Università del Salento, Dipartimento di Ingegneria dell'Innovazione

Corso di laurea Magistrale in Ingegneria Meccanica

Tesi di Laurea in
Meccanica del Veicolo

Studio della Sospensione Attiva di un autoveicolo

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Controrelatore:

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Laureando:

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COSA SI INTENDE PER SOSPENSIONE?

ESIGENZE DEL SISTEMA SOSPENSIVO

- COMFORT Vs. GUIDABILITÀ

Accelerazione della massa sospesa

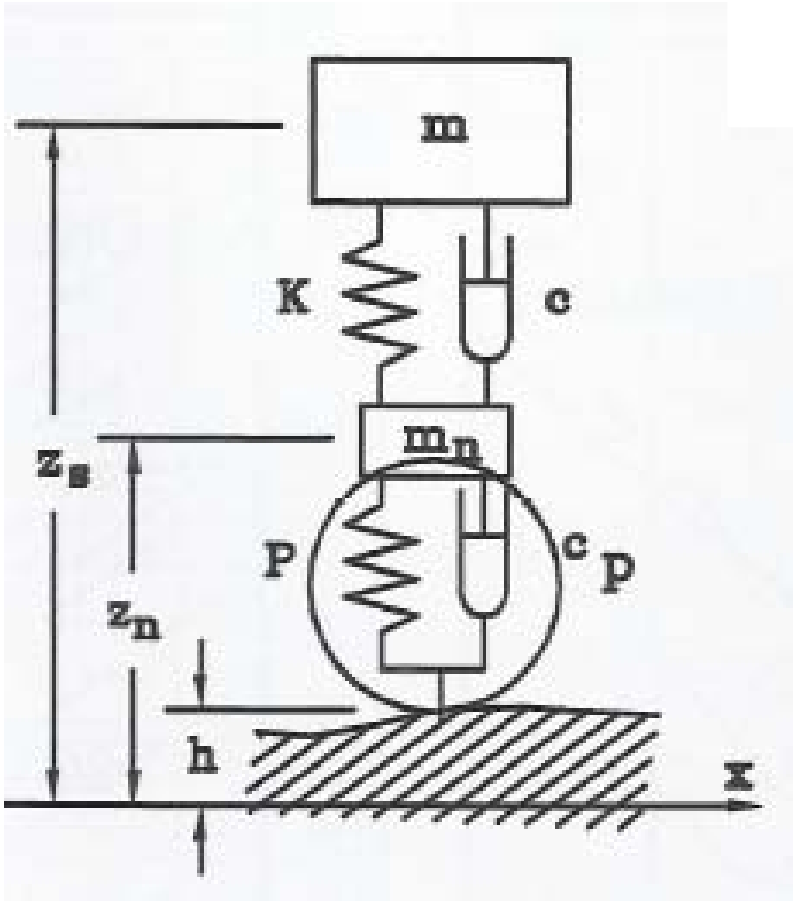
Variazione della forza a terra

SOSPENSIONI CONTROLLATE O ADATTIVE

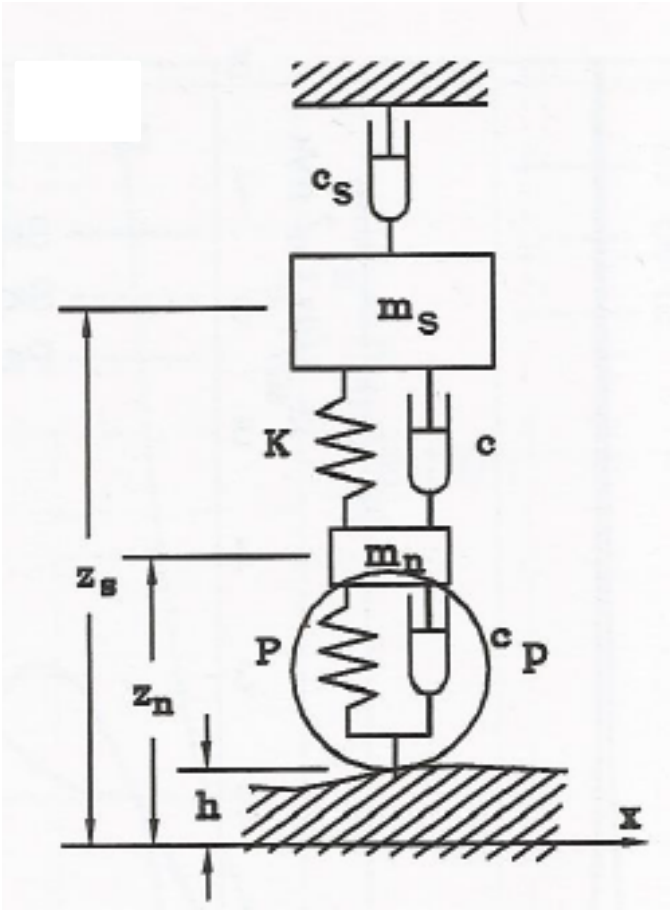
OBIETTIVI

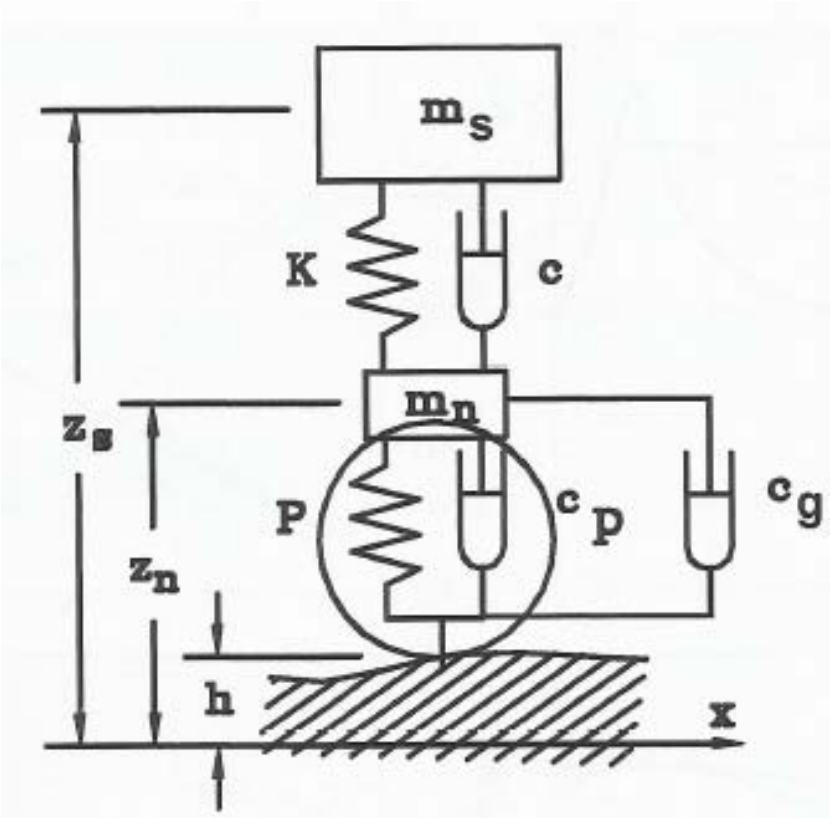
Realizzare un sistema attivo o inerziale di smorzamento che gestisca queste due variabili contrastanti

MODELLO AD ¼ DI VEICOLO (2 GDL)

