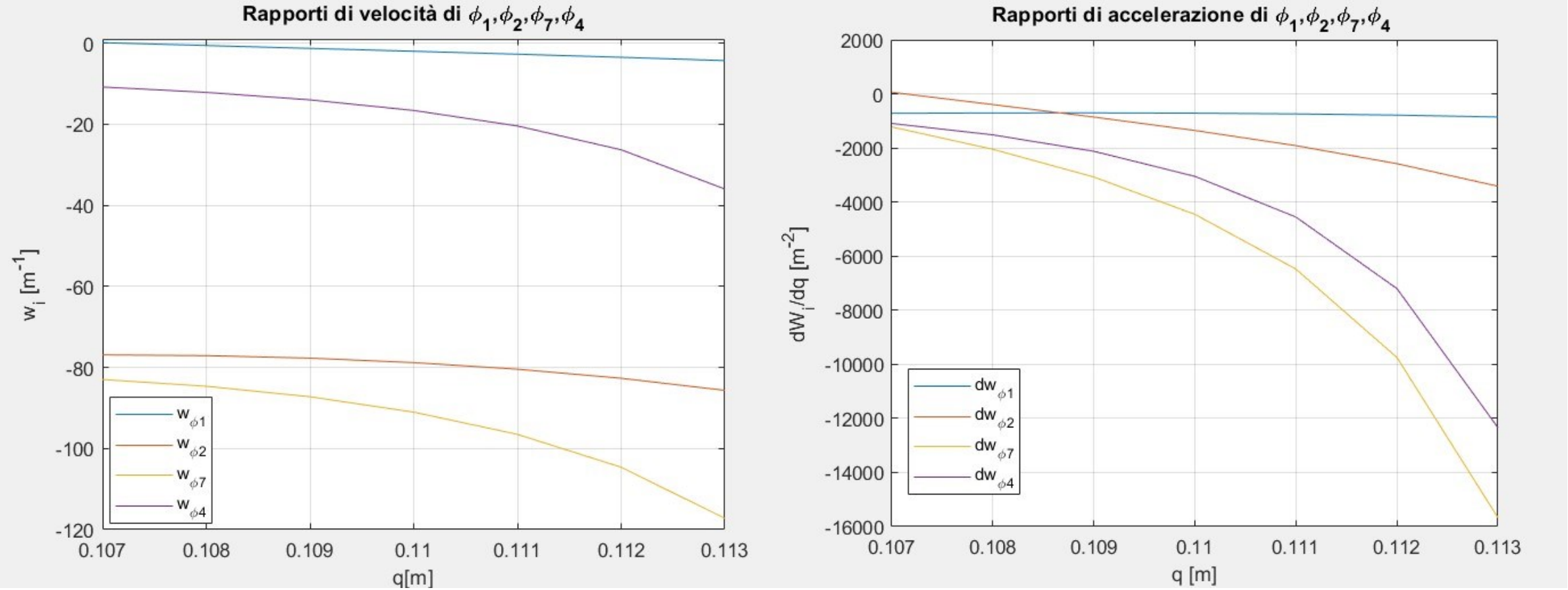
$$w_{\varphi_4} = -\frac{a_3 w_{\varphi_2}\sin(\varphi_7-\varphi_3)}{a_4 sin(\varphi_7-\varphi_4)}\,[m^{-1}]$$

$$\begin{bmatrix}-a_7 sin\varphi_7 & a_4 sin\varphi_4\\ a_7 cos\varphi_7 & -a_4 cos\varphi_4\end{bmatrix}\begin{Bmatrix}\ddot{\varphi}_7\\ \ddot{\varphi}_4\end{Bmatrix} + \begin{Bmatrix}a_3 w_{\varphi_2}\sin\varphi_3\\ -a_3 w_{\varphi_2}\cos\varphi_3\end{Bmatrix}\ddot{q} + \begin{Bmatrix}a_3 w_{\varphi_2}^2\cos\varphi_3 + a_3\frac{dw_{\varphi_2}}{dq}\sin\varphi_3 - a_7 w_{\varphi_7}^2\cos\varphi_7 + a_4 w_{\varphi_4}^2\cos\varphi_4\\ a_3 w_{\varphi_2}^2\sin\varphi_3 - a_3\frac{dw_{\varphi_2}}{dq}\cos\varphi_3 - a_7 w_{\varphi_7}^2\sin\varphi_7 + a_4 w_{\varphi_4}^2\sin\varphi_4\end{Bmatrix}\{\dot{q}^2\} = \begin{Bmatrix}0\\0\end{Bmatrix}$$

