

Università degli Studi di Padova – Dipartimento di Ingegneria Industriale

Corso di Laurea in Ingegneria Meccanica

***Relazione per la prova finale***  
***ANALISI STRUTTURALI DI UN RIDUTTORE AD INGRANAGGI***  
***MEDIANTE SIMULAZIONI FEM SU SOLIDWORKS***  
***SIMULATION***

Tutor universitario: Prof. Alberto Campagnolo

Laureando: *Christian Malghera*

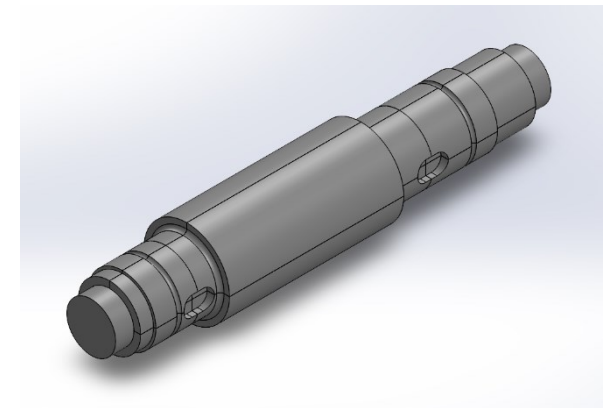
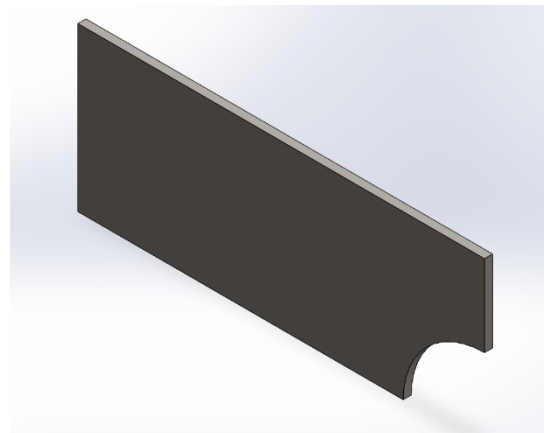
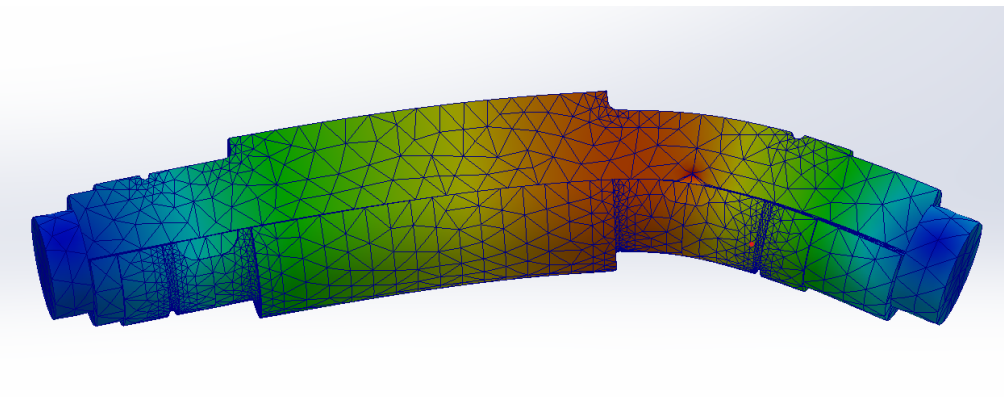
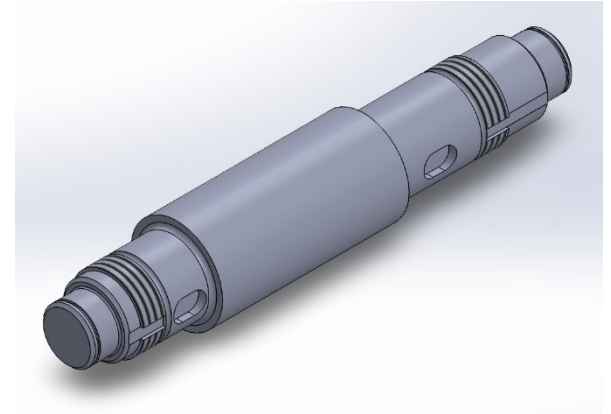
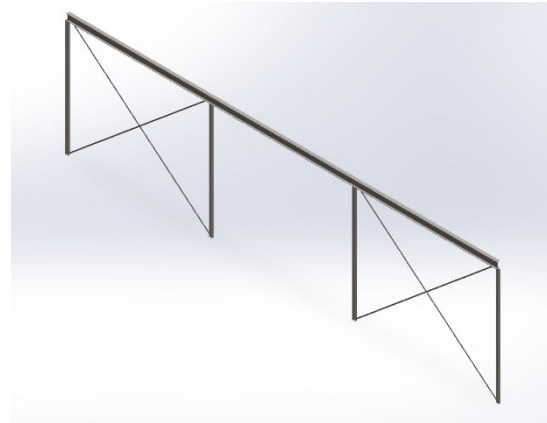
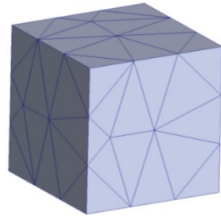
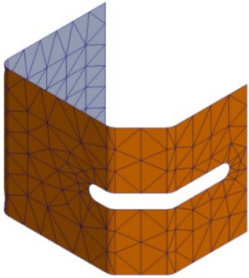
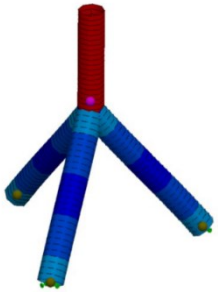
Padova, 13/03/2023

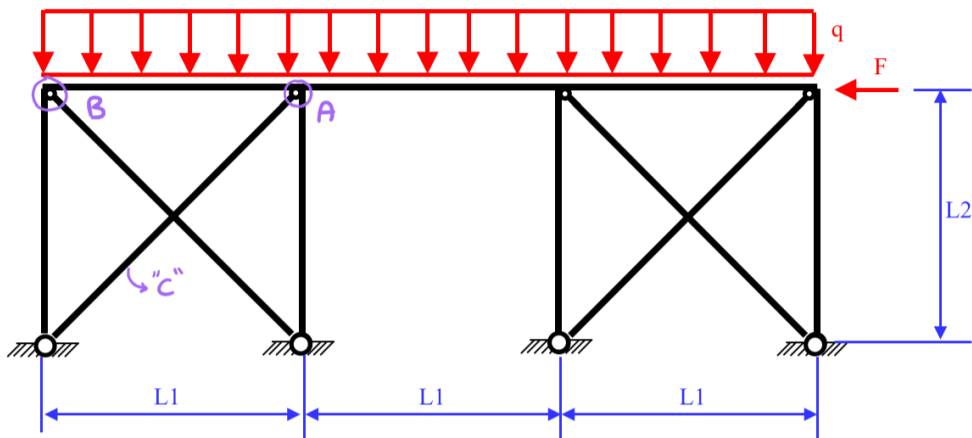
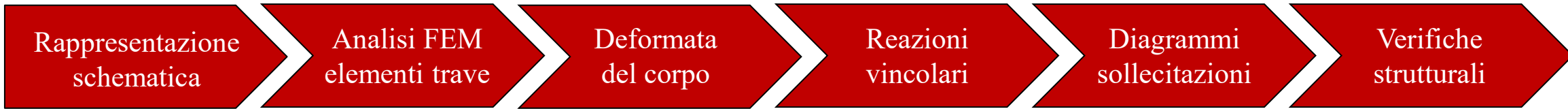
Finalità delle simulazioni  
FEM dell'albero