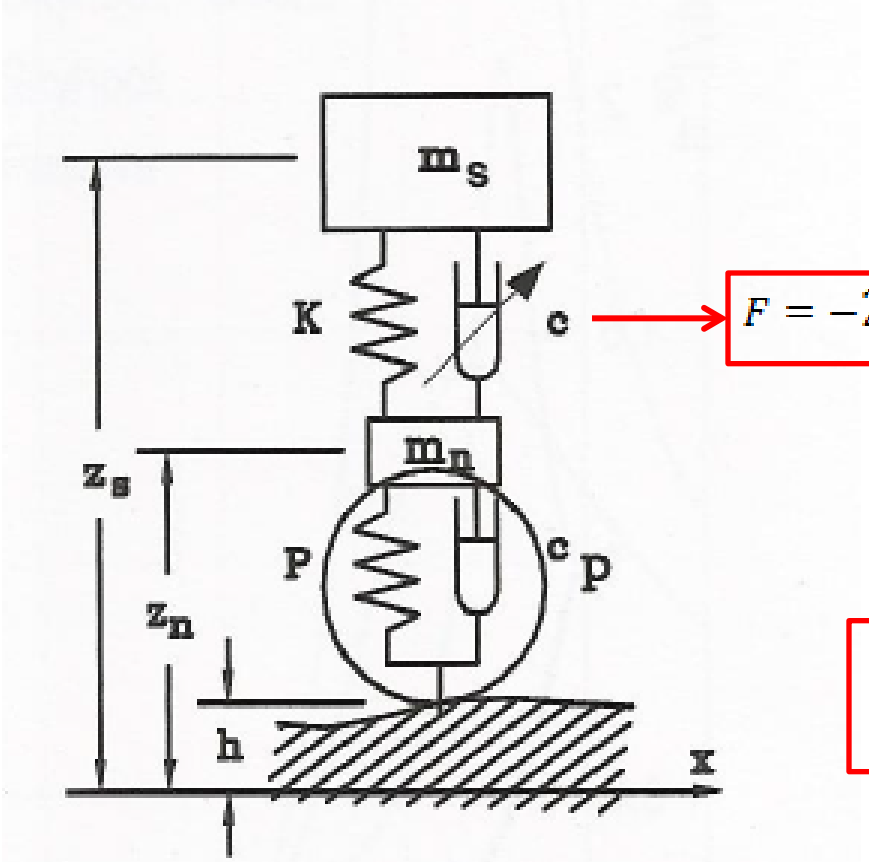


STRATEGIE DI CONTROLLO
SKYHOOK-GROUNDHOOK





SOSPENSIONE ATTIVA



$$F = -2\sqrt{KMs} * \xi d * (\dot{Z}_s + \dot{Z}_n)$$

$$\xi_d = \frac{\xi_s - \xi_g}{2}$$

$$\begin{bmatrix} m_s & 0 \\ 0 & m_n \end{bmatrix} \begin{bmatrix} \ddot{z}_s \\ \ddot{z}_{us} \end{bmatrix} + 2 \begin{bmatrix} \xi_s + \xi & -(\xi_g + \xi) \\ -(\xi_s + \xi) & \xi_g + \xi_s + \xi \end{bmatrix} \sqrt{km_s} \begin{bmatrix} \dot{z}_s \\ \dot{z}_n \end{bmatrix} + \begin{bmatrix} k & -k \\ -k & k \end{bmatrix} \begin{bmatrix} z_s \\ z_n \end{bmatrix}$$

$$= \begin{bmatrix} 0 \\ P \end{bmatrix} h(t) + \begin{bmatrix} 0 \\ c_p \end{bmatrix} h(\dot{t})$$

MODELLO QUARTER-CAR: FORMA DI STATO

$$\dot{y} = Ay + Bu$$

$$z = Cy + Du$$

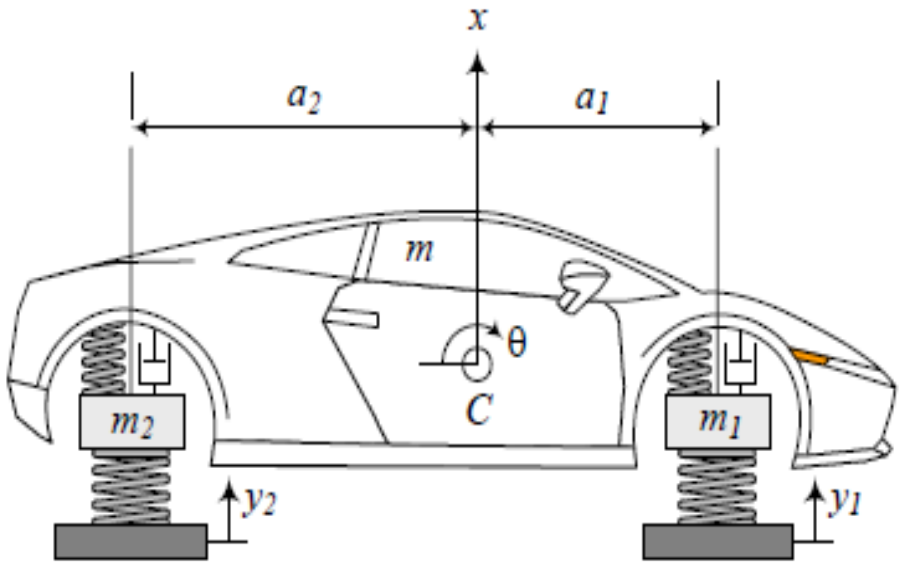
y_1= velocità massa sospesa
y_2= spostamento massa sospesa
y_3= velocità massa non sospesa
y_4= spostamento massa non sospesa

z_1= deformazione pneumatico
z_2= corsa sospensione
z_3= accelerazione massa sospesa
z_4= accelerazione massa non sospesa

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 \\ -\frac{k}{m_s} & -\frac{(c_s+c)}{m_s} & \frac{k}{m_s} & \frac{(c_g+c)}{m_s} \\ 0 & 0 & 0 & 1 \\ \frac{k}{m_n} & \frac{(c_s+c)}{m_n} & -\frac{(P+k)}{m_n} & -\frac{(c_g+c_p+c)}{m_n} \end{bmatrix} \quad B = \begin{bmatrix} 0 \\ 0 \\ 0 \\ P/m_n \end{bmatrix}$$

$$C = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 1 & 0 & -1 & 0 \\ -\frac{k}{m_s} & -\frac{(c_s+c)}{m_s} & \frac{k}{m_s} & \frac{(c_g+c)}{m_s} \\ \frac{k}{m_n} & \frac{(c_s+c)}{m_n} & -\frac{(P+k)}{m_n} & -\frac{(c_g+c_p+c)}{m_n} \end{bmatrix} \quad D = \begin{bmatrix} -1 \\ 0 \\ 0 \\ P/m_n \end{bmatrix}$$

MODELLO HALF-CAR (4 gdl)

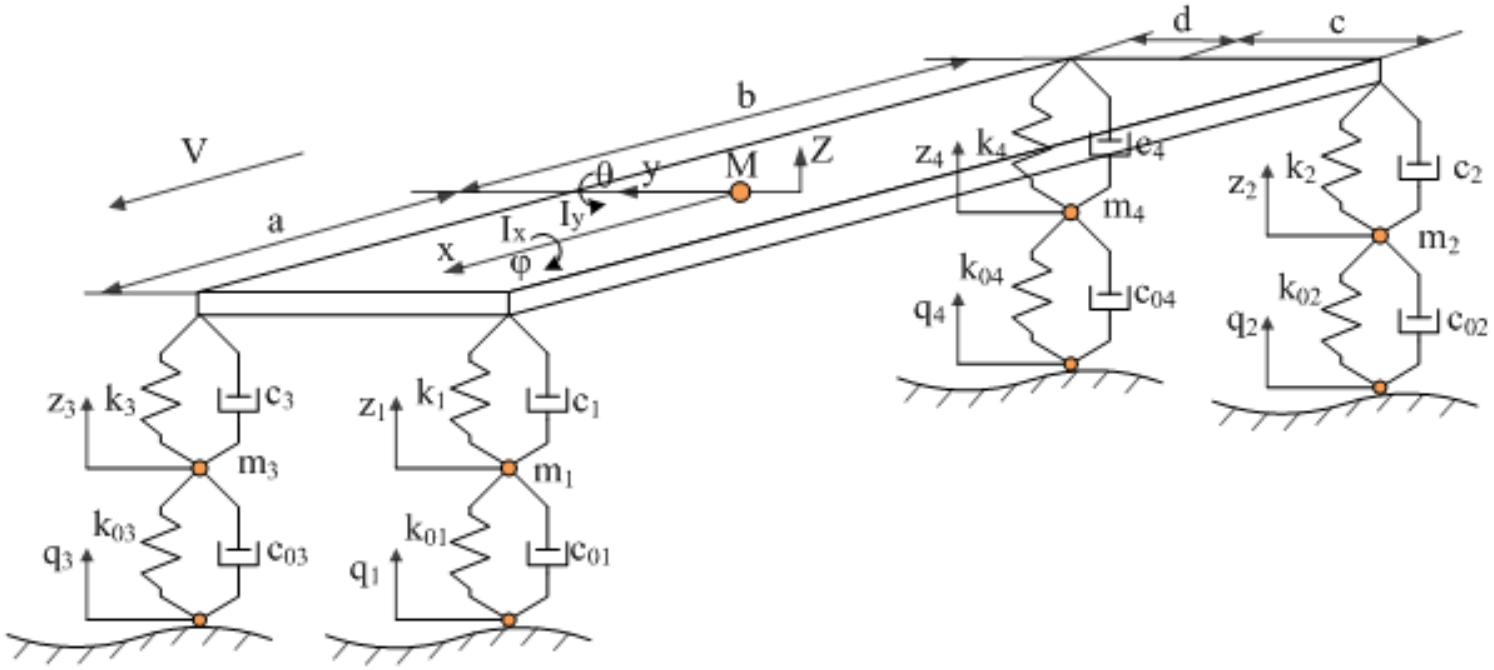


$$\begin{bmatrix} m_s & 0 & 0 & 0 \\ 0 & I_\theta & 0 & 0 \\ 0 & 0 & m_{n1} & 0 \\ 0 & 0 & 0 & m_{n2} \end{bmatrix} \begin{bmatrix} \ddot{z}_s \\ \ddot{z}_\theta \\ \ddot{z}_{n1} \\ \ddot{z}_{n2} \end{bmatrix}$$