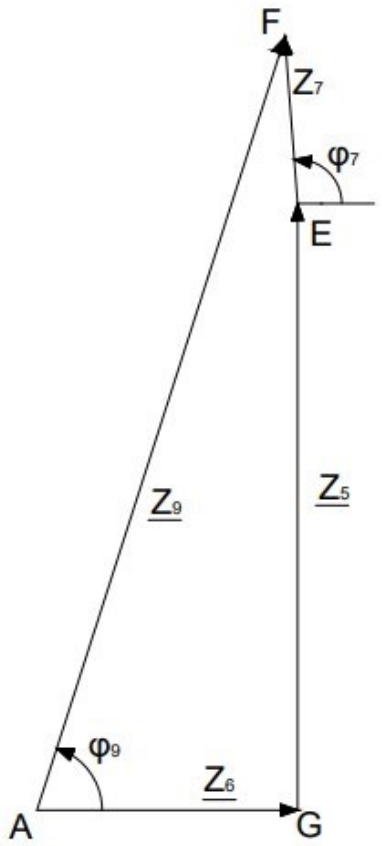
$$\frac{dw_{\varphi_7}}{dq} = \frac{a_3 w_{\varphi_2}^2\cos(\varphi_4-\varphi_3) + a_3\frac{dw_{\varphi_2}}{dq}\sin(\varphi_3-\varphi_4) - a_7 w_{\varphi_7}^2\cos(\varphi_7-\varphi_4) + a_4 w_{\varphi_4}^2}{a_7 sin(\varphi_7-\varphi_4)} \qquad [m^{-2}]$$

$$\frac{dw_{\varphi_4}}{dq} = \frac{a_3 w_{\varphi_2}^2\cos(\varphi_7-\varphi_3) + a_3\frac{dw_{\varphi_2}}{dq}\sin(\varphi_3-\varphi_7) + a_4 w_{\varphi_4}^2\cos(\varphi_7-\varphi_4) - a_7 w_{\varphi_7}^2}{a_4 sin(\varphi_7-\varphi_4)} \qquad [m^{-2}]$$

ANALISI RISULTATI 1^a E 2^a MAGLIA



ANALISI DI VELOCITÀ E ACCELERAZIONE 3^a MAGLIA



$$a_9\begin{Bmatrix}\cos\varphi_9\\ \sin\varphi_9\end{Bmatrix} - a_7\begin{Bmatrix}\cos\varphi_7\\ \sin\varphi_7\end{Bmatrix} - a_5\begin{Bmatrix}0\\1\end{Bmatrix} - a_6\begin{Bmatrix}1\\0\end{Bmatrix} = \begin{Bmatrix}0\\0\end{Bmatrix}$$

$$-a_7\begin{Bmatrix}-\sin\varphi_7\\ \cos\varphi_7\end{Bmatrix} w_{\varphi_7}\dot{q} - \dot{a_5}\begin{Bmatrix}0\\1\end{Bmatrix} - \dot{a_6}\begin{Bmatrix}1\\0\end{Bmatrix} = \begin{Bmatrix}0\\0\end{Bmatrix}$$

$$\begin{bmatrix}0 & 1\\ 1 & 0\end{bmatrix}\begin{Bmatrix}\dot{a_5}\\ \dot{a_6}\end{Bmatrix} = -\begin{Bmatrix}-a_7 w_{\varphi_7} sin\varphi_7\\ a_7 w_{\varphi_7}\cos\varphi_7\end{Bmatrix}\dot{q}$$

$$\begin{Bmatrix}\dot{a_5}\\ \dot{a_6}\end{Bmatrix} = \begin{bmatrix}0 & 1\\ 1 & 0\end{bmatrix}\begin{Bmatrix}-a_7 w_{\varphi_7} sin\varphi_7\\ a_7 w_{\varphi_7}\cos\varphi_7\end{Bmatrix}\dot{q}$$

