

Università degli Studi di Padova – Dipartimento di Ingegneria Industriale

Corso di Laurea in Ingegneria Meccanica

***Relazione per la prova finale***  
***ANALISI NUMERICHE STRUTTURALI DI UN ALBERO IN UN***  
***RIDUTTORE BISTADIO MEDIANTE SOLIDWORKS***  
***SIMULATION***

Tutor universitario: Prof. Alberto Campagnolo

Laureando: *Giacomo Maschio*

Padova, 18/03/2024

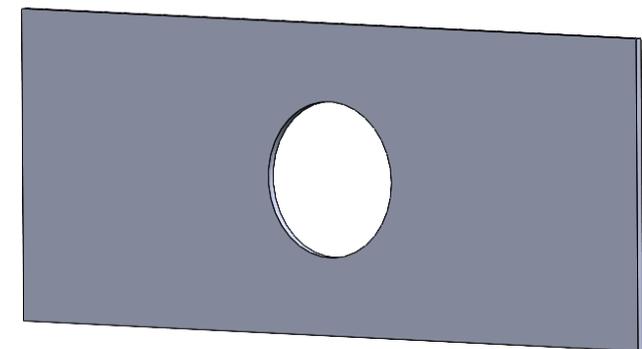
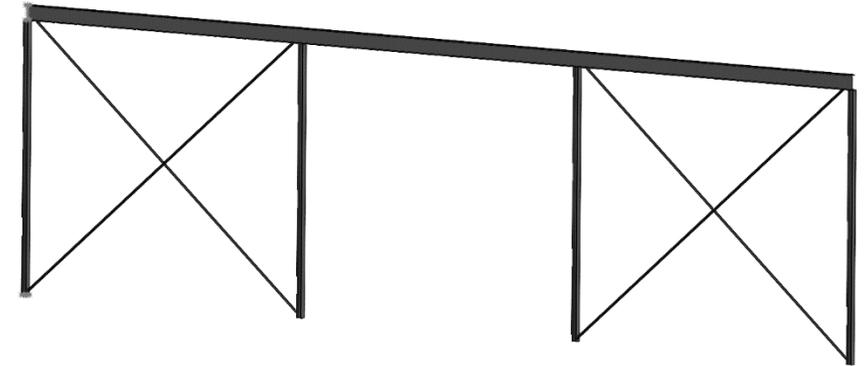
- Albero di un riduttore bistadio come oggetto dell'analisi

- **Obiettivi:**

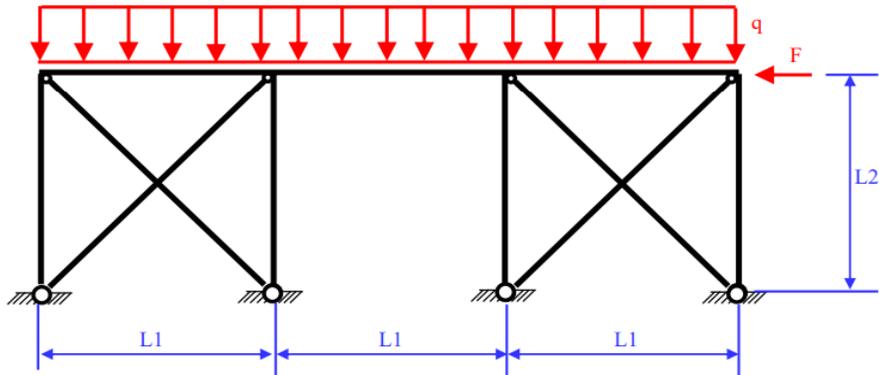
1. verifiche a fatica, calcolo  $k_t$  di alcune sezioni critiche con analisi FEM.
2. verifiche a deformabilità, calcolo degli spostamenti e delle rotazioni con analisi FEM.

- **Fasi di lavoro:**

1. introduzione agli elementi finiti.
2. addestramento Solidworks
  - telaio piano
  - piastra forata
3. studio dell'albero intermedio.



## TELAIO PIANO



### DATI

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

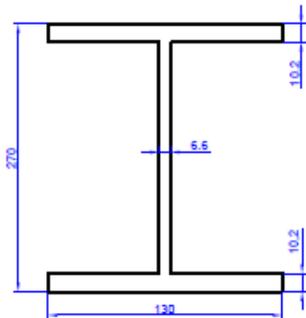
### MATERIALE

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

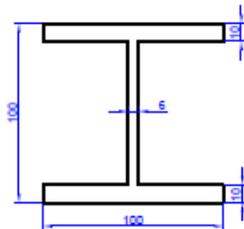
### PROFILI ADOTTATI

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

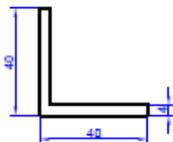
### PROFILI:



Corrente superiore IPE 270

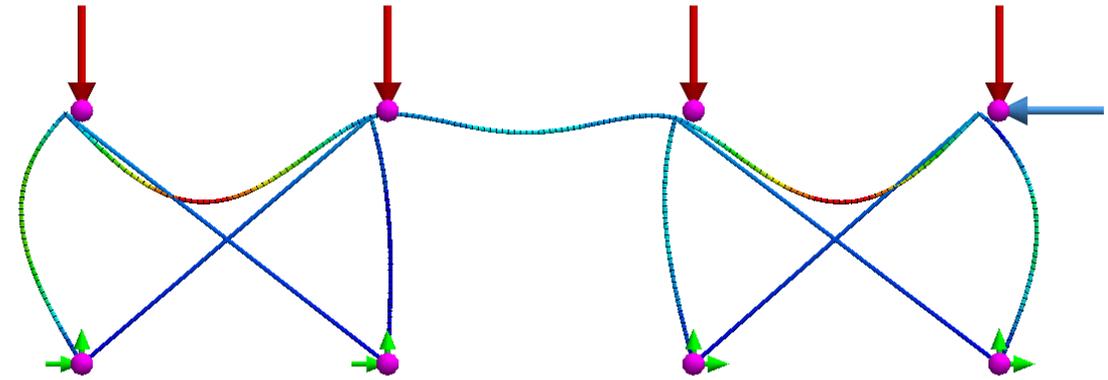
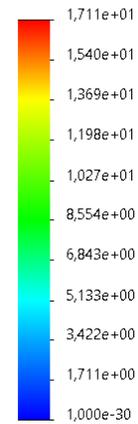