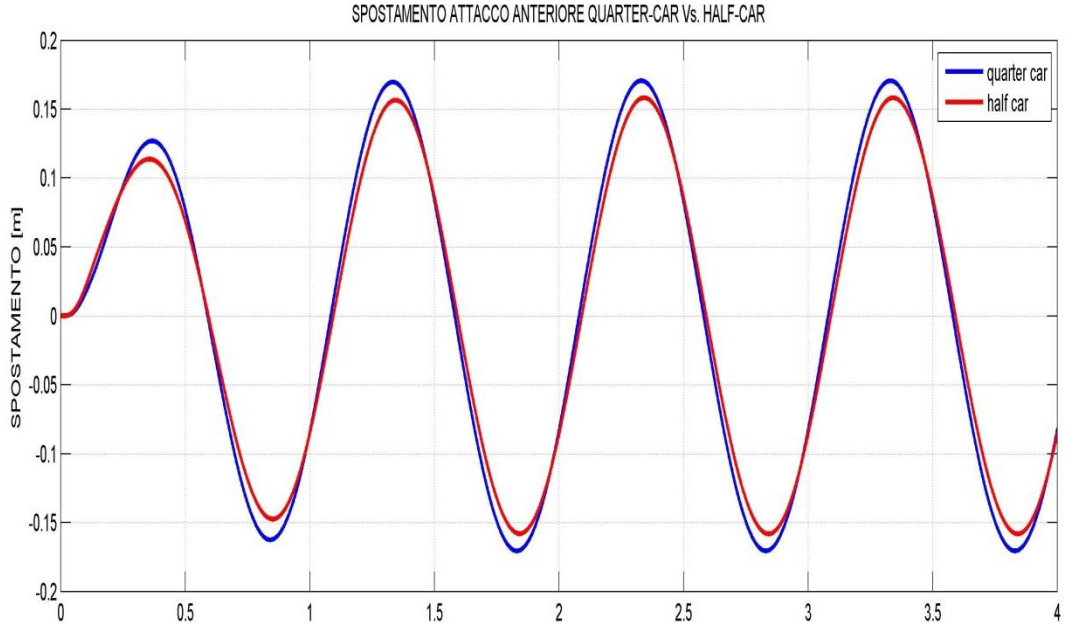
$$+ \begin{bmatrix} c_1 + c_2 - E_1 - E_2 & c_1 b - c_2 a + E_1 a - E_2 b & -c_1 - E_1 & -c_2 - E_2 \\ SYM & c_1 b^2 + c_2 a^2 + E_1 b^2 + E_2 a^2 & c_1 a + E_1 a & -c_2 b - E_2 b \\ SYM & SYM & c_1 + c_{u1} - E_1 & 0 \\ SYM & SYM & SYM & c_2 + c_{u2} - E_2 \end{bmatrix} \begin{bmatrix} \dot{z}_s \\ \dot{z}_\theta \\ \dot{z}_{n1} \\ \dot{z}_{n2} \end{bmatrix}$$

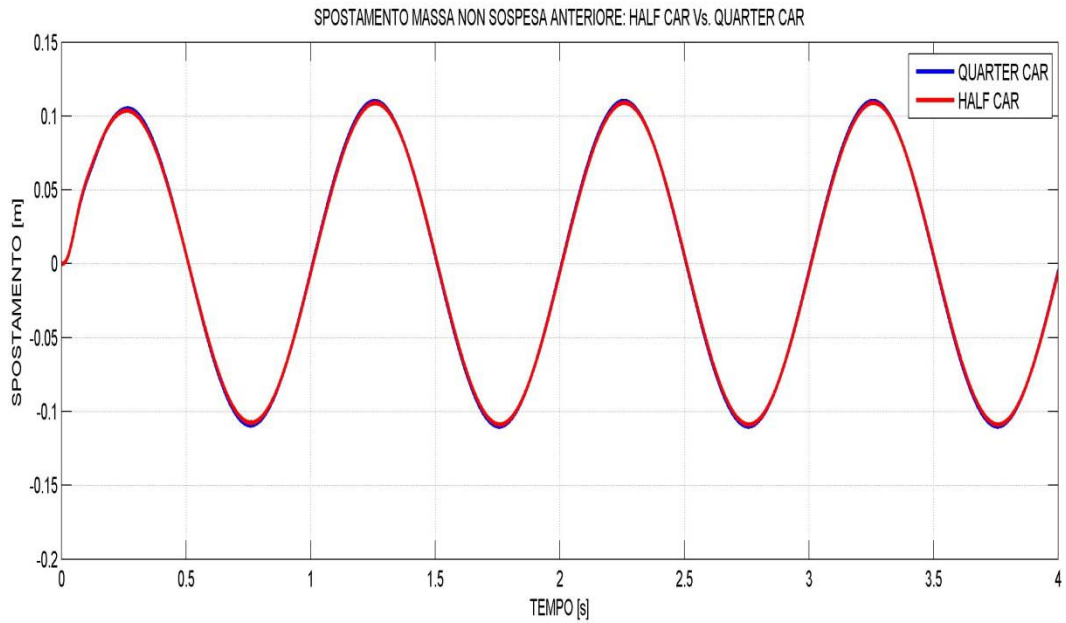
$$+ \begin{bmatrix} k_1 + k_2 & k_1 b - k_2 a & -k_1 & -k_2 \\ SYM & k_1 b^2 + k_2 a^2 & k_1 a & -k_2 b \\ SYM & SYM & k_1 + k_{u1} & 0 \\ SYM & SYM & SYM & k_2 + k_{u2} \end{bmatrix} \begin{bmatrix} z_s \\ z_\theta \\ z_{n1} \\ z_{n2} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ k_{u1} \\ k_{u2} \end{bmatrix} h(t) + \begin{bmatrix} 0 \\ 0 \\ c_{u1} \\ c_{u2} \end{bmatrix} \dot{h}(t)$$

