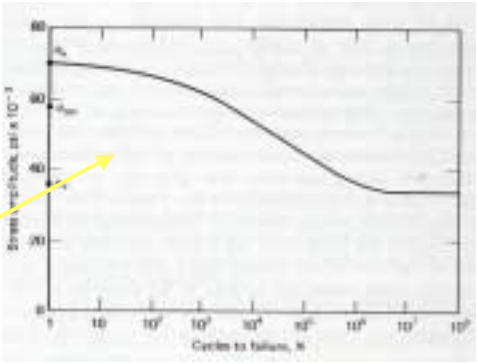
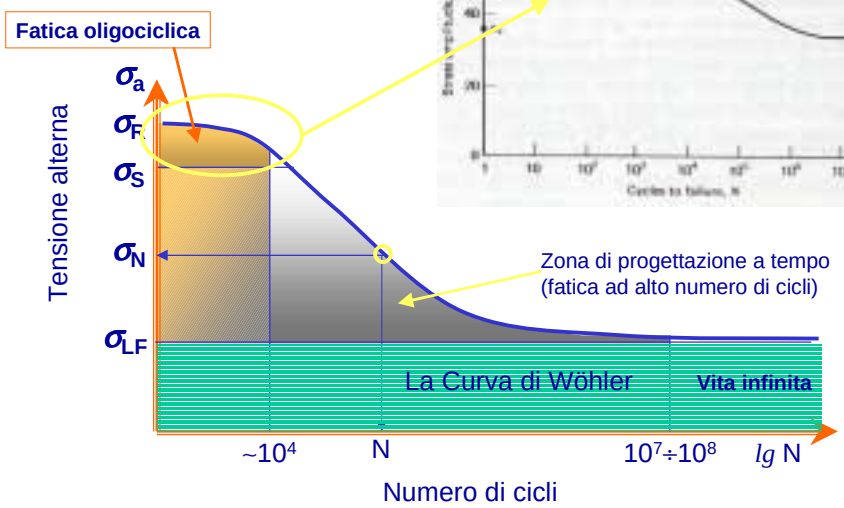
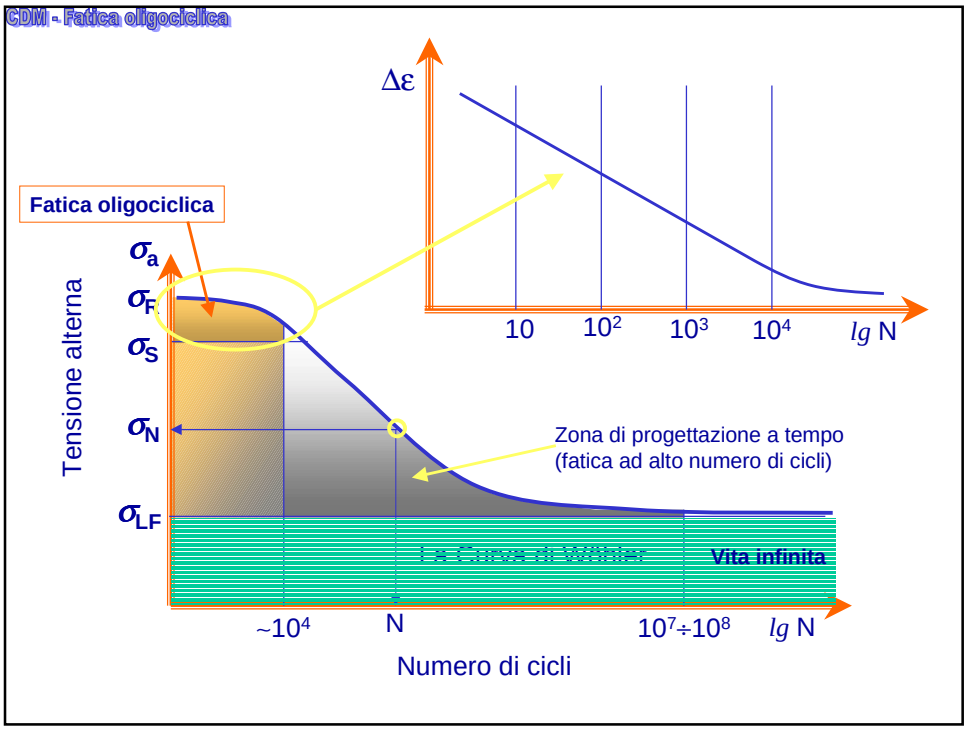
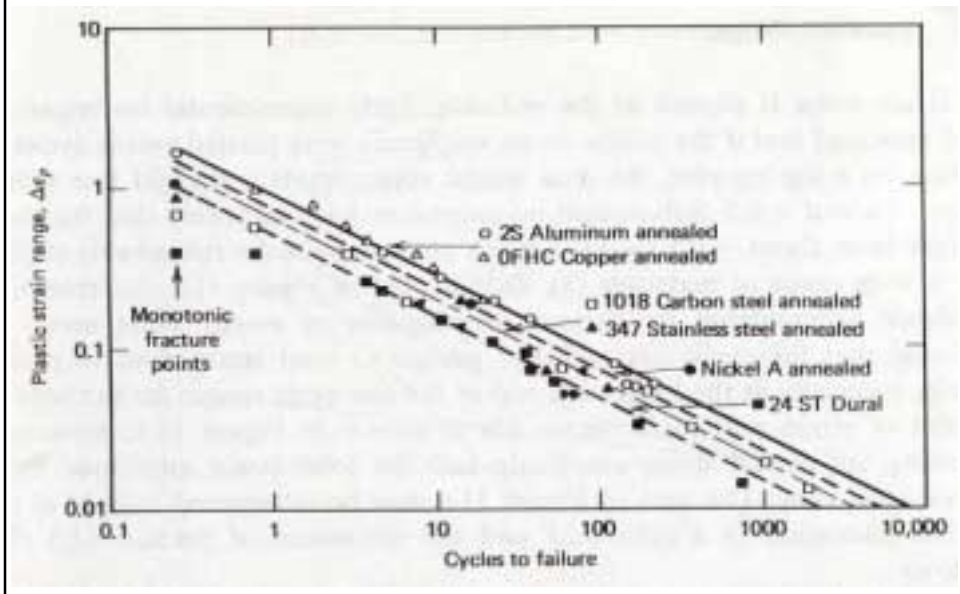
Calcolo a fatica oligociclica di componenti meccanici

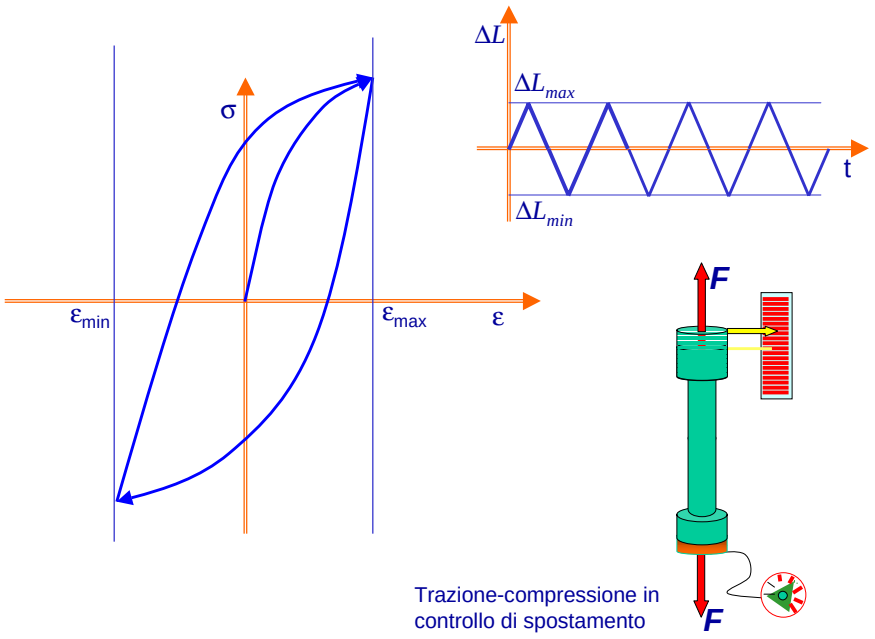






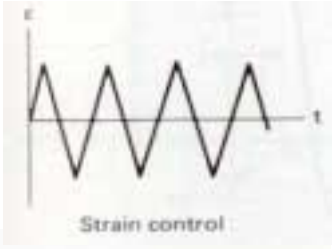
Comportamento a fatica oligociclica di alcuni materiali
(dati ASTM)

