OH Coil Pre Load System
TF hot OH hot

Calculations for the most probable system scenario.
From Pre load of 17.87 mm
(when TF and OH cool down pre load is restored)
TF coil thermal expansion = 8.4 mm
Reduces the stack compression to = 9.47 mm
Then, OH coil thermal expansion = 6.0 mm
Restores stack compression to = 15.47 mm

For a single spring s = .69 mm
For the stack = .69 x26 = 15.47 mm
Maximum obtained force on the OH coil
with 14 stacks = 10,162. x14 = 142,268. N
(31,970. lbs.)

Life based on “Sigma II” is over 2 million cycles

FED4 - Disk Spring Calculation - 14 Stacks TF Hot Oh Hot 2 26 Sp.fd4

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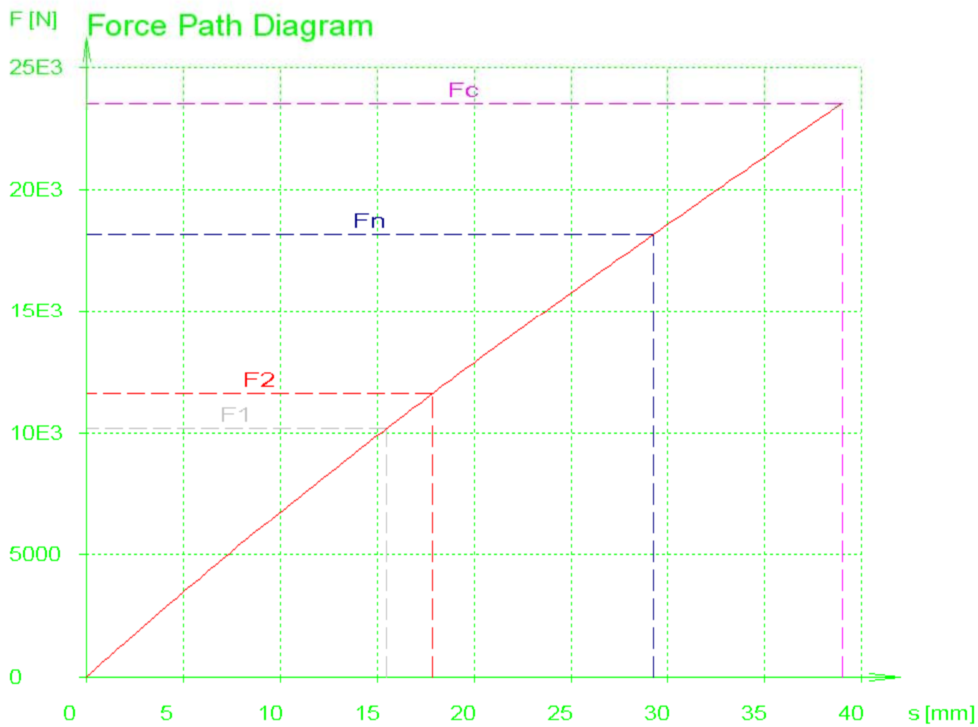


Di = 30.5 mm
De = 60 mm
t = 3.5 mm
L0 = 5 mm

nf = 1
np = 26
Lc = 91 mm
L0 = 130 mm

Stainless Steel Required

E = 206000 MPa
mue = 0.3
rho= 7.85 kg/dm^3
sigma perm = 1230 MPa
(DIN 2092)

	0	1	2	n	c	
s	0.00	15.47	17.87	29.25	39.00	mm
L	130.00	114.53	112.13	100.75	91.00	mm
F	0	10162	11608	18153	23528	N
R	18566	15818	15514	14515	14245	N/mm
sigma I	0	-1357	-1554	-2434	-3121	MPa
sigma III	0	731	835	1297	1650	MPa
si	0.00	0.60	0.69	1.13	1.50	mm
Li	5.00	4.41	4.31	5.00	0.00	mm
Fi	0	10162	11608	18153	23528	N