MODELLO FULL-CAR

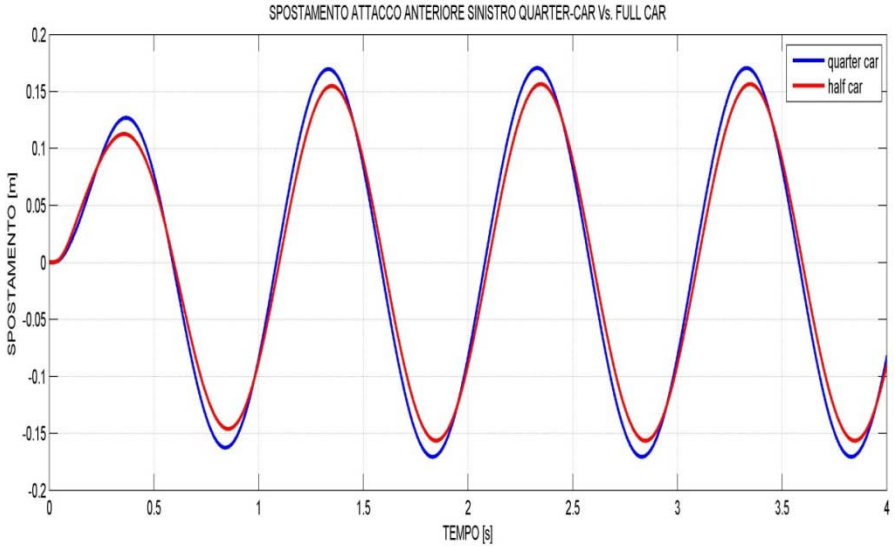


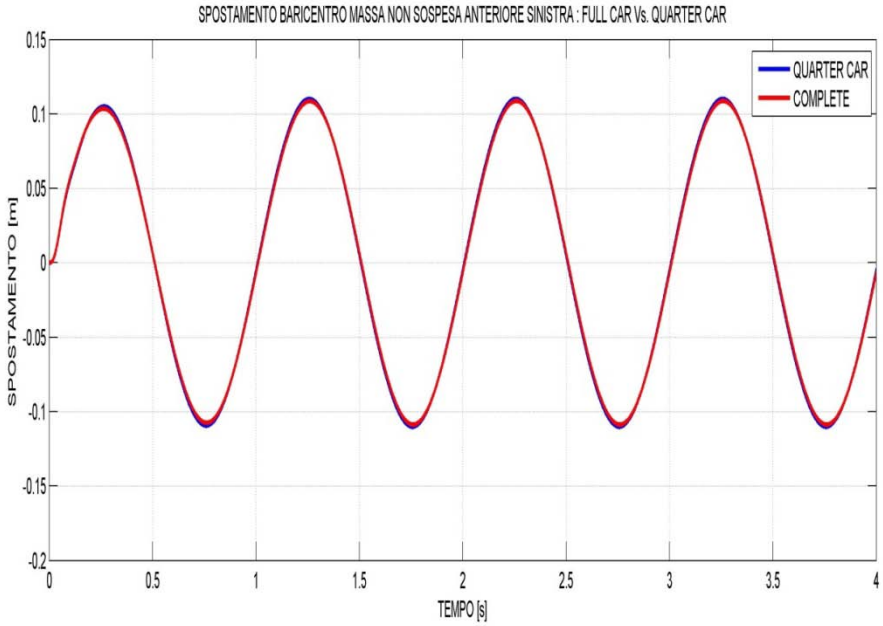
QUARTER-CAR Vs. HALF-CAR



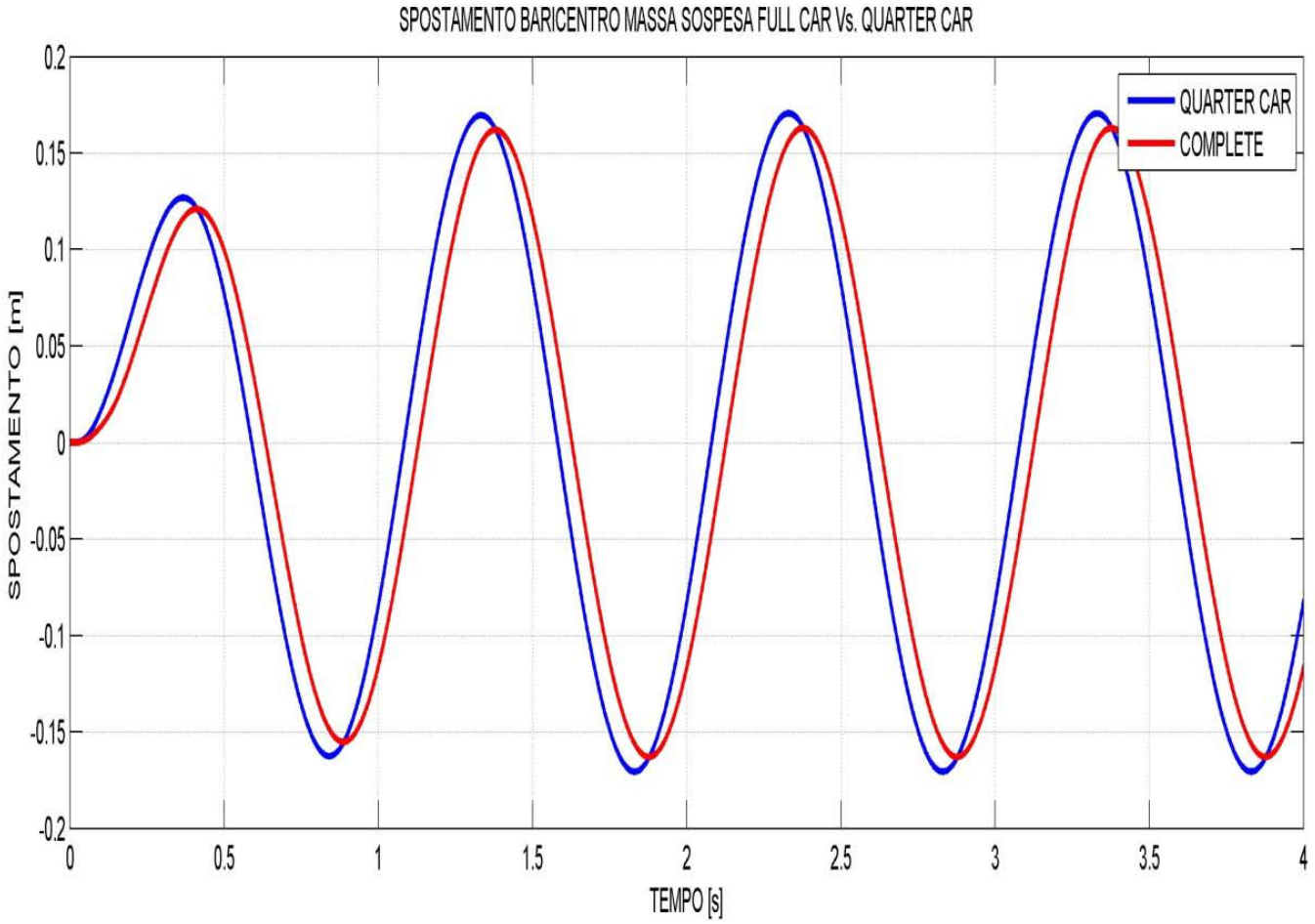


QUARTER-CAR Vs. FULL-CAR

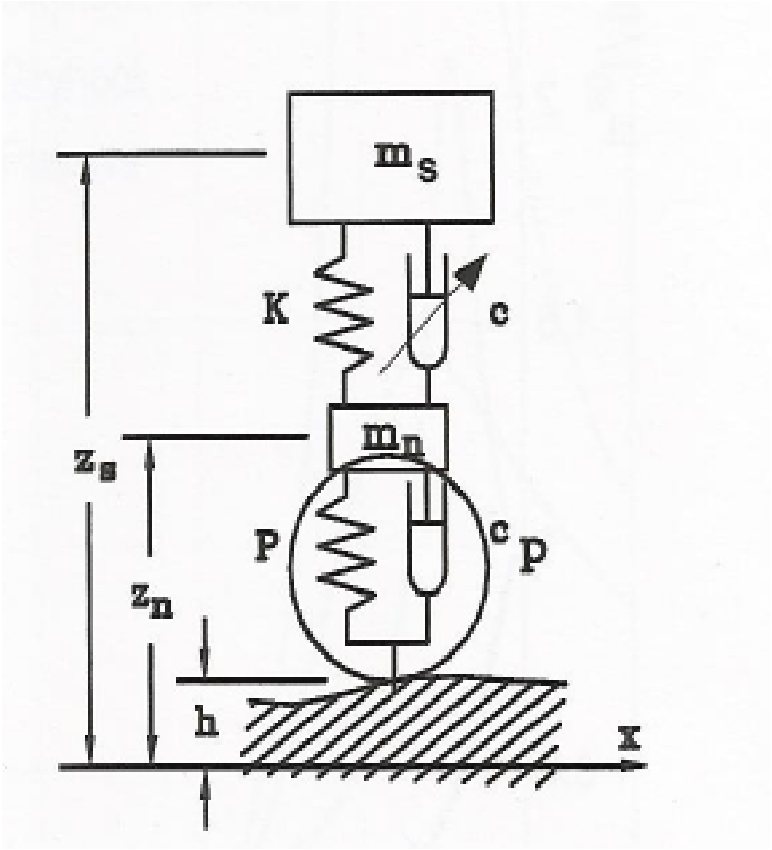




MODELLO QUARTER-CAR Vs. FULL-CAR



MODELLO QUARTER-CAR CON CONTROLLO ATTIVO