Introduzione sul metodo  
degli elementi finiti

Addestramento a  
Solidworks Simulation

Simulazioni FEM  
dell'albero intermedio

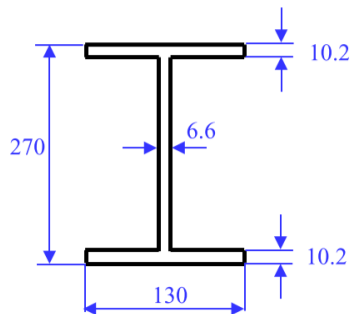




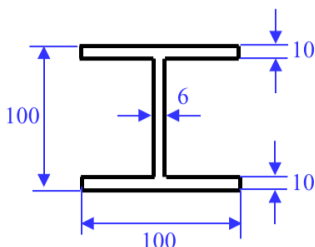
**DATI**  
 $F = 60 \text{ kN}$   
 $q = 20 \text{ kN/m}$   
 $L1 = 6000 \text{ mm}$   
 $L2 = 5000 \text{ mm}$

**MATERIALE**  
 Acciaio Fe 430  
 $\sigma_{adm} = 190 \text{ MPa}$   
 $E = 206000 \text{ MPa}$   
 $\nu = 0.3$

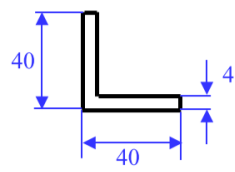
**PROFILI ADOTTATI**  
 Corrente superiore: IPE 270  
 Colonne: HE 100 B  
 Controventi: L 40x4



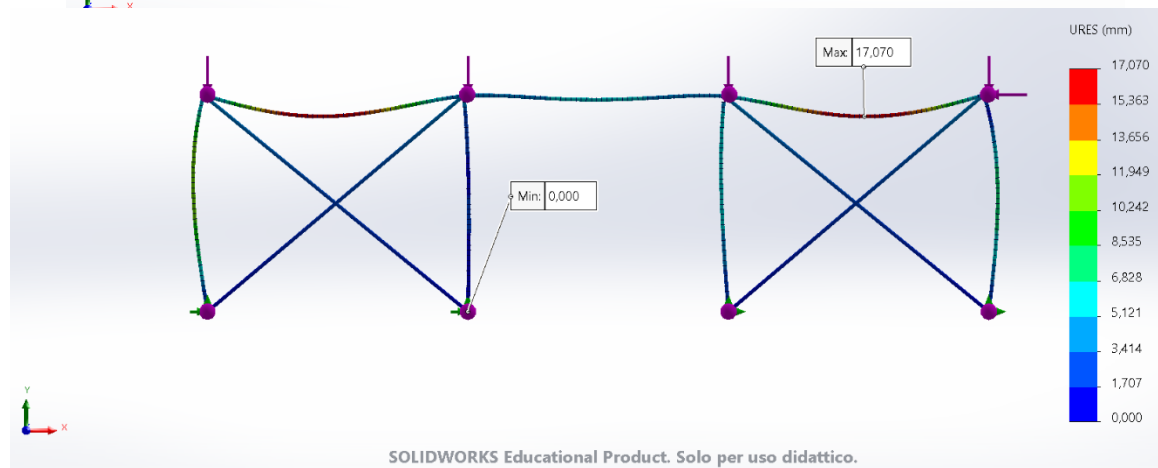
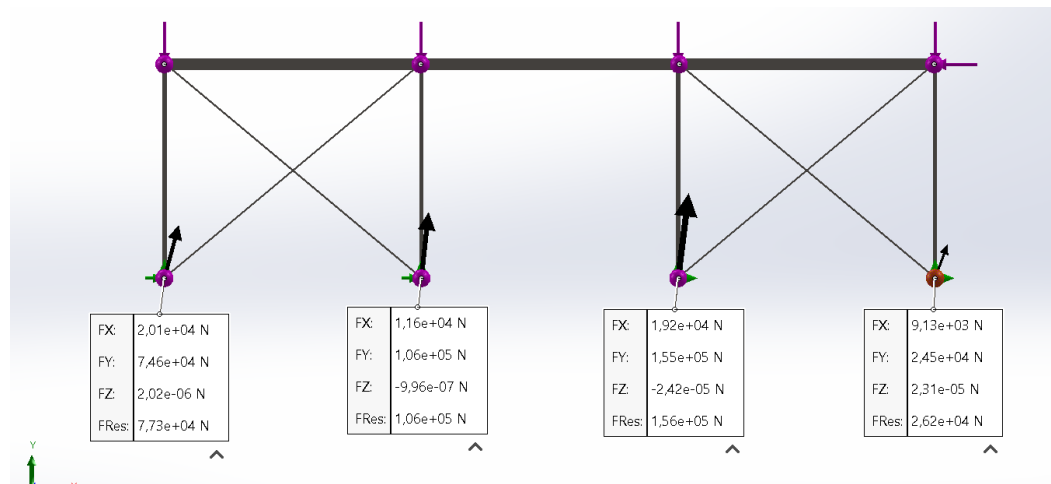
Corrente superiore: IPE 270



Colonne: HE 100 B

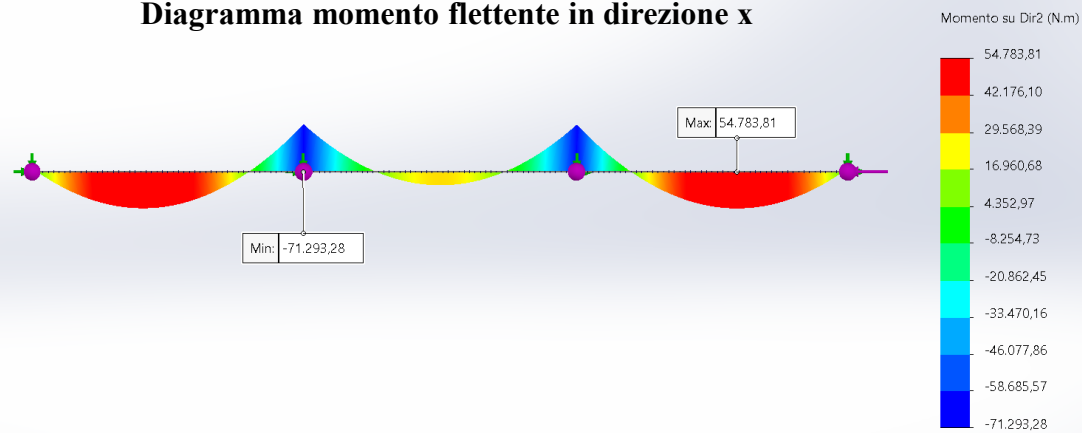


Controventi: L 40x4



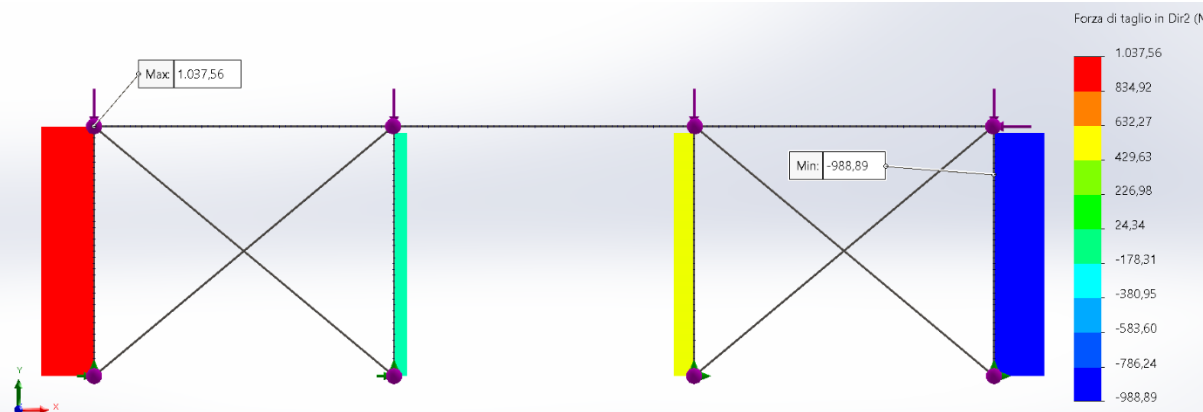
SOLIDWORKS Educational Product. Solo per uso didattico.

