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Disc springs — Quality specifications — Dimensions

National foreword

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European foreword

This document (EN 16983:2016) has been prepared by Technical Committee CEN/TC 407 “Cylindrical helical springs made from round wire and bar - Calculation and design”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2017, and conflicting national standards shall be withdrawn at the latest by May 2017.

This European Standard has been prepared by the initiative of the Association of the European Spring Federation ESF and is based on the German Standard DIN 2093 “Disc springs – Quality specifications – Dimensions”, which is known and used in many European countries.

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1 Scope

This standard specifies the set of requirements that ensure the correct functioning of disc spring. These include requirements relating to the materials and manufacturing process, tolerances on dimensions and spring forces, and also the permissible relaxation and fatigue life of such springs as a function of stress.

All requirements specified here are minimum requirements.

This standard covers three dimensional series of disc springs.

NOTE In this standard, disc springs are divided into three groups and three dimensional series. Classification into groups is based on the manufacturing process, which is a function of the material thickness. The assignment of disc springs to dimensional series is governed by the h_0 / t ratio.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1654, *Copper and copper alloys - Strip for springs and connectors*

EN 10083 (all parts), *Steels for quenching and tempering*

EN 10089, *Hot-rolled steels for quenched and tempered springs - Technical delivery conditions*

EN 10132-4, *Cold rolled narrow steel strip for heat treatment - Technical delivery conditions - Part 4: Spring steels and other applications*

EN 10151, *Stainless steel strip for springs - Technical delivery conditions*

EN ISO 3269, *Fasteners - Acceptance inspection (ISO 3269)*

EN ISO 6507 (all parts), *Metallic materials - Vickers hardness test (ISO 6507)*

EN ISO 6508 (all parts), *Metallic materials - Rockwell hardness test (ISO 6508)*

3 Terms, definitions, symbols, units and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definition given in EN ISO 26909 apply.

NOTE Disc springs are annular coned elements that offer resistance to a compressive load applied axially. They may be designed as single disc springs or as disc springs stacked in parallel or in series, either singly or in multiples. They may be subjected to both static and fatigue loading, and may have flat bearings.

3.2 Symbols, units and abbreviated terms

For the purposes of this document, the following symbols, units and abbreviated terms apply.

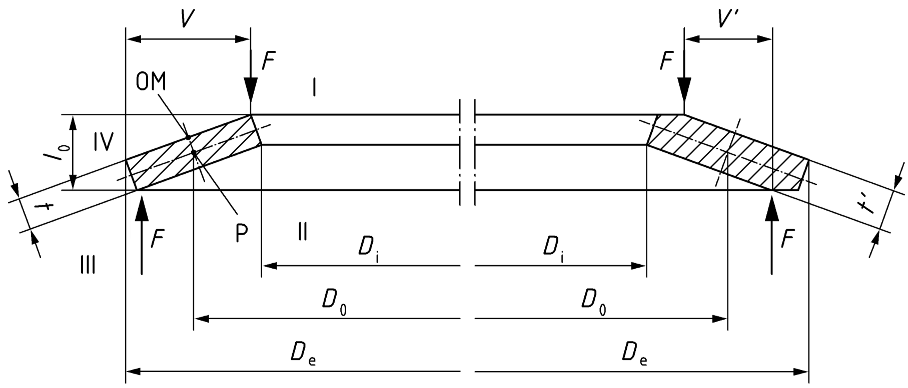
Table 1 — Symbols, units and abbreviated terms

Symbol	Unit	Description
D_e	mm	Outer diameter of spring
D_i	mm	Inner diameter of spring
D_0	mm	Diameter of centre of rotation
E	MPa	Modulus of elasticity
F	N	Spring load
F_c	N	Design spring load when spring is in the flattened position
F_t	N	Test load for length L_t or l_t
ΔF	N	Relaxation
L_0	mm	Length of springs stacked in series or in parallel, in the initial position
L_c	mm	Design length of springs stacked in series or in parallel, in the flattened position
N		Number of cycles to failure
R	N/mm	Spring rate
W	N mm	Energy capacity of spring
h_0	mm	Initial cone height of springs without flat bearings, $h_0 = l_0 - t$
h'_0	mm	Initial cone height of springs with flat bearings, $h'_0 = l_0 - t'$
i		Number of disc springs or packets stacked in series
l_0	mm	Free overall height of spring in its initial position
l_t	mm	Test length of disc spring, $l_t = l_0 - 0{,}75\ h_0$
s	mm	Deflection of single disc spring
s_1, s_2, s_3 ...	mm	Spring deflections related to spring loads F_1, F_2, F_3...
t	mm	Thickness of single disc spring
t'	mm	Reduced thickness of single disc spring with flat bearings (group 3)
μ		Poisson's ratio
σ	MPa	Design stress
$\sigma_{II}, \sigma_{III}, \sigma_{OM}$	MPa	Design stresses at the points designated II, III, OM (see Figure 1)
σ_h	MPa	Fatigue stress related to the deflection of springs subject to fatigue loading
σ_O	MPa	Maximum fatigue stress
σ_U	MPa	Minimum fatigue stress
$\sigma_H = \sigma_O - \sigma_U$	MPa	Permanent range of fatigue stress
P		Theoretical centre of rotation of disc spring cross section (see Figure 1)
V, V'		Lever arms

