



# Springs calculation

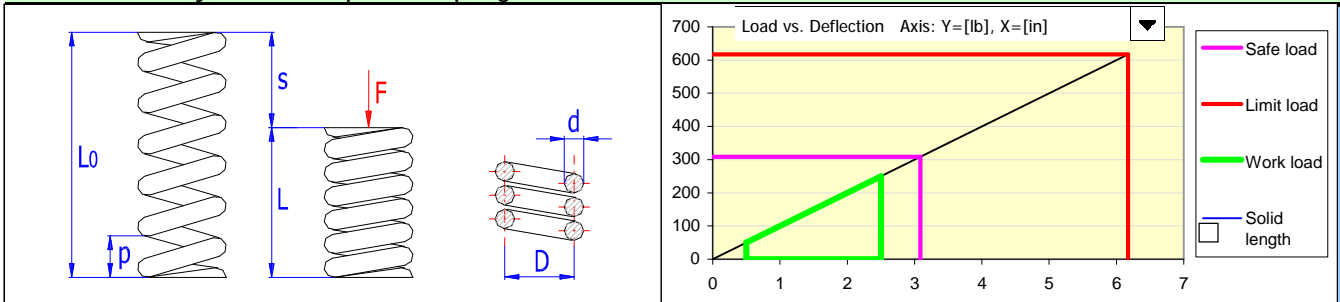
## i Project information

## ? Input parameters section

### 1.0 Selection of material, spring operational and production parameters

1.1 Material standard	ASTM/SAE	1.3 Calculation units	Imperial (lbf, in, HP...)
1.2 Material type	Spring wire	1.4 Graph type	Load vs. Deflection
1.5 Spring material		1.21 Operational parameters, safety	
1.6 Music wire ASTM A228	<input checked="" type="checkbox"/>	1.22 Working temperature	68 [° F] 1,00 <input checked="" type="checkbox"/>
1.7 Suitability for fatigue load	Excellent	1.23 Method of loading	Fatigue loading 2,00 <input checked="" type="checkbox"/>
1.8 Relative strength	High	1.24 Operational loading mode	Light service, continuous loading 1,00 <input checked="" type="checkbox"/>
1.9 Corrosion resistance	Insufficient	1.25 Working environment	Non corrosive 1,00 <input checked="" type="checkbox"/>
1.10 Max. operational temperature	250 [° F]	1.26 Surface treatment	Standard finish 1,00 <input checked="" type="checkbox"/>
1.11 Delivered wire diameters	0,005 - 0,25 [in]	1.27 Total level of safety	2,00 <input checked="" type="checkbox"/>
1.12 Modulus of elasticity in tension	E <sub>20</sub> 29000 [ksi]		
1.13 - at operational temperature	E 29000 [ksi]		
1.14 Modulus of elasticity in shear	G <sub>20</sub> 11750 [ksi]		
1.15 - at operational temperature	G 11750 [ksi]		
1.16 Poisson's ratio	μ 0,29		
1.17 Density	ρ 490 [lb/ft <sup>3</sup> ]		
1.18 Ultimate tensile strength	R <sub>m</sub> 190 [ksi]		
1.19 Max. permissible bending stress	σ <sub>A</sub> 133 [ksi]		
1.20 Max. permissible torsional stress	τ <sub>A</sub> 95 [ksi]		

### 2.0 Helical cylindrical compression springs of round wires and bars



#### 2.1 Spring design

			Calculation	Deviation
2.2 Minimum working loading	F1	50,00 [lb]	50,0474667	0,09%
2.3 Maximum working loading	F8	250,00 [lb]	249,952533	-0,02%
2.4 Spring working stroke	H	2,0000 [in]	2,00047478	0,02%
2.5 Required spring constant	k	100,00 [lb/in]		-0,02%
2.6 Mean spring diameter	D	3,0000 [in]	2,99976265	-0,01%
2.7 Wire diameter	d	0,3750 [in]	0,37502225	0,01%
2.8 Number of active coils	n	10,76	10,7574463	-0,02%

#### 2.9 Optimization

D/d	8
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#### 2.10 Check data

2.11 Spring index	D/d	8,00	2.14 Max. permissible loading	F8 <sub>max</sub>	308,6 [lb]
2.12 Spring constant	k	99,98 [lb/in]	2.15 Max. permissible stroke	H <sub>max</sub>	2,587 [in]
2.13 Spring weight	m	3,536 [lb]	2.16 Level of safety		2,47

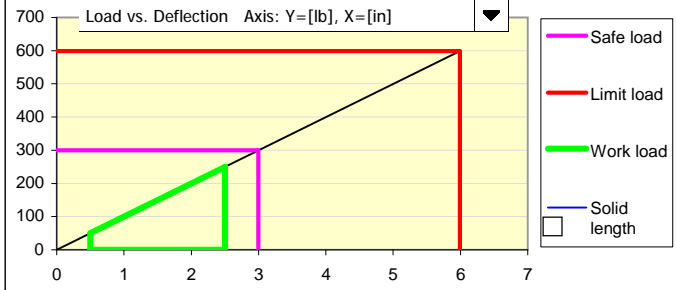
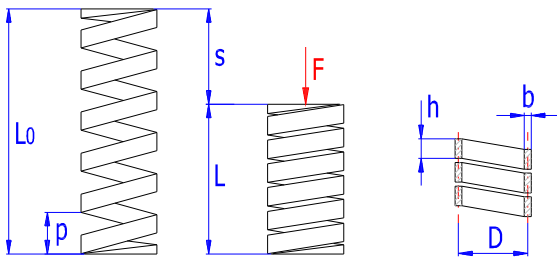
#### 2.17 Design values

2.18 Design of spring ends		Closed ends ground
2.19 Solid length	Ls	4,785 [in]
2.20 Recommended limits of free spring length		7,411   30 [in]
2.21 Free spring length	L0	12,3700 <input checked="" type="checkbox"/> [in]
2.22 Recommended pitch limits		0,9   1,8 [in]
2.23 Pitch between coils of free spring	p	1,08 [in]
2.24 Outer / inner spring diameter	D <sub>e</sub> /D <sub>i</sub>	3,375   2,625 [in]
2.25 Developed wire length	l	122,5 [in]
2.26 Spring deformation energy	W8	26,05 [ft lb]

#### 2.27 Parameters of working cycle

	1	8	9	
F <sub>i</sub>	50,0	250,0	617,2	[lb]
s <sub>i</sub>	0,5001	2,5006	6,1735	[in]
L <sub>i</sub>	11,8699	9,8694	6,1965	[in]
τ <sub>i</sub>	7,7	38,48	95	[ksi]