**Diagramma momento flettente in direzione x**



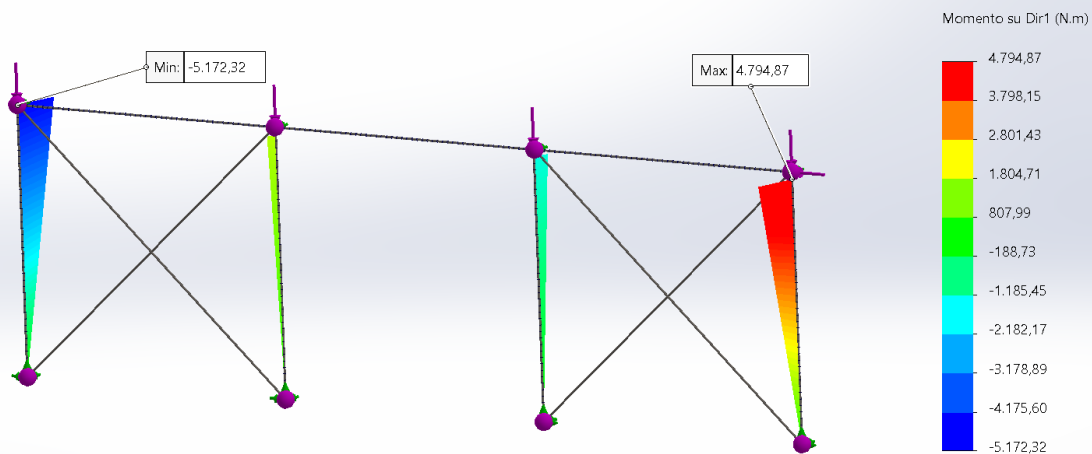
SOLIDWORKS Educational Product. Solo per uso didattico.

**Diagramma del taglio in direzione x**



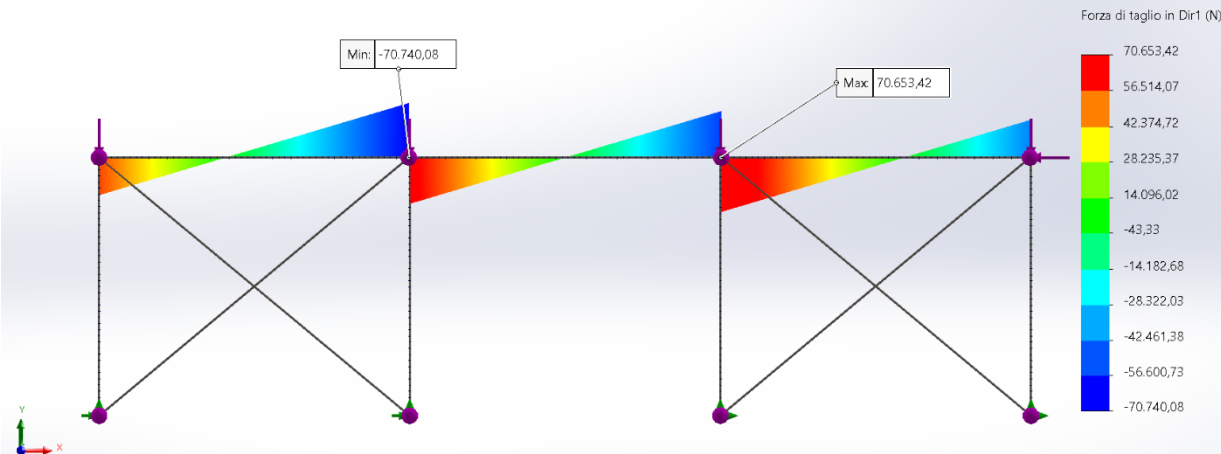
SOLIDWORKS Educational Product. Solo per uso didattico.

**Diagramma momento flettente in direzione y**



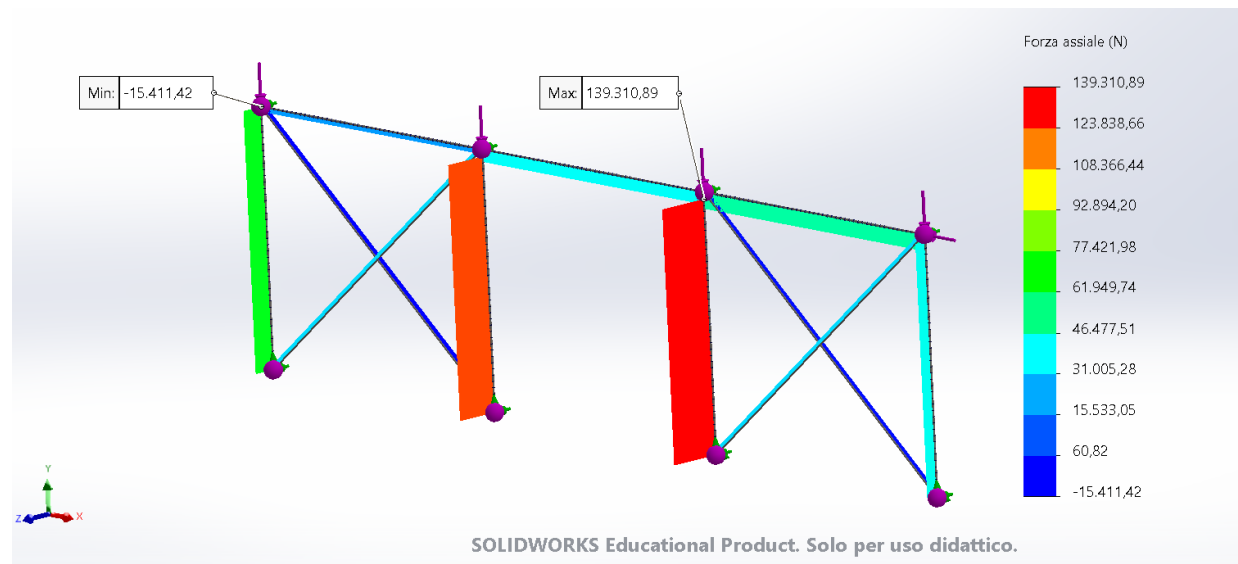
SOLIDWORKS Educational Product. Solo per uso didattico.

**Diagramma del taglio in direzione y**

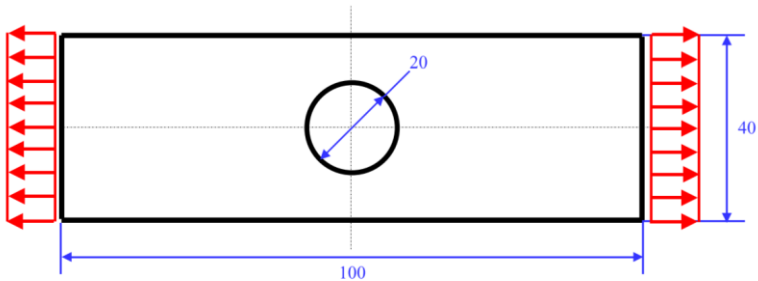


SOLIDWORKS Educational Product. Solo per uso didattico.

