

Università degli Studi di Padova – Dipartimento di Ingegneria Industriale

Corso di Laurea in Ingegneria Meccanica

Relazione per la prova finale

*Dimensionamento e modellazione CAD 3D di un riduttore ad
ingranaggi*

Tutor universitario: Prof. Alberto Campagnolo

Laureando: *Riccardo Griggio*

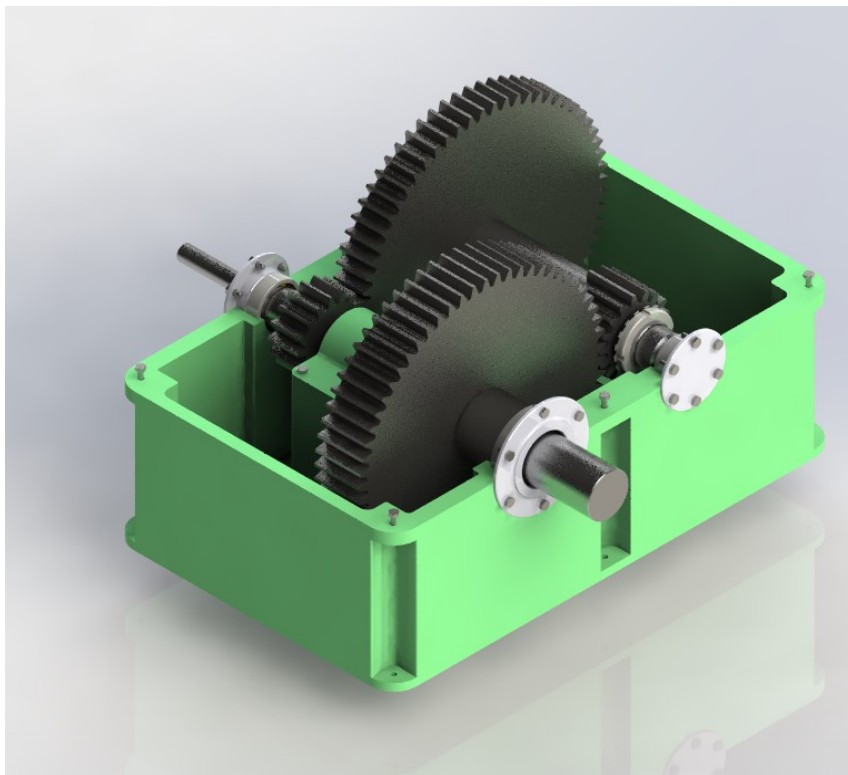
Padova, 11/03/2022

DATI DI PROGETTO		
$M_{2,nom}$	n_2	τ_{tot}
[Nm]	[giri/min]	[]
670	70	14

Compromesso tra:

- **Dimensioni contenute** →
 - Stesso rapporto di riduzione per i due stadi;
 - Stesse coppie di ruote dentate (a meno degli spessori) per i due stadi

- **Costi di produzione ridotti** → Materiali di media qualità per alberi e ruote

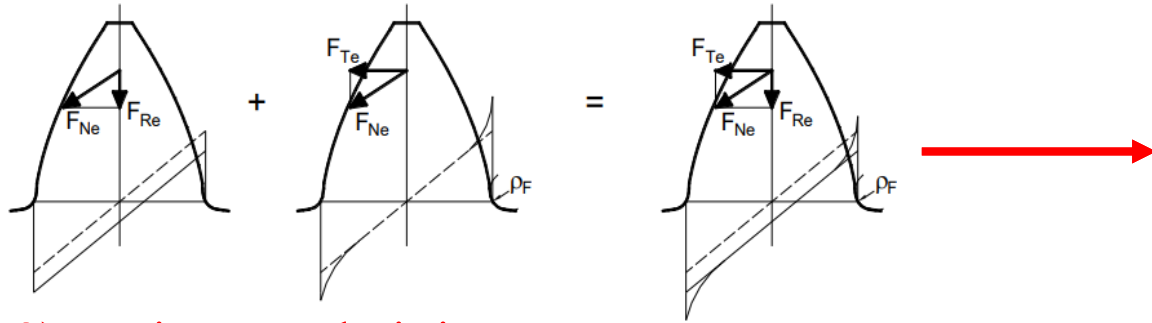


	ω [rad/s]	M [Nm]	P [W]
Albero 1 (input)	102,5	78,0	7994
Albero 0 (intermedio)	27,4	280,1	7674
Albero 2 (output)	7,33	1005	7367

