Helical Springs
Made of Round Wire
Quality Specifications for Cold Coiled Compression Springs

Zylindrische Schraubenfedern aus runden Drähten;
Gütevorschriften für kaltgeformte Druckfedern

This Standard applies to helical compression springs made of spring-hard round wire which, after cold coiling, are subjected only to tempering to relieve residual stresses. Cold coiled compression springs can be made with wire up to about 17 mm diameter. In the range from 10 to 17 mm wire diameter the production method (cold or hot coiled) depends on stressing, the material and the use of spring; cf. also DIN 2089 Sheet 1 (Preliminary Standard).

The materials listed in Section 3.5 and the under-mentioned limiting values also apply to this Standard:

- Mean coil diameter $D_m$ up to 200 mm
- Length of unloaded spring $L_0$ up to 630 mm
- Number of active coils $l_r \geq 2$
- Coil ratio $w$ 4 to 20

Dimensions in mm

1. Representation

2. Formula symbols, dimension letters, designations and units

- $\varepsilon_1$: Quantity for determining variations of spring force and spring length (effect of geometry and dimensions) in N
- $c_0$: Spring rate in N/mm
- $d$: Wire diameter in mm
- $d_{\text{max}}$: Nominal dimension of wire diameter according to DIN 2076 or DIN 1757, increased by the upper allowance in mm
- $e_1$: Permissible variation of the generating line from the vertical, measured on the unloaded spring in mm
- $e_2$: Permissible variation in parallelism of the ground spring bearing surfaces, measured for $D_a$ in mm

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Explanations on page 8
\[ i_f \] Number of active coils
\[ i_g \] Total number of coils
\[ k_f \] Factor for determining variations of spring force and spring length (effect of active coils)

\[ s_1 \] to \( s_n \) Deflections corresponding to spring forces \( F_1 \) to \( F_n \) in mm

\[ s_{BL} \] = \( L_0 - L_1 \) Deflection corresponding to theoretical spring force \( F_{BL} \) theor in mm

\[ w \] = \( \frac{D_m}{d} \) Coil ratio in mm

\[ x \] Factor for determining \( S_a \) in mm

\[ A_D \] Permissible variation of coil diameter (\( D_a, D_i, D_m \)) of unloaded spring in mm

\[ A_P \] Permissible variation of spring force \( F \) at given spring length \( L \) in N

\[ A_{L0} \] Permissible variation of length \( L_0 \) of unloaded spring in mm

\[ D_a \] Outside diameter of coil in mm

\[ D_d \] Mandrel diameter (inner guide) in mm

\[ D_h \] Sleeve diameter (outer guide) in mm

\[ D_i \] Inside diameter of coil in mm

\[ D_m \] = \( D_a + D_i \) Mean diameter of coil in mm

\[ F_1 \] to \( F_n \) Spring forces corresponding to spring lengths \( L_1 \) to \( L_n \) in N

\[ F_{BL} \] theor Theoretical spring force corresponding to solid length \( L_{BL} \) in N

\[ L_0 \] Length of unloaded spring in mm

\[ L_1 < L_0 - A_{L0} \] Length at smallest test load \( F_1 \) in mm

\[ L_1 \] to \( L_n \) Lengths of loaded spring corresponding to spring forces \( F_1 \) to \( F_n \) in mm

\[ L_{BL} \] Solid length of spring (all coils closed) in mm

\[ L_m \] = \( L_{11} + S_a \) Minimum permissible test length of spring in mm

\[ Q \] Coefficient of quality grade

\[ S_a \] Sum of minimum spaces between individual active coils in mm

### 2. Finish

#### 2.1. Coiling direction

Compression springs are generally made with right-hand coiling, or with alternating right-hand and left-hand coiling for nested spring assemblies; in this case the outer spring is usually right-hand coiled. If left-hand coiling for springs is required, this must be obvious from the note "left-hand coiled" which should appear in drawings or enquiry and order documents.

#### 2.2. Spring ends

The spring ends whereby the spring force is transmitted to the connecting components are to be so designed that the deflection of the spring is as nearly axial as possible in every position of the spring. This is generally achieved by reducing the pitch of one finishing coil at each end. To obtain adequate bearing surfaces at right angles to the spring axis, the wire ends are ground in accordance with Figure 1.