Colonne: HE 100 B



Controventi: L 40x40

URES (mm)



Deformata telaio piano, scala 107

Forza assiale (N)

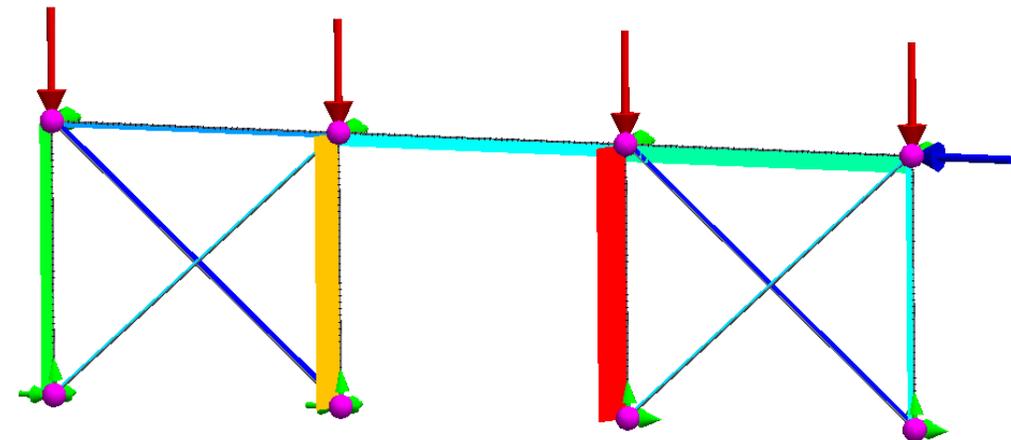
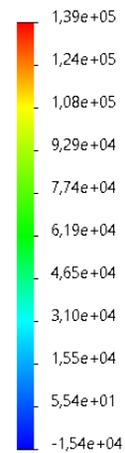


Diagramma sforzo assiale

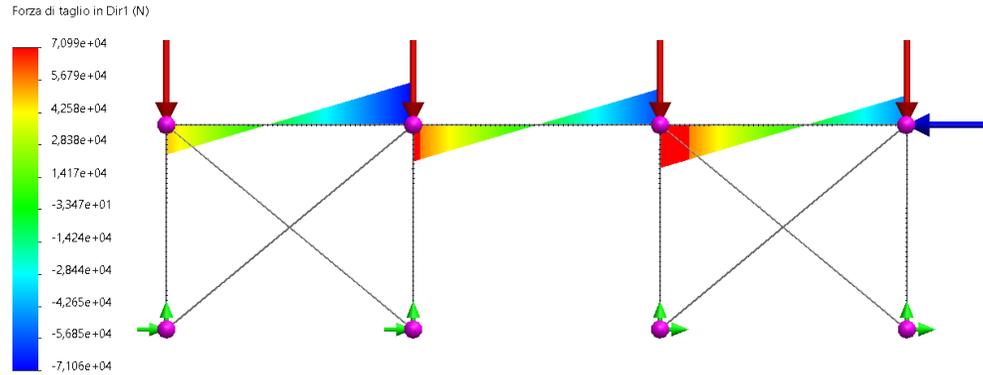


Diagramma di taglio [N] lungo l'asse y.

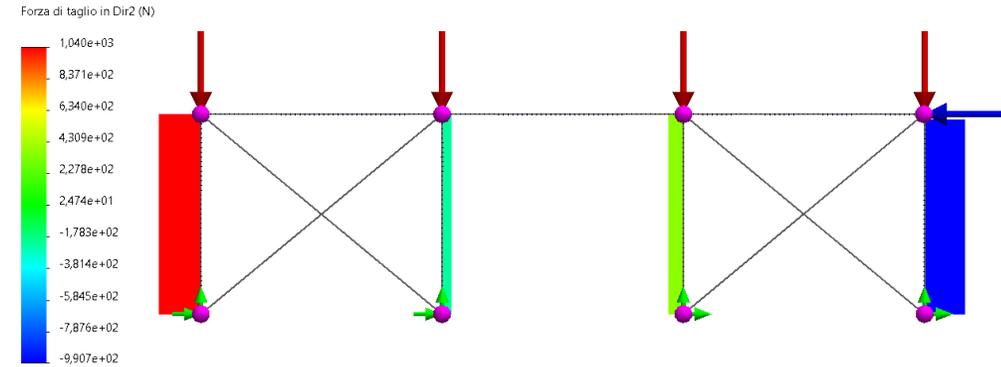


Diagramma di taglio [N] lungo l'asse x.

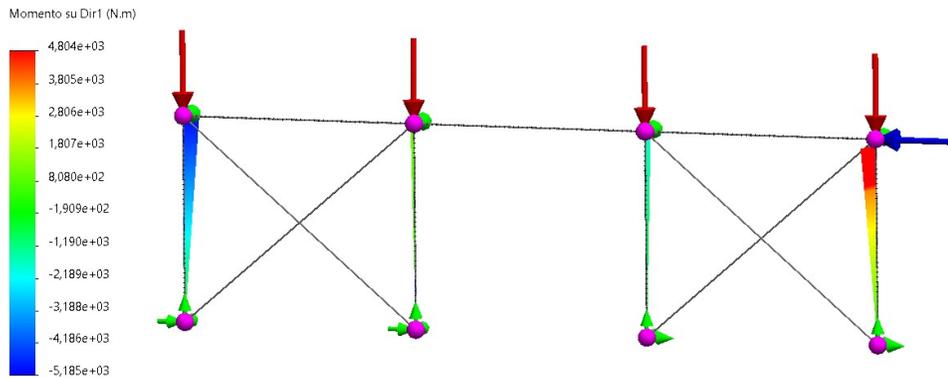


Diagramma momento flettente [N m].