Diagramma del carico assiale

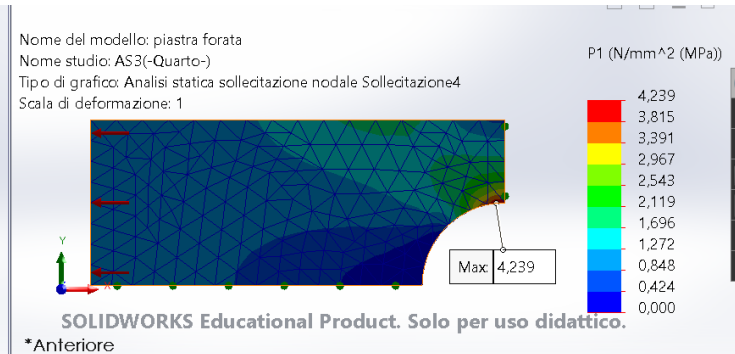
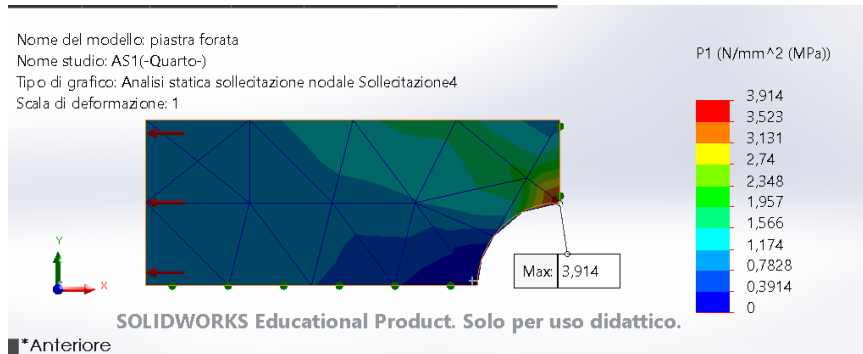


	$\sigma_N$ [MPa]	$\sigma_{Mf}$ [MPa]	$\sigma_{id}$ [Mpa]	$\sigma_{amm}$ [Mpa]
IPE 270 «A»	-3	-180,49	183,49	190
HE 100 B «B»	-23,69	-59,83	83,52	
L 40X4 «C»	-81,57	-	81,57	

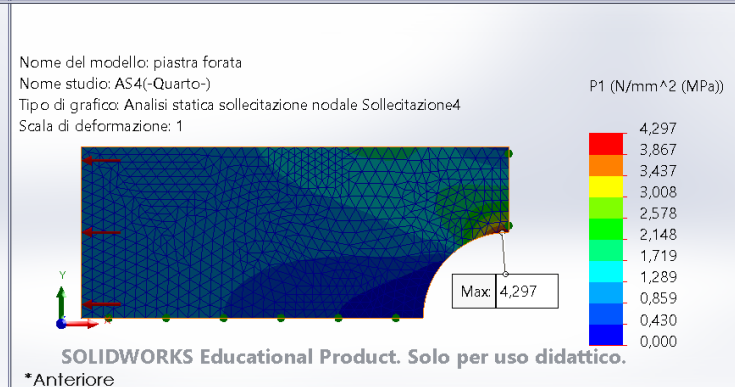
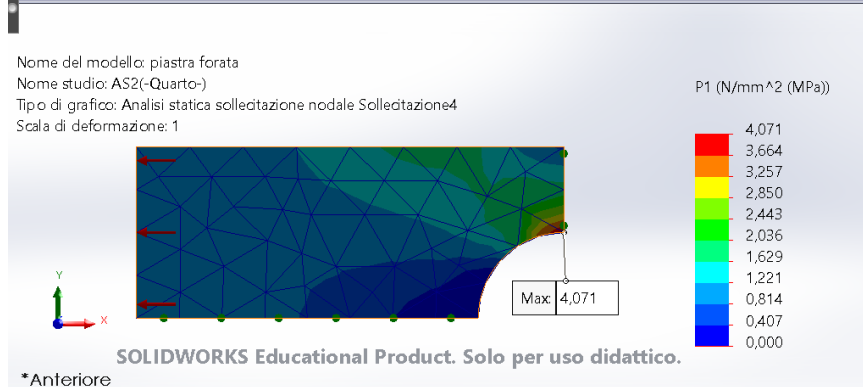


**DATI**  
Spessore piastra = 1 mm

**MATERIALE**  
Acciaio Fe 360  
E=206000 MPa,  $\nu=0,3$

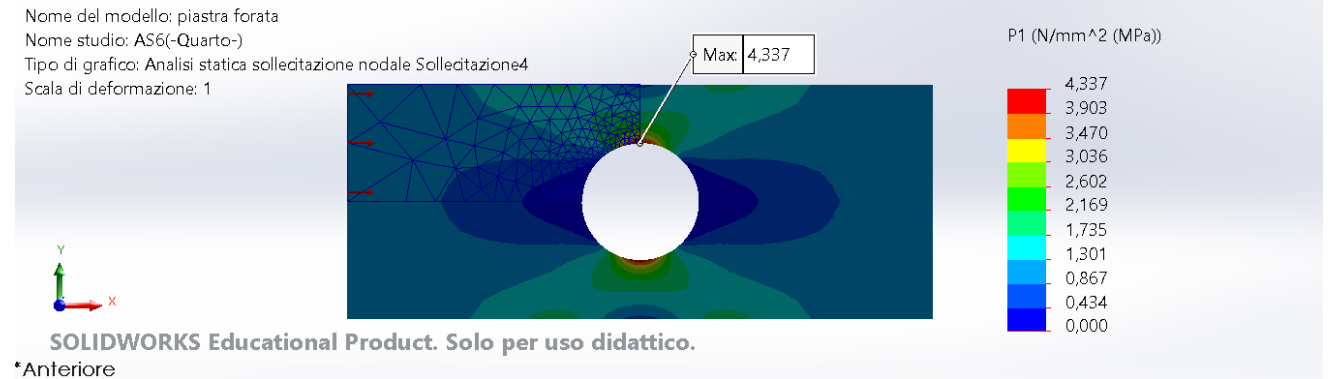
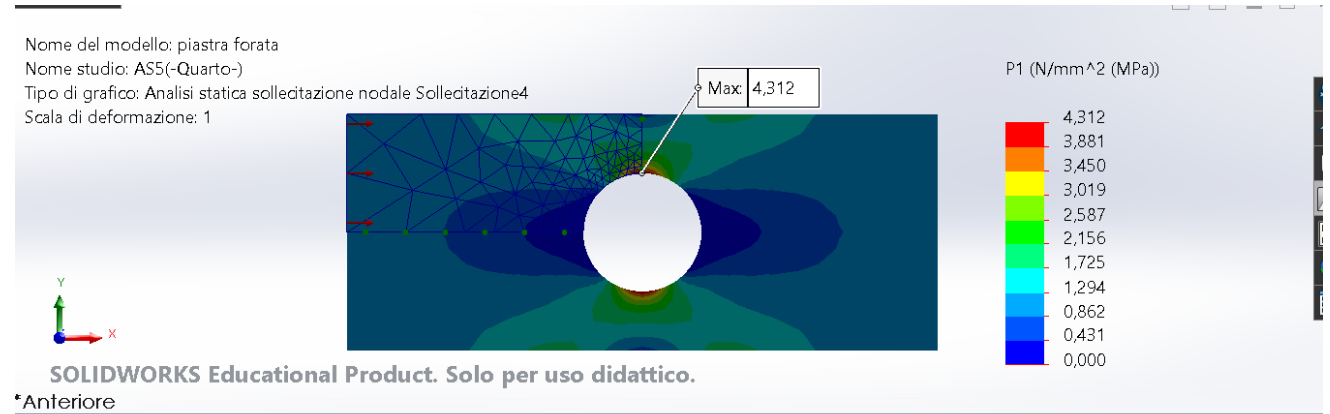
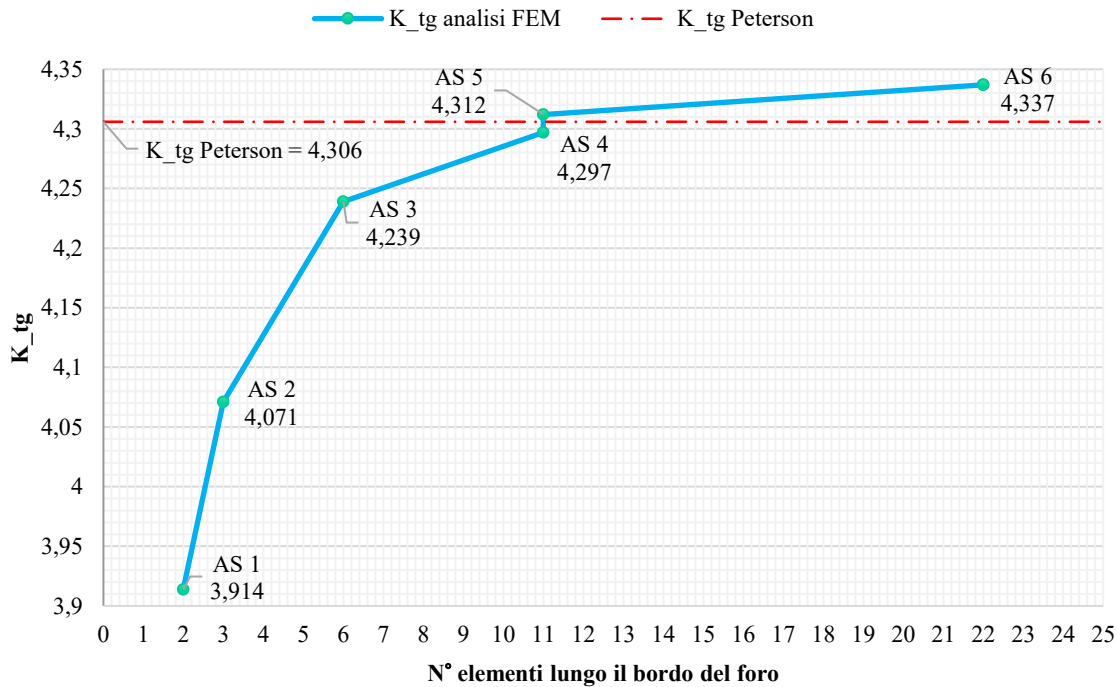