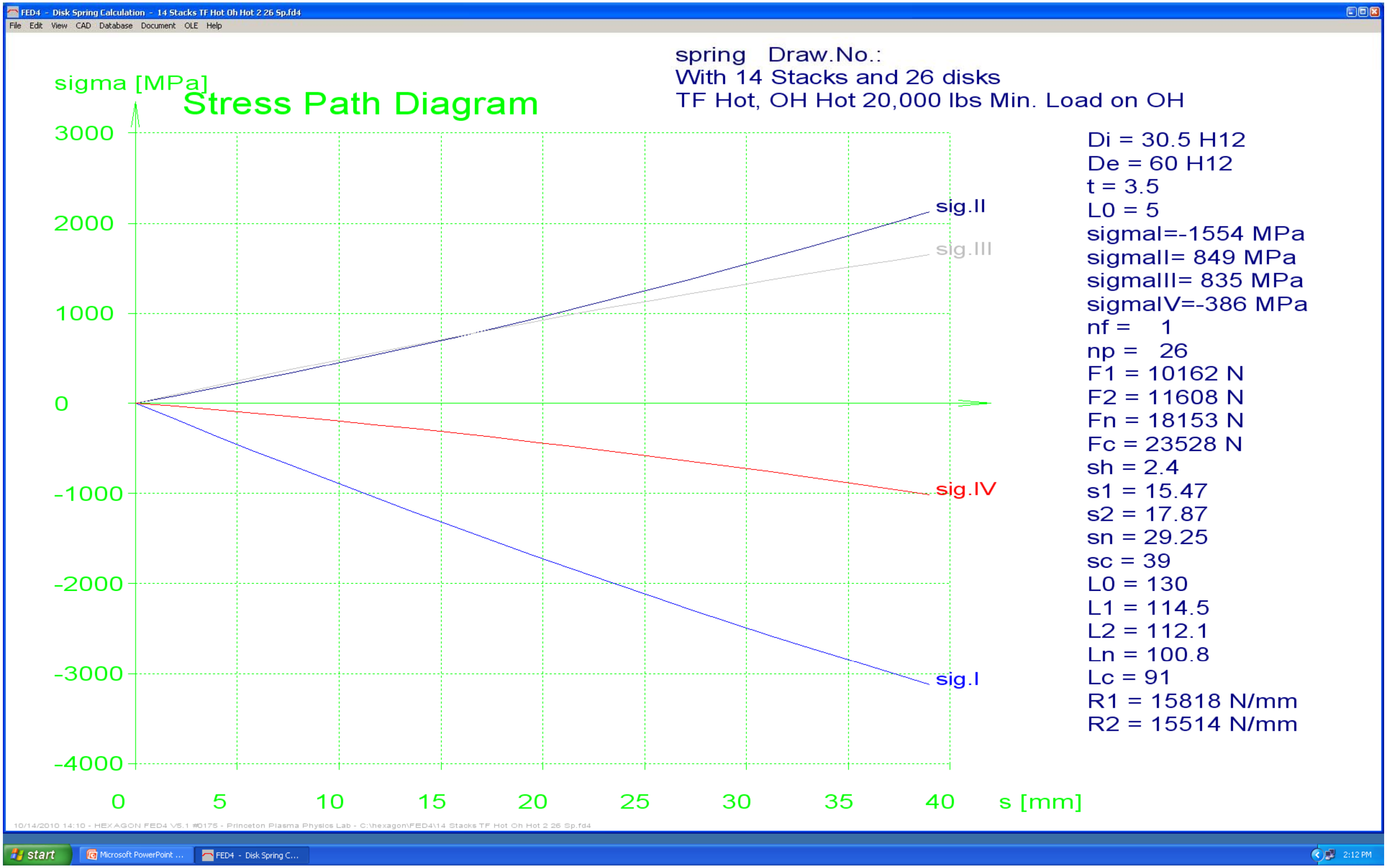
messages

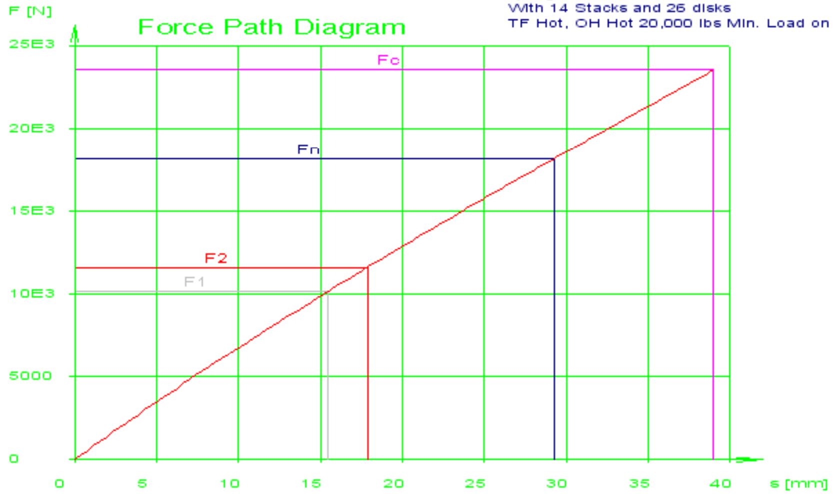
- none -

Total compression = 15.47 mm
Return to Pre Load = 17.87 mm
Total Force/Stack = 10,162 N
(2,284. lbs)
Total force on OH coil =
(2,284. x 14 = 31,970 lbs.)