### 3.0 Helical cylindrical compression springs of rectangular wires and bars



#### 3.1 Spring design

			Calculation	Deviation
3.2 Minimum working loading	F1	50,00 [lb]	50,0497416	0,10%
3.3 Maximum working loading	F8	250,00 [lb]	249,950258	-0,02%
3.4 Spring working stroke	H	2,0000 [in]	2,00049754	0,02%
3.5 Required spring constant	k	100,00 [lb/in]		-0,02%
3.6 Mean spring diameter	D	3,0000 [in]	2,99975127	-0,01%
3.7 Wire width	b	0,3750 [in]	≈ 0,375	0,01%
3.8 Wire height	h	0,3750 [in]	≈ 0,375	0,01%
3.9 Number of active coils	n	15,41	15,4061674	-0,02%

#### 3.10 Optimization

b/h	1:1	D/b	8
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#### 3.11 Check data

3.12 Spring index	D/b	8,00	3.15 Max. permissible loading	F8 <sub>max</sub>	299,4 [lb]
3.13 Spring constant	k	99,98 [lb/in]	3.16 Max. permissible stroke	H <sub>max</sub>	2,495 [in]
3.14 Spring weight	m	6,282 [lb]	3.17 Level of safety		2,40

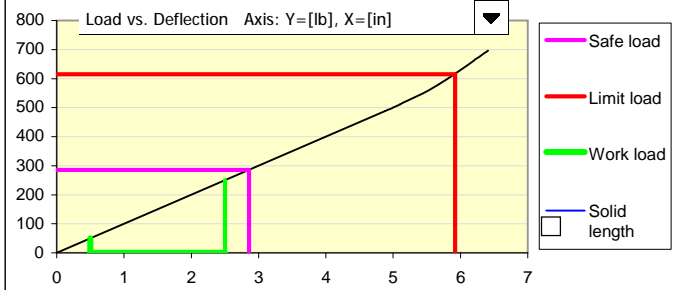
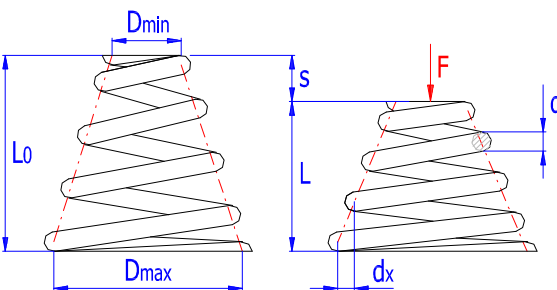
#### 3.18 Design values

3.19 Design of spring ends	Closed ends ground		
3.20 Solid length	Ls	6,5288 [in]	
3.21 Recommended limits of free spring length		9,154   30 [in]	
3.22 Free spring length	LO	17,3900 [in]	<input checked="" type="checkbox"/>
3.23 Recommended pitch limits		0,9   1,8 [in]	
3.24 Pitch between coils of free spring	p	1,08 [in]	
3.25 Outer / inner spring diameter	De/Di	3,375   2,625 [in]	
3.26 Developed wire length	l	167,14 [in]	
3.27 Spring deformation energy	W8	26,05 [ft lb]	

#### 3.28 Parameters of working cycle

	1	8	9	
F <sub>i</sub>	50,0	250,0	598,9	[lb]
s <sub>i</sub>	0,5001	2,5006	5,9902	[in]
L <sub>i</sub>	16,8899	14,8894	11,3998	[in]
τ <sub>i</sub>	7,93	39,66	95	[ksi]

### 4.0 Helical conical compression springs of round wires and bars



#### 4.1 Spring design

			Pre-design
4.2 Minimum working loading	F1	50,00 [lb]	50,0441483
4.3 Maximum working loading	F8	250,00 [lb]	249,955852
4.4 Spring working stroke	H	2,0000 [in]	2,00044158
4.5 Min. mean spring diameter	D <sub>min</sub>	3,5000 [in]	3,49974245
4.6 Max. mean spring diameter	D <sub>max</sub>	5,2500 [in]	5,24961367
4.7 Mean spring diameter	D	4,3750 [in]	
4.8 Wire diameter	d	0,4375 [in]	0,43752415
4.9 Number of active coils	n	6,18	6,17863582

#### 4.10 Calculation

	Calculation	Deviation
	50,0495911	0,10%
	249,954987	-0,02%
	2,0005	0,02%

#### 4.11 Optimization

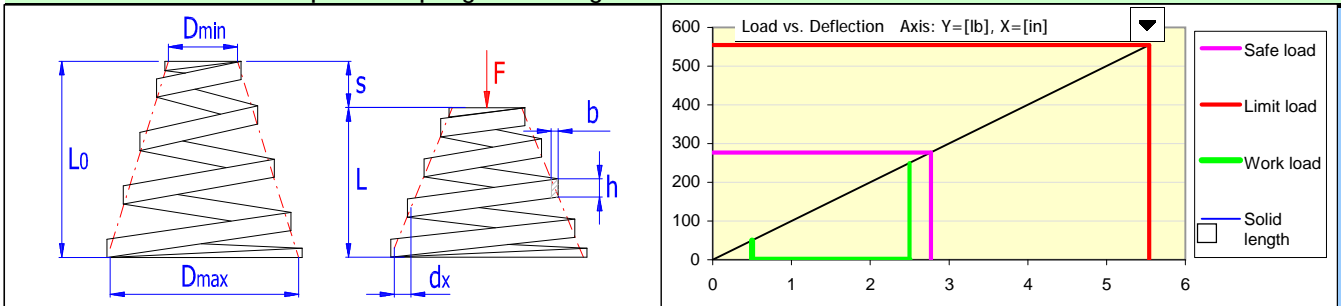
D <sub>max</sub> /min	1,5	D <sub>min</sub> /d	8
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#### 4.12 Check data

4.13 Min. spring index	D <sub>min</sub> /d	8,00	4.18 Max. permissible loading	F8 <sub>max</sub>	285,6 [lb]
4.14 Max. spring index	D <sub>max</sub> /d	12,00	4.19 Level of safety		2,29