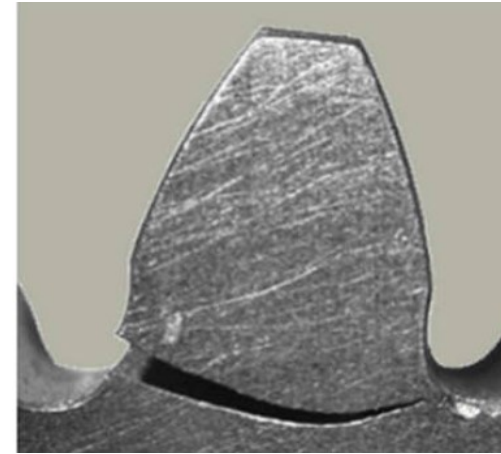
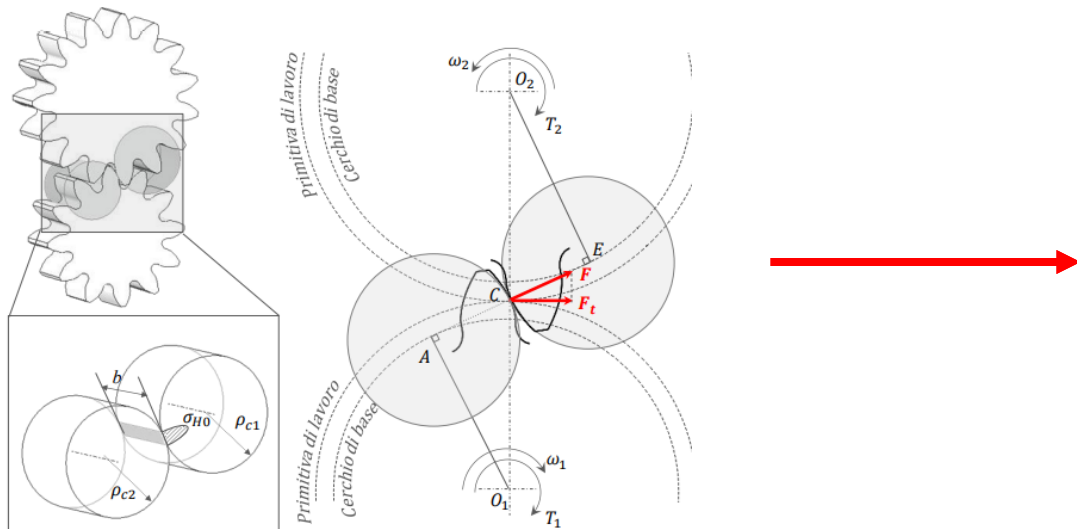
DIMENSIONAMENTO SECONDO ISO 6336

Materiale: Ghisa sferoidale GS55/2 ($\sigma_r = 540 \text{ MPa}$)

1) Resistenza a fatica per flessione a base dente



2) Resistenza al pitting



Con:

- Vita a fatica di 10^{10} cicli;
- P.S. = 99%

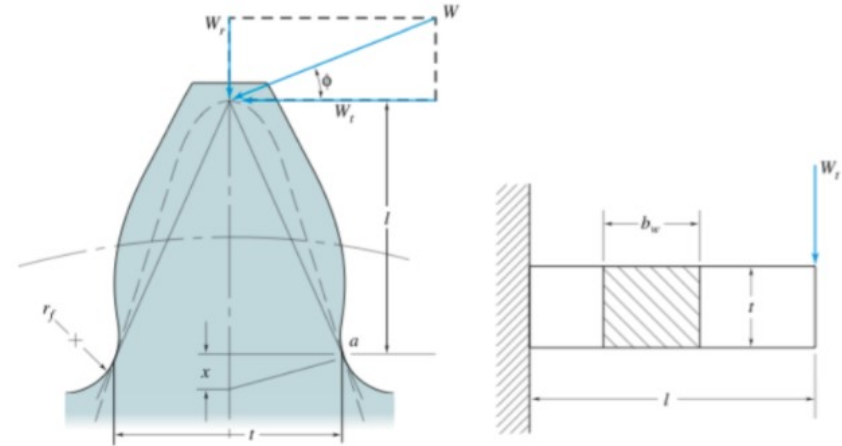
$$\sigma_F \leq \sigma_{FP} \rightarrow m_{cr,3} = 3,17 \text{ mm}$$



$$\sigma_H \leq \sigma_{HP} \rightarrow m_{cr,3} = 4,43 \text{ mm}$$

DIMENSIONAMENTO SECONDO LEWIS

$$\sigma_{f,max} \leq \sigma_{amm,din} \rightarrow m_{cr,3} = 4,82 \text{ mm}$$



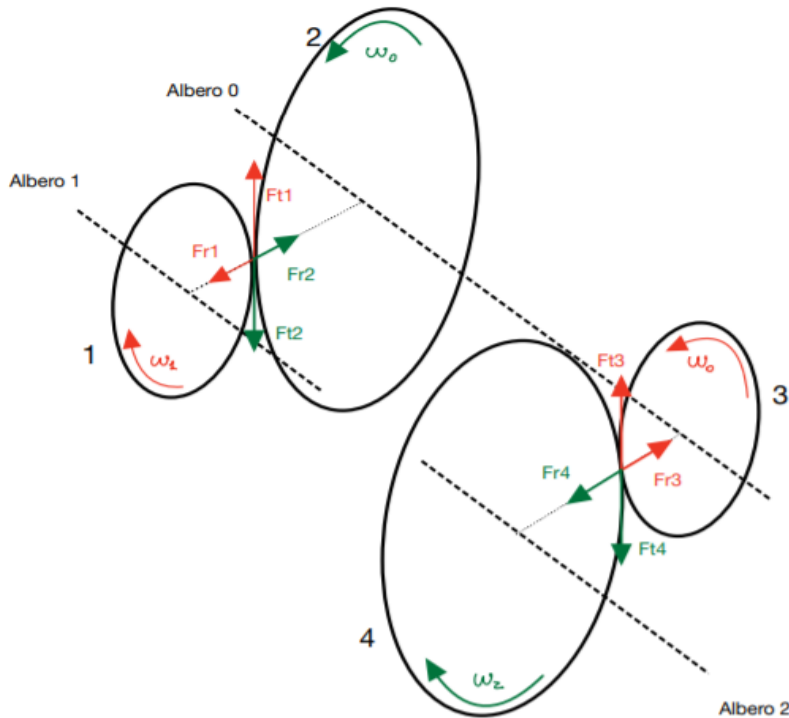
CONFRONTO TRA ISO 6336 E LEWIS

Ruota	Z	m [mm]	Dp [mm]	λ	b [mm]	i [mm]
1	17	4,5	76,5	8	36	182,25
2	64	4,5	288	8	36	
3	17	4,5	76,5	12	54	182,25
4	64	4,5	288	12	54	