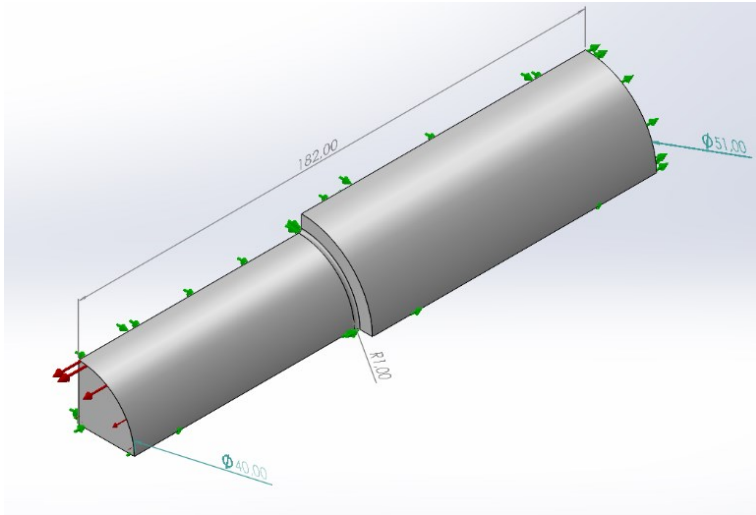
Analisi statica (AS)	Dimensione massima dell'elemento [mm]		N° elementi lungo il bordo del foro	$\sigma_{p\text{el}}$ [MPa]	$K_{tg}$
	Mesh globale	Controllo mesh			
1	10	-	2	3,914	3,914
2	5	-	3	4,071	4,071
3	2,5	-	6	4,239	4,239
4	1,25	-	11	4,297	4,297



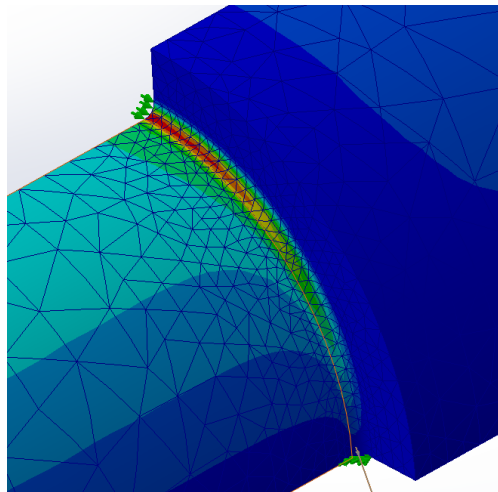
Analisi statica (AS)	Dimensione massima dell'elemento [mm]		N° elementi lungo il bordo del foro	$\sigma_{pel}$ [MPa]	$K_{tg}$
	Mesh globale	Controllo mesh			
5	10	1,25	11	4,312	4,312
6	10	0,75	22	4,337	4,337