4.15	Diameter ratio	$D_{max}/D_{min}$	1,50		4.20	Work area with linear characteristic curve				
4.16	Shift of coils	$dx$	0,107	[in]	4.21	Max. loading	$F_C$ 488,0 [lb]			
4.17	Spring weight	$m$	4,285	[lb]	4.22	Spring constant	$k_C$ 99,98 [lb/			
4.23	<b>Design values</b>									
4.24	Design of spring ends	Closed ends ground			4.33	<b>Parameters of working cycle</b>				
4.25	Solid length	$L_s$	3,4701	[in]		1	8	9		
4.26	Recommended limits of free spring length		5,971	21,875	[in]	$F_i$	50,0	250,0	615,0	[lb]
4.27	Free spring length	$L_0$	11,5800	<input checked="" type="checkbox"/>	[in]	$s_i$	0,5001	2,5006	5,9227	[in]
4.28	Recommended pitch limits		1,75	3,063	[in]	$L_i$	11,0799	9,0794	5,6573	[in]
4.29	Pitch between coils of free spring	$p$	1,75	[in]	$\tau_i$		8,32	41,58	95	[ksi]
4.30	Max. outer / min. inner spring diameter	$D_e/D_i$	5,688	3,063	[in]	$k_i$	99,98	99,98	149,41	[lb/
4.31	Developed wire length	$l$	114,52	[in]						
4.32	Spring deformation energy	$W_8$	26,05	[ft lb]						

5.0  Helical conical compression springs of rectangular wires and bars



5.1 Spring design

5.2	Minimum working loading	$F_1$	50,00	[lb]	Pre-design	49,9973985	5.11	Calculation	49,9992371	Deviation	0,00%
5.3	Maximum working loading	$F_8$	250,00	[lb]		250,002602			250,002901		0,00%
5.4	Spring working stroke	$H$	2,0000	[in]		1,99997398			2		0,00%
5.5	Min. mean spring diameter	$D_{min}$	3,5726	[in]		3,57261549					
5.6	Max. mean spring diameter	$D_{max}$	5,3589	[in]		5,35892324					
5.7	Mean spring diameter	$D$	4,4658	[in]							
5.8	Wire width	$b$	0,4375	[in]		0,43749858					
5.9	Wire height	$h$	0,4375	[in]		0,43749858					
5.10	Number of active coils	$n$	8,32			8,32010822					
5.13	<b>Check data</b>										
5.14	Min. spring index	$D_{min}/b$	8,17								
5.15	Max. spring index	$D_{max}/b$	12,25								
5.16	Diameter ratio	$D_{max}/D_{min}$	1,50								
5.17	Shift of coils	$dx$	0,0865	[in]							
5.18	Spring weight	$m$	7,229	[lb]							
5.19	Max. permissible loading	$F_{8,max}$	277,1	[lb]							
5.20	Level of safety		2,22								
5.21	<b>Work area with linear characteristic curve</b>										
5.22	Max. loading	$F_C$	675,0	[lb]							
5.23	Spring constant	$k_C$	100,00	[lb/							

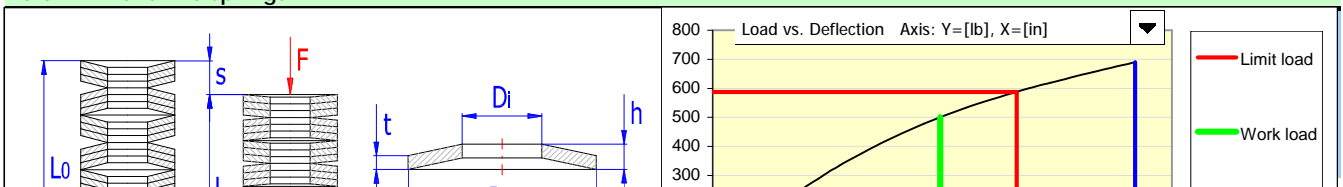
5.12 Optimization

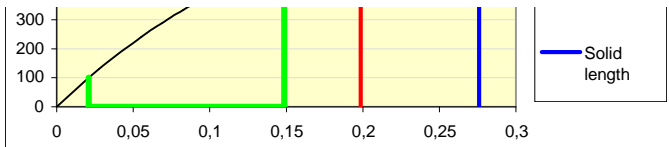
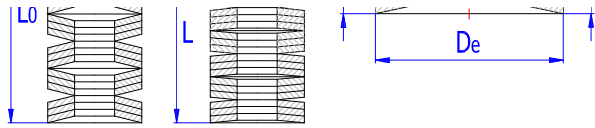
$D_{max}/min$	1,5
$D_{min}/b$	8
$b/h$	1:1

5.24 Design values

5.25	Design of spring ends	Closed ends ground			5.34	<b>Parameters of working cycle</b>				
5.26	Solid length	$L_s$	4,515	[in]		1	8	9		
5.27	Recommended limits of free spring length		7,015	22,329	[in]	$F_i$	50,0	250,0	554,2	[lb]
5.28	Free spring length	$L_0$	15,7300	<input checked="" type="checkbox"/>	[in]	$s_i$	0,5	2,5	5,5422	[in]
5.29	Recommended pitch limits		1,786	3,126	[in]	$L_i$	15,23	13,23	10,1878	[in]
5.30	Pitch between coils of free spring	$p$	1,785	[in]	$\tau_i$		8,57	42,85	95	[ksi]
5.31	Max. outer / min. inner spring diameter	$D_e/D_i$	5,796	3,135	[in]	$k_i$	100,00	100,00	100,00	[lb/
5.32	Developed wire length	$l$	147,48	[in]						
5.33	Spring deformation energy	$W_8$	26,04	[ft lb]						

6.0  Belleville springs





### 6.1 Spring design

6.2	Minimum working loading	F1	100,00	[lb]
6.3	Maximum working loading	F8	500,00	[lb]
6.4	Spring working stroke	H	0,1250	[in]
6.5	Max. permissible spring deflection	s8/s <sub>s</sub>	0,75	▼
6.6	No. of parallel discs in a set	n	1	
6.7	No. of sets (disc) in series in a stack	i	4	
6.8	Outside diameter	De	2,2500	[in]
6.9	Inside diameter	Di	0,7550	[in]
6.10	Material thickness	t	0,0680	[in]
6.11	Disc height	h	0,1370	[in]
6.12	Inside height of disc	h0	0,0690	[in]

### Pre-design

114
495
0,1279

### 6.13 Calculation

111,949424
494,52273
0,12767021

### Deviation

11,95%
-1,10%
2,14%

### 6.16 Check data

6.17	Diameter ratio	De/Di	2,98
6.18	Relative height of disc	h0/t	1,01
6.19	Maximum (full) spring deflection	s <sub>s</sub>	0,276 [in]
6.20	Relative spring deflection	s8/s <sub>s</sub>	0,54
6.21	Force of fully compressed spring	F <sub>s</sub>	689,3 [lb]
6.22	Maximum permissible loading	F <sub>8max</sub>	587,9 [lb]
6.23	Total weight of spring	m	0,272 [lb]

### 6.29 Strength check (static loading)

6.30	Permissible compressive stress	σ <sub>pA</sub>	285	✓
6.31	Max. compressive stress	σ <sub>p8</sub>	223,63	[ksi]
6.32	Max. tensile stress	σ <sub>T8</sub>	87,38	[ksi]
6.33	Recommended level of safety		1,00	
6.34	Level of safety		1,27	