10/14/2010 14:05 - HEXAGON FED4 V5.1 #0175 - Princeton Plasma Physics Lab - C:\hexagon\FED4\14 Stacks TF Hot Oh Hot 2 26 Sp.fd4

start | Microsoft PowerPoint ... | FED4 - Disk Spring C... | 2:06 PM


FED4 - Disk Spring Calculation - 14 Stacks TF Hot Oh Hot 2 26 Sp.fd4
File Edit View CAD Database Document OLE Help
spring Draw.No.:
With 14 Stacks and 26 disks
TF Hot, OH Hot 20,000 lbs Min. Load on OH
sigma [MPa]
Stress Path Diagram
3000
2000
1000
0
-1000
-2000
-3000
-4000
0
5
10
15
20
25
30
35
40
s [mm]
sig.II
sig.III
sig.IV
sig.I
Di = 30.5 H12
De = 60 H12
t = 3.5
L0 = 5
sigmaI=-1554 MPa
sigmaII= 849 MPa
sigmaIII= 835 MPa
sigmaIV=-386 MPa
nf = 1
np = 26
F1 = 10162 N
F2 = 11608 N
Fn = 18153 N
Fc = 23528 N
sh = 2.4
s1 = 15.47
s2 = 17.87
sn = 29.25
sc = 39
L0 = 130
L1 = 114.5
L2 = 112.1
Ln = 100.8
Lc = 91
R1 = 15818 N/mm
R2 = 15514 N/mm
10/14/2010 14:10 - HEXAGON FED4 V5.1 #0175 - Princeton Plasma Physics Lab - C:\hexagon\FED4\14 Stacks TF Hot Oh Hot 2 26 Sp.fd4
start
Microsoft PowerPoint ...
FED4 - Disk Spring C...
2:12 PM



spring Draw.No.:
With 14 Stacks and 26 disks
TF Hot, OH Hot 20,000 lbs Min. Load on OH

Di = 30.5 H12
De = 60 H12
t = 3.5
L0 = 5
sigmaI=-1554 MPa
sigmaII= 849 MPa
sigmaIII= 835 MPa
sigmaIV=-386 MPa
nf = 1
np = 26
F1 = 10162 N
F2 = 11608 N
Fn = 18153 N
Fc = 23528 N
sh = 2.4
s1 = 15.47
s2 = 17.87
sn = 29.25
sc = 39
L0 = 130
L1 = 114.5
L2 = 112.1
Ln = 100.8
Lc = 91
R1 = 15818 N/mm
R2 = 15514 N/mm

spring Draw.No.:
With 14 Stacks and 26 disks
TF Hot, OH Hot 20,000 lbs Min. Load on OH

SINGLE DISK SPRING			
inside diameter	Di	mm	30.5 H12
outside diameter	De	mm	60 H12
thickness	t	mm	3.5
length	L0	mm	5
weight	m	g	57.61
usable spring travel sn=0.75*h0	sin	mm	1.125
max. spring travel h0=sc	sic	mm	1.5
spring force with sn=0.75*sc	Fin	N	18153
No. of springs per package	nf		1
No. of spring packages	np		26

Length mm	Sp.travel mm	Load N	Sigma MPa
L0 = 130.00			
L1 = 114.53	s1 = 15.47	F1 = 10161.96	sigma1 = 731
	sh = 2.40	Fh = 1445.82	sigmah = 104
L2 = 112.13	s2 = 17.87	F2 = 11607.78	sigma2 = 835
Ln = 100.75	sn = 29.25	Fn = 18152.58	sigman = 1297
Lc = 91.00	sc = 39.00	Fc = 23528.21	sigmac = 1650

	Date	Name
Compl.	08/25/2010	P. Rogoff
Check		
Stand.		