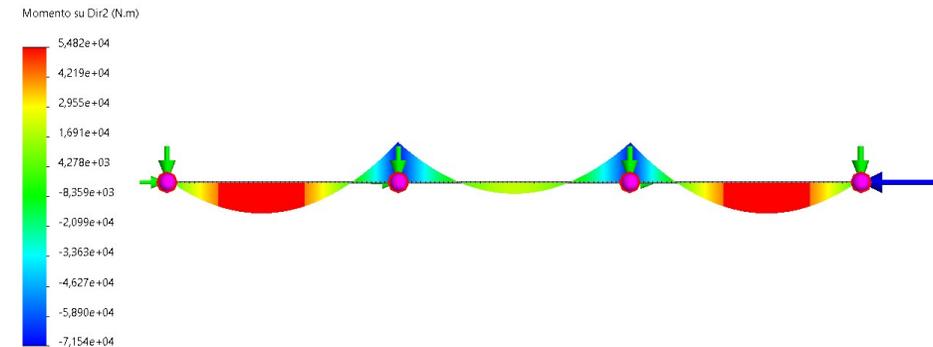
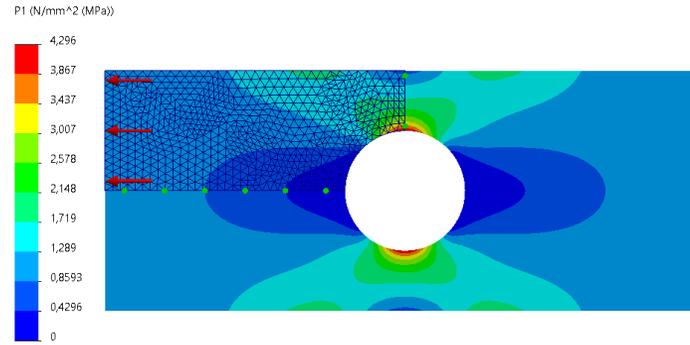
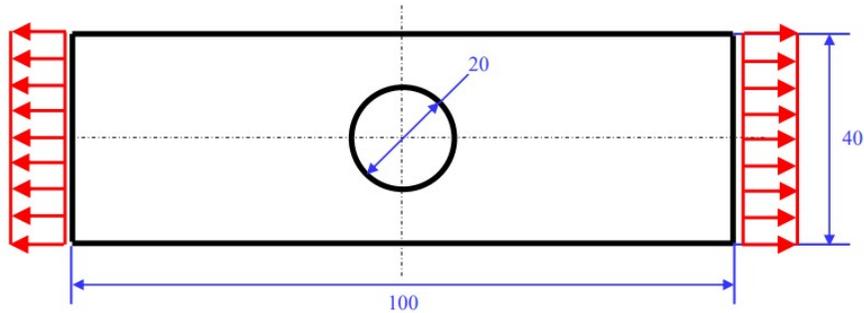


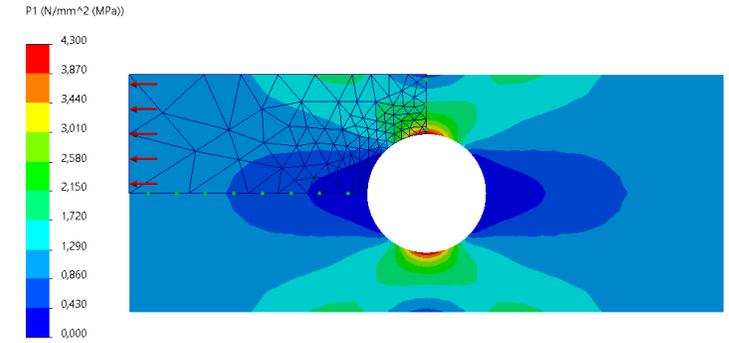
Diagramma momento flettente [N m].

	$\sigma_N$ [MPa]	$\sigma_{Mf}$ [MPa]	$\sigma_{tot}$ [MPa]	$\sigma_{adm}$ [MPa]
IPE 270	7,36	181,11	188,47	190
HE 100 B	23,71	59,97	83,68	190
L 40x40	81,18	/	81,18	190

## PIASTRA FORATA



Analisi 4, dimensione elemento 1 mm.



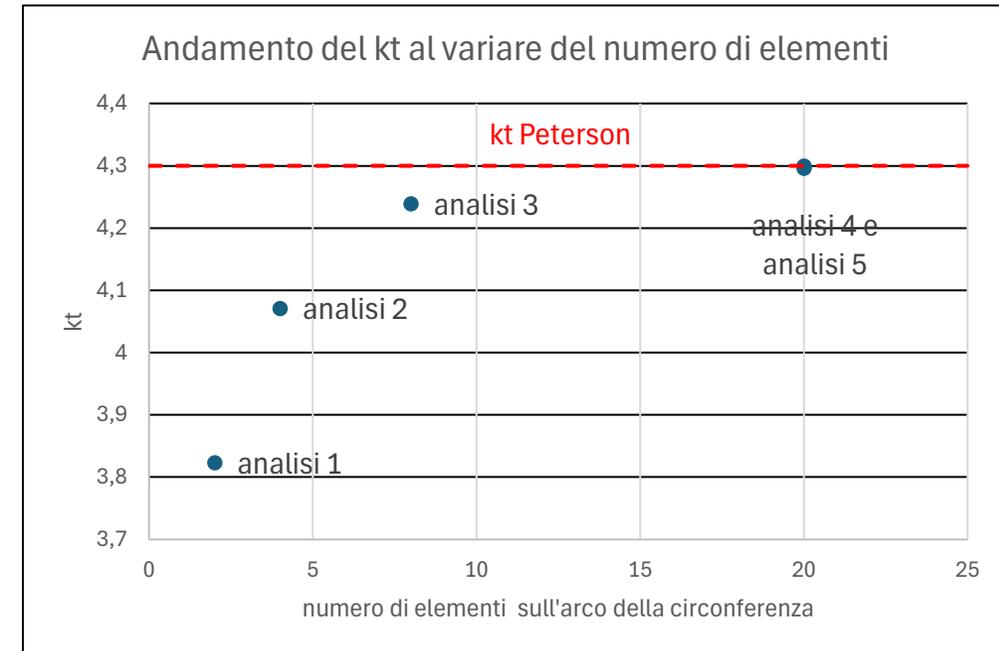
Analisi 5, affinamento della mesh nella parte interessata di 1mm.