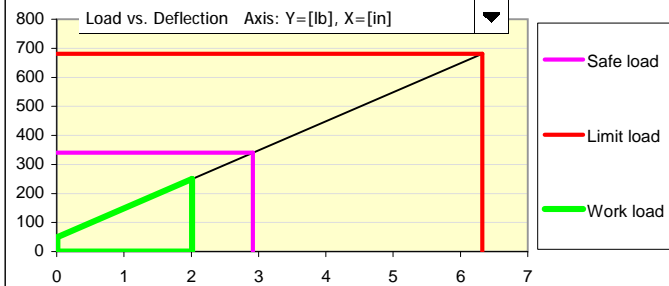
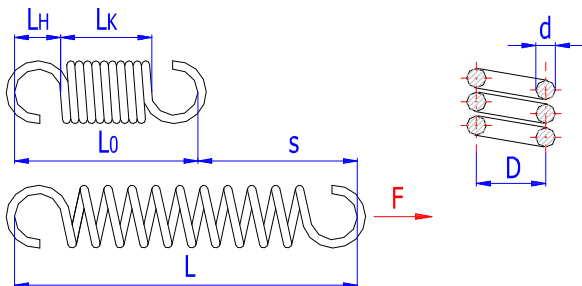
### 6.24 Design values

6.25	Total number of disc		4
6.26	Free spring length	L0	0,55 [in]
6.27	Length of fully compressed spring	Ls	0,27 [in]
6.28	Spring deformation energy	W8	3,561 [ft lb]

### 6.35 Parameters of working cycle

	1	8	9	
Force F <sub>i</sub>	100,0	500,0	587,9	[lb]
Deflection s <sub>i</sub>	0,0209	0,1486	0,1987	[in]
Length L <sub>i</sub>	0,5271	0,3994	0,3493	[in]
Stress σ <sub>pi</sub>	35,23	223,63	285	[ksi]
Spring rate k <sub>i</sub>	4507,11	2034,07	1514,39	[lb/in]

## 7.0 Helical cylindrical tension springs of round wires and bars



### 7.1 Spring type

Spring with initial tension ▼

### 7.2 Spring design

7.3	Initial tension	F0	49	[lb]
7.4	Minimum working loading	F1	50,00	[lb]
7.5	Maximum working loading	F8	250,00	[lb]
7.6	Spring working stroke	H	2,0000	[in]
7.7	Required spring constant	k	100,00	[lb/in]
7.8	Mean spring diameter	D	2,7000	[in]
7.9	Wire diameter	d	0,3750	[in]
7.10	Number of active coils	n	14,76	

### Calculation

50,0482101
249,95179
2,00048222
2,69978304
0,3750226
14,7564421

### Deviation

0,10%
-0,02%
0,02%
-0,02%
-0,01%
0,01%
-0,02%

### 7.11 Optimization

D/d	7,2
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### 7.12 Check data

7.13	Spring index	D/d	7,20
7.14	Spring constant	k	99,98 [lb/in]
7.15	Spring weight (without hooks)	m	3,994 [lb]

7.16	Max. permissible loading	F <sub>8max</sub>	340,7	[lb]
7.17	Max. permissible stroke	H <sub>max</sub>	2,907	[in]
7.18	Level of safety		2,73	

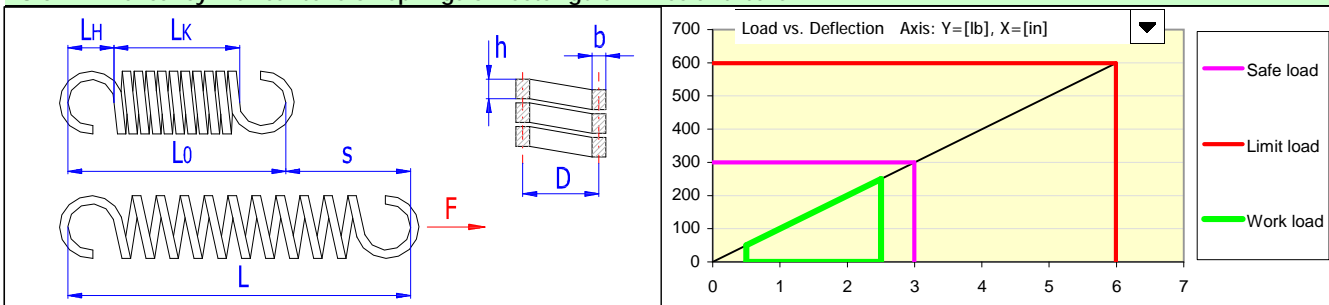
### 7.19 Design values

7.20	Design of spring ends	Full loop	
7.21	Recommended height of spring hook	1,86	2,558 [in]
7.22	Height of spring hook	$L_H$	2,3250 [in] <input checked="" type="checkbox"/>
7.23	Recommended limits of initial stress	10,56	21,11 [ksi]
7.24	Initial stress	$\tau_0$	6,83 [ksi] <input checked="" type="checkbox"/>
7.25	Free spring length	$L_0$	10,5600 [in]
7.26	Length of active spring section	$L_K$	5,91 [in]
7.27	Pitch between coils of free spring	$p$	0,375 [in]
7.28	Outer / inner spring diameter	$D_e/D_i$	3,075   2,325 [in]
7.29	Developed wire length (without hooks)	$l$	127,53 [in]
7.30	Spring deformation energy	W8	25,05 [ft lb]

### 7.31 Parameters of working cycle

	1	8	9	
$F_i$	50,0	250,0	681,3	[lb]
$s_i$	0,01	2,0105	6,3248	[in]
$L_i$	10,57	12,5705	16,8848	[in]
$\tau_i$	6,97	34,86	95	[ksi]

## 8.0 Helical cylindrical tension springs of rectangular wires and bars



### 8.1 Spring design

8.2	Minimum working loading	F1	50,00 [lb]
8.3	Maximum working loading	F8	250,00 [lb]
8.4	Spring working stroke	H	2,0000 [in]
8.5	Required spring constant	k	100,00 [lb/in]
8.6	Mean spring diameter	D	3,0000 [in]
8.7	Wire width	b	0,3750 [in]
8.8	Wire height	h	0,3750 [in]
8.9	Number of active coils	n	15,41

### Calculation

50,0497416
249,950258
2,00049754
2,99975127
≈ 0,375
≈ 0,375
15,4061674

### Deviation

0,10%
-0,02%
0,02%
-0,02%
-0,01%
0,01%
0,01%
-0,02%

### 8.10 Optimization

b/h	1:1	D/b	8
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### 8.11 Check data