## Confronto $K_{tg}$



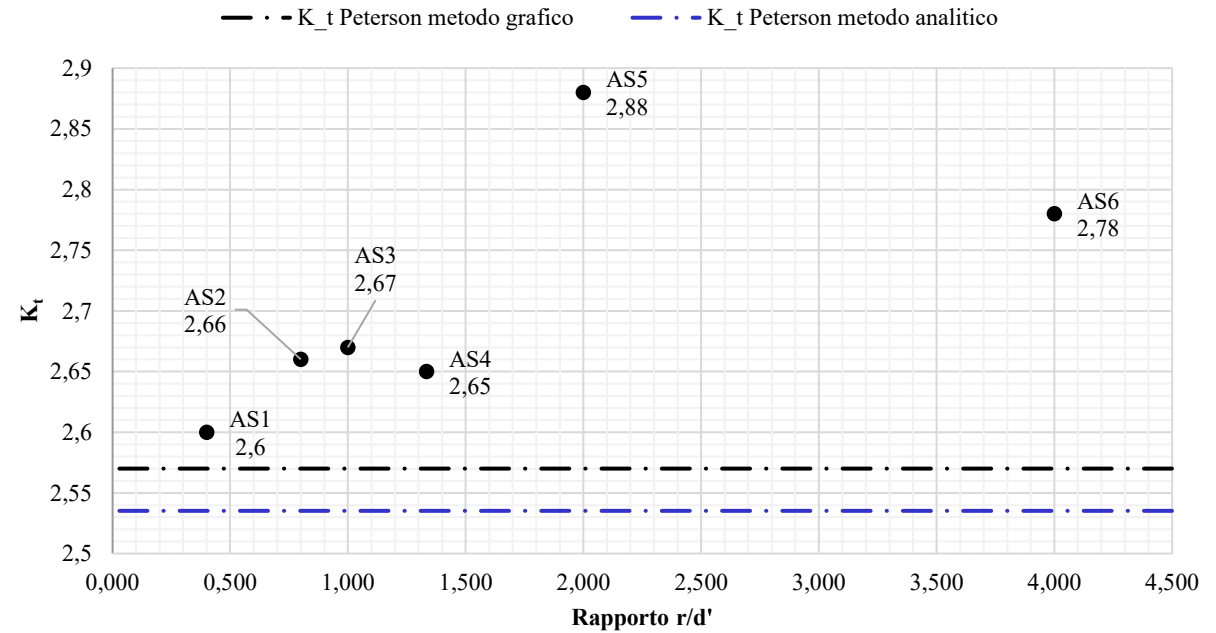


Modello FEM della sezione A



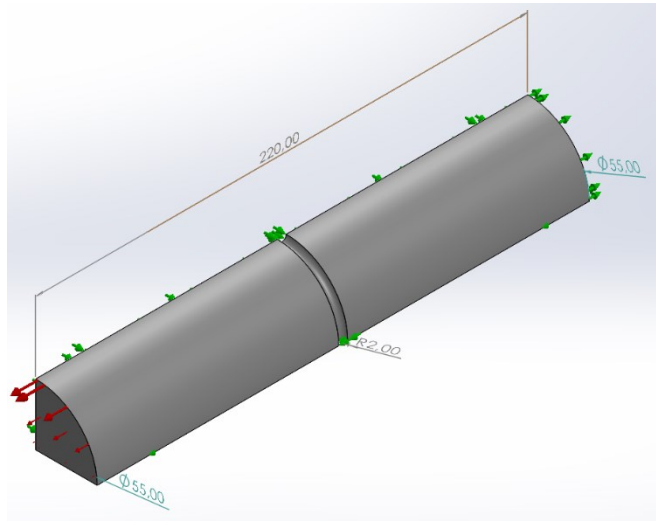
Modello dopo simulazione FEM

## Confronto $K_t$

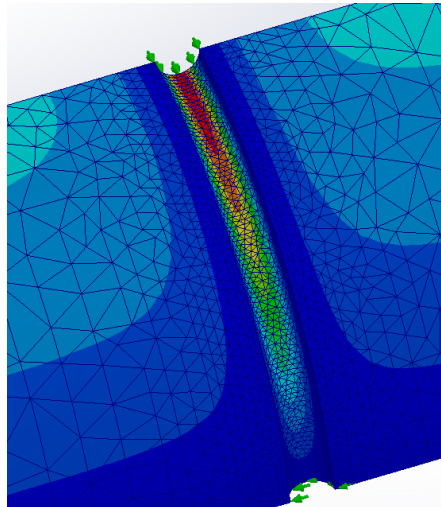


Analisi statica (AS)	Dimensione massima elemento $d'$ [mm]	$r/d'$	$K_t$	$K_t$ Peterson Metodo Analitico	$K_t$ Peterson Metodo Grafico	Deviazione %
1	2,5	0,40	2,6	2,54	2,57	2,556%
2	1,25	0,80	2,66			4,923%
3	1	1,00	2,67			5,318%
4	0,75	1,33	2,65			4,529%
5	0,5	2,00	2,88			13,601%
6	0,25	4,00	2,78			9,657%



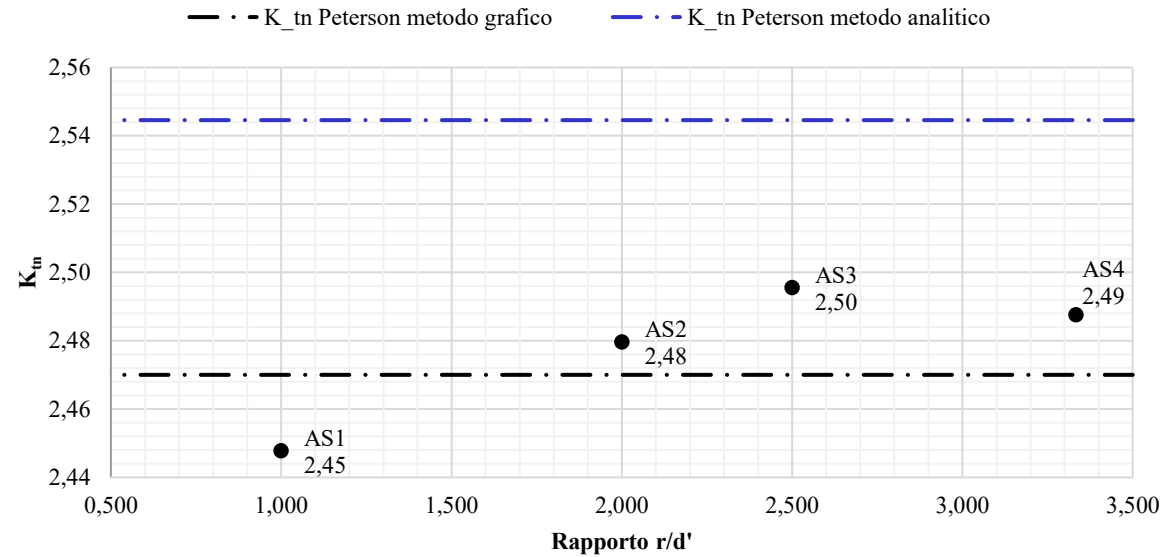


Modello FEM della sezione B

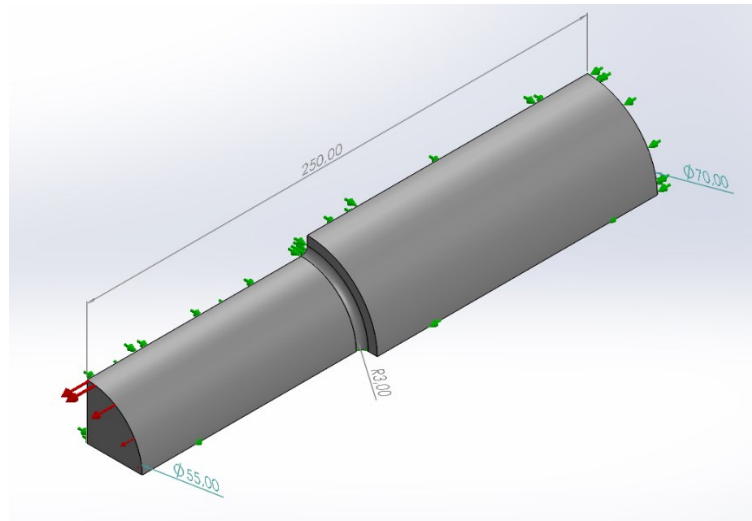


Modello dopo simulazione FEM

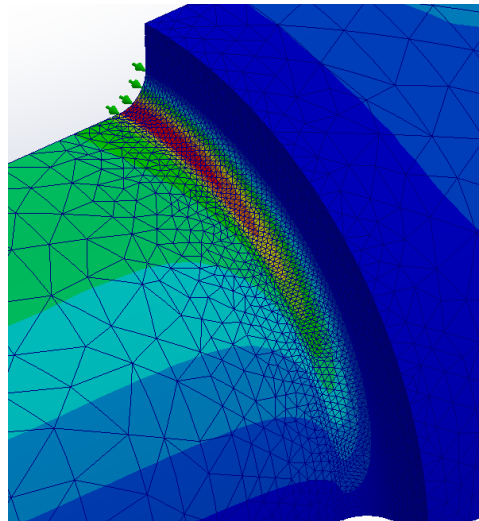
## Confronto $K_{tn}$



Analisi statica (AS)	Dimensione massima elemento $d'$ [mm]	$\frac{r}{d'}$	$K_{tg}$	$K_{tn}$	$K_{tn}$ Peterson Metodo Analitico	$K_{tn}$ Peterson Metodo Grafico	Deviazione %
1	2	1,00	3,07	2,45	2,54	2,47	3,807%
2	1	2,00	3,11	2,48			2,554%
3	0,8	2,50	3,13	2,50			1,927%
4	0,6	3,33	3,12	2,49			2,241%