Symbol	Unit	Description
R_a		Mean surface roughness

4 Dimensions and designation

4.1 General



a) without flat bearings: Group 1, Group 2

b) with flat bearings: Group 3

Figure 1 — Single disc spring of group 1, 2 or 3 (sectional view), including the relevant points of loading

Designation of a disc spring of dimensional series A with an outer diameter, D_e of 40 mm:

Disc spring EN 16983 — A 40

4.2 Disc spring groups

Table 2 — Disc spring groups

Group	*t*	With flat bearings and reduced thickness
1	< 1,25	No
2	1,25 ≤ *t* ≤ 6	No
3	6 < *t* ≤ 14	Yes

4.3 Dimensional series

Table 3 — Dimensional series

series	h_0/t
A	approximately 0,40
B	approximately 0,75
C	~1,30

5 Spring material

Springs complying with this standard shall be made from steel as specified in the EN 10083 series, EN 10089 or EN 10132-4. Carbon steel shall only be used for the manufacture of Group 1 springs (see also Table 7).

The design of disc springs made from steel as above shall be based on a modulus of elasticity, E, of 206 000 MPa.

The modulus of elasticity and strength property of other materials (e.g. stainless steel for springs in accordance with EN 10151, copper alloys (spring bronze) in accordance with EN 1654) will likely be different. The values given for F and σ in Tables 4 to 6 then cease to apply. In such cases, it is recommended to consult the spring manufacturer.

6 Spring dimensions, nominal sizes, design values

6.1 Dimensional series A

Table 4 — Disc springs with $\frac{D_e}{t} \approx 18$; $\frac{h_0}{t} \approx 0,4$; E = 206 000 MPa; μ = 0,3

Group	D_e	D_i	t or (t')[a]	h_0	l_0	F_t	l_t	σIII[b]	σ_{OM}
	h12	H12				s approximately 0,75 h_0			$s = h_0$
1	**8**	4,2	0,4	0,2	0,6	210	0,45	1 218	−1 605
	10	5,2	0,5	0,25	0,75	325	0,56	1 218	−1 595
	12,5	6,2	0,7	0,3	1	660	0,77	1 382	−1 666
	14	7,2	0,8	0,3	1,1	797	0,87	1 308	−1 551
	16	8,2	0,9	0,35	1,25	1 013	0,99	1 301	−1 555
	18	9,2	1	0,4	1,4	1 254	1,1	1 295	−1 558
	20	10,2	1,1	0,45	1,55	1 521	1,21	1 290	−1 560
2	**22,5**	11,2	1,25	0,5	1,75	1 929	1,37	1 296	−1 534
	25	12,2	1,5	0,55	2,05	2 926	1,64	1091	−1 622
	28	14,2	1,5	0,65	2,15	2 841	1,66	1 274	−1 562
	31,5	16,3	1,75	0,7	2,45	3 871	1,92	1 296	−1 570
	35,5	18,3	2	0,8	2,8	5 187	2,2	1 332	−1 611
	40	20,4	2,25	0,9	3,15	6 500	2,47	1 328	−1 595
	45	22,4	2,5	1	3,5	7 716	2,75	1 296	−1 534
	50	25,4	3	1,1	4,1	11 976	3,27	1 418	−1 659
	56	28,5	3	1,3	4,3	11 388	3,32	1 274	−1 565

Group	D_e	D_i	t or (t')[a]	h_0	l_0	F_t	l_t	σ_{III}[b]	σ_{OM}
	h12	H12				s approximately 0,75 h_0			$s = h_0$
	63	31	3,5	1,4	4,9	15 025	3,85	1 296	−1 524
	71	36	4	1,6	5,6	20 535	4,4	1 332	−1 594
	80	41	5	1,7	6,7	33 559	5,42	1 453	−1 679
	90	46	5	2	7	31 354	5,5	1 295	−1 558
	100	51	6	2,2	8,2	48 022	6,55	1 418	−1 663
	112	57	6	2,5	8,5	43 707	6,62	1 239	−1 505
3	**125**	64	8 (7,5)	2,6	10,6	85 926	8,65	1 326	−1 708
	140	72	8 (7,5)	3,2	11,2	85 251	8,8	1 284[c]	−1 675
	160	82	10 (9,4)	3,5	13,5	138 331	10,87	1 338	−1 753
	180	92	10 (9,4)	4	14	125 417	11	1 201[c]	−1 576
	200	102	12 (11,25)	4,2	16,2	183 020	13,05	1 227	−1 611
	225	112	12 (11,25)	5	17	171 016	13,25	1 137[c]	−1 489
	250	127	14 (13,1)	5,6	19,6	248 828	15,4	1 221[c]	−1 596

[a] The values specified for t are nominal values. In the case of springs with flat bearings (cf. Group 3 in Clause 4), the desired spring load, F (where s approximately 0,75 h_0), is to be obtained by reducing the thickness of single disc springs, t, which then gives the value t'. In the case of dimensional series A and B, t' approximately 0,94 × t, and in the case of dimensional series C, t' approximately 0,96 × t.