If unground spring ends are acceptable for the particular use concerned, e.g. when the compression springs are made with wire having a diameter less than approximately 1 mm or with a coil ratio over 15, grinding of the wire ends should be omitted for economic reasons.

When the compression springs are made with wire having a diameter under 0.3 mm the wire ends should never be ground.

With regard to the simultaneous grinding of the spring ends of compression springs having a wire diameter from 0.3 mm up to about 5 mm it should be noted that only springs which allow adequate contact pressure can be ground flat.

Tests so far carried out indicate that this contact pressure must amount to approximately

\[
\frac{C}{D_m} \geq 0.03 \, N/mm^2
\]

If grinding of the spring ends is found to be inexpedient, the spring should be made according to Figure 2, that is to say without ground wire ends. In all cases the type of finish for the spring ends shall be stated verbally in the drawing.

The spring ends should only be deburred if this is required for proper functioning. If an outer or inner chamfer is required on the end coil, the width of chamfer must be stated. The chamfer angle is approximately 45°.

#### 2.3. Minimum space between active coils under maximum permissible test load \( F_n \)

At \( F_n \) the sum of the minimum spaces between the active coils should be

\[ S_a = x \cdot d \cdot i_f \]

Inside \( S_a \) the spring characteristic may show a strongly rising trend.

For a given coil ratio \( w \) the corresponding value of \( x \) is found from Figure 3.
3.4. Solid length \( L_{s1} \)
(all coils closed)
For springs with ground ends according to Figure 1, the solid length is:
\[ L_{s1} \leq i_g \cdot d_{\text{max}} \]
For springs without ground ends according to Figure 2 the following applies:
\[ L_{s1} \leq (i_g + 1) \cdot d_{\text{max}} \]
\( i_g = i_f + 2 \)
2 = Number of non-active coils

3.5. Material

**Group 1**
DIN 17223  Sheet 1  Round spring steel wire, quality specifications; patented drawn spring wire made of unalloyed steels
DIN 17223  Sheet 2  --; quenched and tempered spring wire and quenched and tempered valve spring wire made of unalloyed steels
DIN 17224  (Preliminary Standard) Stainless steel wire and strip for springs; quality specifications

**Group 2**
DIN 17225  (Preliminary Standard) High-temperature steels for springs; quality properties
DIN 17672  Sheet 1  Rod, bar and wire of copper and wrought copper alloys; strength properties
DIN 17672  Sheet 2  --; technical conditions of delivery
DIN 17682  Round spring wire of wrought copper alloys; strength properties, technical conditions of delivery

3.6. Surface treatment
3.6.1. Shot-peening
If so agreed, the springs may be shot-peened to increase their fatigue strength (see DIN 2089 Sheet 1).

3.6.2. Surface protection
The springs are usually protected by oiling or greasing. Other methods of corrosion protection are to be agreed with the manufacturer.

4. Quality grades, permissible variations
For springs the quality grades 1, 2 and 3 are specified (for coefficients \( Q \) see Table 2).
All the permissible variations listed below apply only to material group 1 (see Section 3.5).
For material group 2, permissible variations are to be agreed between manufacturer and user.
The choice between quality grades 1, 2 and 3 will be governed by operational requirements. The quality grade required and the permissible variations are to be expressly agreed or stated in the drawing preprint (see also DIN 2099 Sheet 1).

In the absence of information to this effect, quality grade 2 shall apply.
In the interests of rationalized production quality grade 1 should be specified only when the particular use calls for it. For this purpose not all the quantities in Sections 4.1 to 4.5 necessarily belong to a simple quality grade. If variations smaller than "1" are required, agreements must be reached with the manufacturer.
4.1. Permissible variations of wire diameters
According to DIN 2076 Round spring wire; dimensions, weights, permissible variations (applies also to spring wire of wrought copper alloys according to DIN 17682)
DIN 1757 Wire of copper and wrought copper alloys; drawn; dimensions

4.2. Permissible variations \( \Delta d \) for coil diameter of unloaded spring
See Table 1.

In drawings and in enquiry and order documents only the important coil diameter should be stated.

The permissible variations specified for \( D_m \) apply both to the corresponding diameters \( D_i \) and to \( D_a \).

In the case of springs working in a sleeve or on a mandrel, it is recommended that the smallest sleeve diameter or largest mandrel diameter also should be quoted.

Table 1.