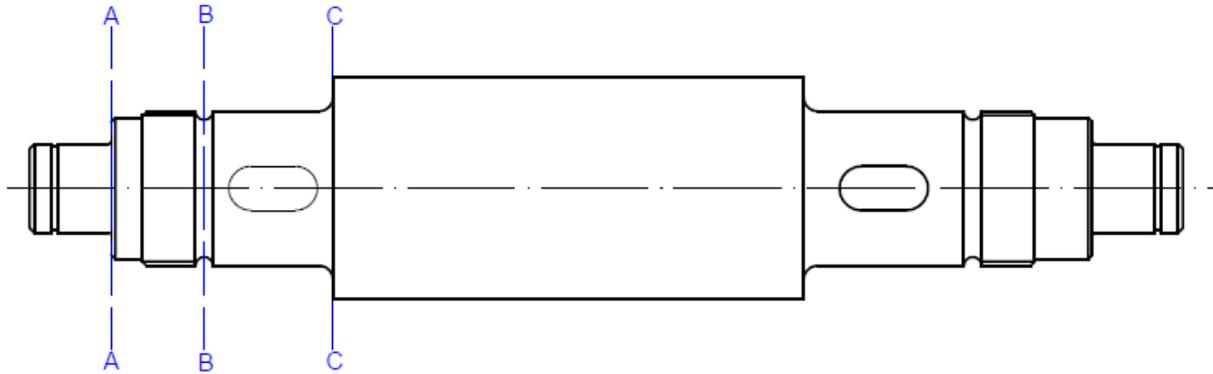
**DATI**  
Spessore piastra = 1 mm

**MATERIALE**  
Acciaio Fe 360  
E=206000 MPa  
 $\nu=0.3$

	Analisi 1	Analisi 2	Analisi 3	Analisi 4	Analisi 5
$k_{tg}$	3,823	4,071	4,239	4,296	4,300
Variazione rispetto kt Peterson: 4,3	11,1 %	5,3 %	1,4 %	0,093 %	0 %

Valori del  $k_t$  in funzione della grandezza dell'elemento della mesh.





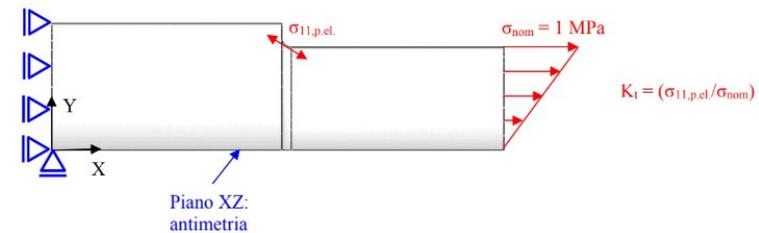
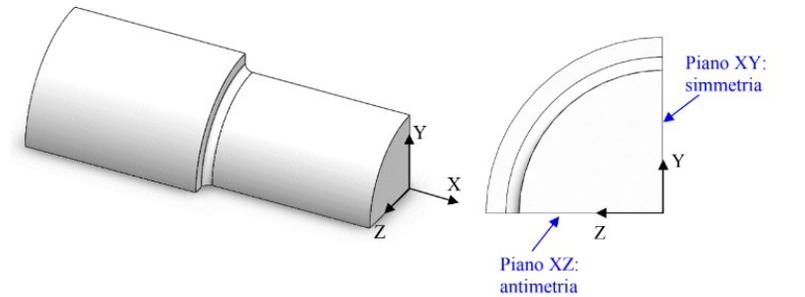
- **sezione A-A:** spallamento cuscinetto
- **sezione B-B:** gola di sarico
- **sezione C-C:** spallamento ruota dentata

**Materiale:** C45 bonificato

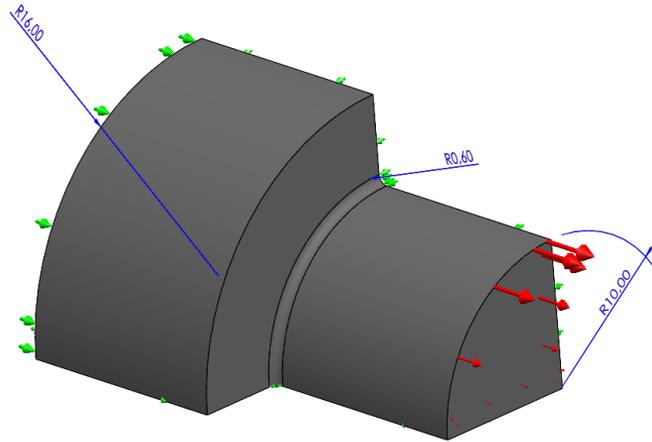
$$-\sigma_R = 690 \text{ [Mpa]}$$

$$\sigma_S = 460 \text{ [Mpa]}$$

$$E = 206000 \text{ [Mpa]}$$



Condizioni di vincolo e carico adottate



Modello CAD 3D spallamento cuscinetto con quote, carichi e vincoli.