[b] The values specified apply for the largest calculated tensile stress on the lower edges of the spring.

[c] The values specified apply for the largest calculated tensile stress at the point designated III.

6.2 Dimensional series B

Table 5 — Disc springs with $\frac{D_e}{t} \approx 28$; $\frac{h_0}{t} \approx 0{,}75$; E = 206 000 MPa; μ = 0,3

Group	D_e	D_i	t or (t')[a]	h_0	l_0	F_t	l_t	σ_{III}	σ_{OM}
	h12	H12				s approximately 0,75 h_0			$s = h_0$
	8	4,2	0,3	0,25	0,55	118	0,36	1 312	−1 505
	10	5,2	0,4	0,3	0,7	209	0,47	1 281	−1 531
	12,5	6,2	0,5	0,35	0,85	294	0,59	1 114	−1 388
	14	7,2	0,5	0,4	0,9	279	0,6	1 101	−1 293
	16	8,2	0,6	0,45	1,05	410	0,71	1 109	−1 333
1									
	18	9,2	0,7	0,5	1,2	566	0,82	1 114	−1 363
	20	10,2	0,8	0,55	1,35	748	0,94	1 118	−1 386
	22,5	11,2	0,8	0,65	1,45	707	0,96	1 079	−1 276
	25	12,2	0,9	0,7	1,6	862	1,07	1 023	−1 238
	28	14,2	1	0,8	1,8	1 107	1,2	1 086	−1 282
	31,5	16,3	1,25	0,9	2,15	1 913	1,47	1 187	−1 442
2	**35,5**	18,3	1,25	1	2,25	1 699	1,5	1 073	−1 258
	40	20,4	1,5	1,15	2,65	2 622	1,79	1 136	−1 359
	45	22,4	1,75	1,3	3,05	3 646	2,07	1 144	−1 396

Group	D_e h12	D_i H12	t or (t')[a]	h_0	l_0	F_t	l_t	σ_{III}	σ_{OM}
						s approximately 0,75 h_0			$s = h_0$
	50	25,4	2	1,4	3,4	4 762	2,35	1 140	−1 408
	56	28,5	2	1,6	3,6	4 438	2,4	1 092	−1 284
	63	31	2,5	1,75	4,25	7 189	2,94	1 088	−1 360
	71	36	2,5	2	4,5	6 725	3	1 055	−1 246
	80	41	3	2,3	5,3	10 518	3,57	1 142	−1 363
	90	46	3,5	2,5	6	14 161	4,12	1 114	−1 363
	100	51	3,5	2,8	6,3	13 070	4,2	1 049	−1 235
	112	57	4	3,2	7,2	17 752	4,8	1 090	−1 284
	125	64	5	3,5	8,5	29 908	5,87	1 149	−1 415
	140	72	5	4	9	27 920	6	1 101	−1 293
	160	82	6	4,5	10,5	41 008	7,12	1 109	−1 333
	180	92	6	5,1	11,1	37 502	7,27	1 035	−1 192
3	**200**	102	8 (7,5)	5,6	13,6	76 378	9,4	1 254	−1 409
	225	112	8 (7,5)	6,5	14,5	70 749	9,62	1 176	−1 267
	250	127	10 (9,4)	7	17	119 050	11,75	1 244	−1 406

[a] The values specified for t are nominal values. In the case of disc springs with flat bearings (cf. Group 3 in Clause 4), the desired spring load, F (where s approximately 0,75 h_0), is to be obtained by reducing the thickness of single disc springs, t, which then gives the value t'. In the case of dimensional series A and B, t' approximately 0,94 × t, and in the case of dimensional series C, t' approximately 0,96 × t.

6.3 Dimensional series C

Table 6 — Disc springs with $\frac{D_e}{t} \approx 40$; $\frac{h_0}{t} \approx 1,3$; E = 206 000 MPa; μ = 0,3

Group	D_e h12	D_i H12	t or (t')[a]	h_0	l_0	F_t	l_t	σ_{III}	σ_{OM}
						s approximately 0,75 h_0			$s = h_0$
	8	4,2	0,2	0,25	0,45	39	0,26	1 034	−1 003
	10	5,2	0,25	0,3	0,55	58	0,32	965	− 957
	12,5	6,2	0,35	0,45	0,8	151	0,46	1 278	−1 250
	14	7,2	0,35	0,45	0,8	123	0,46	1 055	−1 018
	16	8,2	0,4	0,5	0,9	154	0,52	1 009	− 988
	18	9,2	0,45	0,6	1,05	214	0,6	1 106	−1 052
1									
	20	10,2	0,5	0,65	1,15	254	0,66	1 063	−1 024
	22,5	11,2	0,6	0,8	1,4	426	0,8	1 227	−1 178
	25	12,2	0,7	0,9	1,6	600	0,92	1 259	−1 238
	28	14,2	0,8	1	1,8	801	1,05	1 304	−1 282
	31,5	16,3	0,8	1,05	1,85	687	1,06	1 130	−1 077
	35,5	18,3	0,9	1,15	2,05	832	1,19	1 078	−1 042