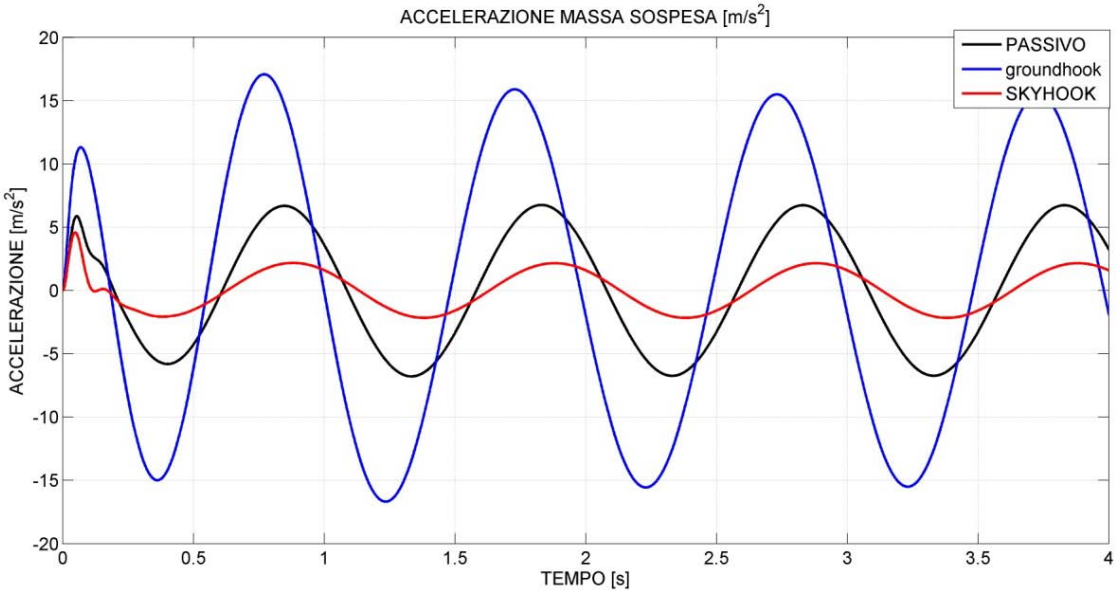
INGRESSI

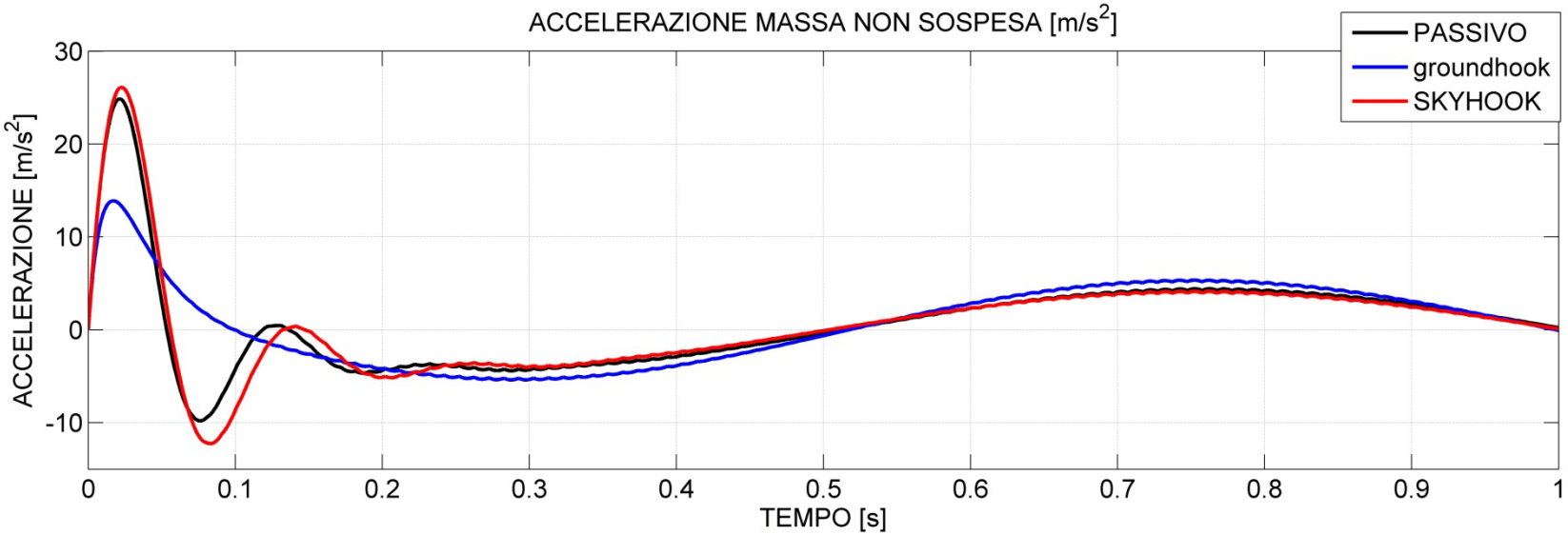
1. Sinusoide ad 1 hz e amp= 0.1m
2. Sinusoide a 10 hz e amp=0.1 m
3. Scalino di 0.1 m

OUTPUT

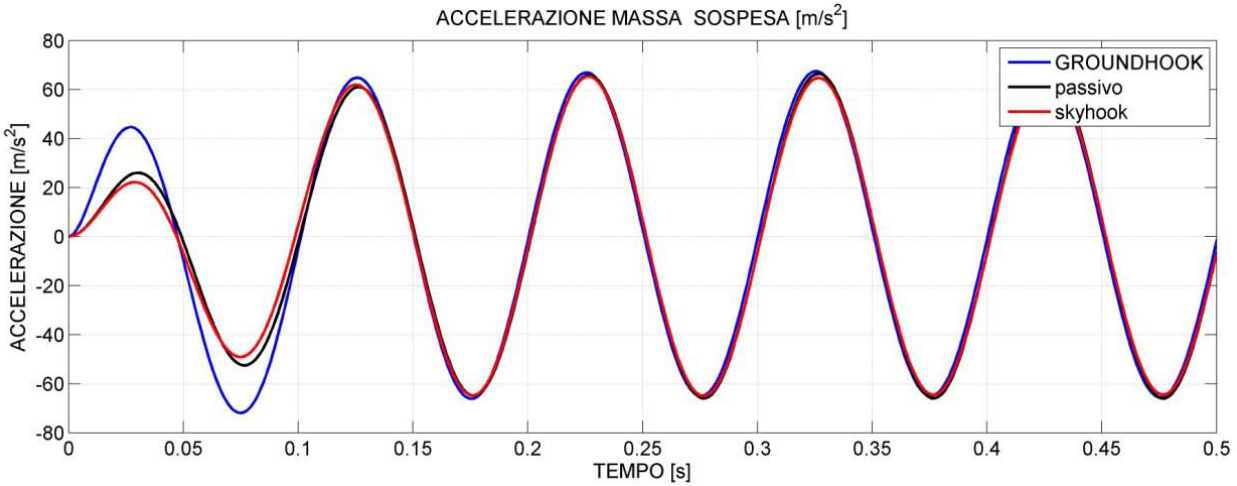
1. Accelerazione massa sospesa
2. Accelerazione massa non sospesa