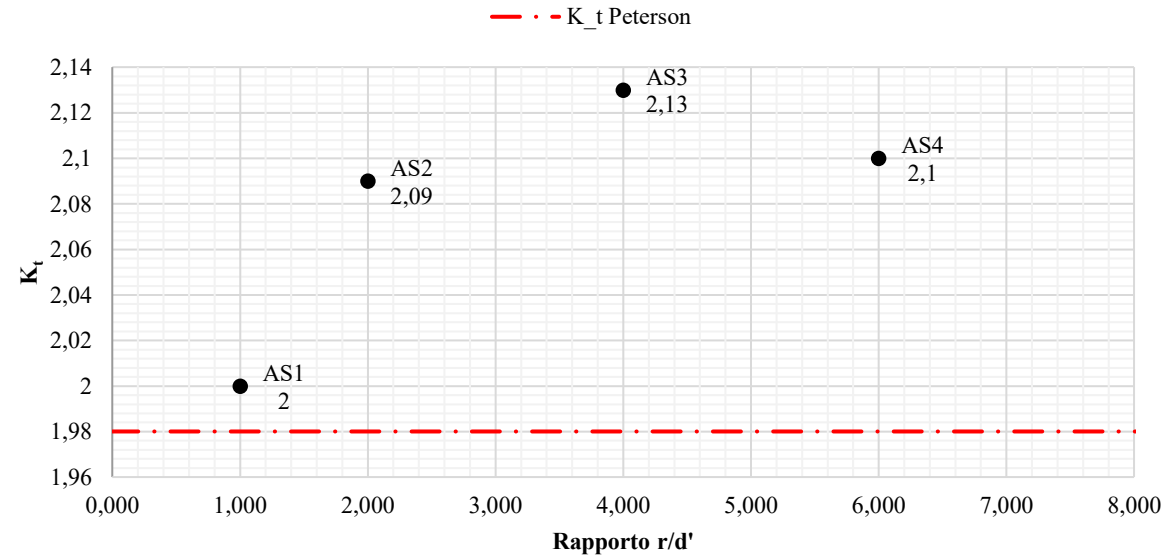


Modello FEM della sezione D



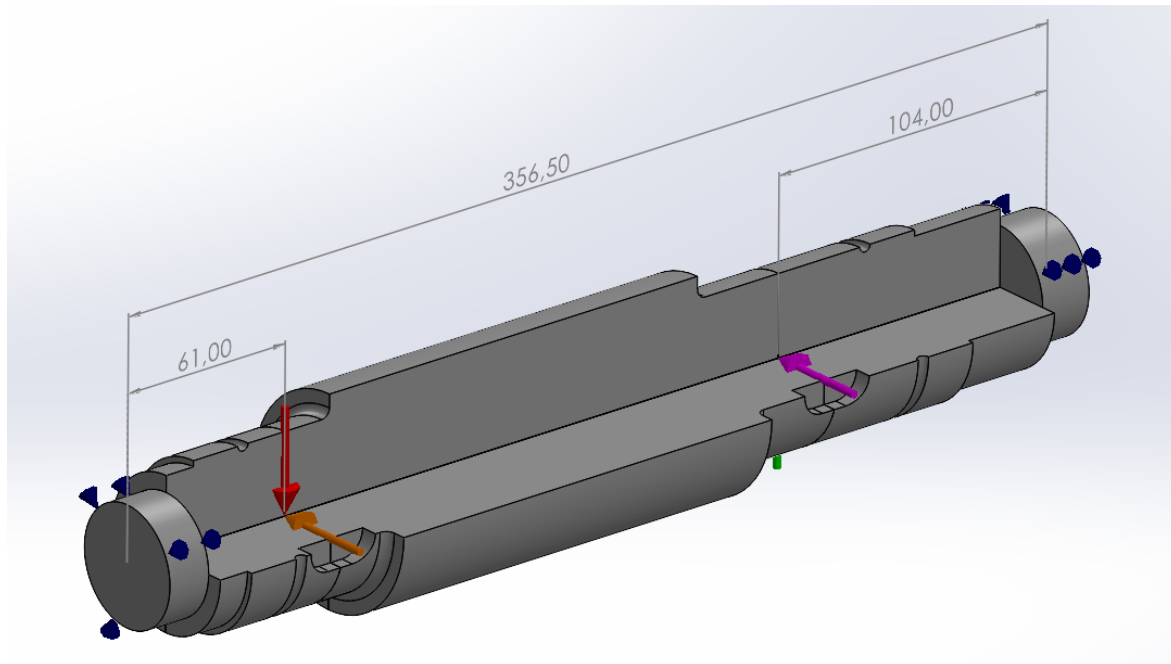
Modello dopo simulazione FEM

## Confronto $K_t$

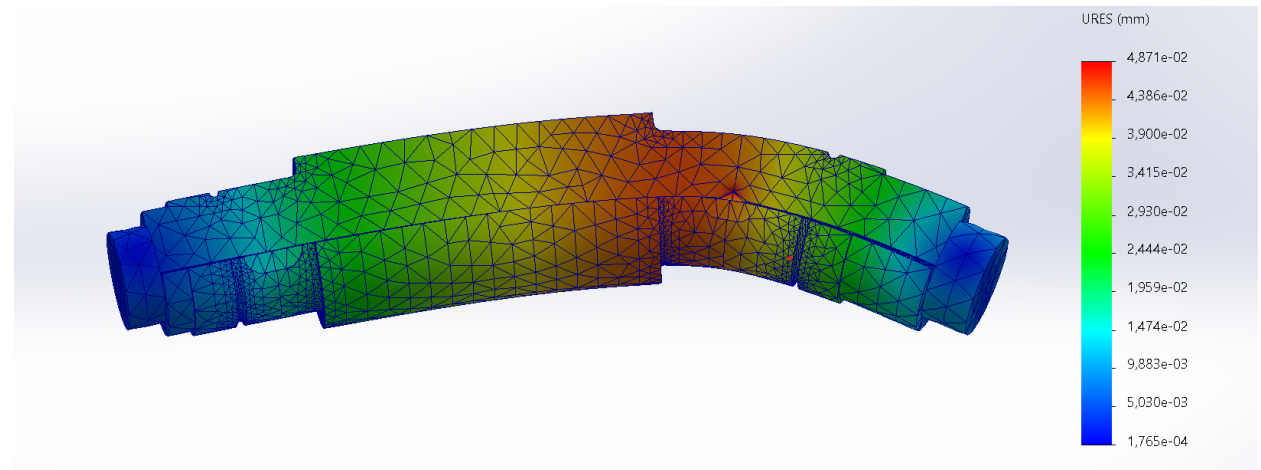


Analisi statica (AS)	Dimensione massima elemento $d'$ [mm]	$\frac{r}{d'}$	$K_t$	$K_t$ Peterson	Deviazione %
1	3	1,00	2	1,98	0,932%
2	1,5	2,00	2,09		5,474%
3	0,75	4,00	2,13		7,493%
4	0,5	6,00	2,1		5,979%

Forza	Simbolo	Valore [N]	Colore
Tangenziale 2	$F_{t2}$	1936,69	Rosso
Radiale 2	$F_{r2}$	704,9	Arancione
Tangenziale 3	$F_{t3}$	9102,46	Verde
Radiale 3	$F_{r3}$	3313,03	Viola

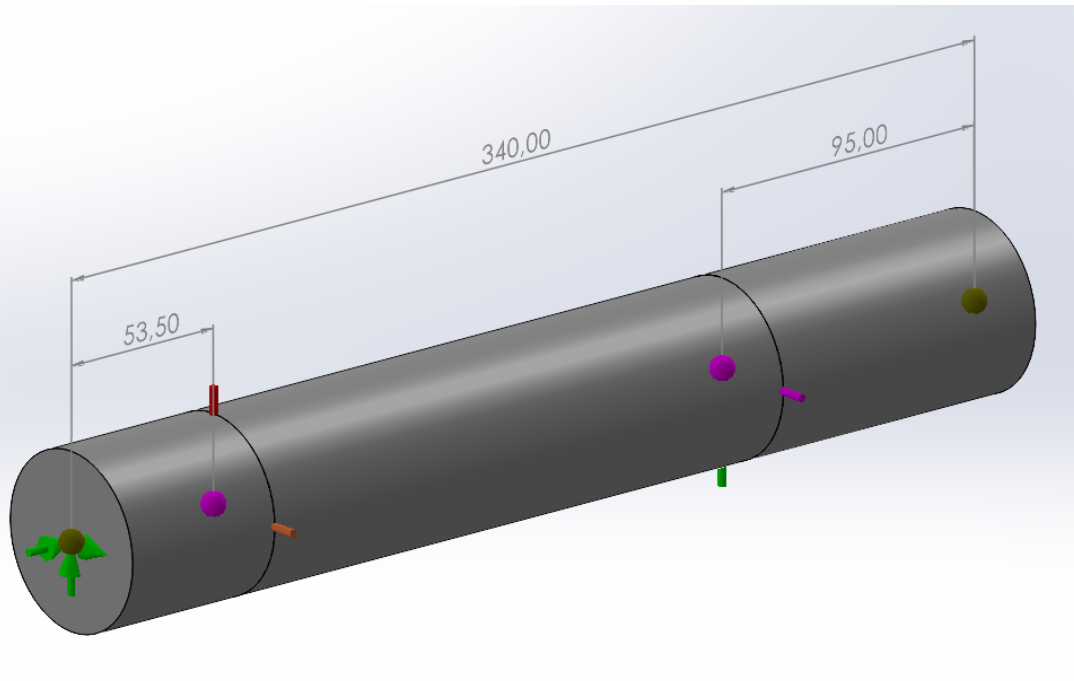


Modello tridimensionale dell'albero intermedio opportunamente sezionato, con carichi e vincoli.