Group	D_e	D_i	t or (t')[a]	h_0	l_0	F_t	l_t	σ_{III}	σ_{OM}
	h12	H12				s approximately 0,75 h_0			$s = h_0$
	40	20,4	1	1,3	2,3	1 017	1,32	1 063	−1 024
2	**45**	22,4	1,25	1,6	2,85	1 891	1,65	1 253	−1 227
	50	25,4	1,25	1,6	2,85	1 550	1,65	1 035	−1 006
	56	28,5	1,5	1,95	3,45	2 622	1,99	1 218	−1 174
	63	31	1,8	2,35	4,15	4 238	2,39	1 351	−1 315
	71	36	2	2,6	4,6	5 144	2,65	1 342	−1 295
	80	41	2,25	2,95	5,2	6 613	2,99	1 370	−1 311
	90	46	2,5	3,2	5,7	7 684	3,3	1 286	−1 246
	100	51	2,7	3,5	6,2	8 609	3,57	1 235	−1 191
	112	57	3	3,9	6,9	10 489	3,97	1 218	−1 174
	125	64	3,5	4,5	8	15 416	4,62	1 318	−1 273
	140	72	3,8	4,9	8,7	17 195	5,02	1 249	−1 203
	160	82	4,3	5,6	9,9	21 843	5,7	1 238	−1 189
	180	92	4,8	6,2	11	26 442	6,35	1 201	−1 159
	200	102	5,5	7	12,5	36 111	7,25	1 247	−1 213
3	**225**	112	6,5 (6,2)	7,1	13,6	44 580	8,27	1 137	−1 119
	250	127	7 (6,7)	7,8	14,8	50 466	8,95	1 116	−1 086

[a] The values specified for t are nominal values. In the case of disc springs with flat bearings (cf. Group 3 in Clause 4), the desired spring load, F (where s approximately 0,75 h_0), is to be obtained by reducing the thickness of single disc springs, t, which then gives the value t'. In the case of dimensional series A and B, t' approximately 0,94 × t, and in the case of dimensional series C, t' approximately 0,96 × t.

7 Manufacture

7.1 Manufacturing process and surface quality

Disc springs shall be manufactured as specified in Table 7.

Table 7 — Prescribed manufacturing processes and surface quality

Group	Manufacturing process	Surface roughness[a] on upper and bottom surfaces µm	Surface roughness[a] on outer and inner edges µm	Material as in
1	Stamping, cold forming, edge rounding	$R_a < 3{,}2$	$R_a < 12{,}5$	EN 10132–4
2	Stamping[b], cold forming, D_e and D_i turning, edge rounding	$R_a < 6{,}3$	$R_a < 6{,}3$	EN 10132–4
	or fine blanking[c], cold forming, edge rounding	$R_a < 6{,}3$	$R_a < 3{,}2$	EN 10132–4

Group	Manufacturing process	Surface roughness[a] on upper and bottom surfaces µm	Surface roughness[a] on outer and inner edges µm	Material as in
3	Cold or hot forming, turning on all sides, edge rounding	R_a < 12,5	R_a < 12,5	EN 10083 series EN 10089
		R_a < 12,5	R_a < 12,5	EN 10132–4
	or stamping[b], cold forming, D_e and D_i turning, edge rounding or fine blanking[c], cold forming, edge rounding	R_a < 12,5	R_a < 12,5	EN 10132–4

[a] The values specified do not apply to shot peened springs.

[b] Stamping without D_e and D_i turning is not permitted.

[c] Fine blanking in accordance with VDI/Guideline 2906 Part 5: Clean cut min. 75 %, scar category 2, tear off max. 25 %.

7.2 Heat treatment

To ensure satisfactory fatigue life with minimum relaxation, the hardness of disc springs shall lie within the range of 42 HRC to 52 HRC.

For Group 1 disc springs, the hardness shall be determined according to Vickers (425 HV10 to 510 HV10).

After heat treatment, the disc spring shall not exhibit a depth of decarburization exceeding 3 % of its thickness.

7.3 Shot peening

In order to increase the values given in Figures 5 to 7, shot peening according to ISO 26910-1 is recommended.

This procedure shall be the subject of agreement between customer and manufacturer.

7.4 Presetting

After heat treatment, each disc spring shall be loaded until it is in the flat position.

After loading the disc spring with twice of its test load F_t, the tolerances for the spring load as specified in Table 10 shall be met.

7.5 Surface treatment and corrosion protection

The surface shall be free from defects such as scars, cracks and corrosion.