$$w_{a_5} = -a_7 w_{\varphi_7}\cos\varphi_7 \;[\;]$$

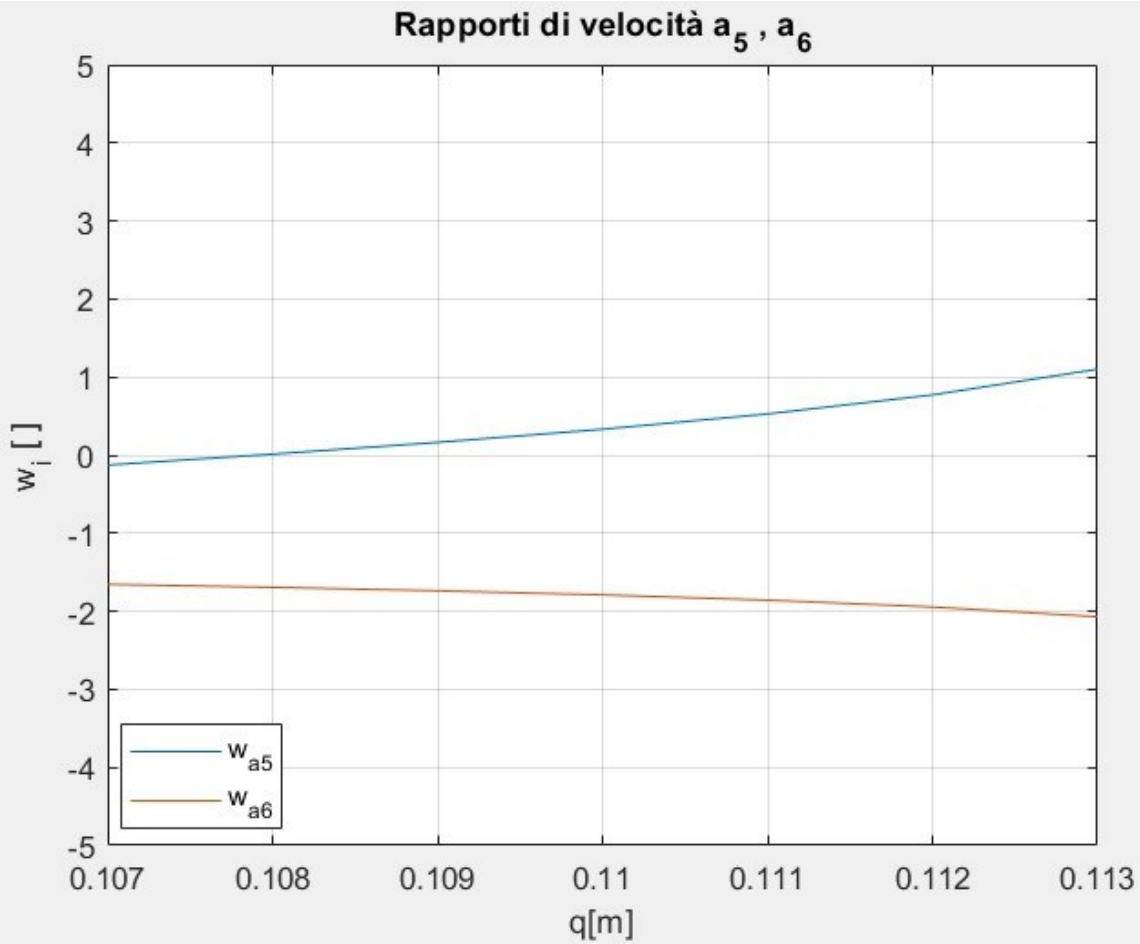
$$w_{a_6} = +a_7 w_{\varphi_7}\sin\varphi_7 \;[\;]$$