8.12	Spring index	D/b	8,00
8.13	Spring constant	k	99,98 [lb/in]
8.14	Spring weight (without hooks)	m	5,899 [lb]

8.15	Max. permissible loading	$F_{8,max}$	299,4 [lb]
8.16	Max. permissible stroke	$H_{max}$	2,495 [in]
8.17	Level of safety		2,40

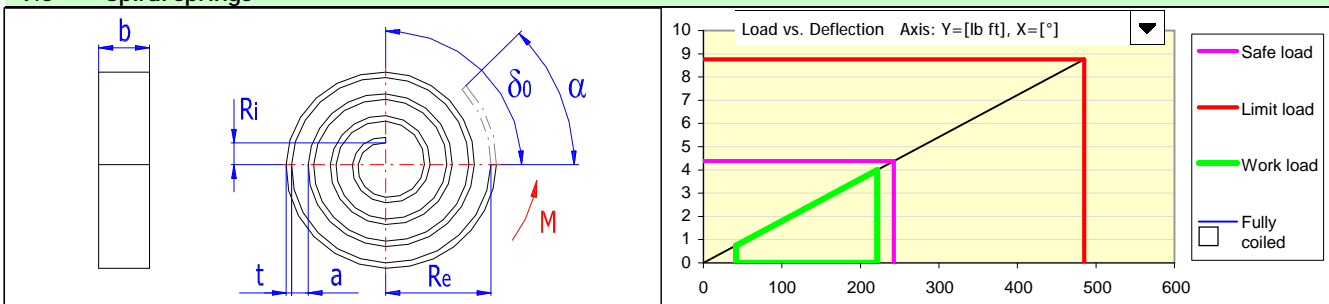
### 8.18 Design values

8.19	Design of spring ends	Other	
8.20	Recommended height of spring hook		[in]
8.21	Height of spring hook	$L_H$	3,0000 [in] <input type="checkbox"/>
8.22	Recommended limits of free spring length	12,461	24,867 [in]
8.23	Free spring length	$L_0$	15,6200 [in] <input checked="" type="checkbox"/>
8.24	Length of active spring section	$L_K$	9,62 [in]
8.25	Pitch between coils of free spring	$p$	0,5999 [in]
8.26	Outer / inner spring diameter	$D_e/D_i$	3,375   2,625 [in]
8.27	Developed wire length (without hooks)	$l$	147,94 [in]
8.28	Spring deformation energy	W8	26,05 [ft lb]

### 8.29 Parameters of working cycle

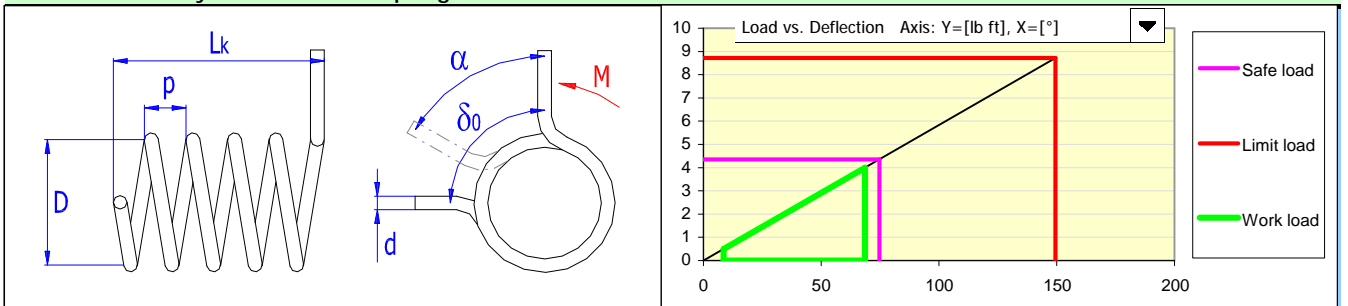
	1	8	9	
$F_i$	50,0	250,0	598,9	[lb]
$s_i$	0,5001	2,5006	5,9902	[in]
$L_i$	16,1201	18,1206	21,6102	[in]
$\tau_i$	7,93	39,66	95	[ksi]

## 9.0 Spiral springs



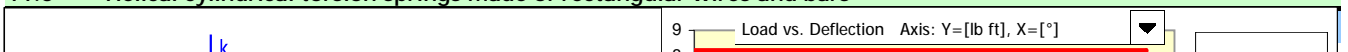
9.1 Spring design				Calculation		Deviation	
9.2	Minimum working loading	M1	0,750 [lb ft]	0,74920635	-0,11%		
9.3	Maximum working loading	M8	4,000 [lb ft]	4,00079365	0,02%		
9.4	Spring working stroke	$\alpha_H$	180,0 [°]	179,956055	-0,02%		
9.5	Required spring constant	k	0,2167 [lb in/°]		0,02%	9.11 Optimization	
9.6	Outer radius	Re	2,0000 [in]	2,0006105	0,03%	b/t	10
9.7	Inner radius	Ri	0,5000 [in]	0,5006105	0,12%	Ri/t	7
9.8	Width of spring strip	b	0,8000 [in]	0,79980469	-0,02%	a0/t	1
9.9	Thickness of spring strip	t	0,0800 [in]	0,07999349	-0,01%		
9.10	Number of active coils	n0	10,15	10,1524786	0,02%		
9.12 Check data							
9.13	Space between coils of free spring	a0	0,0678	9.16 Max. permissible loading	M8 <sub>max</sub>	4,379	[lb]
9.14	Torque spring rate	k	0,2167 [lb in/°]	9.17 Max. permissible stroke	$\alpha_{Hmax}$	200,9	[°]
9.15	Spring weight	m	1,447 [lb]	9.18 Level of safety		2,19	
9.19 Design values				9.26 Parameters of working cycle			
9.20	Leg angle of free spring	$\delta_0$	306,0 [°]	Moment $M_i$	1	8	9
9.21	Angular deflection of fully coiled spring	$\alpha_s$	890,9 [°]	No. of coils $n_i$	10,27	10,77	11,50
9.22	Number of coils of fully coiled spring	$n_s$	12,62	Deflection $\alpha_i$	41,5	221,5	484,9
9.23	Developed spring length	L	79,72 [in]	Leg angle $\delta_i$	264,5	84,5	-
9.24	Space between coils of fully loaded spring	a8	0,0461 [in]	Stress $\sigma_i$	11,39	60,75	133
9.25	Spring deformation energy	W8	7,73 [ft lb]				