Whether and which corrosion protection is to be provided shall be a function of the particular spring application. Suitable corrosion protections includes phosphating, black finishing, and the application of protective metallic coatings such as zinc or nickel. This shall be agreed between customer and manufacturer.

Galvanizing processes using aqueous solutions that are currently available may not preclude the risk of hydrogen embrittlement. Disc springs with a hardness exceeding 40 HRC are more prone to the risk of hydrogen embrittlement than softer springs. Particular care shall therefore be taken when selecting the material, manufacturing process, heat treatment and surface treatment (e.g. DIN 50969). When ordering disc springs with galvanic surface protection it is advisable to consult the spring manufacturer.

For disc springs with dynamic loading galvanic surface protection should be avoided and process in which inclement effects occur should be avoided.

Phosphating and oiling is the standard corrosion protection for disc springs.

8 Tolerances

8.1 Tolerances on diameter

D_e: tolerance class h12;

Coaxiality tolerance for $D_e \leq 50$: 2 × IT11;

Coaxiality tolerance for $D_e > 50$: 2 × IT12;

D_i: tolerance class H12.

8.2 Tolerances on thickness

Table 8 — Tolerances on thickness

Group	t	Tolerances
1	$0{,}2 \leq t \leq 0{,}6$	+ 0,02 − 0,06
	$0{,}6 < t < 1{,}25$	+ 0,03 − 0,09
2	$1{,}25 \leq t \leq 3{,}8$	+ 0,04 − 0,12
	$3{,}8 < t \leq 6{,}0$	+ 0,05 − 0,15
3	$6{,}0 < t \leq 14{,}0$	±0,10

8.3 Tolerances on free overall height, l_0

Table 9 — Tolerances on free overall height, l_0

Group	t	Tolerances
1	$t < 1{,}25$	+ 0,10 − 0,05
2	$1{,}25 \leq t \leq 2{,}0$	+ 0,15 − 0,08
	$2{,}0 < t \leq 3{,}0$	+ 0,20 − 0,10
	$3{,}0 < t \leq 6{,}0$	+ 0,30 − 0,15
3	$6{,}0 < t \leq 14{,}0$	±0,30

8.4 Tolerances on spring load

8.4.1 Single disc springs

The spring load F_t shall be determined at test length $l_t = l_0 - 0{,}75\ h_0$. The measurement is taken while loading between flat plates, using a suitable lubricant. The flat plates shall be hardened, ground, and polished.

Table 10 — Tolerances on spring load

Group	t	**Tolerances for F_t at $l_t = l_0 - 0{,}75\ h_0$, %**
1	$t < 1{,}25$	+ 25 − 7,5
2	$1{,}25 \leq t \leq 3{,}0$	+ 15 − 7,5
	$3{,}0 < t \leq 6{,}0$	+ 10 − 5
3	$6{,}0 < t \leq 14{,}0$	±5

To comply with the specified load tolerances, it may be necessary to exceed the tolerance values specified for l_0 and t.

8.4.2 Springs stacked in series

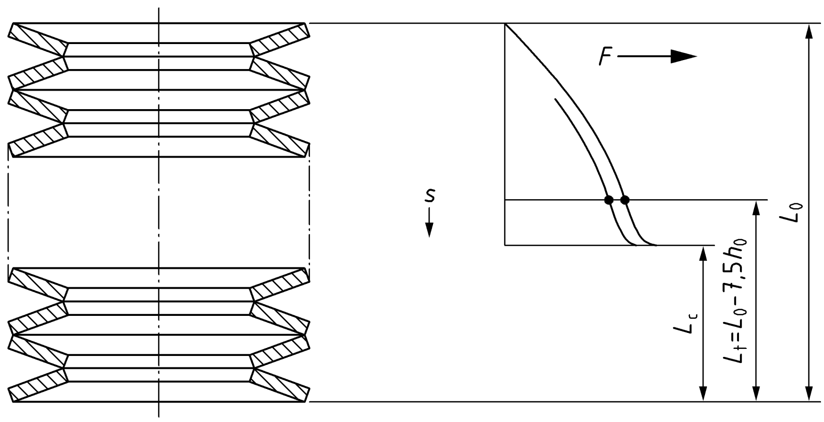


Figure 2 — Loading and unloading curves obtained from testing springs stacked in series

Ten single disc springs stacked in series shall be used to determine the deviation in load between the loading curve and the unloading curve.

Prior to testing, the disc spring shall be compressed to twice its test load, F_t. The individual disc springs shall be centred by a mandrel in compliance with Clause 12. The clearance between disc springs and mandrel shall be as specified in Table 12. The flat plates shall meet the requirements specified in 8.4.1.

At $L_t = L_0 - 7{,}5\ h_0$, the spring load determined for the unloading curve shall make up at least the minimum percentages specified in Table 11 of the spring load determined for the loading curve (see also Figure 2).