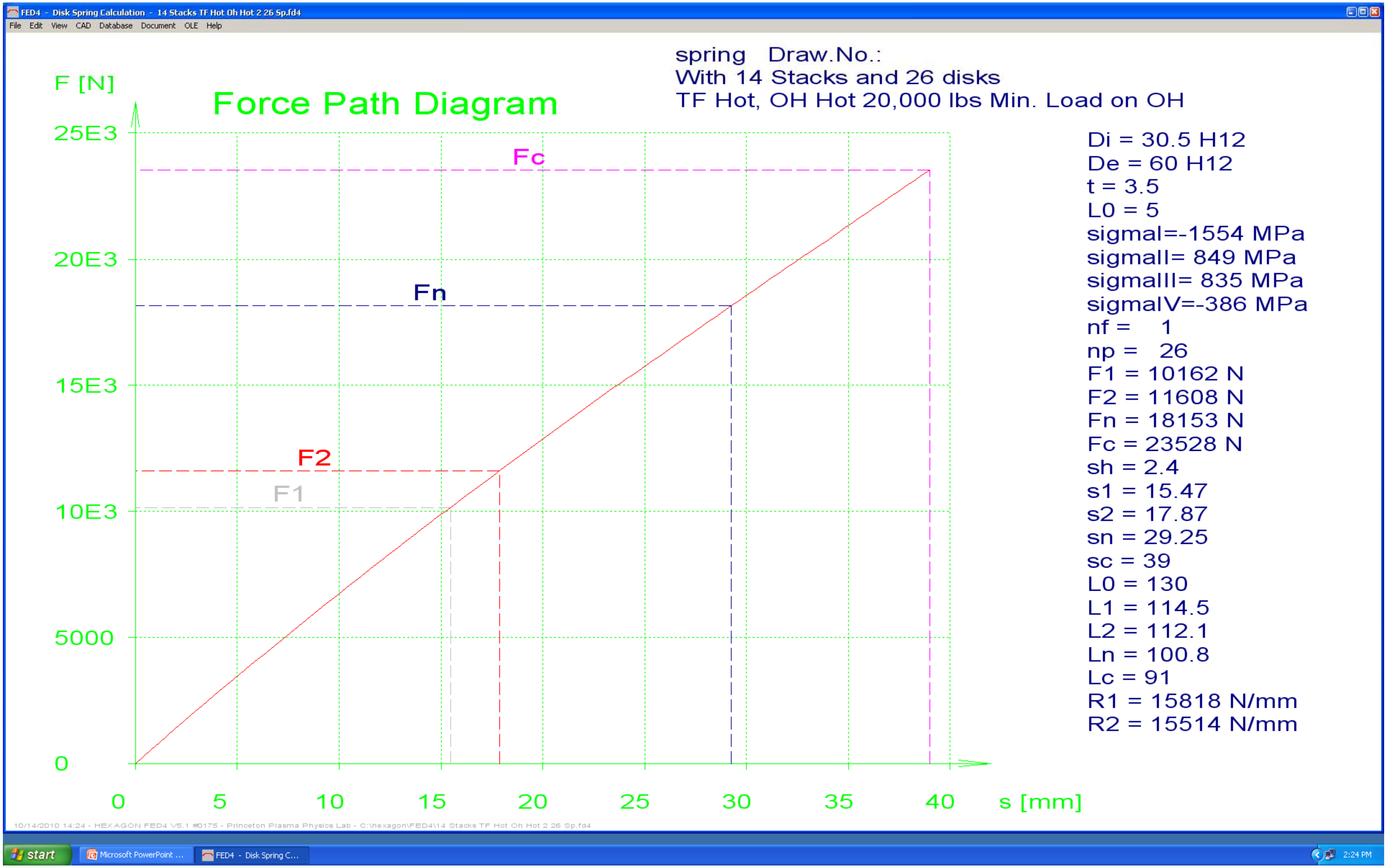
Disk Spring

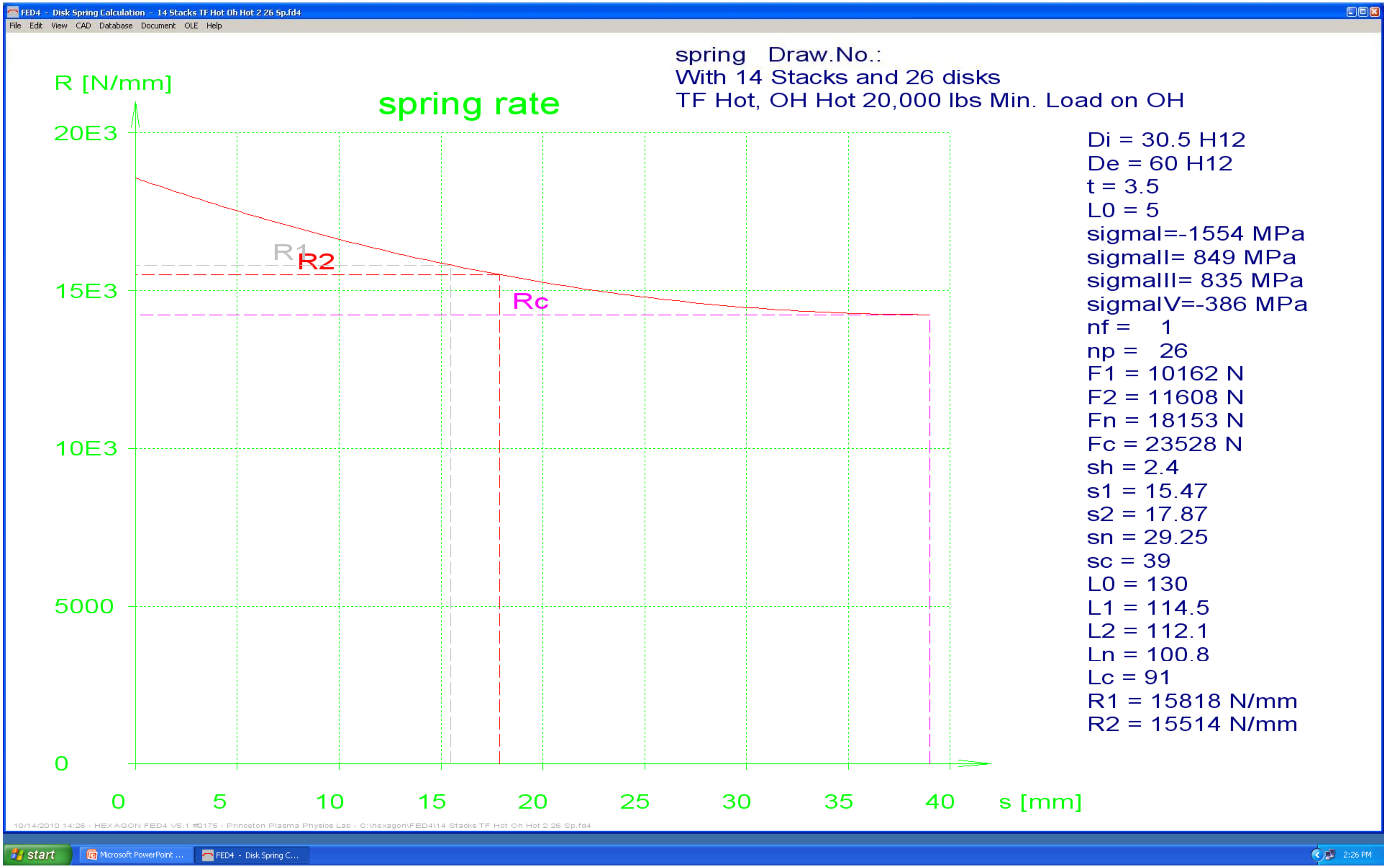