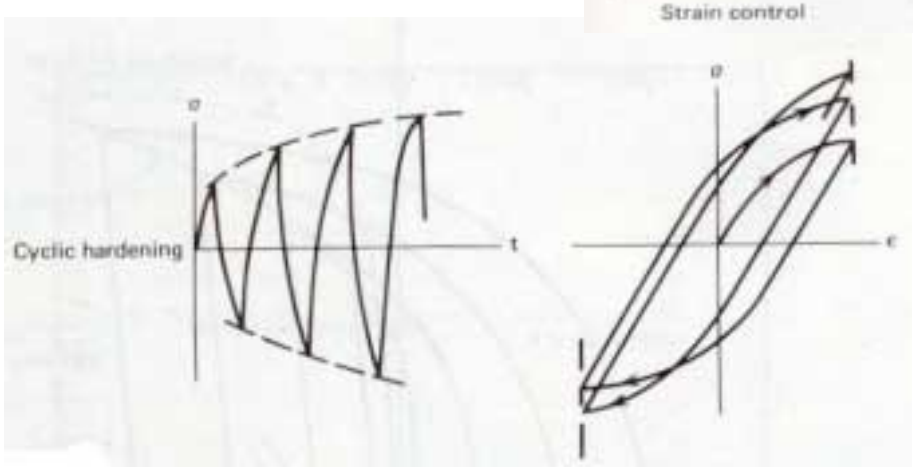




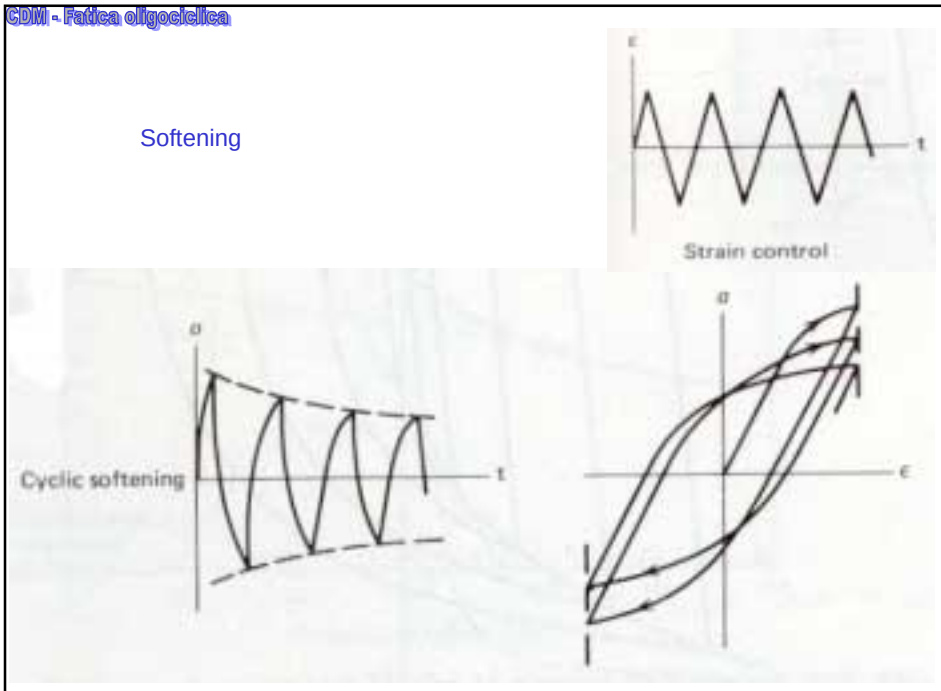
Trazione-compressione in controllo di spostamento