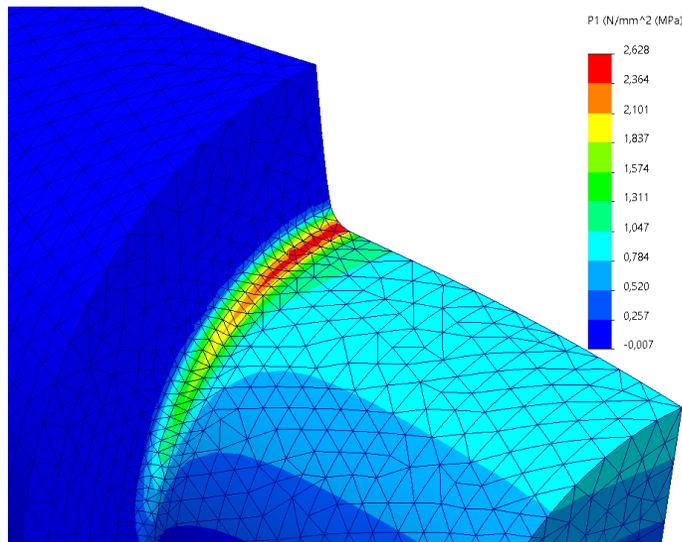
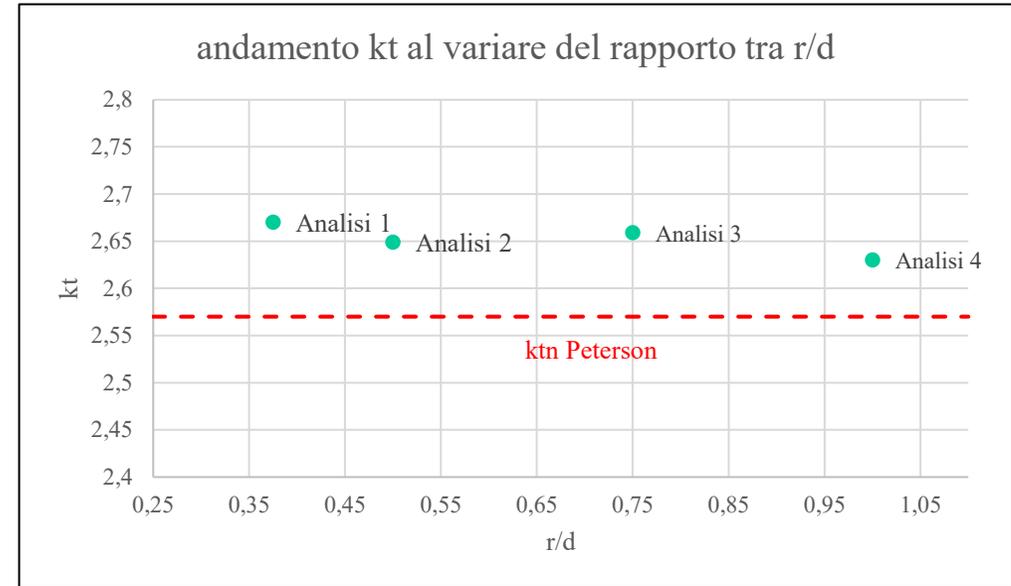
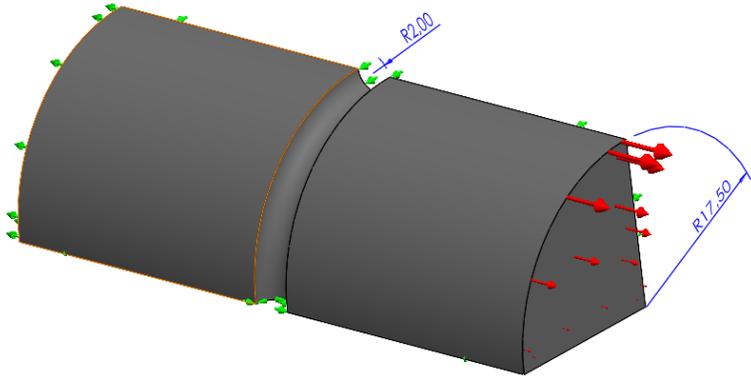


Grafico sollecitazione normale



	<b>Analisi 1</b>	<b>Analisi 2</b>	<b>Analisi 3</b>	<b>Analisi 4</b>
<b>Dimensioni elemento (d) [mm]</b>	1,6	1,2	0,8	0,6
<b><math>k_t</math> analisi FEM</b>	2,67	2,649	2,659	2,628
<b><math>K_t</math> Peterson</b>	2,58	2,58	2,58	2,58
<b>variazione</b>	3,49%	2,67%	3,06 %	1,86%



Modello CAD 3D gola di scarico con quote, carichi e vincoli.