Configurazione delle ruote dentate ottenute dal dimensionamento secondo ISO 6336

Ruota	Z	m [mm]	Dp [mm]	λ	b [mm]	i [mm]
1	17	5	85	8	40	202,5
2	64	5	320	8	40	
3	17	5	85	12	60	202,5
4	64	5	320	12	60	

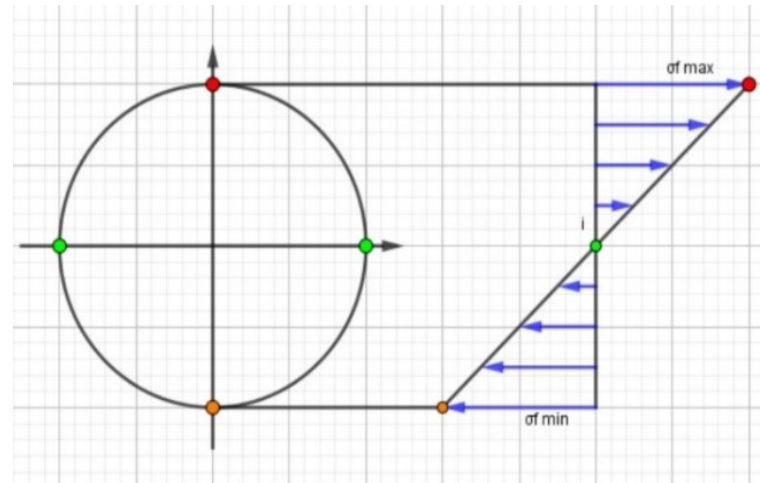
Configurazione delle ruote dentate ottenute dal dimensionamento secondo Lewis



$$\sum_i M_i = 0$$

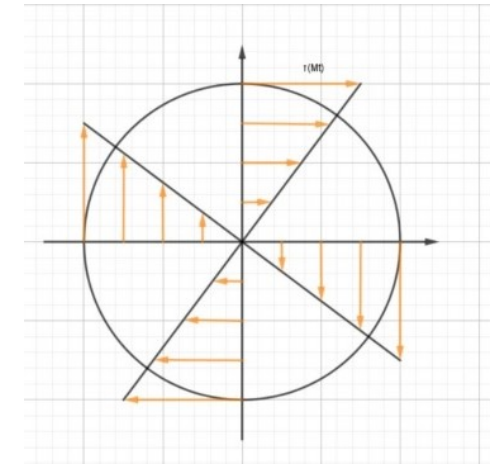
$$\sum_i F_i = 0$$

Torsione



$$\sigma_f = \frac{M_f}{W_f} = \frac{16M_f}{\pi d^3}$$

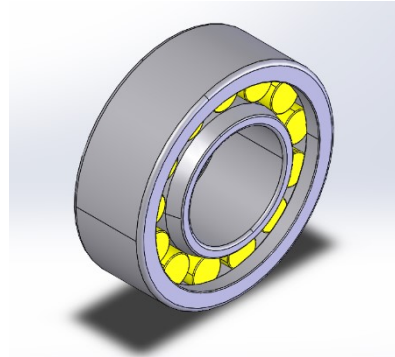
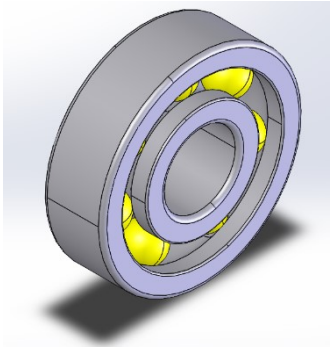
Flessione



$$\tau_t = \frac{M_t}{W_t} = \frac{32M_t}{\pi d^3}$$

Albero	ϕ [mm]	σ_f [MPa]	τ_t [MPa]	$\sigma_{id,VM}$ [MPa]	acciaio C40 (da bonifica)	u_{St}
Ingresso	30	22,1	14,7	33,7	$\sigma_R = 640 \text{ MPa}$ $\sigma_S = 420 \text{ MPa}$	12,44 snello
Intermedio	50	36,0	11,4	41,1	$\sigma_R = 590 \text{ MPa}$ $\sigma_S = 370 \text{ MPa}$	9,0 snello
Uscita	60	14,2	23,7	43,4	$\sigma_R = 590 \text{ MPa}$ $\sigma_S = 370 \text{ MPa}$	8,54 tozzo

Cuscinetti SKF:



A una corona di sfere

A rulli senza orletti

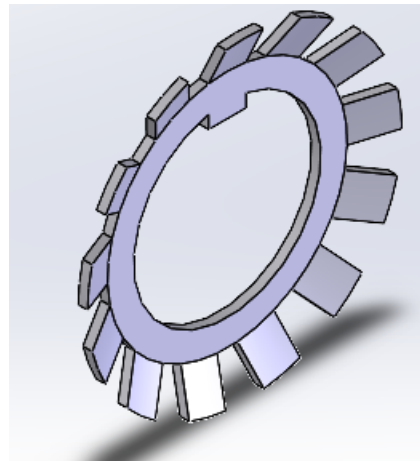
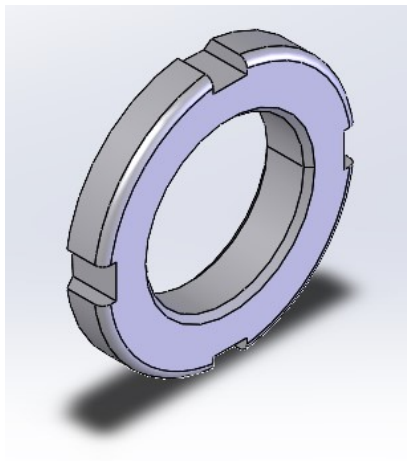


$$L_{10} = \left(\frac{C}{P}\right)^p$$

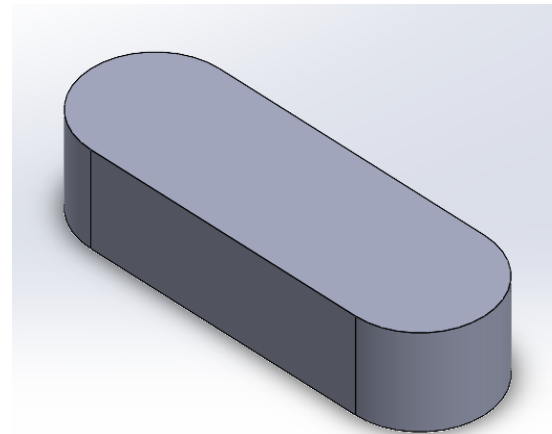
Imponendo durata della vita a fatica
dei cuscinetti:

$$L_{10h} = 40000 \text{ ore}$$

Ghiere e rosette di sicurezza



Linguette (tipo A)



Anelli elastici



Albero di ingresso

Cuscinetto	C [kN]
SKF 62/28 (sfere)	16,8
SKF NU 203 (rulli)	17,2

Ghiera M30	d=30 mm
Rosetta MB6	d =30 mm
Linguetta A	8x7x20 UNI 6604

Albero intermedio

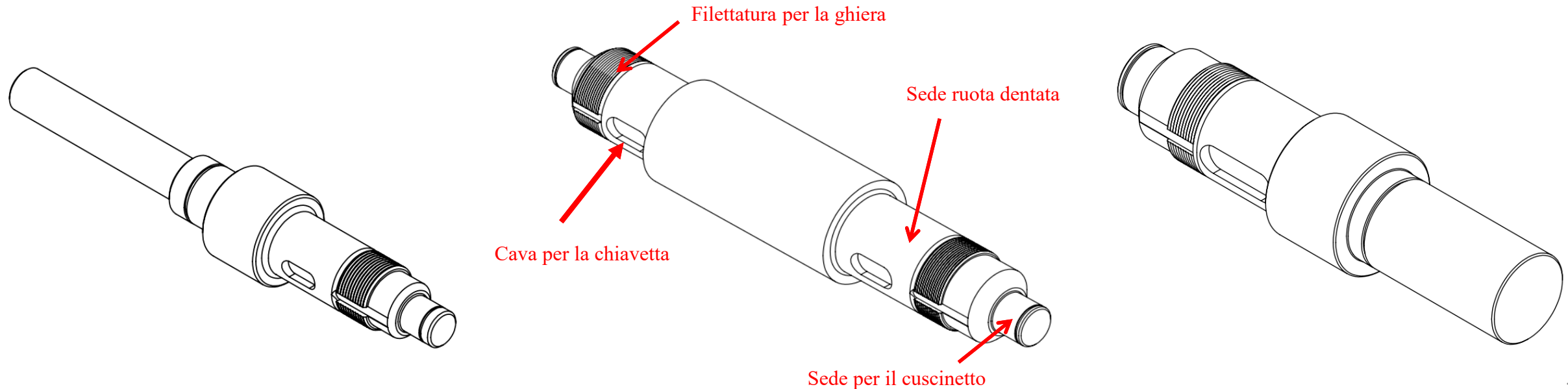
Cuscinetto	C [kN]
SKF W6205 (sfere)	39
SKF NU 2205 (rulli)	39

Ghiera M50	d=50 mm
Rosetta MB10	d =50 mm
Linguetta A	14x9x32 UNI 6604

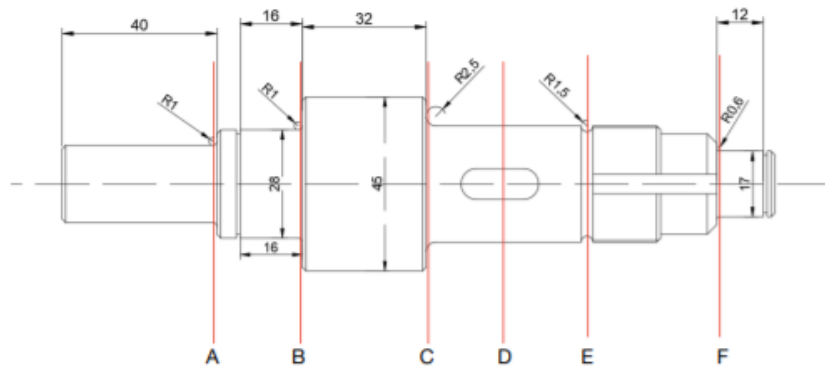
Albero di uscita

Cuscinetto	C [kN]
SKF 16011 (sfere)	20,4
SKF NU 1008 (rulli)	25,1

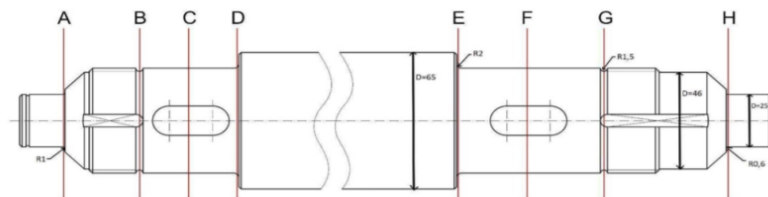
Ghiera M60	d=60 mm
Rosetta MB12	d =60 mm
Linguetta A	18x11x55 UNI 6604