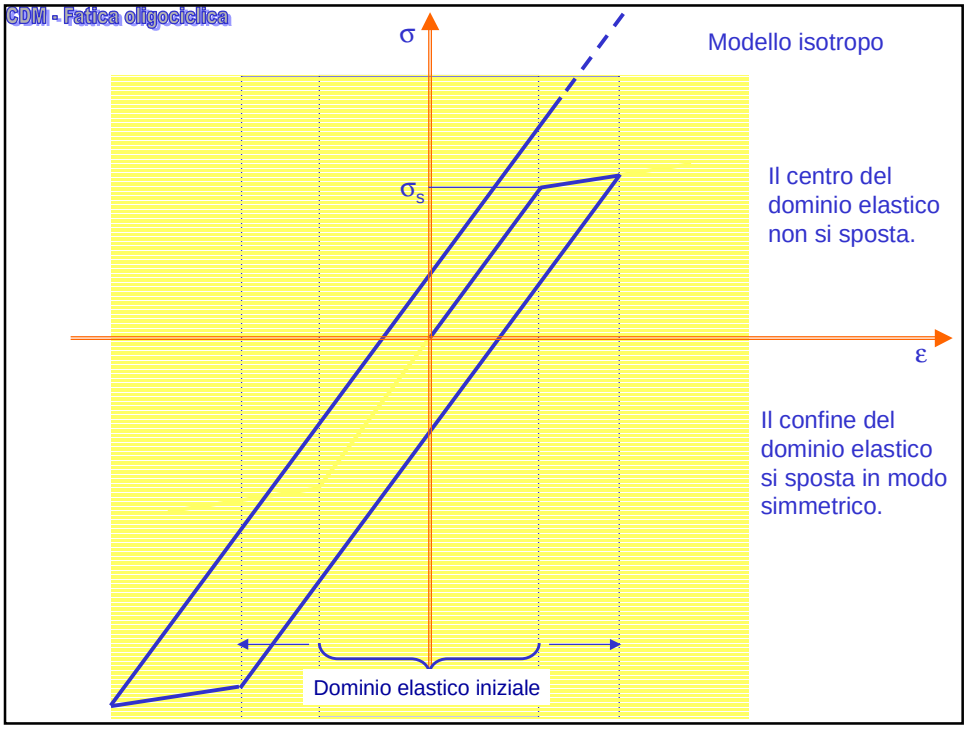
Hardening





Softening

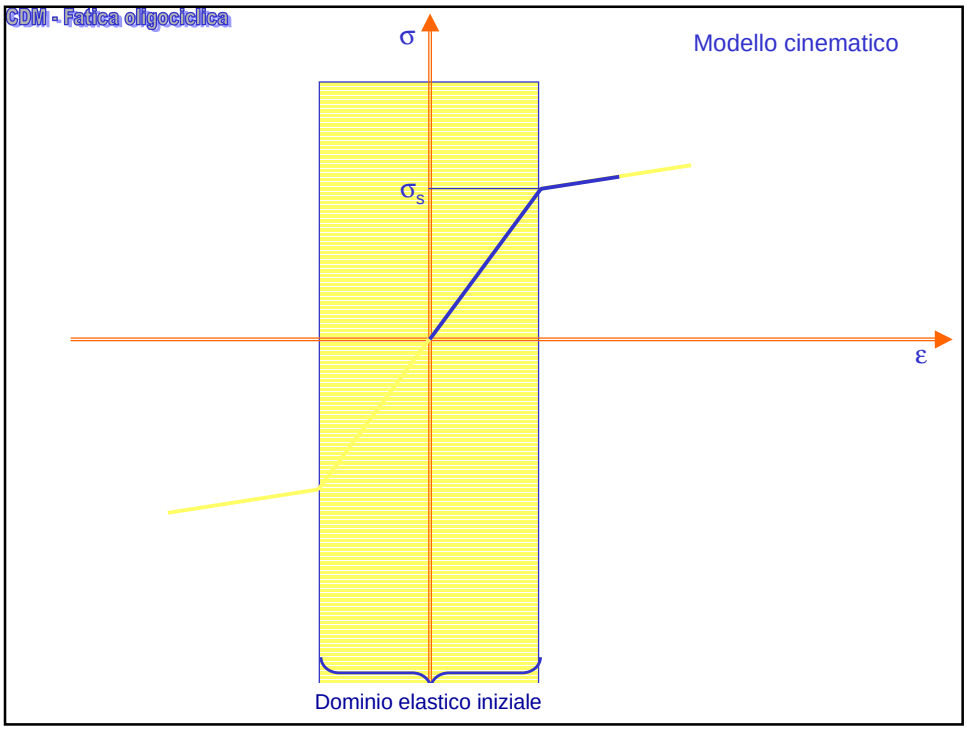


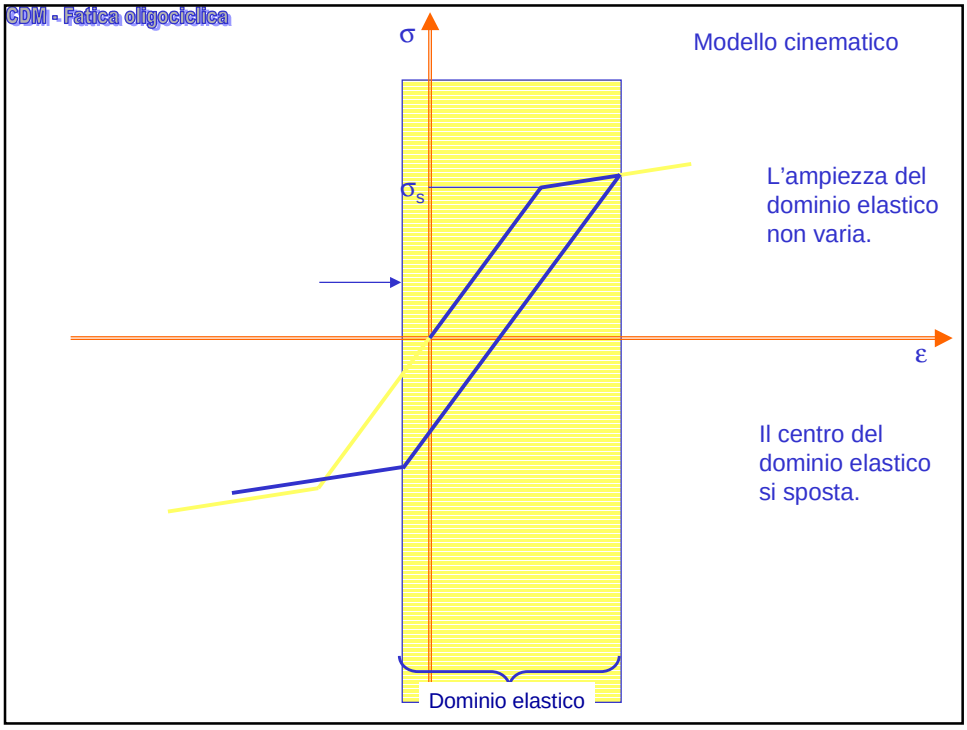


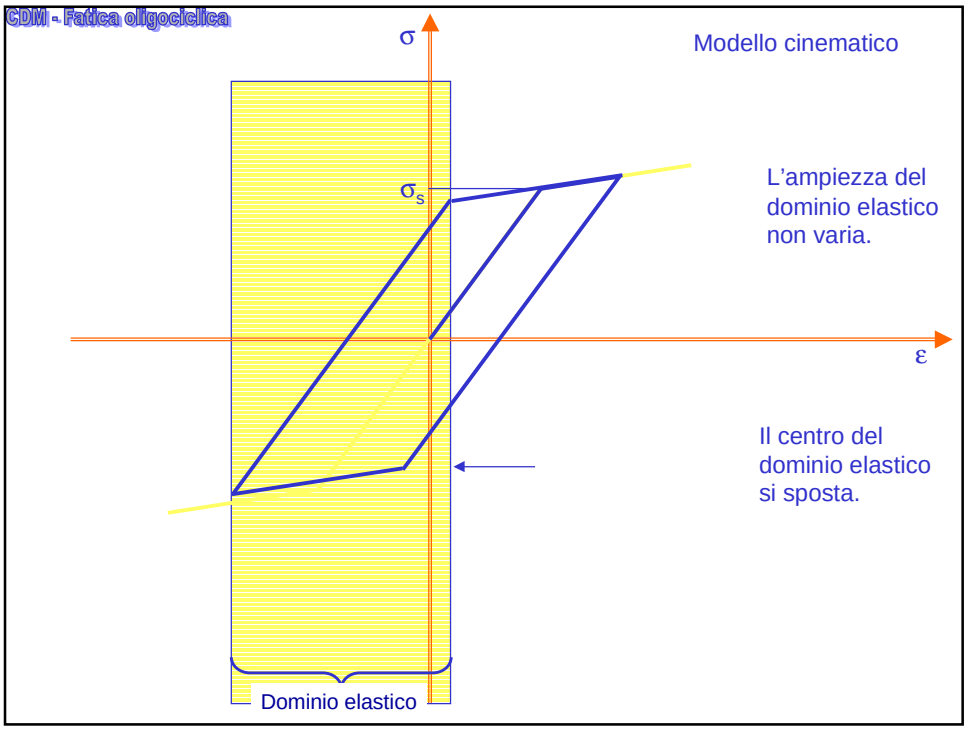
Modello isotropo

Il centro del dominio elastico non si sposta.

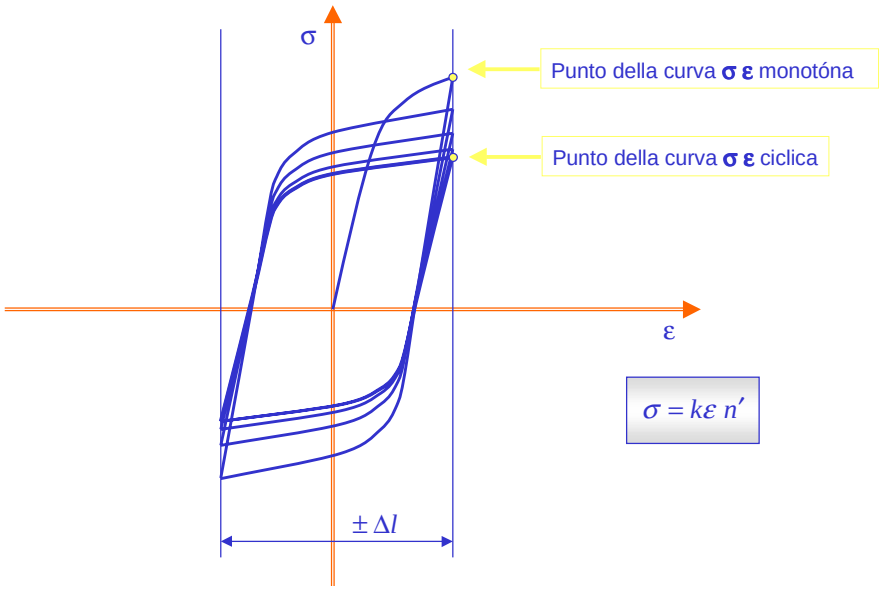
Il confine del dominio elastico si sposta in modo simmetrico.