Table 11 — Minimum spring load at unloading, as a percentage of the spring load at loading at L_t

Group	Series		
	A	B	C
1	90		85
2	92,5		87,5
3	95		90

8.5 Clearance between disc spring and guiding element

A guiding element is necessary to keep the disc spring in position. This should be preferably a mandrel. In the case of external positioning, a sleeve is preferred.

Table 12 — Recommended clearance between disc spring and guiding element

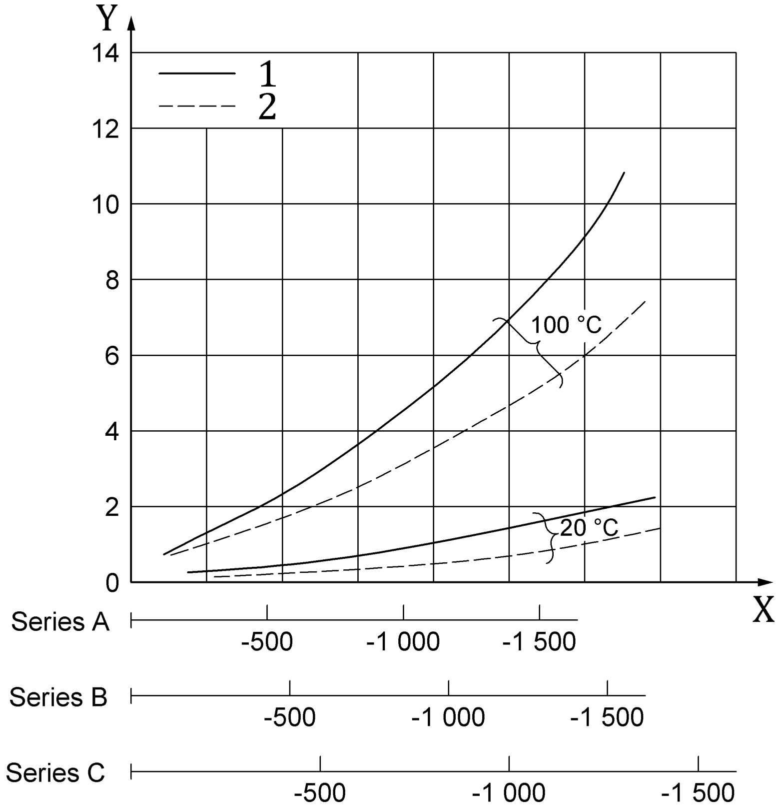
D_i or D_e		Total clearance
	Up to 16	0,2
Over 16	up to 20	0,3
Over 20	up to 26	0,4
Over 26	up to 31,5	0,5
Over 31,5	up to 50	0,6
Over 50	up to 80	0,8
Over 80	up to 140	1,0
Over 140	up to 250	1,6

9 Creep and relaxation

All disc springs lose load during usage. Depending on the application, this is expressed by creep or relaxation. Both creep and relaxation are largely a result of the stress distribution over the cross section of the disc spring. Its influence can be estimated on the basis of the design stress σ_{OM} (see EN 16984:2016, Clause 9).

Creep is defined as the further decrease in length of the disc spring with time, Δl, when subjected to a constant load. Relaxation is defined as the decrease in load with time, ΔF, when the disc spring is compressed to a constant length.

For disc springs under static load, the guideline values for relaxation illustrated in Figures 3 and 4 should not be exceeded.



Key

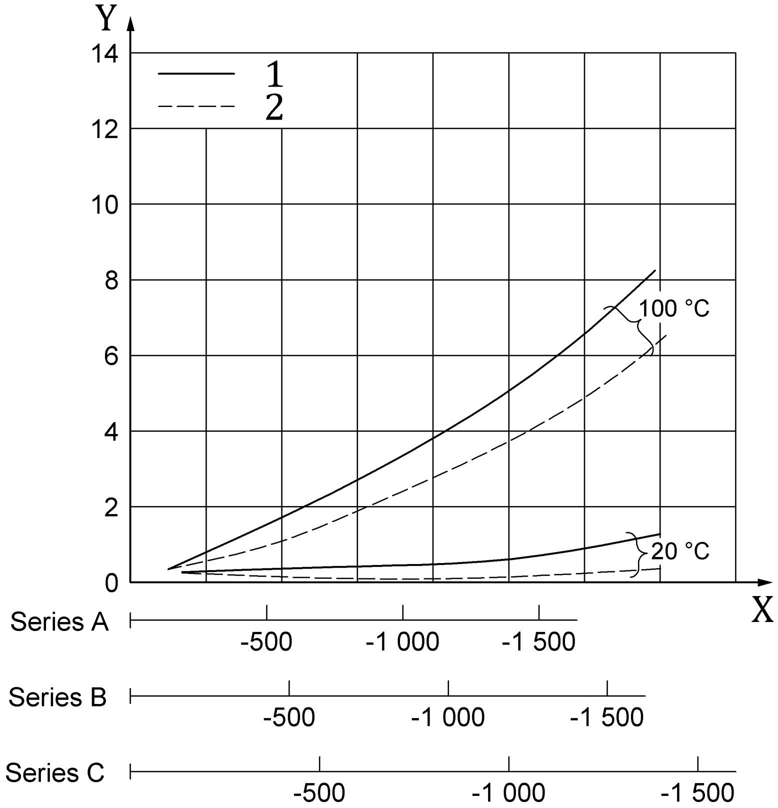
Y relaxation $\Delta F/F \cdot 100$ %

X σ_{OM} in MPa

1 after 1 000 h

2 after 48 h

Figure 3 — Permissible relaxation for disc springs made of carbon steel in accordance with EN 10132-4