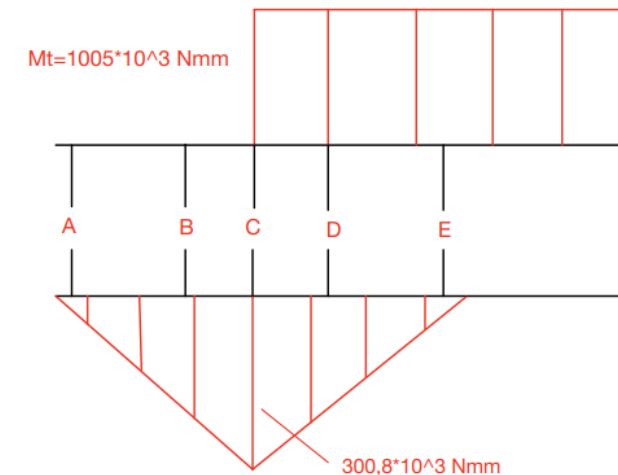
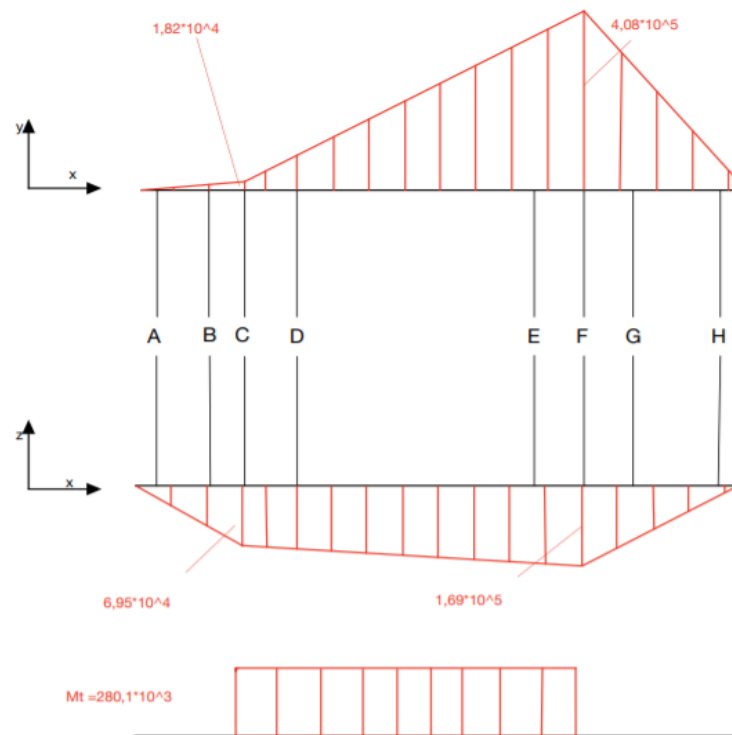
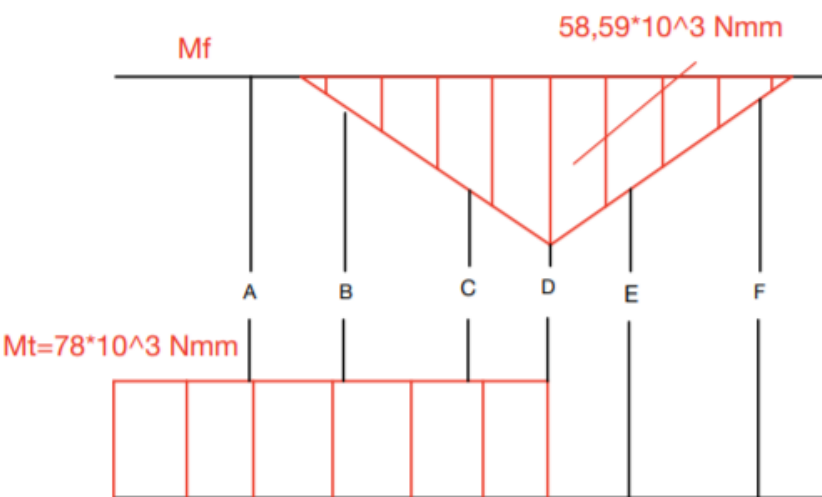
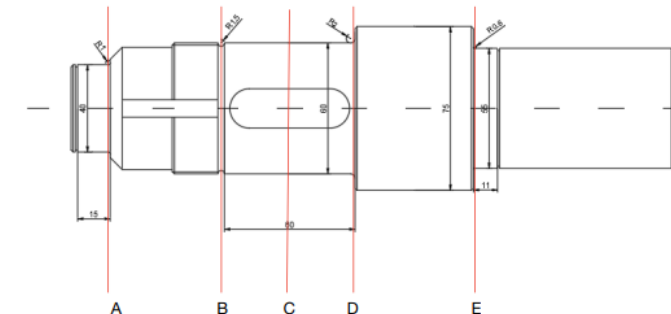
Albero di ingresso