σ
Modello cinematico
σs
ε
Dominio elastico iniziale


σ
Modello cinematico
σs
L'ampiezza del dominio elastico non varia.
ε
Il centro del dominio elastico si sposta.
Dominio elastico

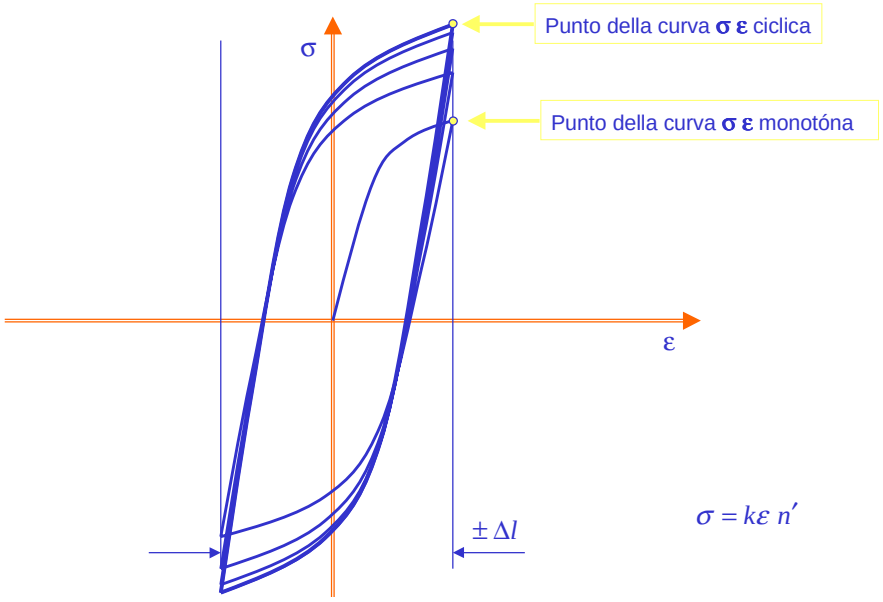


Curva ciclica tensione deformazione



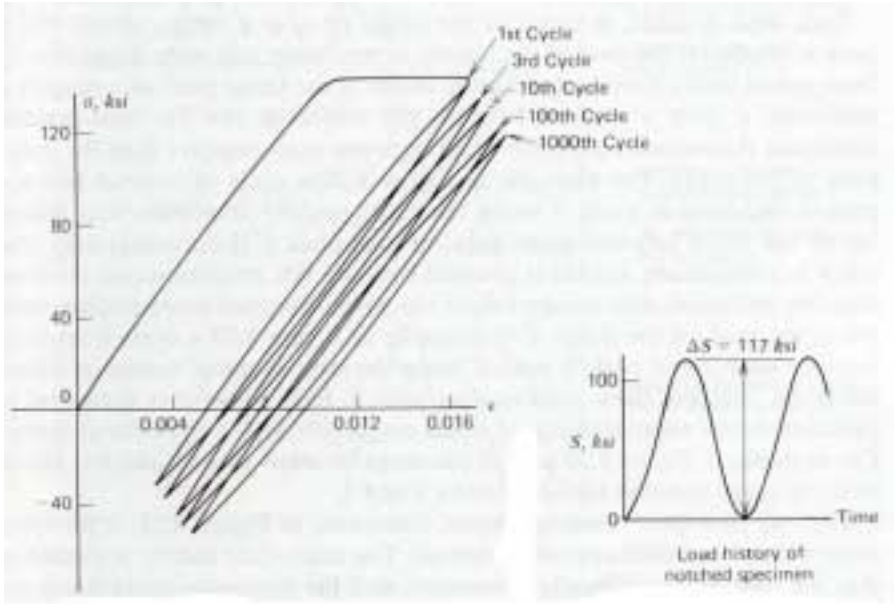
Provino sollecitato ciclicamente in controllo di spostamento