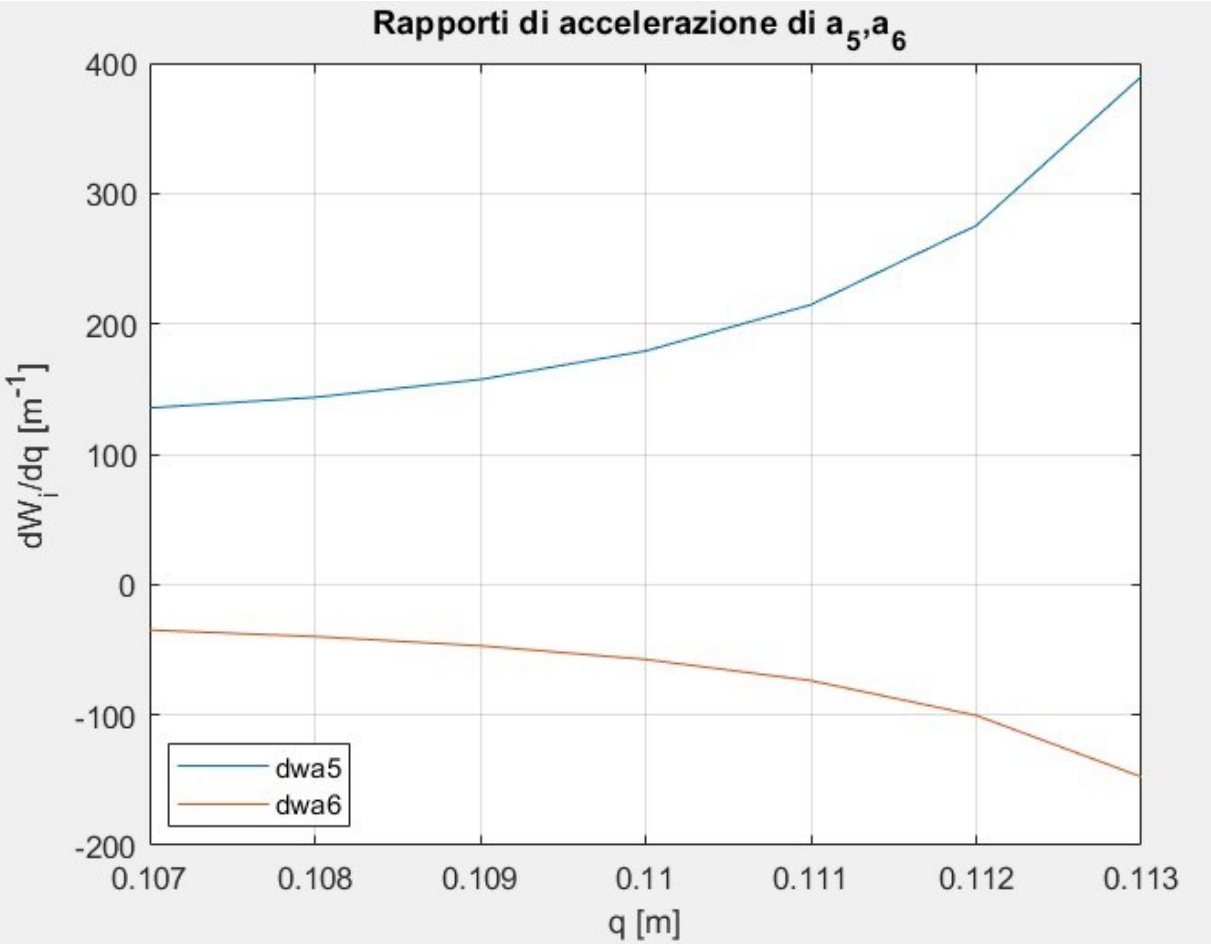
$$\begin{bmatrix}0 & 1\\ 1 & 0\end{bmatrix}\begin{Bmatrix}\ddot{a_5}\\ \ddot{a_6}\end{Bmatrix} + \begin{Bmatrix}-a_7 w_{\varphi_7}\sin\varphi_7\\ a_7 w_{\varphi_7}\cos\varphi_7\end{Bmatrix}\ddot{q} + \begin{Bmatrix}a_7 w_{\varphi_7}^2\sin\varphi_7 - a_7\frac{dw_{\varphi_7}}{dq}\cos\varphi_7\\ a_7 w_{\varphi_7}^2\cos\varphi_7 + a_7\frac{dw_{\varphi_7}}{dq}\sin\varphi_7\end{Bmatrix}\{\dot{q}^2\} = \begin{Bmatrix}0\\0\end{Bmatrix}$$

$$\frac{dw_{a_5}}{dq} = a_7 w_{\varphi_7}^2\sin\varphi_7 - a_7\frac{dw_{\varphi_7}}{dq}\cos\varphi_7 \quad [m^{-1}]$$

$$\frac{dw_{a_6}}{dq} = a_7 w_{\varphi_7}^2\cos\varphi_7 + a_7\frac{dw_{\varphi_7}}{dq}\sin\varphi_7 \quad [m^{-1}]$$