Cond. | Modification | Date | Name

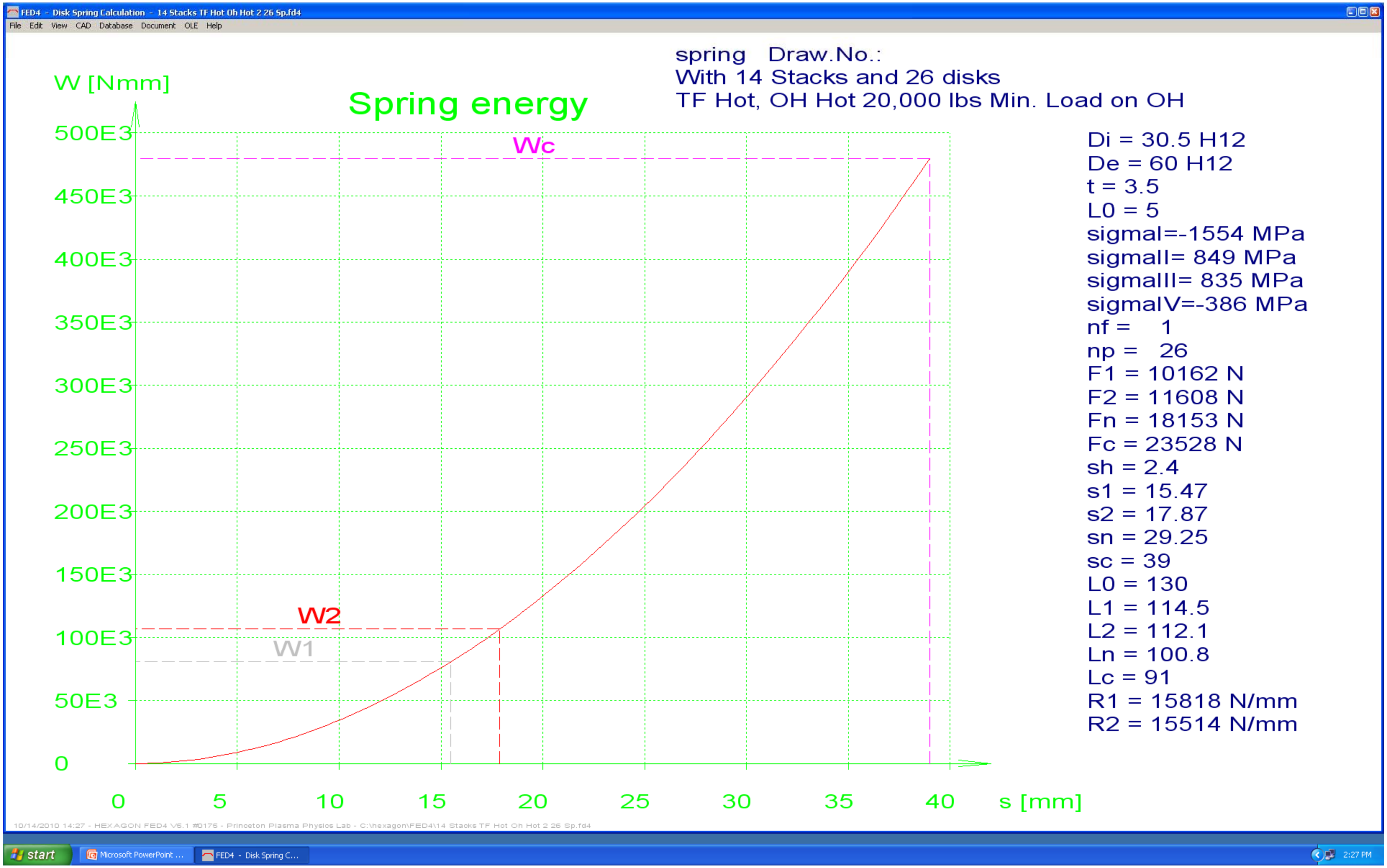