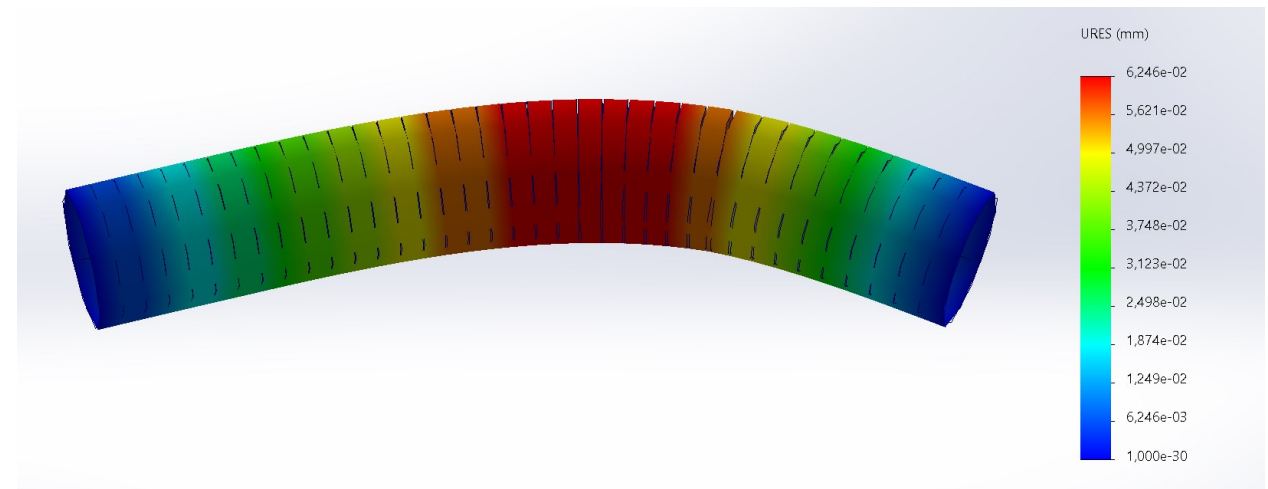


Modello solido tridimensionale dopo la simulazione FEM, spostamento in scala.

Forza	Simbolo	Valore [N]	Colore
Tangenziale 2	$F_{t2}$	1936,69	Rosso
Radiale 2	$F_{r2}$	704,9	Arancione
Tangenziale 3	$F_{t3}$	9102,46	Verde
Radiale 3	$F_{r3}$	3313,03	Viola



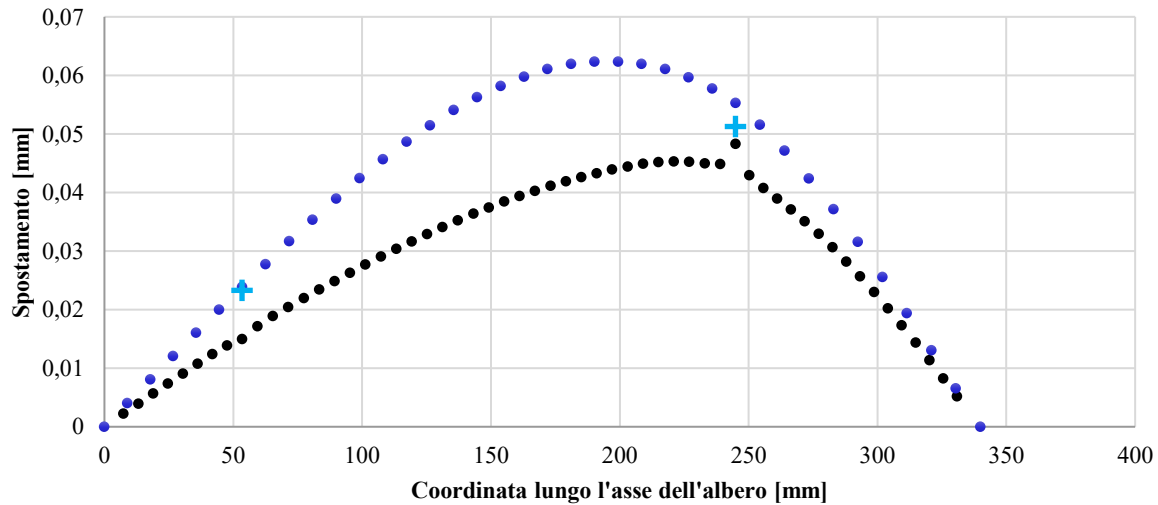
Modello monodimensionale dell'albero intermedio opportunamente sezionato, con carichi e vincoli.



Modello solido monodimensionale dopo la simulazione FEM, spostamento in scala.

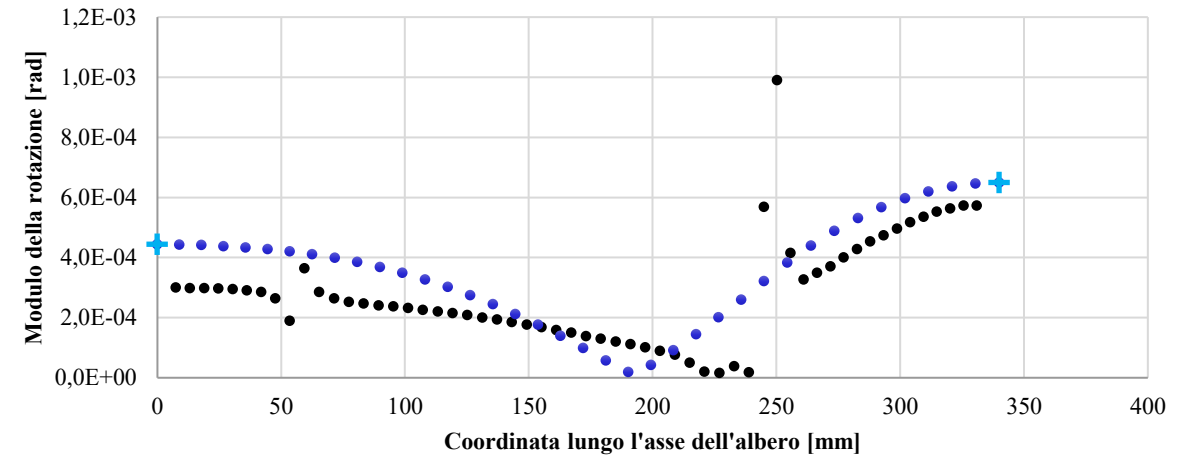
## Andamento della freccia dell'asse dell'albero

● Modello solido 3D ● Modello trave 1D + Modello analitico



## Andamento dell'angolo di inclinazione dell'asse dell'albero

● Modello solido 3D ● Modello trave 1D + Modello analitico



Modello	Freccia nella sezione C $f_2$ [mm]	Freccia nella sezione F $f_3$ [mm]
Solido tridimensionale	0,01501	0,04831
Trave monodimensionale	0,02390	0,05530
Analitico	0,02335	0,05132

Modello	Rotazione del cuscinetto di sinistra $\varphi_S$ [rad]	Rotazione del cuscinetto di destra $\varphi_D$ [rad]
Solido tridimensionale	0,0003000	0,0005727
Trave monodimensionale	0,0004442	0,0006495
Analitico	0,0004444	0,0006496

## Verifiche flessionali dell'albero intermedio:

Sezione	$K_t$	$K_t$ Peterson	Deviazione %
A	2,65	2,54	4,529%
B	2,49	2,54	2,241%
D	2,1	1,98	5,979%

## Verifiche a deformabilità dell'albero intermedio:

Modello	Freccia nella sezione C $f_2$ [mm]	Freccia nella sezione F $f_3$ [mm]	Rotazione del cuscinetto di sinistra $\varphi_S$ [rad]	Rotazione del cuscinetto di destra $\varphi_D$ [rad]
Solido tridimensionale	0,01501	0,04831	0,0003000	0,0005727
Trave monodimensionale	0,02390	0,05530	0,0004442	0,0006495
Analitico	0,02335	0,05132	0,0004444	0,0006496