Curva ciclica tensione deformazione

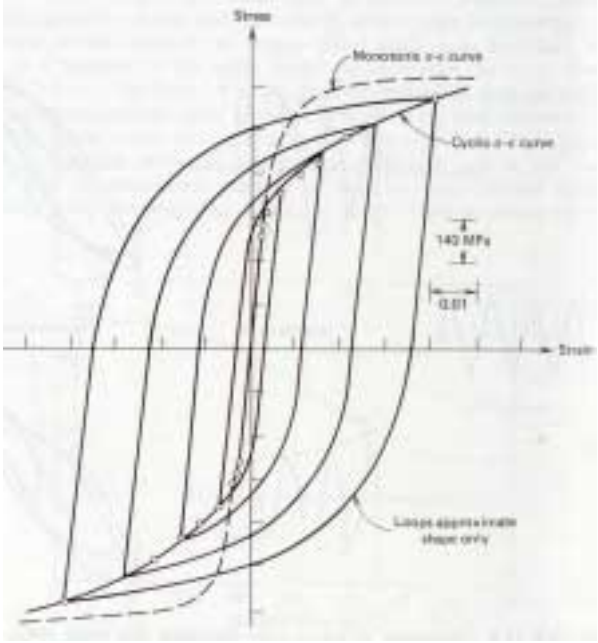


Provino sollecitato ciclicamente in controllo di spostamento

Curva ciclica tensione deformazione

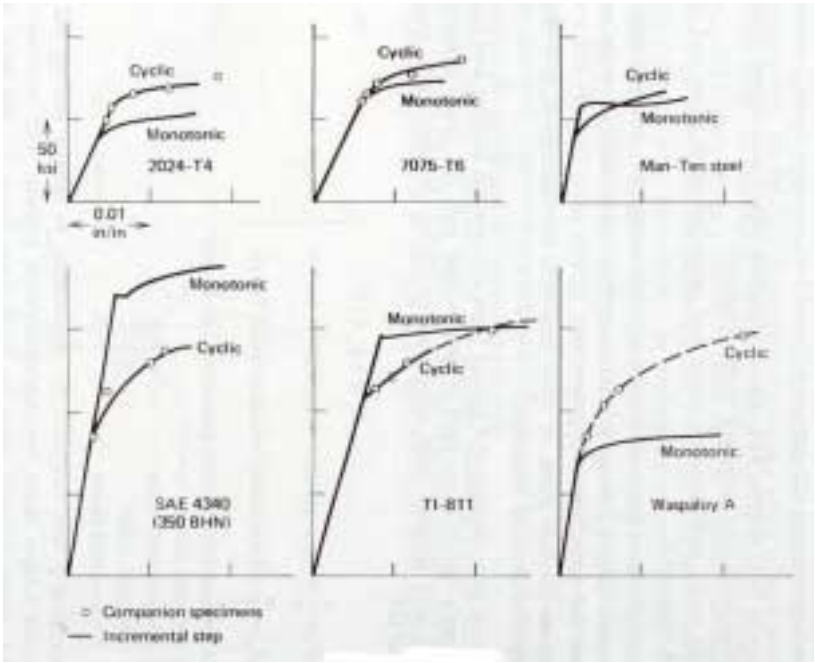


Curva ciclica tensione deformazione



Confronto tra la curva σ ε monotóna e quella ciclica per l'acciaio SAE 4340

Curva ciclica tensione deformazione



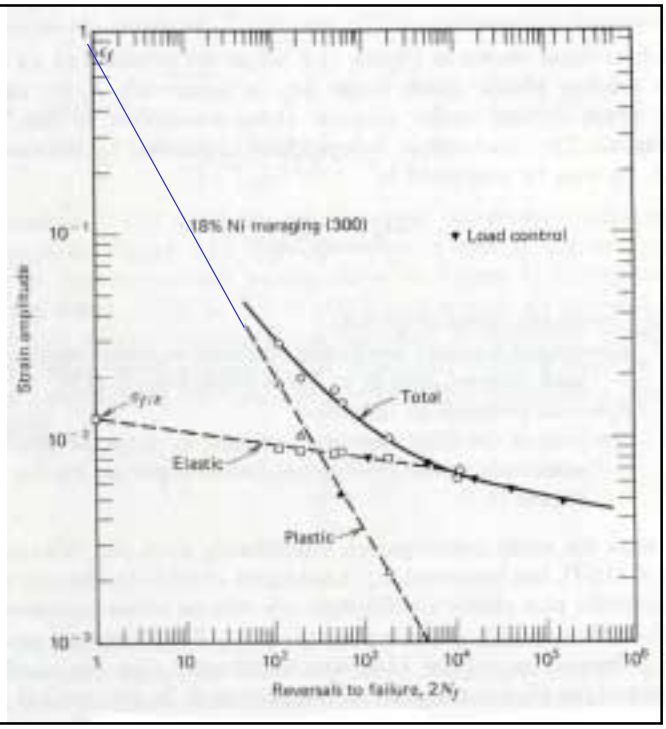
Curva ciclica tensione deformazione

Material	Condition	0.2 percent yield strength, monotonic σ_{y_p}/cyclic σ_{y_c} ksi	Strain-hardening exponent n(monotonic)/n'(cyclic)	Cyclic behavior
OFHC copper	Annealed	3/20	0.40/0.15	Hardens
	Partial annealed	37/29	0.13/0.16	Stable
	Cold worked	50/34	0.10/0.12	Softens
2024 aluminum alloy	T4	44/65	0.20/0.11	Hardens
7075 aluminum alloy	T6	68/75	0.11/0.11	Hardens
Man-Ten steel	As-received	55/50	0.15/0.16	Softens and hardens
SAE 4340 steel	Quenched and tempered, 350 BHN	170/110	0.066/0.14	Softens
Ti-8Al-1Mo-1V	Duplex annealed	145/115	0.078/0.14	Softens and hardens
Waspaloy		79/102	0.11/0.17	Hardens
SAE 1045 steel	Quenched and tempered, 595 BHN	270/250	0.071/0.14	Stable
	Quenched and tempered, 500 BHN	245/185	0.047/0.12	Softens
	Quenched and tempered, 450 BHN	220/140	0.041/0.15	Softens
	Quenched and tempered, 390 BHN	185/110	0.044/0.17	Softens
SAE 4142 steel	As-quenched, 670 BHN	235/	0.14/	Hardens
	Quenched and tempered, 560 BHN	245/250	0.092/0.13	Stable
	Quenched and tempered, 475 BHN	250/195	0.048/0.12	Softens
	Quenched and tempered, 450 BHN	230/155	0.040/0.17	Softens
	Quenched and tempered, 380 BHN	200/120	0.051/0.18	Softens

Modello di Manson-Coffin

$$\frac{\Delta\varepsilon_p}{2} = \varepsilon_f^{'}(2N_f)^c$$

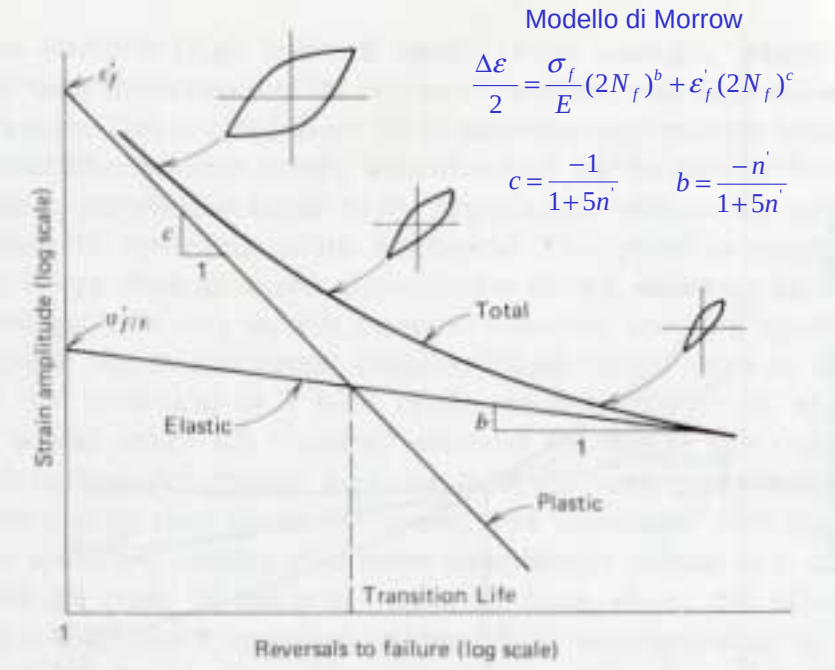
$$c = \frac{-1}{1+5n^{'}}$$



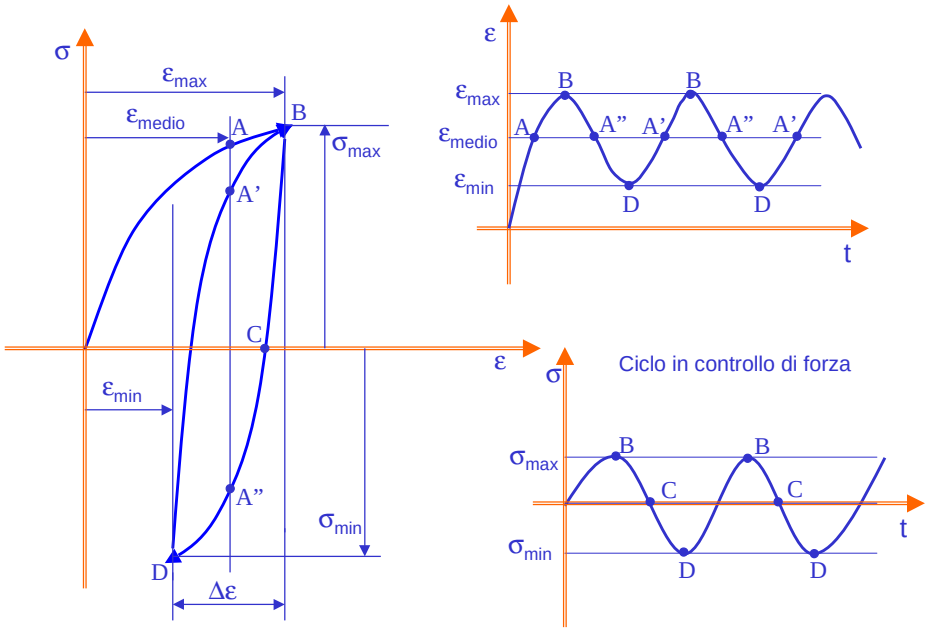
Modello di Morrow

$$\frac{\Delta\varepsilon}{2} = \frac{\sigma_f}{E}(2N_f)^b + \varepsilon_f'(2N_f)^c$$