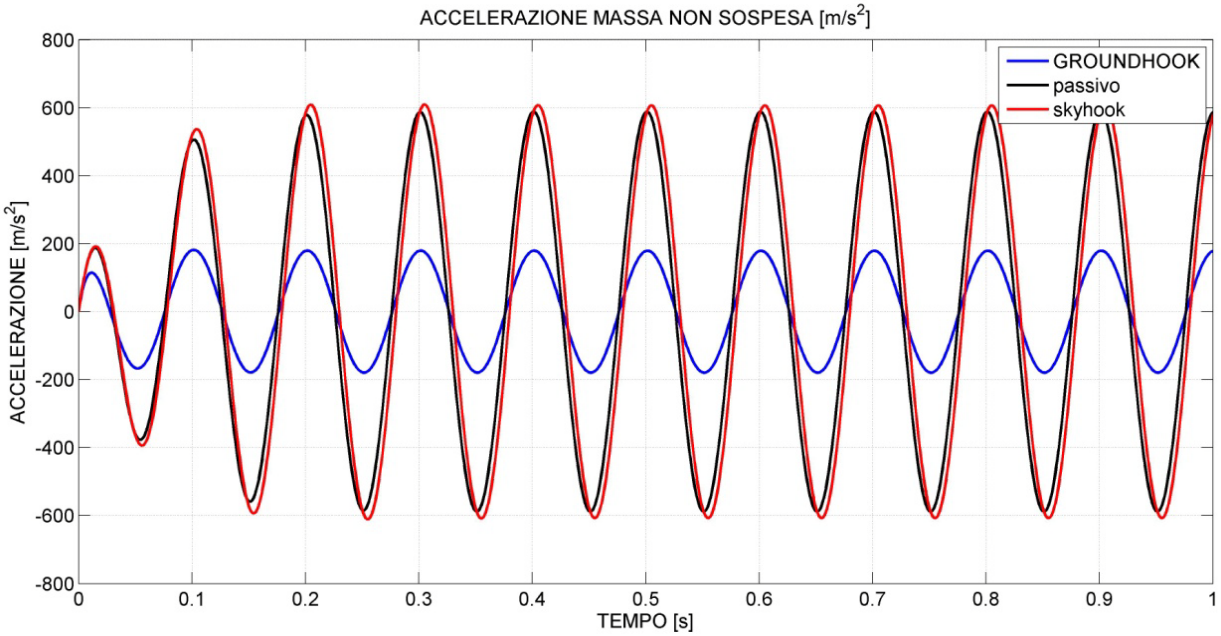
INGRESSO SINUSOIDALE 1 Hz



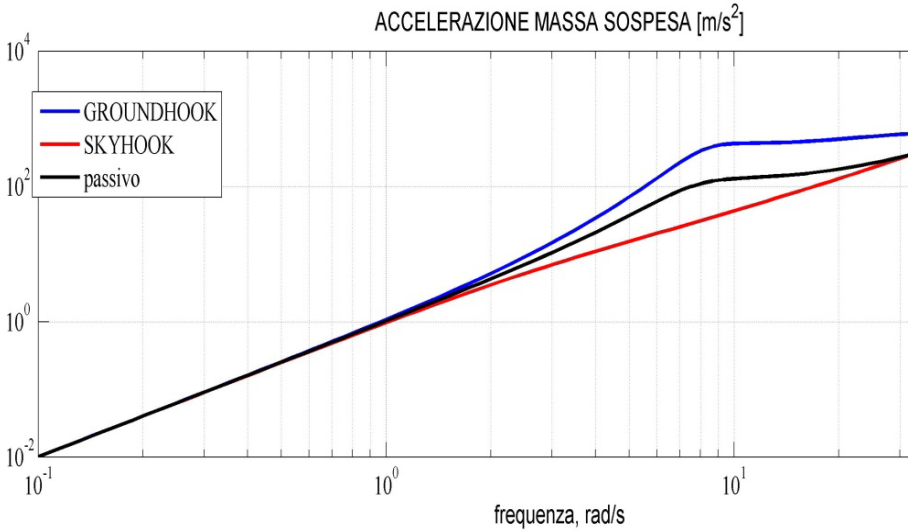


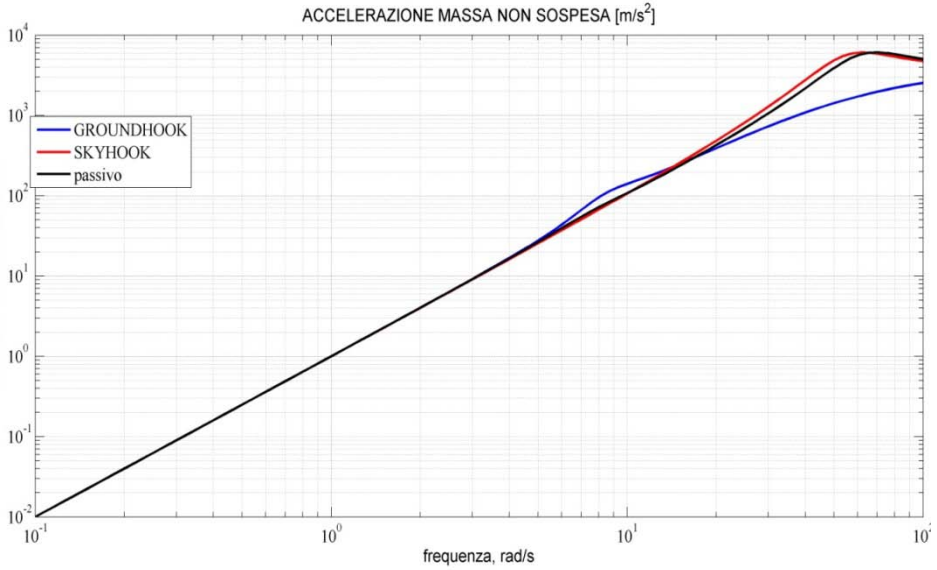
INGRESSO SINUSOIDALE 10 Hz



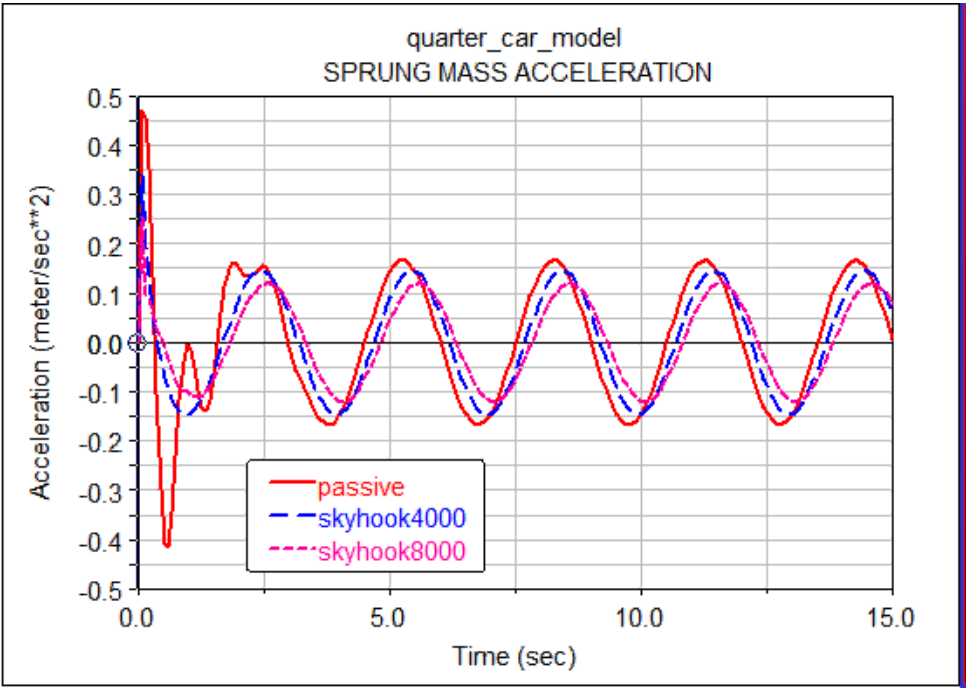


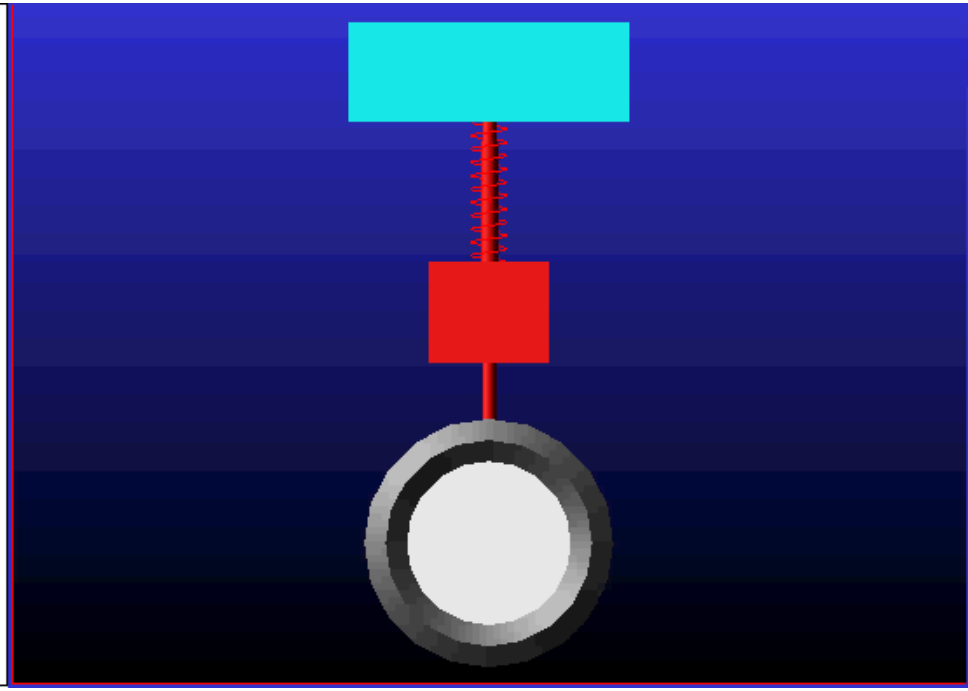
ANALISI NEL DOMINIO DELLA FREQUENZA