Key

Y relaxation $\Delta F/F \cdot 100$ %

X σ_{OM} in MPa

1 after 1 000 h

2 after 48 h

Figure 4 — Permissible relaxation for disc springs made of alloy steel in accordance with EN 10089 and EN 10132-4

If the ambient temperature exceeds 100 °C, the spring manufacturer should be consulted.

10 Permissible stresses

10.1 Static and rarely alternating loading

For disc springs made of steels according to EN 10089 or EN 10132-4, which are subject to static loading or to moderate fatigue conditions, the design stress, σ_{OM}, at maximum deflection shall not exceed 1 600 MPa.

Higher stresses may cause a higher loss of spring load (see Clause 9).

10.2 Dynamic loading

10.2.1 General

Minimum initial deflection to avoid cracking:

Disc springs subject to fatigue loading shall be designed and installed in such a way that the initial deflection is s_1 approximately 0,15 h_0 to s_1 approximately 0,20 h_0 in order to avoid cracking at the upper inner edge, point I (see Figure 1) as a result of residual stresses from the presetting process.

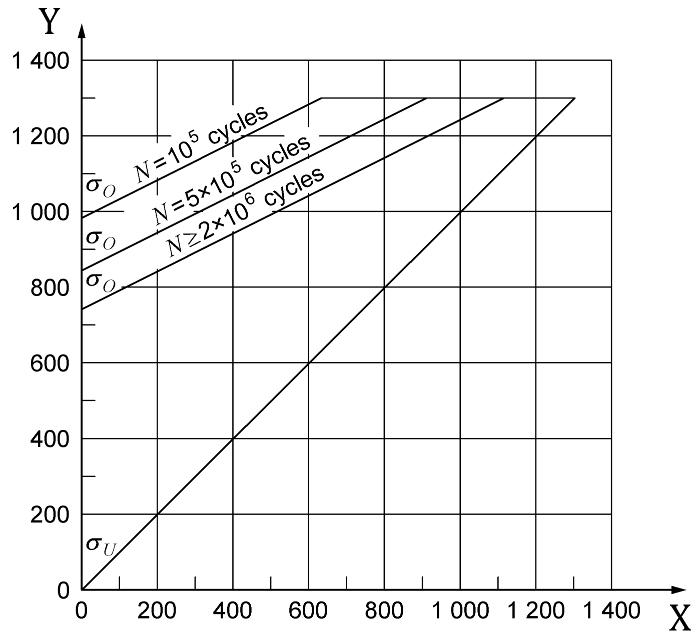
10.2.2 Permissible loading

Figures 5 to 7 illustrate the fatigue life of disc springs subject to dynamic loading that have not been shot peened. They specify guideline values for the permanent range of stress, σ_H, as a function of the minimum stress, σ_U, at three different numbers of stress cycles namely where $N \leq 2 \cdot 10^6$, $N = 10^5$, and $N = 5 \cdot 10^5$.

Intermediate values for other numbers of stress cycles may be estimated based on this information.

The information given in Figures 5 to 7 represents the results of laboratory testing using fatigue testing equipment capable of producing sinusoidal loading cycles and the statistical results obtained for a 99 % probability of fatigue life. The figures are valid for single disc springs and stacks with $I \leq 10$ disc springs stacked in series. Test conditions are: room temperature, disc springs preloaded from s_1 approximately 0,15 h_0 to s_1 approximately 0,20 h_0, surface hardened and perfectly processed inner and outer guidance.

To ensure the expected fatigue life of disc springs, they shall be protected from mechanical damage and other adverse conditions.