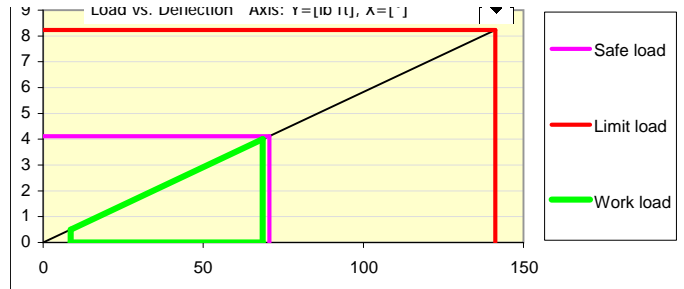
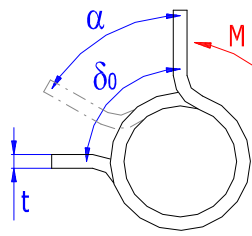
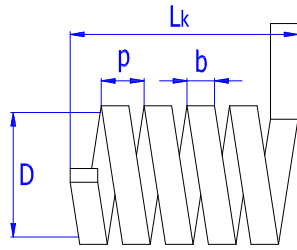
10.0  Helical cylindrical torsion springs made of round wires a bars



10.1 Spring design				Calculation		Deviation	
10.2	Minimum working loading	M1	0,500 [lb ft]	0,50106903	0,21%		
10.3	Maximum working loading	M8	4,000 [lb ft]	3,99893097	-0,03%		
10.4	Spring working stroke	$\alpha_H$	60,0 [°]	60,0183319	0,03%		
10.5	Required spring constant	k	0,7 [lb in/°]		-0,03%	10.9 Optimization	
10.6	Mean spring diameter	D	1,6560 [in]	1,6554942	-0,03%	D/d	8
10.7	Wire diameter	d	0,2070 [in]	0,20701581	0,01%		
10.8	Number of active coils	n	12,53	12,5261729	-0,03%		
10.10 Check data							
10.11	Spring index	D/d	8,00	10.14 Max. permissible loading	M8 <sub>max</sub>	4,359	[lb]
10.12	Torque spring rate	k	0,6998 [lb in/°]	10.15 Max. permissible stroke	$\alpha_{Hmax}$	66,2	[°]
10.13	Spring weight (without legs)	m	0,634 [lb]	10.16 Level of safety		2,18	
10.17 Design values				10.27 Parameters of working cycle			
10.18	Design of spring ends	Radial legs		Moment $M_i$	1	8	9
10.19	Leg angle of free spring	$\delta_0$	169,2 [°]	No. of coils $n_i$	0,500	4,000	8,717
10.20	Recommended limits of spring length		2,941   7,988 [in]	Deflection $\alpha_i$	8,6	68,6	149,5
10.21	Length of coiled section	$L_K$	2,9400 [in]	Leg angle $\delta_i$	160,6	100,6	-
10.22	Pitch between coils of free spring	p	0,2181 [in]	Stress $\sigma_i$	7,63	61,03	133
10.23	Outer / inner spring diameter	$D_e/D_i$	1,863   1,449 [in]				
10.24	Developed wire length (without legs)	l	66,4 [in]				
10.25	Dimensions of fully loaded spring	$L_K/8/D_i/8$	2,94   1,424 [in]				
10.26	Spring deformation energy	W8	2,39 [ft lb]				

11.0  Helical cylindrical torsion springs made of rectangular wires and bars





### 11.1 Spring design

			Calculation	Deviation	
11.2	Minimum working loading	M1	0,500 [lb ft]	0,50105258	0,21%
11.3	Maximum working loading	M8	4,000 [lb ft]	3,99894742	-0,03%
11.4	Spring working stroke	$\alpha_H$	60,0 [°]	60,0180496	0,03%
11.5	Required spring constant	k	0,7 [lb in/°]		-0,03%
11.6	Mean spring diameter	D	1,0000 [in]	0,99969926	-0,03%
11.7	Wire width	b	0,3125 [in]	0,31259401	0,03%
11.8	Wire thickness	t	0,1250 [in]	0,12501253	0,01%
11.9	Number of active coils	n	11,71	11,7064784	-0,03%

### 11.10 Optimization

D/t	8	b/t	2,5
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### 11.11 Check data

11.12	Spring index	D/t	8,00	11.15	Max. permissible loading	M8 <sub>max</sub>	4,118	[lb ft]
11.13	Torque spring rate	k	0,6998 [lb in/°]	11.16	Max. permissible stroke	$\alpha_{Hmax}$	62	[°]
11.14	Spring weight (without legs)	m	0,415 [lb]	11.17	Level of safety		2,06	

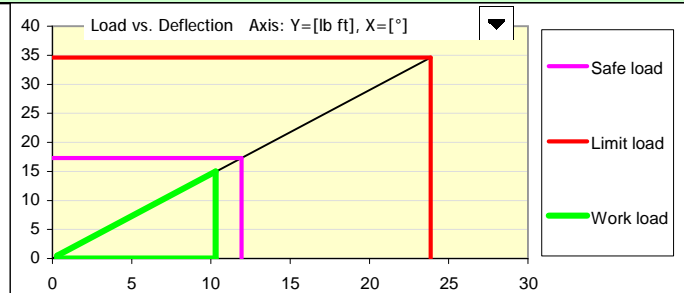
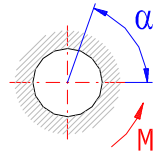
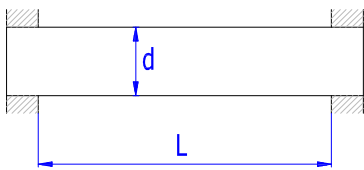
### 11.18 Design values

11.19	Design of spring ends	Radial legs			
11.20	Leg angle of free spring	$\delta_0$	104,4 [°]		
11.21	Recommended limits of spring length		4,17   6,168 [in]		
11.22	Length of coiled section	L <sub>k</sub>	4,1700 [in]	<input checked="" type="checkbox"/>	
11.23	Pitch between coils of free spring	p	0,3294 [in]		
11.24	Outer / inner spring diameter	D <sub>e</sub> /D <sub>i</sub>	1,125   0,875 [in]		
11.25	Developed wire length (without legs)	l	37,47 [in]		
11.26	Dimensions of fully loaded spring	L <sub>k8</sub> /D <sub>i8</sub>	4,17   0,859 [in]		
11.27	Spring deformation energy	W8	2,39 [ft lb]		

### 11.28 Parameters of working cycle

	1	8	9	
M <sub>i</sub>	0,500	4,000	8,235	[lb ft]
$\alpha_i$	8,6	68,6	141,2	[°]
$\delta_i$	95,8	35,8	-	[°]
$\sigma_i$	8,07	64,6	133	[ksi]