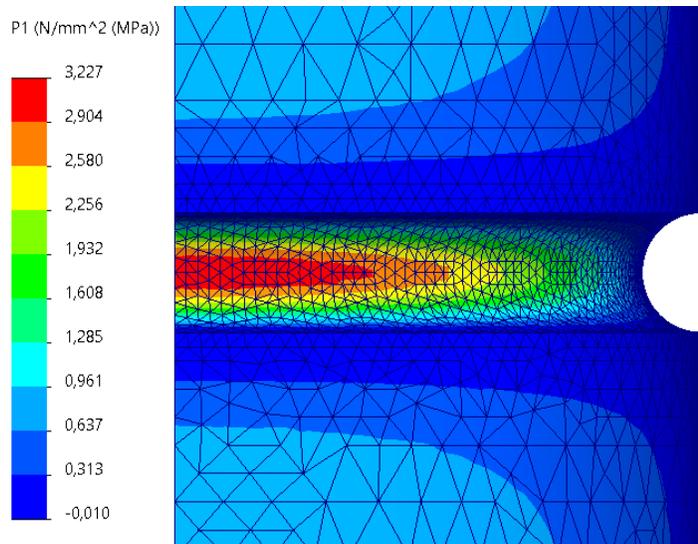
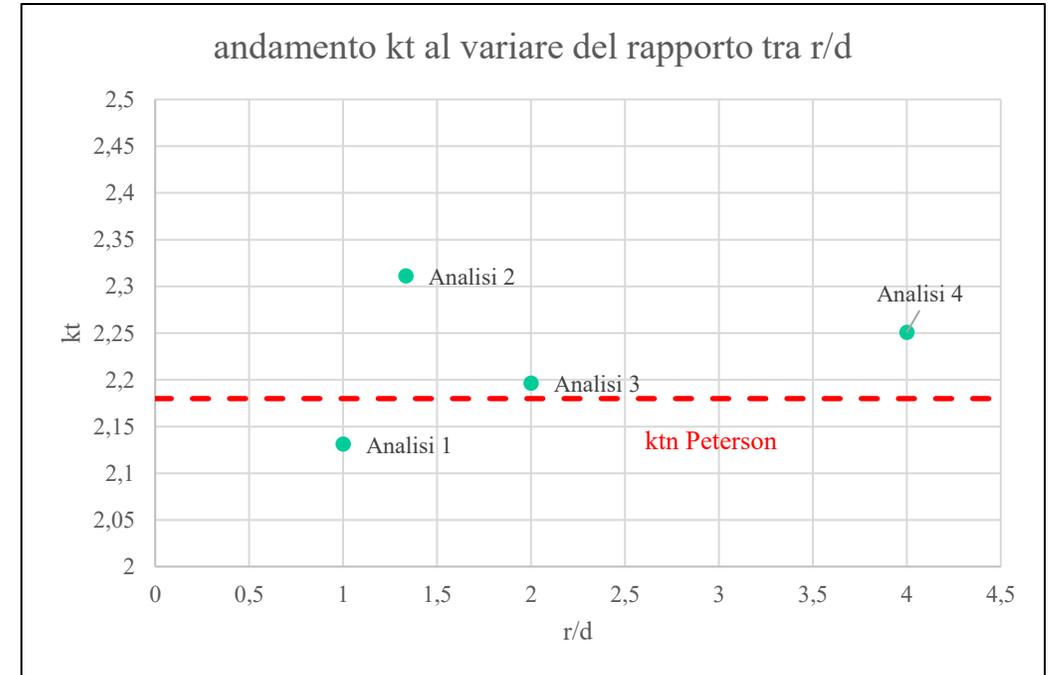
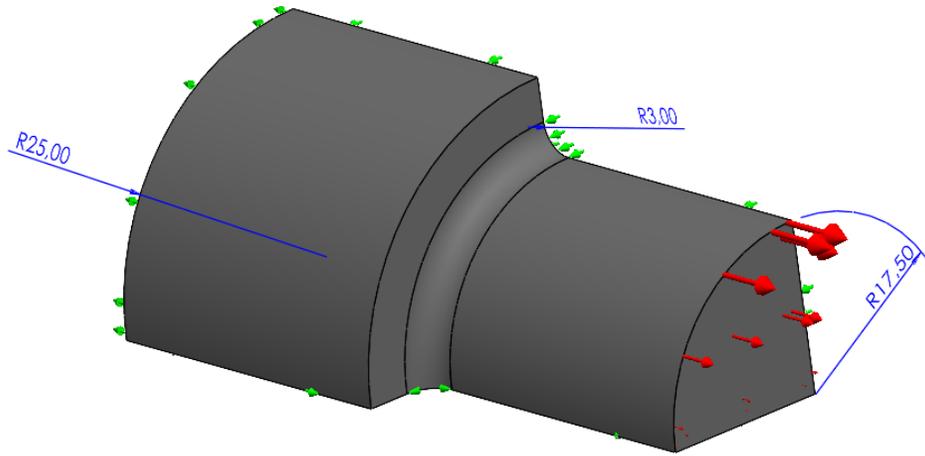


Grafico sollecitazione normale



	Analisi 1	Analisi 3	Analisi 3	Analisi 4
<b>Dimensione elemento (d) [mm]</b>	2	1,5	1	0,5
<b><math>k_{tg}</math> analisi FEM</b>	3,067	3,326	3,161	3,239
<b><math>k_{tn}</math> analisi FEM</b>	2,13	2,31	2,19	2,25
<b><math>K_{tn}</math> Peterson</b>	2,18	2,18	2,18	2,18
<b>variazione</b>	-2,29%	5,96%	0,46%	3,21%



Modello CAD 3D spallamento ruota dentata con quote, carichi e vincoli.

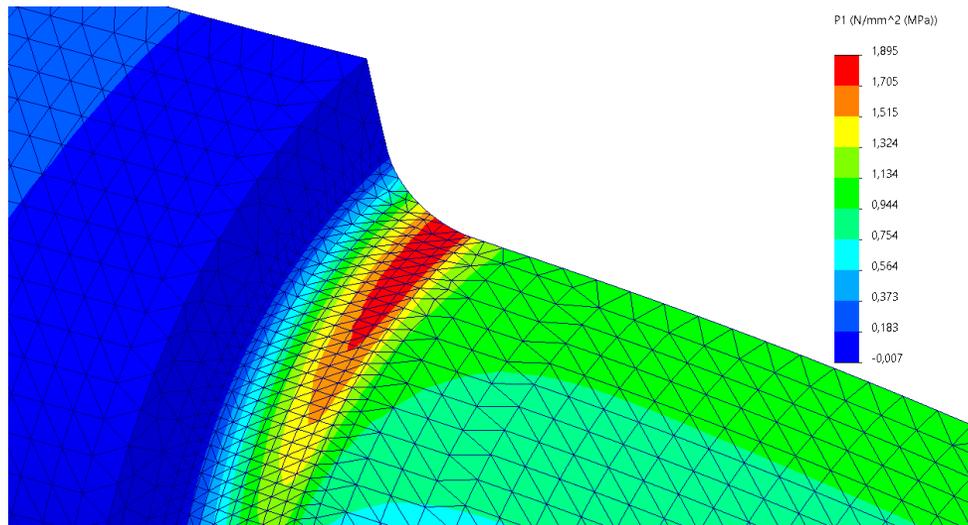
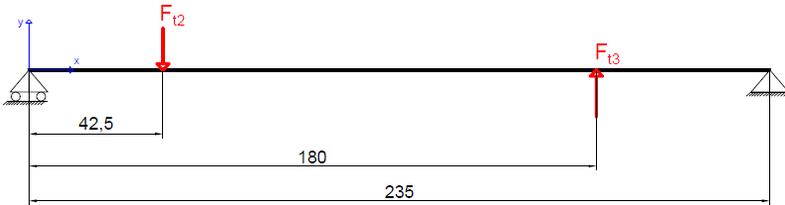