$$c = \frac{-1}{1+5n'} \qquad b = \frac{-n'}{1+5n'}$$

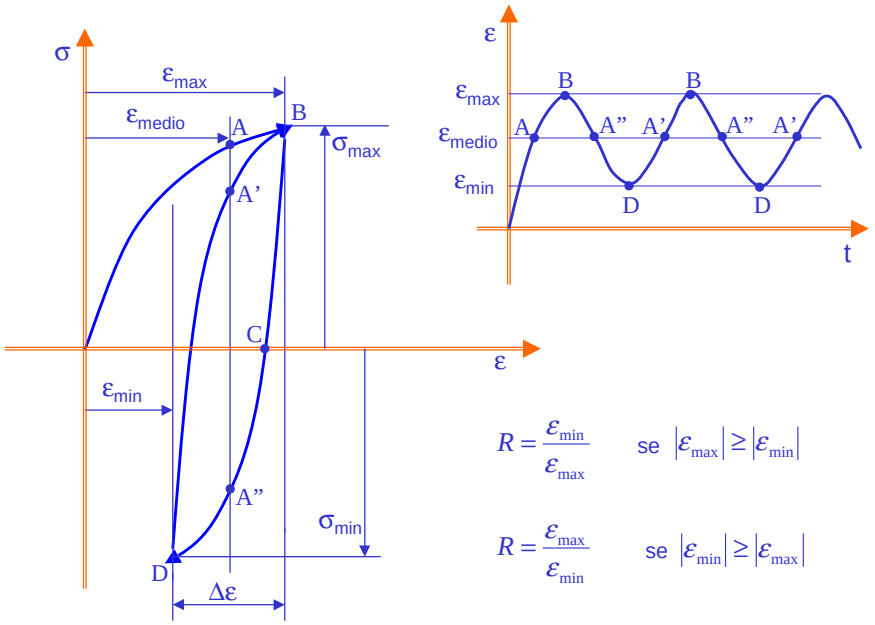


Influenza di una deformazione media non nulla sul comportamento a fatica oligociclica



Ciclo in controllo di forza

Influenza di una deformazione media non nulla sul comportamento a fatica oligociclica



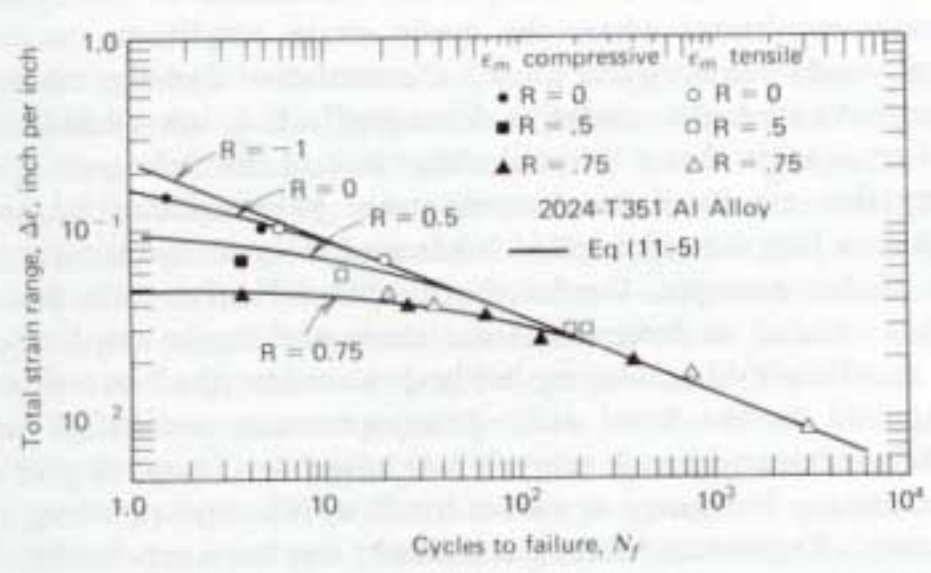
$$R = \frac{\varepsilon_{min}}{\varepsilon_{max}} \quad \text{se} \quad |\varepsilon_{max}| \geq |\varepsilon_{min}|$$

$$R = \frac{\varepsilon_{max}}{\varepsilon_{min}} \quad \text{se} \quad |\varepsilon_{min}| \geq |\varepsilon_{max}|$$

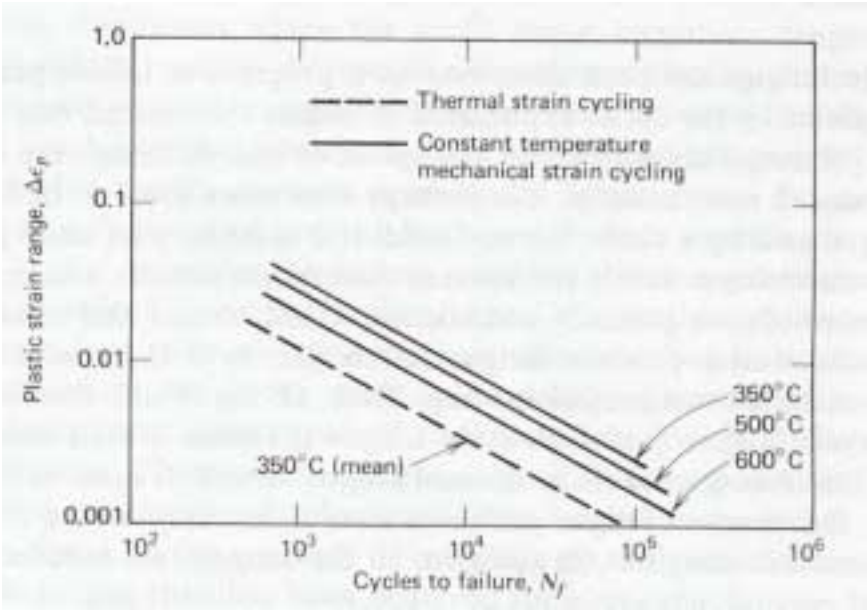
CDM - Fatica oligociclica

Influenza di una deformazione media non nulla sul comportamento a fatica oligociclica

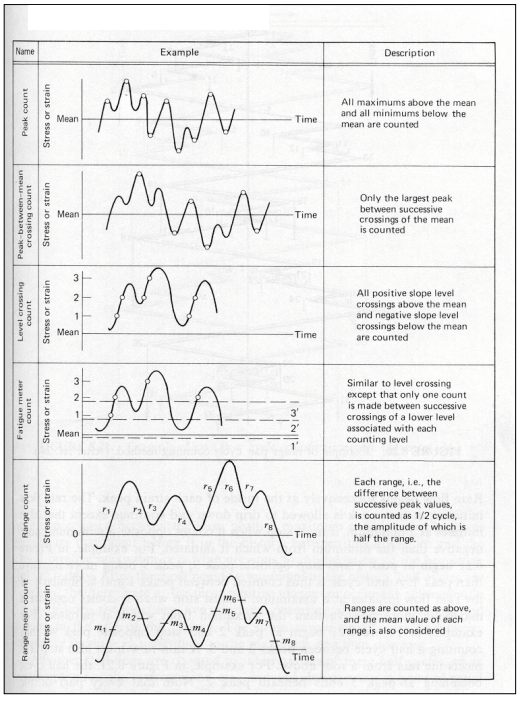
$$\Delta\varepsilon = \frac{2(1-R)\varepsilon_f'}{\left[(4N_f - 1)(1-R)^a + 2^a\right]^{1/a}} \qquad a = -\frac{1}{c}$$



Effetti del ciclo di deformazione termica
sul comportamento a fatica oligociclica