## 12.0 Torsion bar springs with round section



### 12.1 Spring design

			Calculation	Deviation	
12.2	Minimum working loading	M1	0,500 [lb ft]	0,49998582	0,00%
12.3	Maximum working loading	M8	15,000 [lb ft]	15,0000142	0,00%
12.4	Spring working stroke	$\alpha_H$	10,0 [°]	9,99999022	0,00%
12.5	Required spring constant	k	17,4 [lb in/°]		0,00%
12.6	Functional spring length	L	7,2451 [in]	7,24510709	0,00%
12.7	Bar diameter	d	0,2813 [in]	0,28129993	0,00%

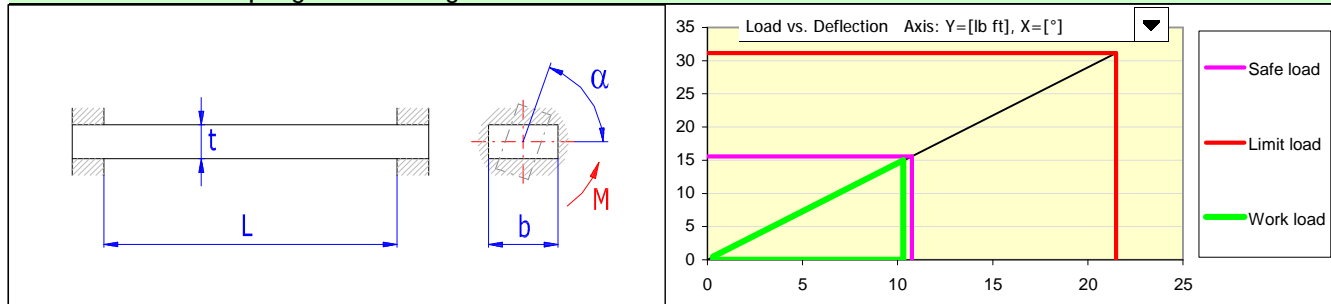
### 12.8 Optimization

### 12.9 Check data

12.10	Torque spring rate	k	17,4 [lb in/°]	12.16	Parameters of working cycle				
12.11	Spring weight	m	0,128 [lb]			1	8	9	
12.12	Spring deformation energy	W8	1,35 [ft lb]	Moment	M <sub>i</sub>	0,500	15,000	34,600	[lb ft]
12.13	Max. permissible loading	M8 <sub>max</sub>	17,300 [lb ft]	Deflection	$\alpha_i$	0,3	10,3	23,9	[°]
12.14	Max. permissible stroke	$\alpha_{Hmax}$	11,6 [°]	Stress	$\tau_i$	1,37	41,18	95	[ksi]

12.15 Level of safety 2,31

13.0  Torsion bar springs with rectangular section



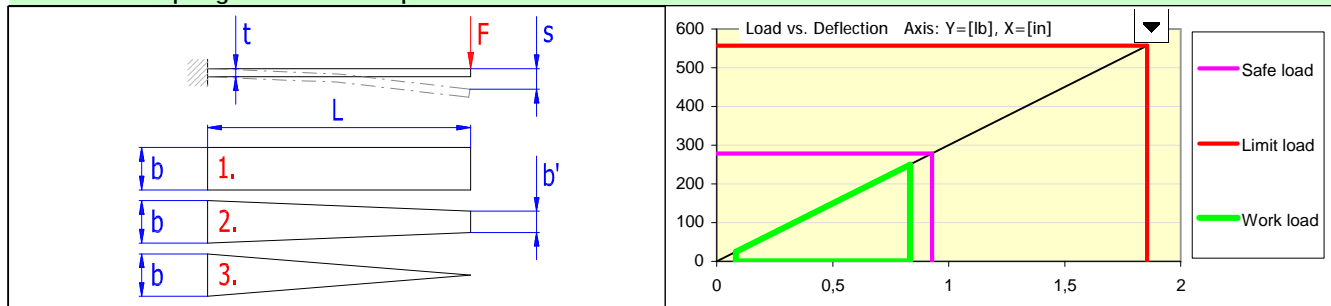
13.1 Spring design		Calculation		Deviation	
13.2	Minimum working loading	M1	0,500 [lb ft]	0,4999284	-0,01%
13.3	Maximum working loading	M8	15,000 [lb ft]	15,0000716	0,00%
13.4	Spring working stroke	$\alpha_H$	10,0 [°]	9,99995062	0,00%
13.5	Required spring constant	k	17,4 [lb in/°]		0,00%
13.6	Functional spring length	L	7,7667 [in]	7,76673835	0,00%
13.7	Bar width	b	0,5100 [in]	≈ 0,51	0,00%
13.8	Bar thickness	t	0,1700 [in]	≈ 0,17	0,00%

13.9 Optimization b/t 3

13.10 Check data		13.17 Parameters of working cycle	
13.11	Torque spring rate	k	17,4001 [lb in/°]
13.12	Spring weight	m	0,191 [lb]
13.13	Spring deformation energy	W8	1,35 [ft lb]
13.14	Max. permissible loading	M8 <sub>max</sub>	15,577 [lb ft]
13.15	Max. permissible stroke	$\alpha_{Hmax}$	10,4 [°]
13.16	Level of safety		2,08

	1	8	9	
Moment $M_i$	0,500	15,000	31,155	[lb ft]
Deflection $\alpha_i$	0,3	10,3	21,5	[°]
Stress $\tau_i$	1,52	45,74	95	[ksi]

14.0  Leaf springs with constant profile



14.1 Spring type		Cantilever spring	
14.2	Shape of spring leaf	1. Rectangular	

14.3 Spring design		Calculation		Deviation	
14.4	Minimum working loading	F1	25,00 [lb]	25,0010755	0,00%
14.5	Maximum working loading	F8	250,00 [lb]	249,998924	0,00%
14.6	Spring working stroke	H	0,7500 [in]	0,75000359	0,00%
14.7	Required spring constant	k	300,00 [lb/in]		0,00%
14.8	Functional spring length	L	17,4203 [in]	17,4202722	0,00%
14.9	Width of spring leaf	b	1,7500 [in]	1,75000837	0,00%
14.10	Leaf width at end of spring	b'	1,7500 [in]	1,75000837	0,00%
14.11	Thickness of spring leaf	t	0,5000 [in]	0,50000008	0,00%