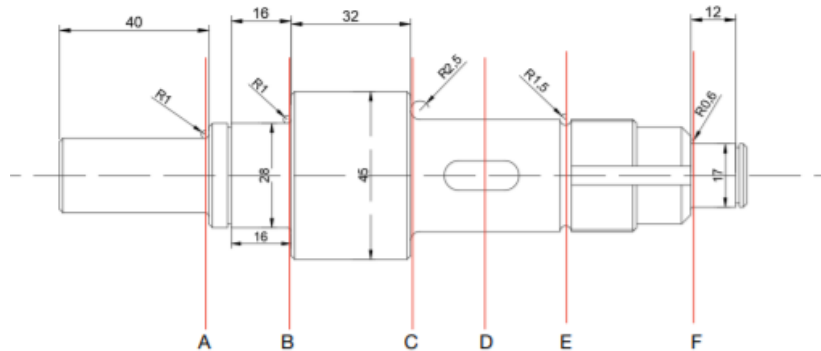
Albero intermedio



Albero di uscita

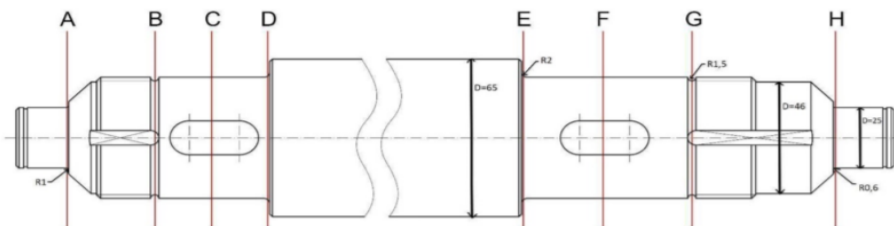


Albero ingresso

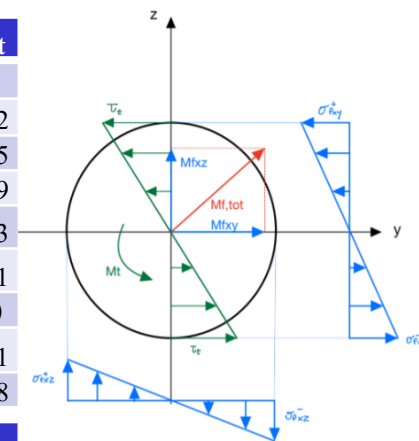


SEZIONE	ϕ	Mf	Mt	$\sigma(Mf,tot)$	$\tau(Mt)$	$\sigma_{id,VM}$	v_{st}
	[mm]	[Nmm]	[Nmm]	[MPa]	[MPa]	[MPa]	[]
A-A	20	0	78000	0	49,66	86,00	4,90
B-B	28	7812	78000	3,62	18,10	31,55	13,3
C-C	30	39060	78000	14,73	14,71	29,44	14,3
D-D	30	58590	78000	22,10	14,71	33,73	12,4
E-E	27	37595	0	19,45	0	19,45	21,6
F-F	17	5859	0	12,15	0	12,15	34,6