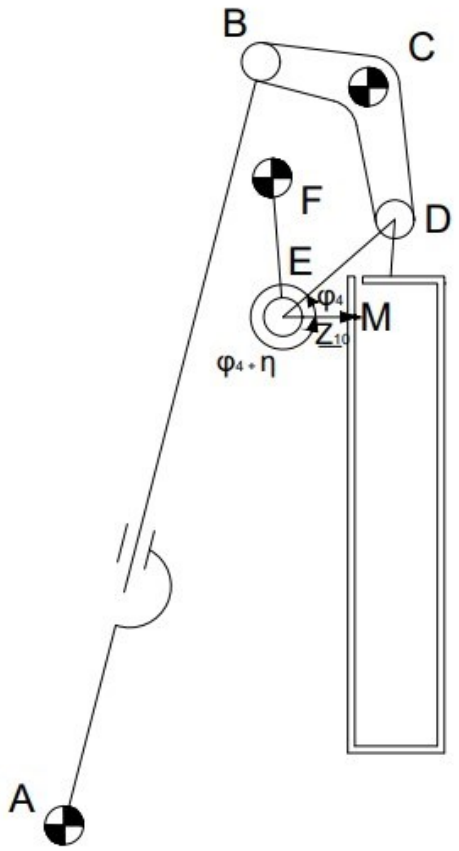
ANALISI RISULTATI 3^a MAGLIA

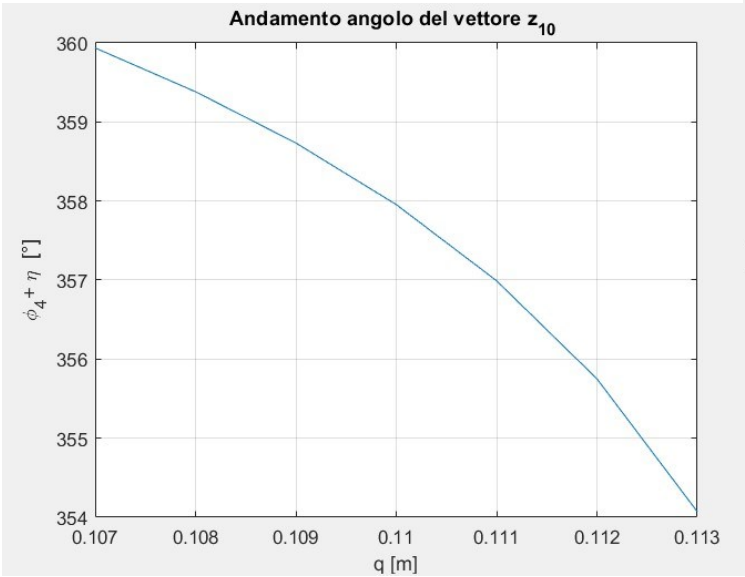


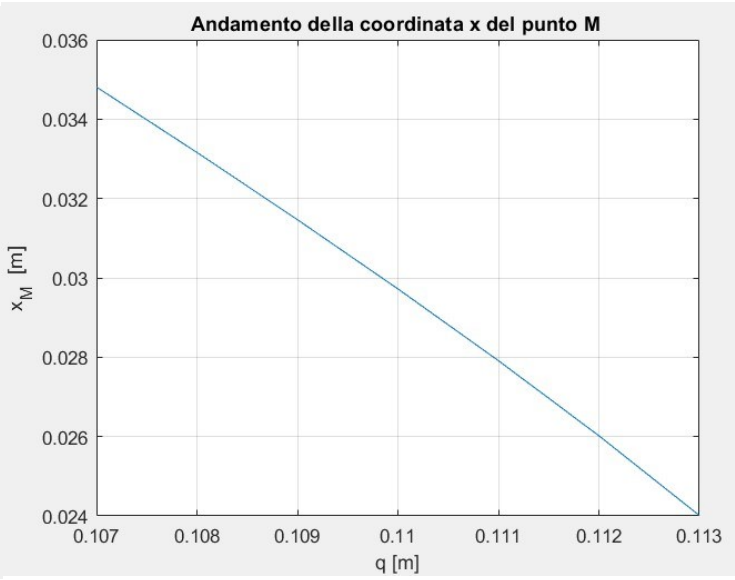


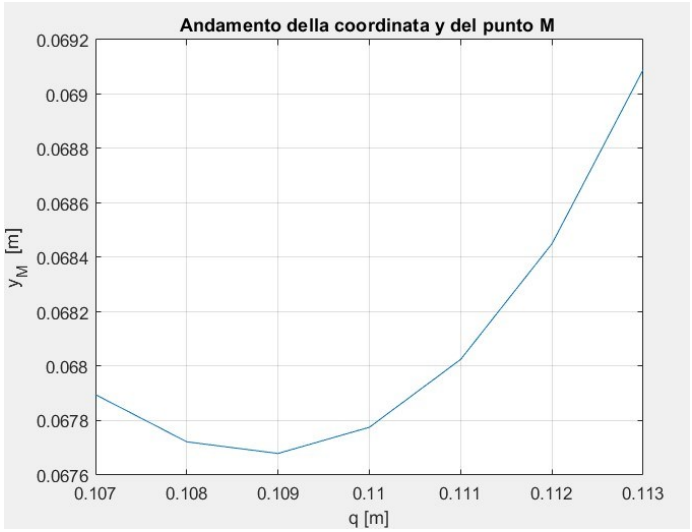
ANALISI PUNTO M

$$x_M = x_E + a_{10}\cos(\varphi_4 + \eta) \quad ; \quad y_M = y_E + a_{10}\sin(\varphi_4 + \eta)$$









SIMULAZIONE MECCANISMO