Princeton Plasma Physics Lab

Page

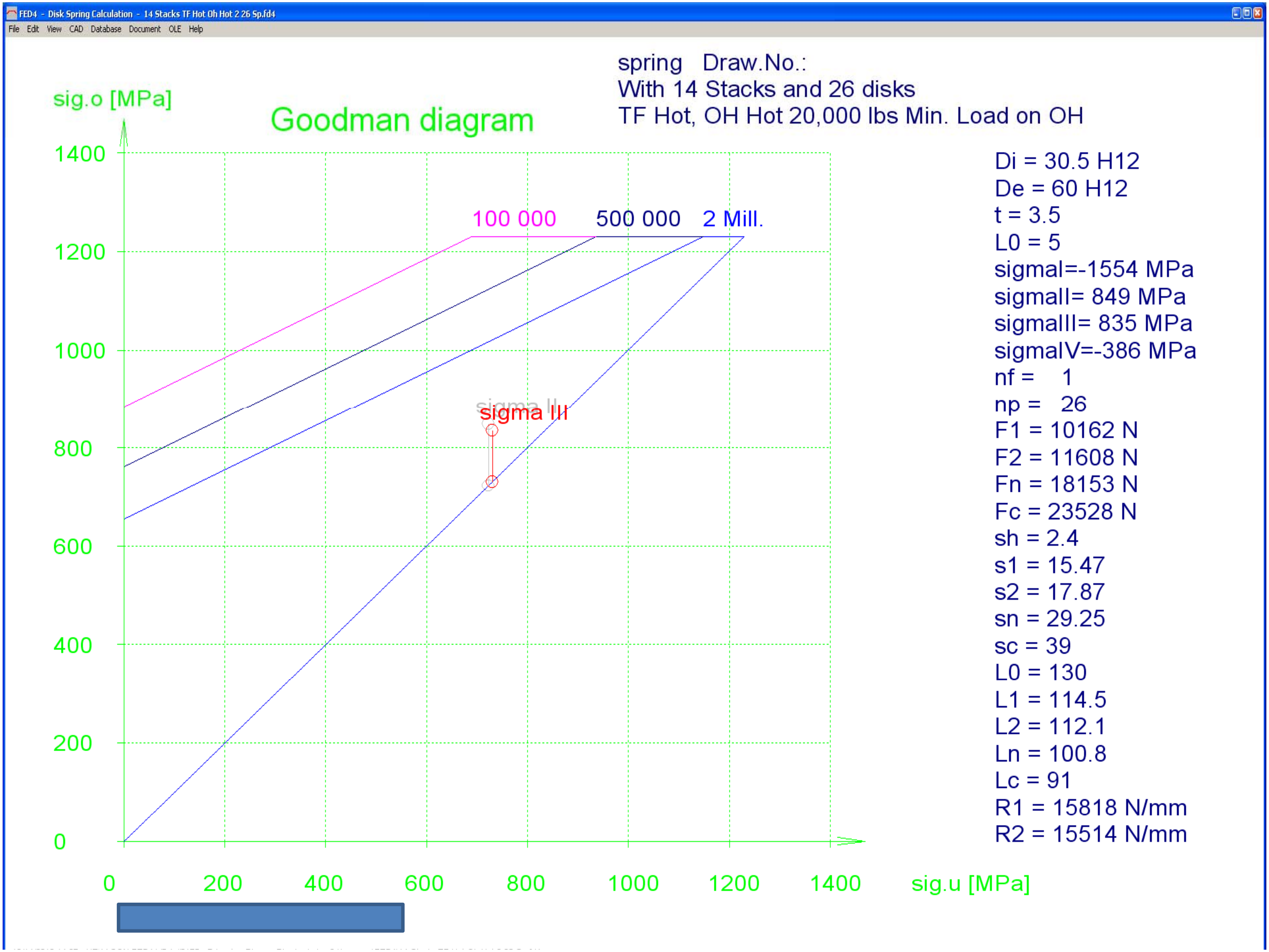
Pg.