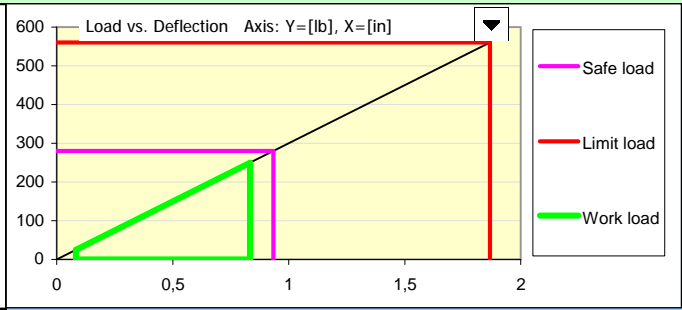
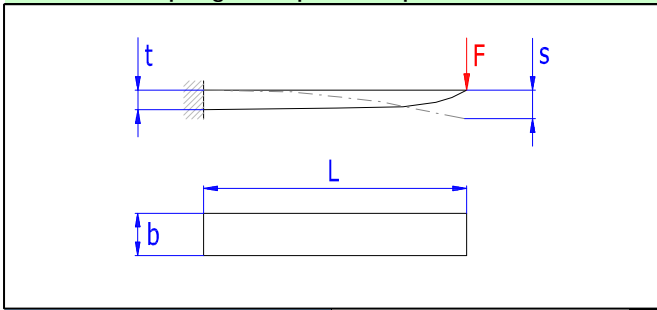
14.12 Optimization b'/b 1 L/b 10

14.13 Check data		14.20 Parameters of working cycle	
14.14	Spring constant	k	300,00 [lb/in]
14.15	Spring weight	m	4,322 [lb]
14.16	Spring deformation energy	W8	8,68 [ft lb]
14.17	Max. permissible loading	F8 <sub>max</sub>	278,4 [lb]
14.18	Max. permissible stroke	H <sub>max</sub>	0,845 [in]
14.19	Level of safety		2,23

	1	8	9	
Force $F_i$	25,0	250,0	556,7	[lb]
Deflection $s_i$	0,0833	0,8333	1,8557	[in]
Stress $\sigma_i$	5,97	59,73	133	[ksi]



15.0  Leaf springs with parabolic profile



15.1 Spring type Cantilever spring

Parabolic profile with thickened leaf

15.2 Spring design

Parameter	Symbol	Value	Unit
15.3 Minimum working loading	F1	25,00	[lb]
15.4 Maximum working loading	F8	250,00	[lb]
15.5 Spring working stroke	H	0,7500	[in]
15.6 Required spring constant	k	300,00	[lb/in]
15.7 Functional spring length	L	12,3595	[in]
15.8 Length of leaf with constant thickness	L'	0,0000	[in]
15.9 Width of spring leaf	b	1,2500	[in]
15.10 Thickness of spring leaf	t	0,5000	[in]
15.11 Leaf thickness at end of spring	t'	0,0000	[in]

Parameter	Calculation	Deviation
F1	24,997888	-0,01%
F8	250,002112	0,00%
H	0,74999296	0,00%
k	300,00	0,00%
L	12,3595387	0,00%
L'	0	0,00%
b	1,24998827	0,00%
t	0,49999844	0,00%
t'	0	0,00%

15.12 Optimization L/b 10

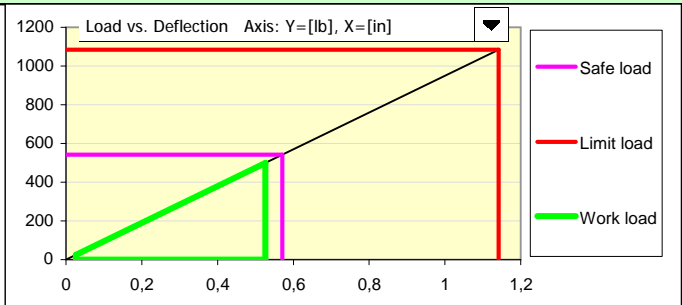
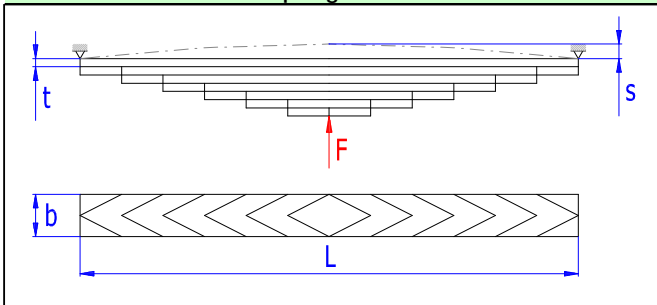
15.13 Check data

15.14 Spring constant	k	300,00	[lb/in]
15.15 Spring weight	m	1,460	[lb]
15.16 Spring deformation energy	W8	8,68	[ft lb]
15.17 Max. permissible loading	F8 <sub>max</sub>	280,2	[lb]
15.18 Max. permissible stroke	H <sub>max</sub>	0,851	[in]
15.19 Level of safety		2,24	

15.20 Parameters of working cycle

	1	8	9	
Force F <sub>i</sub>	25,0	250,0	560,5	[lb]
Deflection s <sub>i</sub>	0,0833	0,8333	1,8682	[in]
Stress σ <sub>i</sub>	5,93	59,33	133	[ksi]

16.0  Laminated leaf springs



16.1 Shape of spring leaf Triangular

16.2 Spring design

Parameter	Symbol	Value	Unit
16.3 Minimum working loading	F1	25,00	[lb]
16.4 Maximum working loading	F8	500,00	[lb]
16.5 Spring working stroke	H	0,5000	[in]
16.6 Required spring constant	k	950,00	[lb/in]
16.7 Number of extra full-length leaves	n'	0	
16.8 Total number of spring leaves	n	5	[in]
16.9 Functional spring length	L	12,4777	[in]
16.10 Width of spring leaf	b	1,2500	[in]
16.11 Thickness of spring leaf	t	0,1563	[in]

Parameter	Calculation	Deviation
F1	25,0038749	0,02%
F8	499,996125	0,00%
H	0,50000408	0,00%
k	950,00	0,00%
n	5,00	0,00%
L	12,4776661	0,00%
b	1,2500102	0,00%
t	0,15630043	0,00%

16.12 Optimization n 5 L/b 10

16.13 Check data

16.14 Spring constant	k	949,99	[lb/in]
16.15 Spring weight	m	1,728	[lb]
16.16 Spring deformation energy	W8	10,96	[ft lb]
16.17 Max. permissible loading	F8 <sub>max</sub>	542,5	[lb]

16.20 Parameters of working cycle

	1	8	9	
Force F <sub>i</sub>	25,0	500,0	1085,0	[lb]
Deflection s <sub>i</sub>	0,0263	0,5263	1,1421	[in]
Stress σ <sub>i</sub>	3,06	61,29	133	[ksi]

16.18	Max. permissible stroke	$H_{\max}$	0,545	[in]
16.19	Level of safety		2,17	
17.0	<input type="checkbox"/> Check of loading capacity of a spring exposed to fatigue loading			