Grafico sollecitazione normale

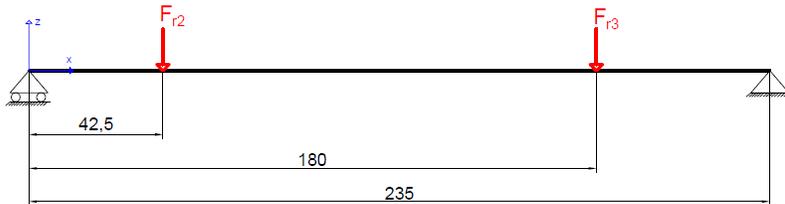


	Analisi 1	Analisi 2	Analisi 3	Analisi 4
<b>Dimensioni elemento (d) [mm]</b>	3	1,5	1	0,6
<b><math>k_t</math> analisi FEM</b>	1,755	1,755	1,888	1,895
<b><math>K_t</math> Peterson</b>	1,78	1,78	1,78	1,78
<b>variazione</b>	1,40 %	1,40%	-6,07 %	-6,46%

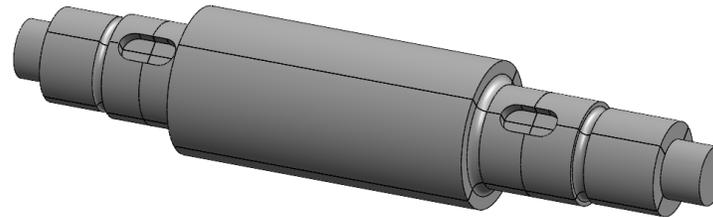
piano x-y:



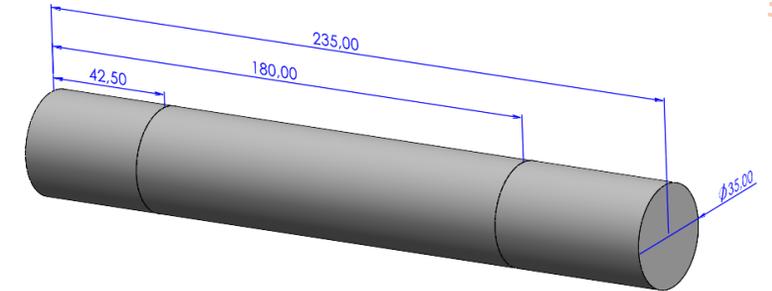
piano x-z:



**Modello tridimensionale:**



**Modello monodimensionale:**



**Forze:**

$$F_{t2} = 935,90 \text{ N}$$

$$F_{t3} = 3909,02 \text{ N}$$

$$F_{r2} = 340,64 \text{ N}$$

$$F_{r3} = 612,02 \text{ N}$$

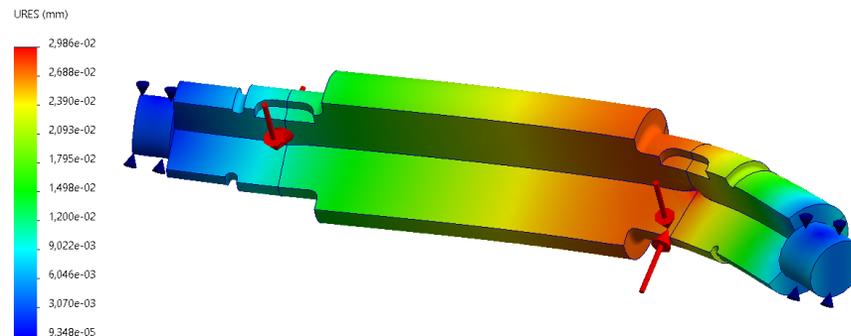


Grafico spostamento modello tridimensionale, mesh di tipo solido

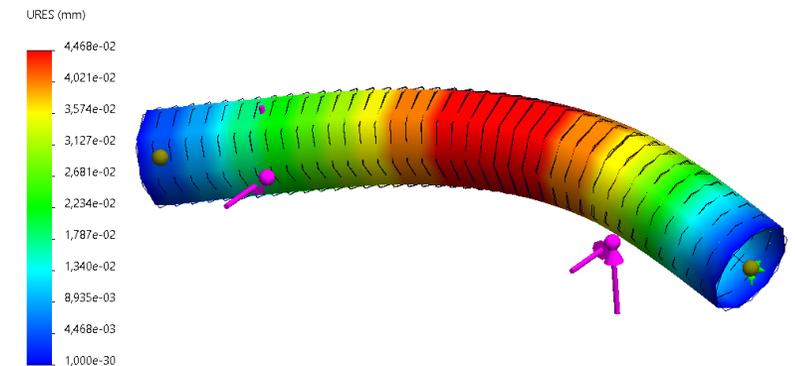
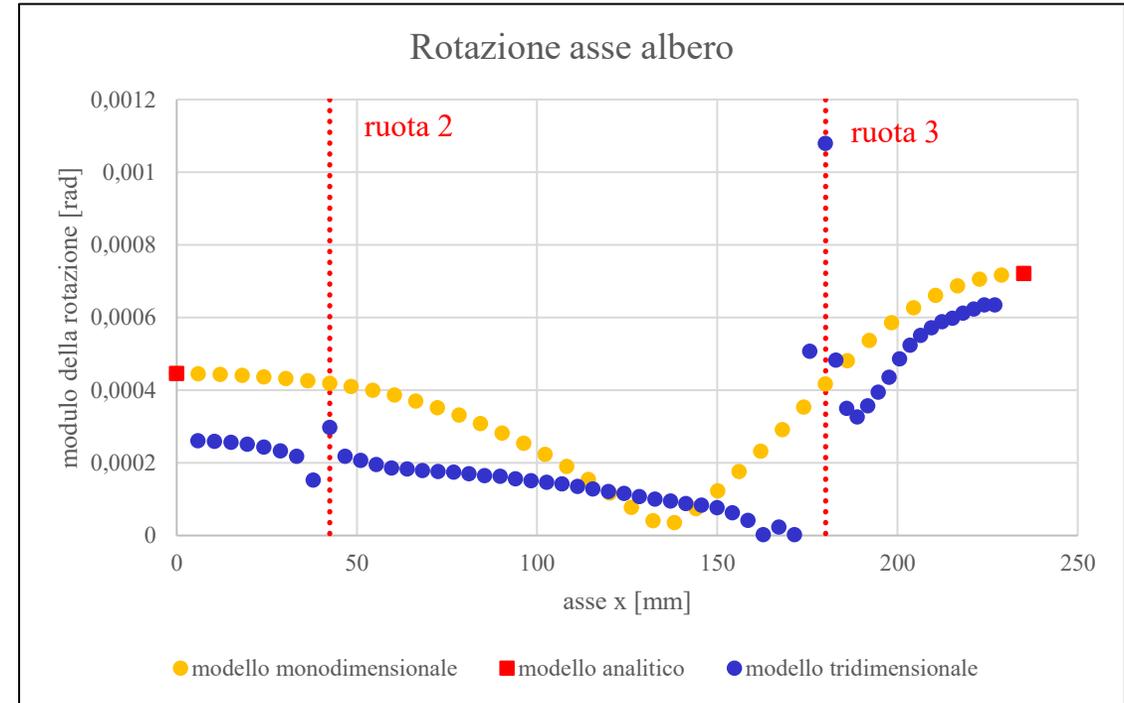
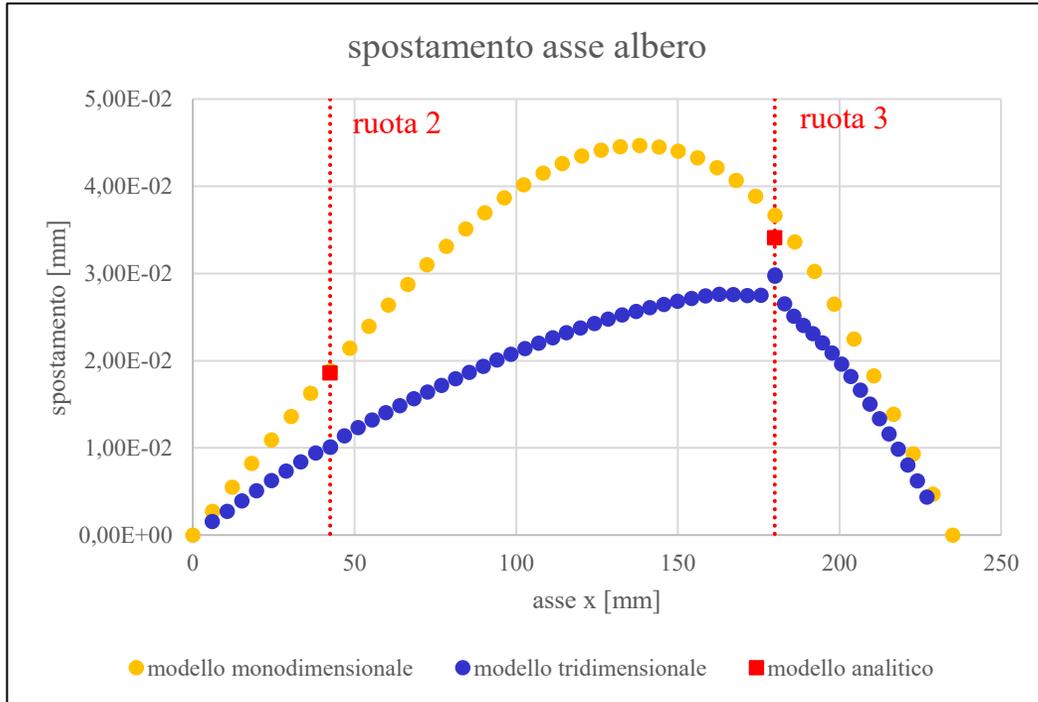


Grafico spostamento modello monodimensionale, mesh di tipo trave



	F2 [mm]	F3 [mm]
<b>Modello analitico</b>	$1,856 * 10^{-2}$	$3,409 * 10^{-2}$
<b>Modello monodimensionale</b>	$1,887 * 10^{-2}$	$3,668 * 10^{-2}$
<b>Δ % valore analitico</b>	1,67 %	7,60%
<b>Modello tridimensionale</b>	$1,012 * 10^{-2}$	$2,986 * 10^{-2}$
<b>Δ % valore analitico</b>	-45,47 %	-12,41 %

	$\varphi_s$ [rad]	$\varphi_d$ [rad]
<b>Modello analitico</b>	$4,459 * 10^{-4}$	$7,211 * 10^{-4}$
<b>Modello monodimensionale</b>	$4,459 * 10^{-4}$	$7,211 * 10^{-4}$
<b>Δ % valore analitico</b>	0 %	0 %
<b>Modello tridimensionale</b>	$2,615 * 10^{-4}$	$6,349 * 10^{-4}$
<b>Δ % valore analitico</b>	-41,35 %	-2,62 %

**Valutazione stato tensionale nei punti di concentrazione delle tensioni:**

	Spallamento cuscinetto	Gola di scarico	Spallamento ruota dentata
<b>Kt analisi FEM</b>	2,628	2,25	1,895
<b>Kt Peterson</b>	2,58	2,18	1,78

**Valutazione stato di deformazione dell'albero:**

	F2 [mm]	F3 [mm]	$\varphi_s$ [rad]	$\varphi_d$ [rad]
<b>Modello solido</b>	$1,012 * 10^{-2}$	$2,986 * 10^{-2}$	$2,615 * 10^{-4}$	$6,349 * 10^{-4}$
<b>Modello trave</b>	$1,887 * 10^{-2}$	$3,668 * 10^{-2}$	$4,459 * 10^{-4}$	$7,211 * 10^{-4}$
<b>Modello analitico</b>	$1,856 * 10^{-2}$	$3,409 * 10^{-2}$	$4,459 * 10^{-4}$	$7,211 * 10^{-4}$