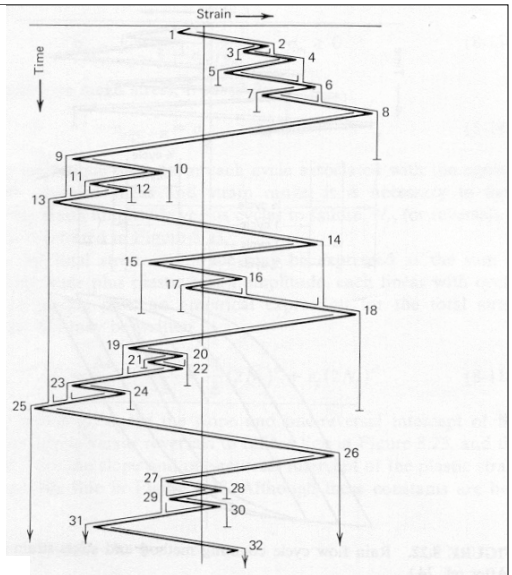


Metodi di conteggio dei cicli

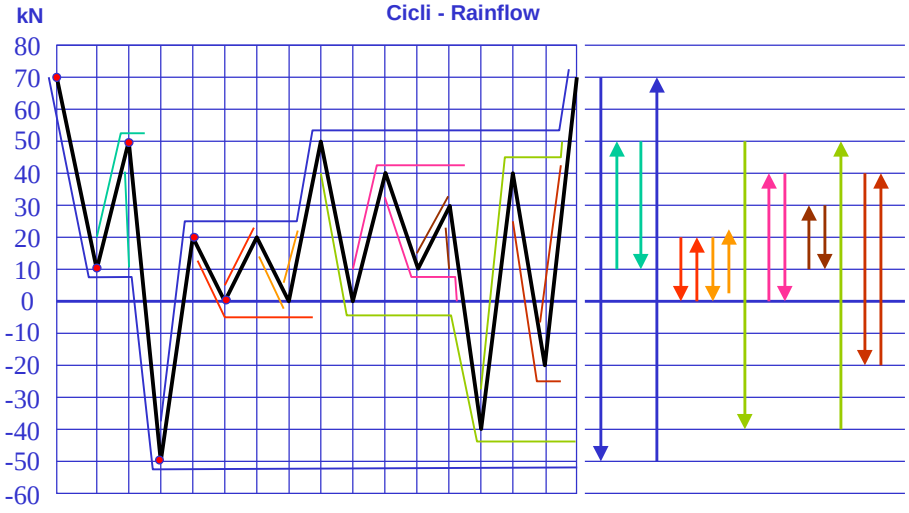


Metodi di conteggio dei cicli

Metodo del Rain Flow



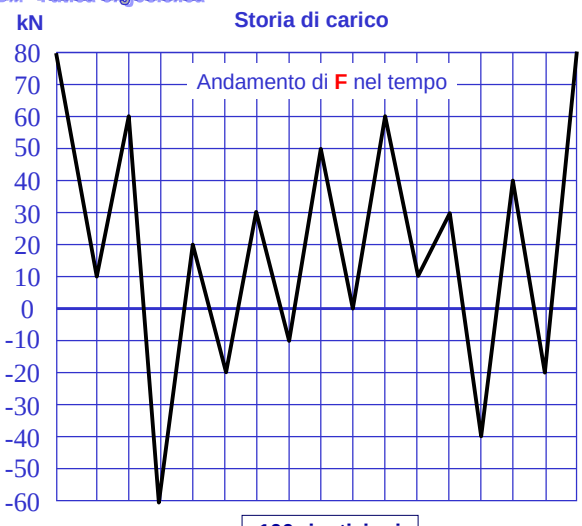
Example of rain flow cycle counting method. (After ref. 24.)



Ciclo 1	Fmax =+70	Fmin = -50
Ciclo 2	Fmax =+50	Fmin =+10
Ciclo 3	Fmax =+20	Fmin = 0
Ciclo 4	Fmax =+20	Fmin = 0

Ciclo 5	Fmax =+50	Fmin = -40
Ciclo 6	Fmax =+40	Fmin = 0
Ciclo 7	Fmax =+30	Fmin =+10
Ciclo 8	Fmax =+40	Fmin = -20

Esempio di calcolo



100 ripetizioni

Il tirante-puntone è soggetto ad un carico assiale il cui andamento nel tempo è riportato nel grafico al lato.

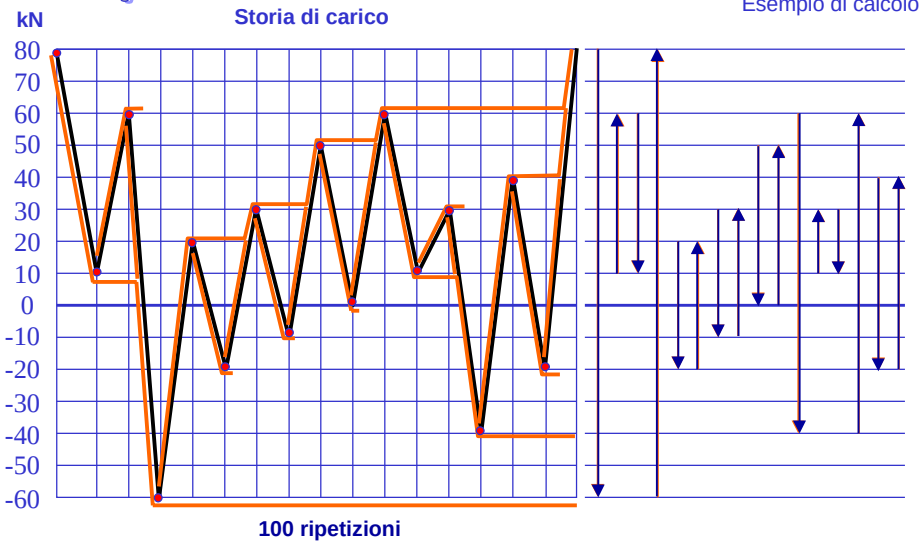
Si vuole calcolare la sezione A in modo che il tirante resista per 100 ripetizioni del diagramma di carico.

eps f	k (MPa)	n'
0,4800	1200,0	0,2000

Dati del materiale.

CDM - Fatica oligociclica

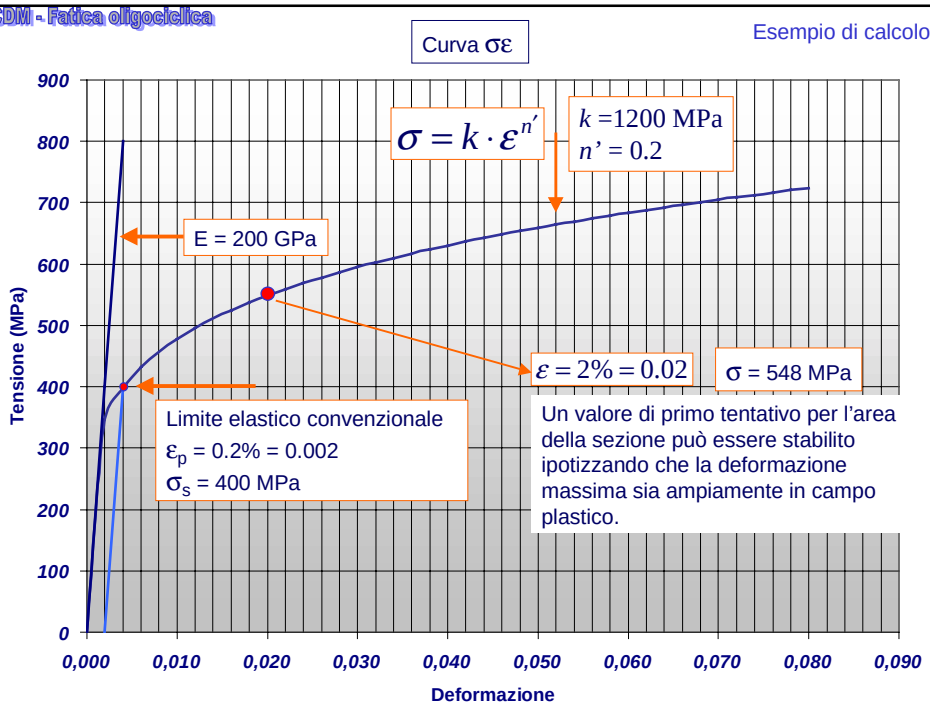
Esempio di calcolo



100 ripetizioni

Ciclo 1	Fmax =+80	Fmin = -60	Ciclo 5	Fmax =+50	Fmin = 0
Ciclo 2	Fmax =+60	Fmin = +10	Ciclo 6	Fmax =+60	Fmin = -40
Ciclo 3	Fmax =+20	Fmin = -20	Ciclo 7	Fmax =+30	Fmin = +10
Ciclo 4	Fmax =+30	Fmin = -10	Ciclo 8	Fmax =+40	Fmin = -20