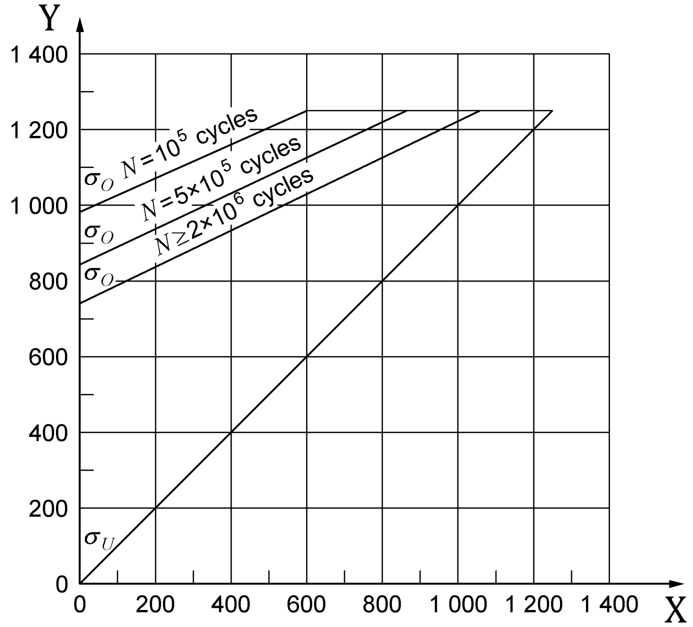


Key

Y minimum stress σ_u /maximum stress σ_o in MPa

X minimum stress σ_u in MPa

Figure 5 — Fatigue life of not shot peened disc springs with *t* < 1,25 mm

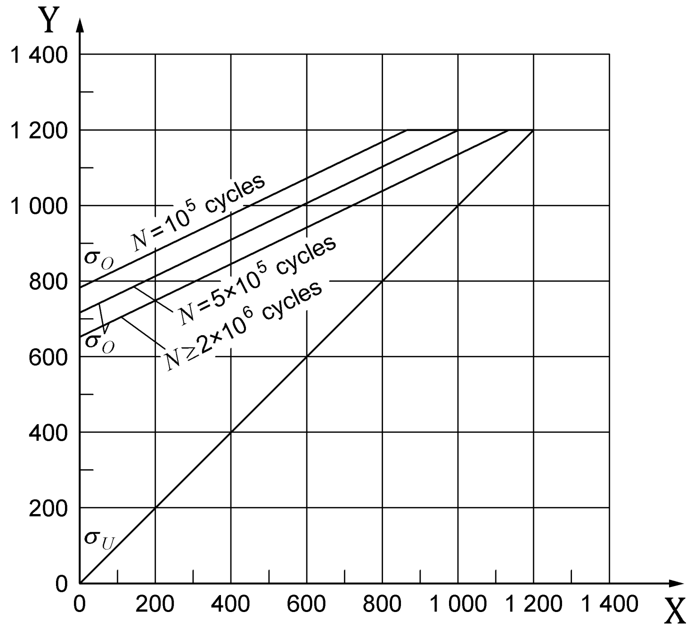


Key

Y minimum stress σ_u /maximum stress σ_o in MPa

X minimum stress σ_u in MPa

Figure 6 — Fatigue life of not shot peened disc springs with 1,25 mm ≤ *t* ≤ 6 mm



Key

Y minimum stress σ_u /maximum stress σ_o in MPa

X minimum stress σ_u in MPa

Figure 7 — Fatigue life of not shot peened disc springs with 6 mm < *t* ≤ 14 mm

It should be noted that stress cycles in practice are generally not sinusoidal in form. Any additional type of loads (e.g. sudden dynamic loading, shock loads and resonance) will shorten the fatigue life.

In this case, the values given in the above figures shall be converted by appropriate factors of safety; the spring manufacturer should be consulted where necessary.

NOTE Reliable information regarding the fatigue life is not available for disc springs made from materials other than those specified here, for disc springs consisting of more than 10 single disc springs stacked in series, for other unfavourable arrangements of stacks of springs, nor for springs subjected to chemical or thermal effects, although some relevant information is usually obtainable from the spring manufacturer.

In the case of stacks with a highly degressive load/deflection curve (dimensional series C) and a large number of single disc springs stacked in series, an uneven deflection of the single disc springs can be expected. This effect is caused by friction between the disc springs and the guiding element and dimensional tolerances.

Disc springs at the moving end of the stack deflect more than the others. This will result in a shorter fatigue life than shown in Figures 5 to 7.

The fatigue life of disc springs can be prolonged considerably by additional shot peening.

11 Testing

11.1 General

Determination of the properties covered in 11.2 and 11.3 shall be the subject of agreement between customer and manufacturer.

11.2 Check of dimensions and other spring characteristics

The specifications given in EN ISO 3269 shall be applied in addition to the characteristics and quality levels specified in Table 13.

Table 13 — characteristics and quality levels of springs

Spring characteristics	AQL value
Major characteristics Spring load, F (s approximately 0,75 h_0) Outer diameter, D_e Inner diameter, D_i	1
Minor characteristics Free overall height in initial position, l_0 Spring thickness, t or t' Surface roughness, R_a	1,5

11.3 Hardness testing

Vickers hardness testing shall be carried out according to the EN ISO 6507- series, and Rockwell hardness testing shall be carried out according to the EN ISO 6508- series.

The indentation shall be made on the upper surface of the disc spring, at a point that lies centrally between the inner and outer edges.

12 Other relevant requirements

Where possible, the guiding element and the support plate shall be made from case-hardened materials, with a case depth of approximately 0,8 mm, and have a minimum hardness of 60 HRC. The surface of the guiding element should be smooth and perfectly finished. It shall be permitted to use unhardened guiding elements where the disc spring is subject to static loading.

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