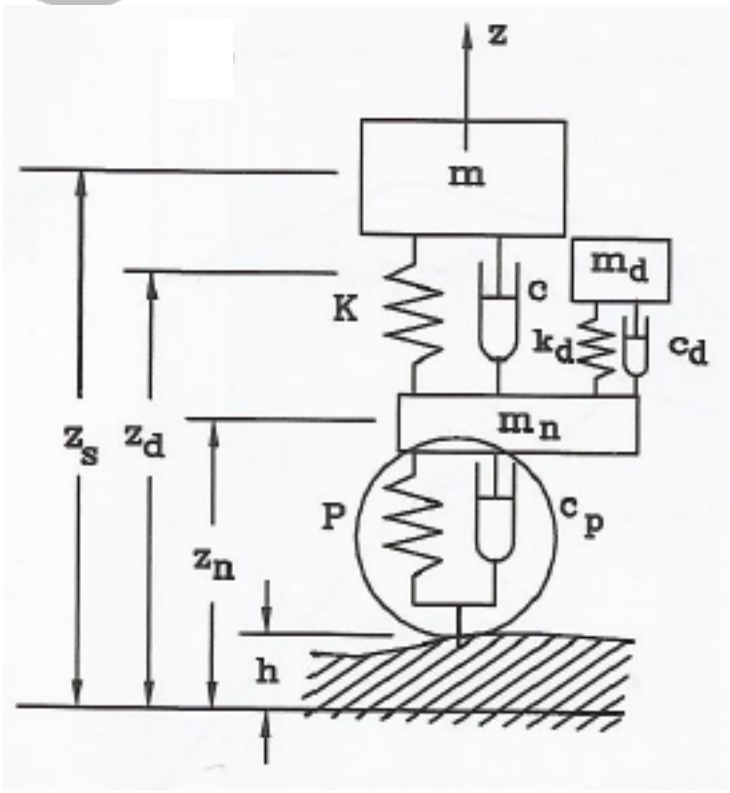


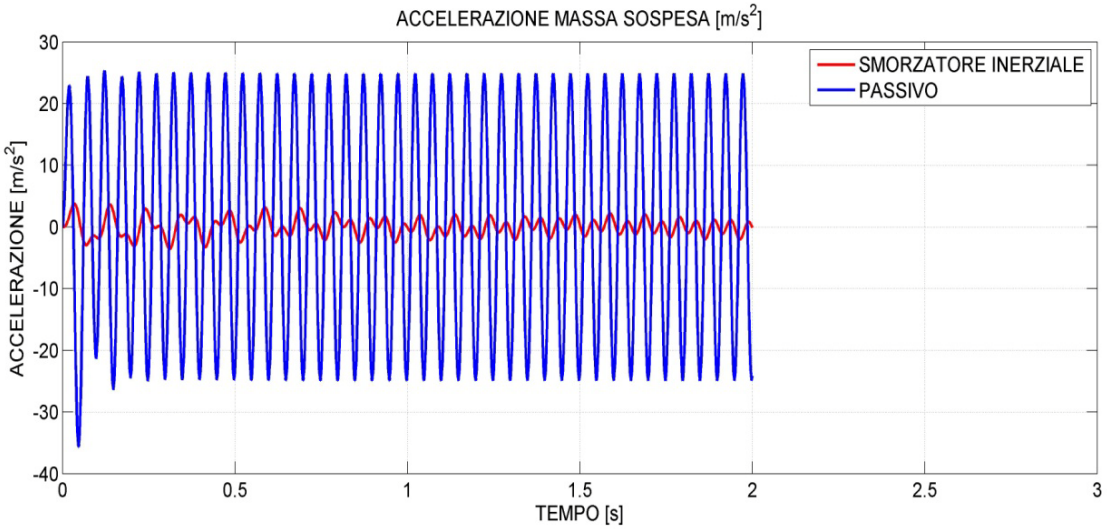
SIMULAZIONE IN AMBIENTE MSC ADAMS

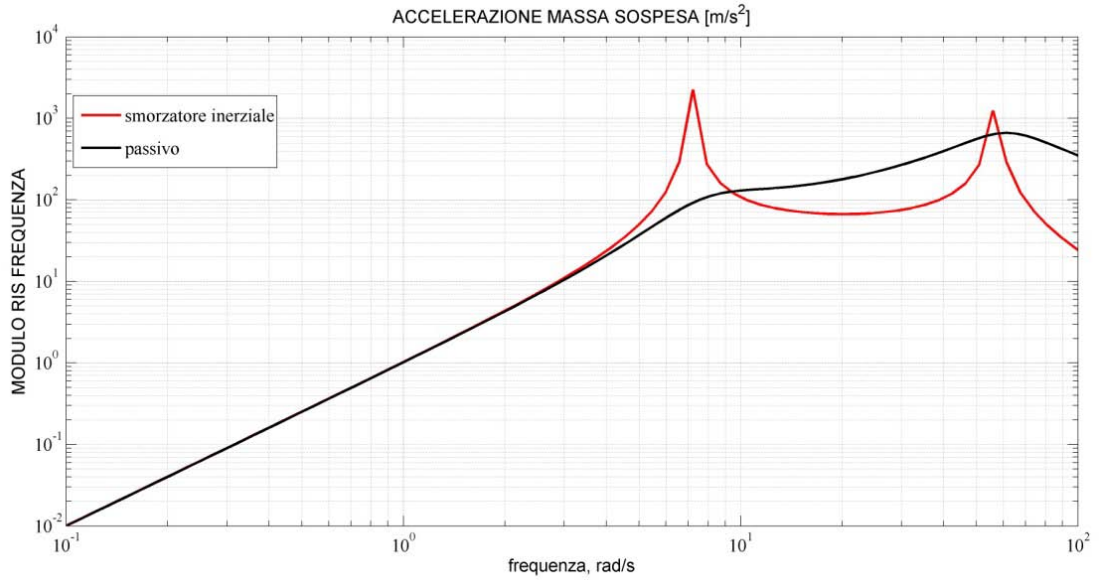


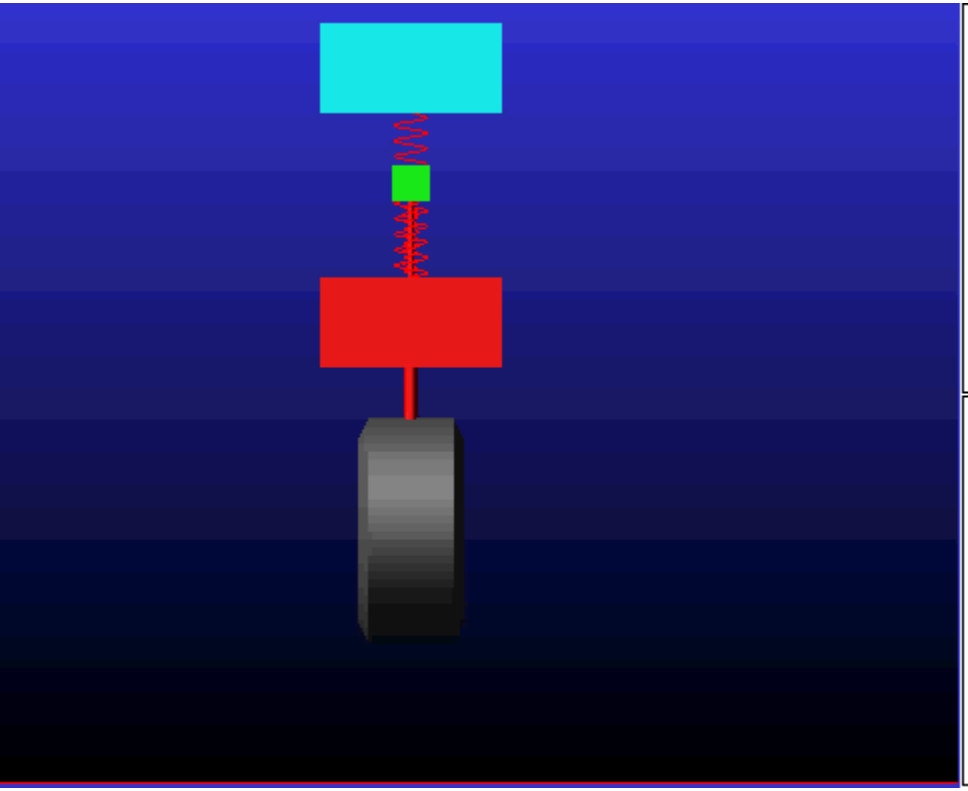


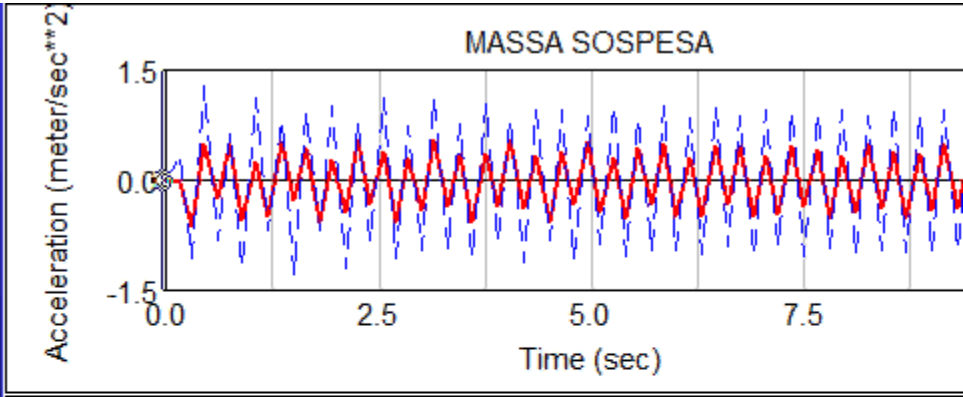
MASS-DAMPER: CONVIENE?