Esempio di calcolo



CDM - Fatica oligociclica

Esempio di calcolo

Posto:

$$\varepsilon = 2\% = 0.02$$

si ha:

$$\sigma = 1200 \cdot (0.02)^{0.2} = 548 \ MPa$$

e quindi:

$$A = \frac{F}{\sigma} \rightarrow A = \frac{80000 \ N}{548 \ MPa} = 146 \ mm^2 \rightarrow d \cong 13.6 \ mm$$

Questo è il valore di primo tentativo del diametro

Esempio di calcolo

$$\Delta\varepsilon = \frac{2(1-R)\varepsilon_f'}{\left[(4N_f - 1)(1-R)^a + 2^a\right]^{1/a}} \longrightarrow N_f = \frac{1}{4}\left[1 + \left(\frac{2\varepsilon_f'}{\Delta\varepsilon}\right)^a - \left(\frac{2}{1-R}\right)^a\right]$$

eps f	k (MPa)	n'	a	d (mm)	Area (mm2)
0,4800	1200,0	0,200	2,000	13,60	145,263

$$d \cong 13.6 \ mm$$

$$R = \frac{\varepsilon_{min}}{\varepsilon_{max}}$$

Spettro di carico

F max (N)	Fmin (N)	S max (MPa)	S min (MPa)	eps max	eps min	Delta eps	R	Nf	1/Nf
80000	-60000	550,7	-413,0	2,0360E-02	-4,8314E-03	2,5191E-02	-0,24	3,6267E+02	2,7574E-03
60000	10000	413,0	68,8	4,8314E-03	6,2133E-07	4,8308E-03	0,00	9,8721E+03	1,0130E-04
20000	-20000	137,7	-137,7	1,9882E-05	-1,9882E-05	3,9765E-05	-1,00	1,4571E+08	6,8630E-09
30000	-10000	206,5	-68,8	1,5098E-04	-6,2133E-07	1,5160E-04	-0,00	1,0025E+07	9,9755E-08
50000	0	344,2	0,0	1,9416E-03	0,0000E+00	1,9416E-03	0,00	6,1114E+04	1,6363E-05
60000	-40000	413,0	-275,4	4,8314E-03	-6,3624E-04	5,4677E-03	-0,13	7,7063E+03	1,2976E-04
30000	10000	206,5	68,8	1,5098E-04	6,2133E-07	1,5036E-04	0,00	1,0191E+07	9,8127E-08
40000	-20000	275,4	-137,7	6,3624E-04	-1,9882E-05	6,5612E-04	-0,03	5,3520E+05	1,8685E-06
							N° di ripetizioni possibili dello spettro di carico		333

$$\sigma = \frac{F}{A} \qquad \varepsilon = \left(\frac{\sigma}{k}\right)^{\frac{1}{n'}} \qquad \Delta\varepsilon = \varepsilon_{max} - \varepsilon_{min}$$

La sezione è eccessiva

CDM - Fatica oligociclica

Esempio di calcolo

$$\Delta\varepsilon = \frac{2(1-R)\varepsilon_f'}{\left[(4N_f - 1)(1-R)^a + 2^a\right]^{1/a}} \longrightarrow N_f = \frac{1}{4}\left[1 + \left(\frac{2\varepsilon_f'}{\Delta\varepsilon}\right)^a - \left(\frac{2}{1-R}\right)^a\right]$$

eps f	k (MPa)	n'	a	d (mm)	Area (mm2)
0,4800	1200,0	0,200	2,000	13,00	132,728

Spettro di carico

F max (N)	Fmin (N)	S max (MPa)	S min (MPa)	eps max	eps min	Delta eps	R	Nf	1/Nf
80000	-60000	602,7	-452,1	3,1969E-02	-7,5863E-03	3,9555E-02	-0,24	1,4686E+02	6,8094E-03
60000	10000	452,1	75,3	7,5863E-03	9,7561E-07	7,5853E-03	0,00	4,0036E+03	2,4978E-04
20000	-20000	150,7	-150,7	3,1219E-05	-3,1219E-05	6,2439E-05	-1,00	5,9098E+07	1,6921E-08
30000	-10000	226,0	-75,3	2,3707E-04	-9,7561E-07	2,3805E-04	-0,00	4,0659E+06	2,4595E-07
50000	0	376,7	0,0	3,0488E-03	0,0000E+00	3,0488E-03	0,00	2,4787E+04	4,0344E-05
60000	-40000	452,1	-301,4	7,5863E-03	-9,9902E-04	8,5853E-03	-0,13	3,1253E+03	3,1997E-04
30000	10000	226,0	75,3	2,3707E-04	9,7561E-07	2,3610E-04	0,00	4,1333E+06	2,4193E-07
40000	-20000	301,4	-150,7	9,9902E-04	-3,1219E-05	1,0302E-03	-0,03	2,1707E+05	4,6068E-06
							N° di ripetizioni possibili dello spettro di carico		135

La sezione può essere ulteriormente ridotta

Esempio di calcolo

$$\Delta\varepsilon = \frac{2(1-R)\varepsilon_f'}{\left[(4N_f - 1)(1-R)^a + 2^a\right]^{1/a}} \quad \rightarrow \quad N_f = \frac{1}{4}\left[1 + \left(\frac{2\varepsilon_f'}{\Delta\varepsilon}\right)^a - \left(\frac{2}{1-R}\right)^a\right]$$

eps f	k (MPa)	n'	a	d (mm)	Area (mm2)
0,4800	1200,0	0,200	2,000	12,81	128,877

Spettro di carico

F max (N)	Fmin (N)	S max (MPa)	S min (MPa)	eps max	eps min	Delta eps	R	Nf	1/Nf
80000	-60000	620,7	-465,6	3,7040E-02	-8,7897E-03	4,5829E-02	-0,24	1,0929E+02	9,1496E-03
60000	10000	465,6	77,6	8,7897E-03	1,1304E-06	8,7886E-03	0,00	2,9822E+03	3,3532E-04
20000	-20000	155,2	-155,2	3,6172E-05	-3,6172E-05	7,2343E-05	-1,00	4,4024E+07	2,2715E-08
30000	-10000	232,8	-77,6	2,7468E-04	-1,1304E-06	2,7581E-04	-0,00	3,0288E+06	3,3017E-07
50000	0	388,0	0,0	3,5324E-03	0,0000E+00	3,5324E-03	0,00	1,8464E+04	5,4159E-05
60000	-40000	465,6	-310,4	8,7897E-03	-1,1575E-03	9,9472E-03	-0,13	2,3280E+03	4,2955E-04
30000	10000	232,8	77,6	2,7468E-04	1,1304E-06	2,7355E-04	0,00	3,0791E+06	3,2477E-07
40000	-20000	310,4	-155,2	1,1575E-03	-3,6172E-05	1,1937E-03	-0,03	1,6170E+05	6,1842E-06
							N° di ripetizioni possibili dello spettro di carico		100

Dopo alcune iterazioni viene calcolata la sezione del tirante in grado di sopportare esattamente 100 ripetizioni dello spettro di carico.

CDM - Fatica oligociclica

Calcolo a fatica oligociclica

di componenti meccanici