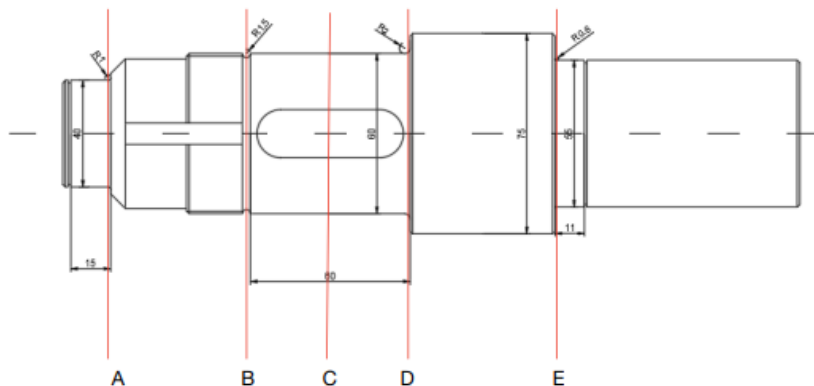
Albero intermedio



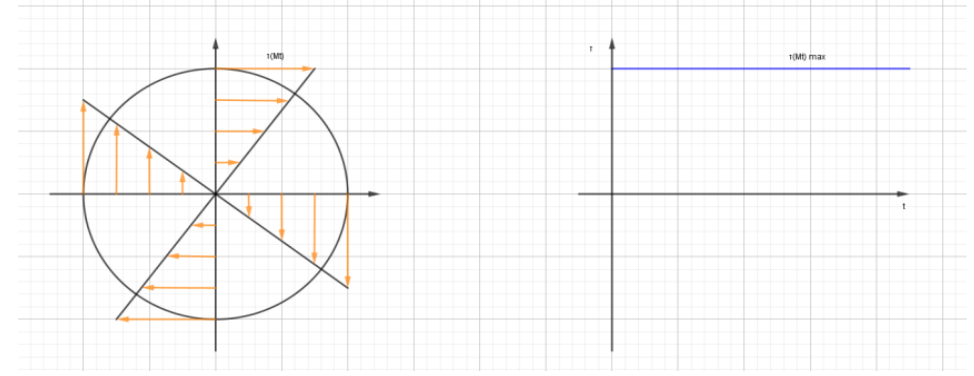
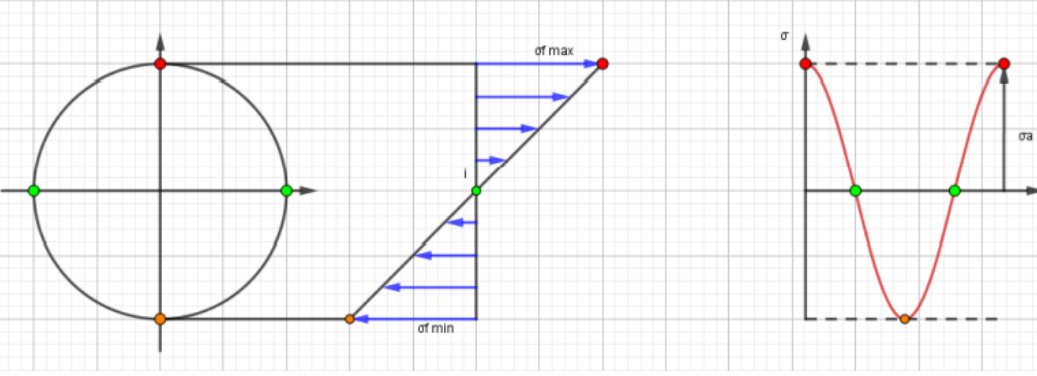
SEZIONE	ϕ	Mf,tot	Mt	$\sigma(Mf,tot)$	$\tau(Mt)$	$\sigma_{id,VM}$	v_{st}
	[mm]	[Nmm]	[Nmm]	[Mpa]	[Mpa]	[Mpa]	[]
A-A	25	8985,5	0	5,86	0	5,86	63,2
B-B	47	48063	0	4,71	0	4,72	78,5
C-C	50	71884	280100	5,86	11,41	20,6	17,9
D-D	50	99528	280100	8,11	11,41	21,4	17,3
E-E	50	378881	280100	30,87	11,41	36,7	10,1
F-F	50	441662	280100	36,0	11,41	41,1	9,0
G-G	47	287084	0	28,16	0	28,16	13,1
H-H	25	44174	0	28,80	0	28,8	12,8



Albero di uscita



SEZIONE	ϕ	Mf	Mt	$\sigma(Mf,tot)$	$\tau(Mt)$	$\sigma_{id,VM}$	v_{st}
	[mm]	[Nmm]	[Nmm]	[MPa]	[MPa]	[MPa]	[]
A-A	40	25067	0	4,00	0	4,00	92,74
B-B	57	195520	0	10,75	0	10,74	34,41
C-C	60	300800	1005000	14,18	23,70	43,42	8,52
D-D	60	200533	1005000	9,45	23,70	42,11	8,78
E-E	55	18382	1005000	1,13	30,76	53,30	6,94



Solo il momento torcente causa un ciclo di carico variabile nel tempo (sinusoidale, con $R = -1$)

Albero di ingresso

Albero intermedio

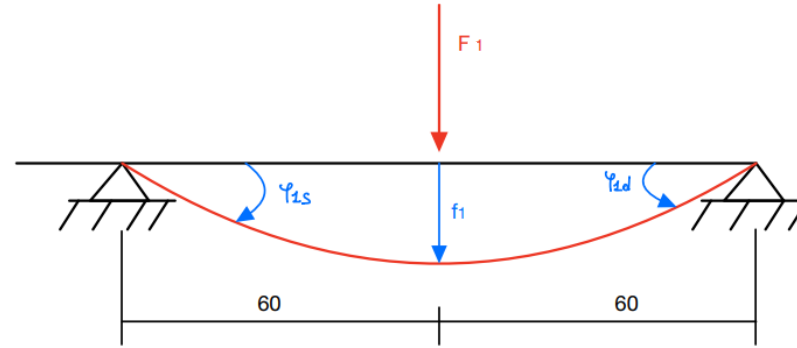
Albero di uscita

	σ_a	k_d	k_l	k_{tn}	q	k_f	$\sigma_{a,\infty,-1}^*$	$v\sigma$
	[Mpa]						[Mpa]	
A-A	0	1,1					0	
B-B	3,62	1,16	1,13	2,6	0,835	2,336	104,51	28,9
C-C	14,7	1,18	1,13	1,8	0,927	1,742	137,80	9,37
D-D	22,1	1,18	1,15			2	117,91	5,33
E-E	19,5	1,17	1,15	2,2	0,88	2,056	115,68	5,93
F-F	12,2	1,08	1,13	1,5	0,75	1,375	190,70	15,63

	σ_a	k_d	k_l	k_{tn}	q	k_f	$\sigma_{a,\infty,-1}^*$	$v\sigma$
	[MPa]						[Mpa]	
A-A	5,86	1,15	1,08	2,42	0,82	2,15	110,47	18,85
B-B	4,25	1,28	1,13	2,6	0,87	2,39	85,34	20,08
C-C	5,86	1,22	1,13			1,95	109,74	18,73
D-D	8,11	1,22	1,08	2,17	0,9	2,05	109,22	13,47
E-E	30,9	1,22	1,08	2,17	0,9	2,05	109,22	3,53
F-F	36	1,22	1,13			1,95	109,74	3,05
G-G	28,2	1,28	1,13	2,6	0,87	2,39	85,34	3,03
H-H	28,8	1,15	1,08	2,7	0,73	2,24	106,04	3,68