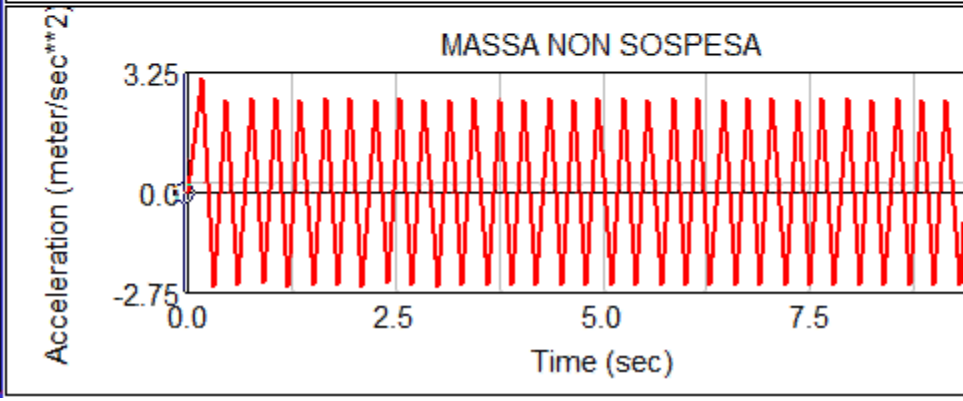






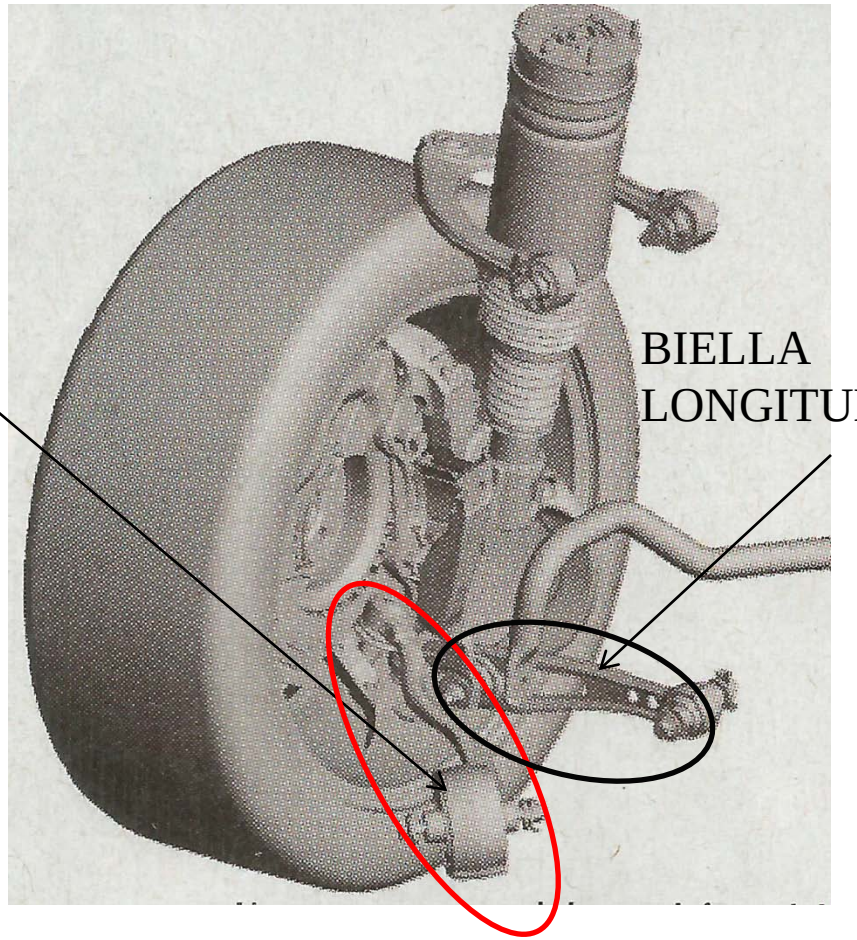



MASSA SOSPESA
Acceleration (meter/sec**2)
1.5
0.0
-1.5
0.0
2.5
5.0
7.5
Time (sec)


MASSA NON SOSPESA
Acceleration (meter/sec**2)
3.25
0.0
-2.75
0.0
2.5
5.0
7.5
Time (sec)

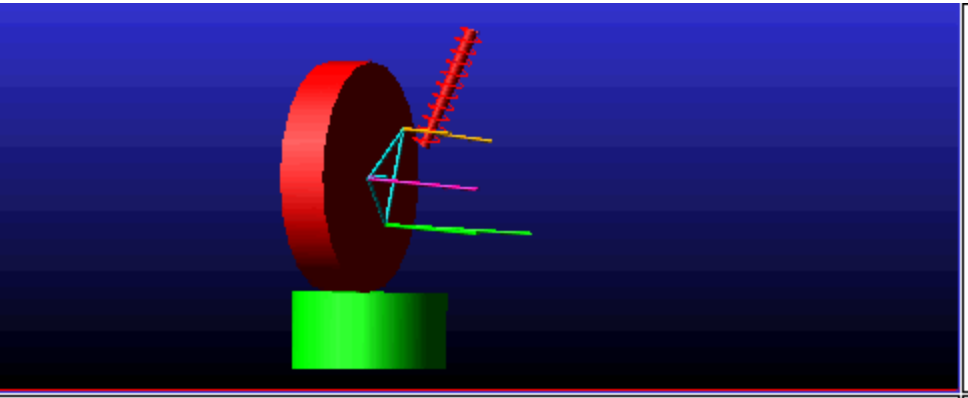
SVILUPPI FUTURI: SOSPENSIONE REALE

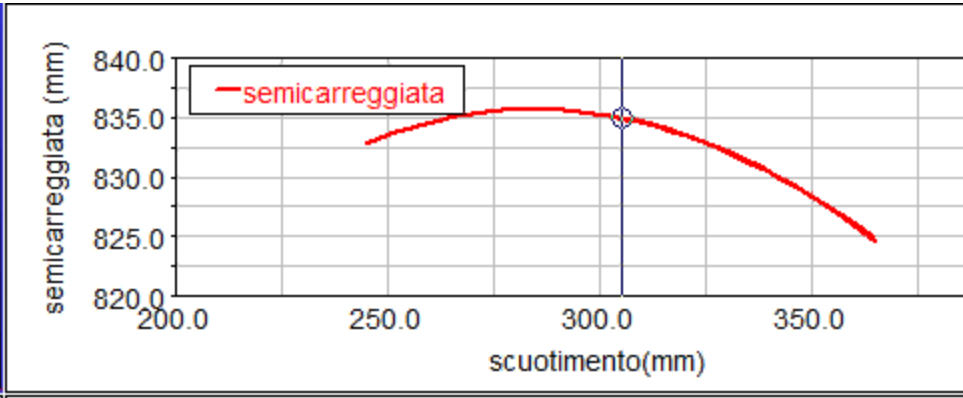
BIELLA
TRASVERSALE

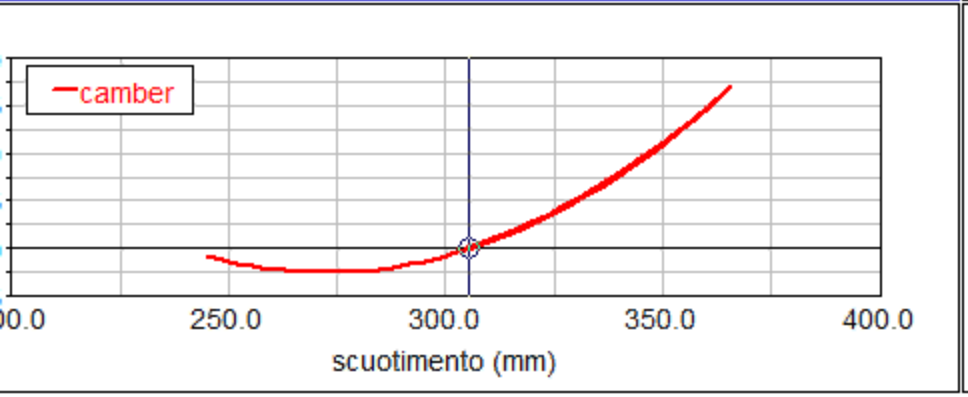


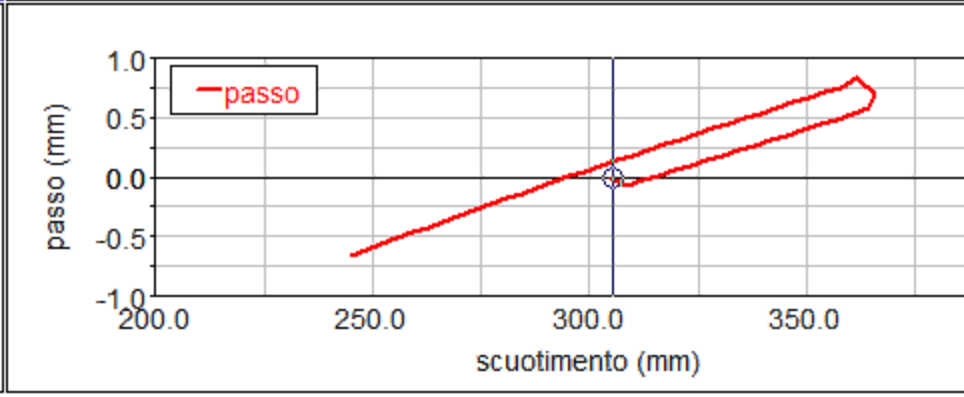
BIELLA
LONGITUDINALE

SVILUPPI FUTURI: SOSPENSIONE REALE









CONCLUSIONI

• Utilizzare modello quarter-car in luogo di altri più complessi è una valida alternativa a patto di sapere bene cosa si vuole analizzare

• La sospensione attiva con strategia skyhook e groundhook consente un netto miglioramento delle prestazioni del sistema sospensivo

• Lo smorzatore inerziale posto su massa sospesa è una valida alternativa all' utilizzo di sistemi più complessi e costosi di ammortizzamento