FED4 - Disk Spring Calculation - 14 Stacks TF Hot Oh Hot 2 26 Sp.fd4
File Edit View CAD Database Document OLE Help
spring Draw.No.:
With 14 Stacks and 26 disks
TF Hot, OH Hot 20,000 lbs Min. Load on OH
Force Path Diagram
F [N]
25E3
20E3
15E3
10E3
5000
0
Fc
Fn
F2
F1
0
5
10
15
20
25
30
35
40
s [mm]
Di = 30.5 H12
De = 60 H12
t = 3.5
L0 = 5
sigmaI=-1554 MPa
sigmaII= 849 MPa
sigmaIII= 835 MPa
sigmaIV=-386 MPa
nf = 1
np = 26
F1 = 10162 N
F2 = 11608 N
Fn = 18153 N
Fc = 23528 N
sh = 2.4
s1 = 15.47
s2 = 17.87
sn = 29.25
sc = 39
L0 = 130
L1 = 114.5
L2 = 112.1
Ln = 100.8
Lc = 91
R1 = 15818 N/mm
R2 = 15514 N/mm
10/14/2010 14:24 - HEXAGON FED4 V5.1 #0175 - Princeton Plasma Physics Lab - C:\hexagon\FED4\14 Stacks TF Hot Oh Hot 2 26 Sp.fd4
start
Microsoft PowerPoint ...
FED4 - Disk Spring C...
2:24 PM


FED4 - Disk Spring Calculation - 14 Stacks TF Hot Oh Hot 2 26 Sp.fd4
File Edit View CAD Database Document OLE Help
spring Draw.No.:
With 14 Stacks and 26 disks
TF Hot, OH Hot 20,000 lbs Min. Load on OH
R [N/mm]
spring rate
20E3
15E3
10E3
5000
0
R1
R2
Rc
0
5
10
15
20
25
30
35
40
s [mm]
Di = 30.5 H12
De = 60 H12
t = 3.5
L0 = 5
sigmaI=-1554 MPa
sigmaII= 849 MPa
sigmaIII= 835 MPa
sigmaIV=-386 MPa
nf = 1
np = 26
F1 = 10162 N
F2 = 11608 N
Fn = 18153 N
Fc = 23528 N
sh = 2.4
s1 = 15.47
s2 = 17.87
sn = 29.25
sc = 39
L0 = 130
L1 = 114.5
L2 = 112.1
Ln = 100.8
Lc = 91
R1 = 15818 N/mm
R2 = 15514 N/mm
10/14/2010 14:26 - HEXAGON FED4 V5.1 #0175 - Princeton Plasma Physics Lab - C:\hexagon\FED4\14 Stacks TF Hot Oh Hot 2 26 Sp.fd4
start
Microsoft PowerPoint ...
FED4 - Disk Spring C...
2:26 PM



FED4 - Disk Spring Calculation - 14 Stacks TF Hot Oh Hot 2 26 Sp.fd4
File Edit View CAD Database Document OLE Help
spring Draw.No.:
With 14 Stacks and 26 disks
TF Hot, OH Hot 20,000 lbs Min. Load on OH
Spring energy
W [Nmm]
500E3
450E3
400E3
350E3
300E3
250E3
200E3
150E3
100E3
50E3
0
Wc
W2
W1
0
5
10
15
20
25
30
35
40
s [mm]
Di = 30.5 H12
De = 60 H12
t = 3.5
L0 = 5
sigmaI=-1554 MPa
sigmaII= 849 MPa
sigmaIII= 835 MPa
sigmaIV=-386 MPa
nf = 1
np = 26
F1 = 10162 N
F2 = 11608 N
Fn = 18153 N
Fc = 23528 N
sh = 2.4
s1 = 15.47
s2 = 17.87
sn = 29.25
sc = 39
L0 = 130
L1 = 114.5
L2 = 112.1
Ln = 100.8
Lc = 91
R1 = 15818 N/mm
R2 = 15514 N/mm
10/14/2010 14:27 - HEXAGON FED4 V5.1 #0175 - Princeton Plasma Physics Lab - C:\hexagon\FED4\14 Stacks TF Hot Oh Hot 2 26 Sp.fd4
start
Microsoft PowerPoint ...
FED4 - Disk Spring C...
2:27 PM