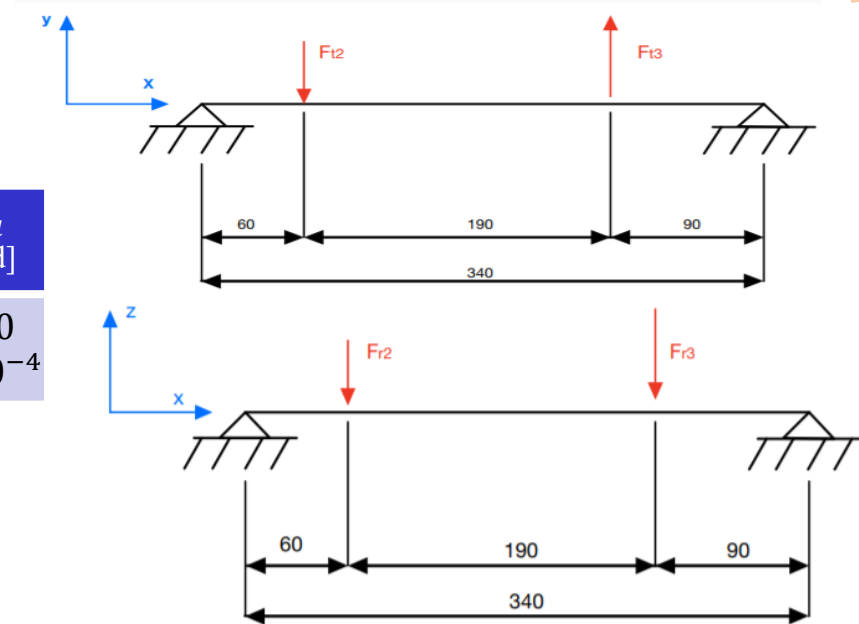
	σ_a	k_d	k_l	k_{tn}	q	k_f	$\sigma_{a,\infty,-1}^*$	$v\sigma$
	[MPa]						[Mpa]	
A-A	4	1,2	1,08	2,75	0,82	2,43	93,48	23,40
B-B	10,8	1,25	1,13	2,7	0,87	2,48	84,25	7,80
C-C	14,2	1,25	1,13			2	104,42	7,35
D-D	9,45	1,25	1,08	2,4	0,902	2,26	96,57	10,22
E-E	1,12	1,23	1,08	3,75	0,73	3,01	73,84	65,93

Albero di ingresso



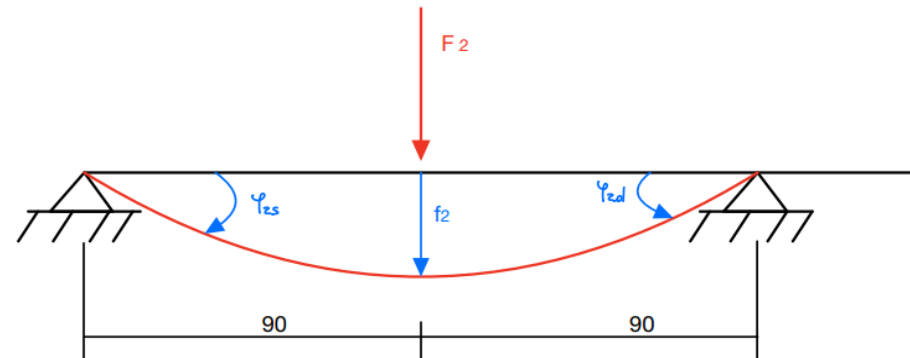
f_1 [mm]	$\varphi_s = \varphi_d$ [rad]
$8,58 \cdot 10^{-3}$	$2,14 \cdot 10^{-4}$

Albero intermedio



f_2 [mm]	f_3 [mm]	φ_s [rad]	φ_d [rad]
$2,48 \cdot 10^{-2}$	$4,91 \cdot 10^{-2}$	$4,22 \cdot 10^{-4}$	$6,50 \cdot 10^{-4}$

Albero di uscita



f_4 [mm]	$\varphi_s = \varphi_d$ [rad]
$6,20 \cdot 10^{-3}$	$1,03 \cdot 10^{-4}$

f'_{2xy} [mm]	f'_{3xy} [mm]	φ'_{sxy} [rad]	φ'_{dxy} [rad]	f''_{2xy} [mm]	f''_{3xy} [mm]	φ''_{sxy} [rad]	φ''_{dxy} [rad]
$7,66 \cdot 10^{-3}$	$7,62 \cdot 10^{-3}$	$1,41 \cdot 10^{-4}$	$-9,12 \cdot 10^{-5}$	$-2,87 \cdot 10^{-2}$	$-5,17 \cdot 10^{-2}$	$-4,95 \cdot 10^{-4}$	$6,79 \cdot 10^{-4}$
f'_{2xz} [mm]	f'_{3xz} [mm]	φ'_{sxz} [rad]	φ'_{dxz} [rad]	f''_{2xz} [mm]	f''_{3xz} [mm]	φ''_{sxz} [rad]	φ''_{dxz} [rad]
$2,79 \cdot 10^{-3}$	$2,77 \cdot 10^{-3}$	$5,15 \cdot 10^{-5}$	$-3,32 \cdot 10^{-5}$	$1,04 \cdot 10^{-2}$	$1,88 \cdot 10^{-2}$	$1,80 \cdot 10^{-4}$	$-2,47 \cdot 10^{-4}$