FED4 - Disk Spring Calculation - 14 Stacks TF Hot Oh Hot 2 26 Sp.fd4
File Edit View CAD Database Document OLE Help
spring Draw.No.:
With 14 Stacks and 26 disks
TF Hot, OH Hot 20,000 lbs Min. Load on OH
sig.o [MPa]
Goodman diagram
1400
1200
1000
800
600
400
200
0
100 000
500 000
2 Mill.
sigma III
0
200
400
600
800
1000
1200
1400
sig.u [MPa]
Di = 30.5 H12
De = 60 H12
t = 3.5
L0 = 5
sigmaI=-1554 MPa
sigmaII= 849 MPa
sigmaIII= 835 MPa
sigmaIV=-386 MPa
nf = 1
np = 26
F1 = 10162 N
F2 = 11608 N
Fn = 18153 N
Fc = 23528 N
sh = 2.4
s1 = 15.47
s2 = 17.87
sn = 29.25
sc = 39
L0 = 130
L1 = 114.5
L2 = 112.1
Ln = 100.8
Lc = 91
R1 = 15818 N/mm
R2 = 15514 N/mm

	A	B	C	D
1				
2		Calculations in (N and mm) units		
3				
4		Calcs Based on the SCHNORR data formulas.		
5				
6		Note: These calculations are for SCHNORR #15900 as basic shape		
7				
8				
9		De - Ouside diameter	60	mm
10		Di - Inside diameter	30.5	mm
11				
12		pi	3.14	
13		1/pi	0.3185	
14		3/pi	0.9554	
15		6/pi	1.9108	
16				
17		del=De/Di Schnorr Formula #2	1.9672	
18				
19		lndel=ln(De/Di)	0.6766	
20				
21		del-1	0.9672	
22		del+1	2.9672	
23				
24				
25				
26		(del-1/del)^2	0.2417	
27		(del+1)/(del-1)	3.0678	
28		(2/lndel)	2.9559	
29				
30				
31		K1 =1/pi(((del-1/del)^2))/((del+1)/((del-1)-(2/lndel))) Formula #3	0.6879	
32				
33		K2=6/pi(((del-1)/(lndel))-1)))/(lndel) Formula #4	1.2129	
34				
35		K3=3/pi(del-1/lndel) Formula #5	1.3657	
36				
37		K4=1 since thikness is less than 6 mm Formula #6 (see chapter	1	
38				
39				
40		FORCE and STRESS Calculations		
41				
42				
43				
44		lo= total height	5.004	mm
45		ho= lo-t	1.499	mm
46		t=average spring thickness	3.505	mm

Calculations based on SCHNORR catalogue equations for a single disk at constant compression s = .595 mm

Stack compression in this case: s = 15.47 mm.

Or (.595 x 26) = 15.47 mm.

Force = 10,196. N

(“HEXAGON” F=10,162N)

See slide #2

s= deflection of the single spring (from 75% of ho))	0.595	mm
E= modulus for steel	206000	N/mm^2
mu= Poisson's ratio	0.3	
1-mu^2	0.91	
4E/(1-mu^2)	905494.505	
t^4/(K1*de^2)	0.06094519	
s/t	0.16975749	
ho/t	0.42767475	
s/2t	0.08487874	
Formula #8a	10196.43	N
Formula #9 Stresses at the center of rotation (point OM)	-728.57	N/mm^2
(should be less then -1600N/mm^2)		
t^2/(K1*de^2)	0.00496093	
formula #10 Stress at point (I)	-1358.53	N/mm^2
formula #11 Stress at point (II)	724.417318	N/mm^2
formula #12 Stress at point (III)	731.21	N/mm^2
1/del	0.50833333	
(K2-2K3)	-1.5185995	
(ho/t-s/2t)	0.34279601	
Formula #13 Stress at point (IV)	-327.62	N/mm^2
t^3/(K1*de^2)	0.01738807	
Formula #14 Spring Rate (dF/ds)	15875.94	N/mm
Formula #15 Spring Work (Integral from 0 to s, of F*ds)	3114.53	N-mm
2E/(1-mu^2)	452747.253	
t^5/(K1*de^2)	0.2136129	
Basic requirements for a good Disk spring design		
For the above basic equations to work		
This Spring is linear because ho/t=.428 (since for ho/t<0.4 are lii	slightly non-LINEAR	
del=De/Di=2.3923 and it should be between 1.75 and 2.5	O.K.	
Outside diameter De, Inside diameter Di		

ho/t=(lo-t)/t=.428 and it should be between 0.4 to 1.3 O.K.

ho=lo-t cone height, t=disk thickness

De/t=17.12 and it should be between 16. and 40. O.K.

Conclusion: This spring under the constant load of 3790.0 N is O.K.

Basic machine operation requirements:

1) TF coil inner leg maximum thermal expansion was calculated at 8.4mm
2) OH coil requires a preload of 20,000.0 lbs total or 7,413.3 N (12 St) per stack. Must calculate the required deflection (s) for the preload force?
3) OH coil thermal expansion was calculated at 6.0mm

So, the total each spring stack travel is = 8.4+6.0+calculated from minimum preload ?

For Fatigue predictions, using fatigue life diagrams for disk springs, one requires the Pre and Maximum loads stresses at points II or III (depending on del and ho/t).