<table>
<thead>
<tr>
<th>( D_m ) above to</th>
<th>( \Delta d ) in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>( D_m ) above to</td>
<td>( \Delta d ) in mm</td>
</tr>
<tr>
<td>0.63 1 to 4</td>
<td>±0.06 ±0.07 ±0.1 ±0.07 ±0.1 ±0.15 ±0.1 ±0.15 ±0.2 ±0.15 ±0.2 ±0.3 ±0.4</td>
</tr>
<tr>
<td>1,6 4 to 8</td>
<td>±0.1 ±0.15 ±0.15 ±0.1 ±0.15 ±0.2 ±0.1 ±0.15 ±0.2 ±0.3 ±0.4 ±0.5 ±0.6 ±0.7</td>
</tr>
<tr>
<td>2,5 10</td>
<td>±0.1 ±0.15 ±0.2 ±0.1 ±0.15 ±0.2 ±0.1 ±0.15 ±0.2 ±0.3 ±0.4 ±0.5 ±0.6 ±0.7</td>
</tr>
<tr>
<td>4,6,3 10</td>
<td>±0.15 ±0.2 ±0.25 ±0.15 ±0.2 ±0.25 ±0.15 ±0.2 ±0.25 ±0.3 ±0.35 ±0.4 ±0.5 ±0.6 ±0.7</td>
</tr>
<tr>
<td>8,16 25</td>
<td>±0.2 ±0.3 ±0.35 ±0.2 ±0.3 ±0.35 ±0.2 ±0.3 ±0.35 ±0.3 ±0.35 ±0.4 ±0.5 ±0.6 ±0.7</td>
</tr>
<tr>
<td>16,25 40</td>
<td>±0.25 ±0.3 ±0.35 ±0.25 ±0.3 ±0.35 ±0.25 ±0.3 ±0.35 ±0.3 ±0.35 ±0.4 ±0.5 ±0.6 ±0.7</td>
</tr>
<tr>
<td>40,63 80</td>
<td>±0.5 ±0.7 ±0.8 ±0.5 ±0.7 ±0.8 ±0.5 ±0.7 ±0.8 ±0.5 ±0.7 ±0.8 ±0.5 ±0.7 ±0.8</td>
</tr>
<tr>
<td>63,80 100</td>
<td>±0.6 ±0.8 ±0.9 ±0.6 ±0.8 ±0.9 ±0.6 ±0.8 ±0.9 ±0.6 ±0.8 ±0.9 ±0.6 ±0.8 ±0.9</td>
</tr>
<tr>
<td>100,125 160</td>
<td>±0.7 ±1.0 ±1.1 ±1.4 ±1.2 ±1.5 ±1.4 ±1.2 ±1.5 ±1.4 ±1.2 ±1.5 ±1.4 ±1.2 ±1.5</td>
</tr>
<tr>
<td>125,160 200</td>
<td>±0.9 ±1.2 ±1.4 ±1.8 ±2.3 ±2.7 ±2.1 ±2.9 ±3.3 ±2.1 ±2.9 ±3.3 ±2.1 ±2.9 ±3.3</td>
</tr>
</tbody>
</table>

4.2. Permissible variations \( \Delta p \) for spring force \( F \) at given spring length \( L \)
The permissible variation for spring force is

\[
\Delta p = \left( a_p \cdot k_f + \frac{1.5 \cdot F}{100} \right) \cdot Q
\]

The quantity \( a_p \) can be found from Figures 4 and 5.
The factor \( k_f \) is obtainable from Figure 6 and the coefficient \( Q \) from Table 2.

Table 2.

<table>
<thead>
<tr>
<th>Quality grade</th>
<th>( Q )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.63</td>
</tr>
<tr>
<td>2</td>
<td>1.00</td>
</tr>
<tr>
<td>3</td>
<td>1.60</td>
</tr>
</tbody>
</table>

The \( a_p \) quantities specified in Figures 4 and 5 for springs according to Figure 1 apply only to springs which are resistant to buckling (see also Section 5.1 and also DIN 2089 Sheet 1, Preliminary Standard).
Figure 4. Quantity $a_p$ 
Influence of geometry and dimensions on variations of spring force and spring length for wire diameters from 0.07 to 1.1 mm

4.4. Permissible variations $A_{LO}$ for length $L_0$ of unloaded spring
$L_0$ is to be tolerated only in agreement with Section 4.6.
The permissible variation is 

$$A_{LO} = \frac{a_p \cdot k \cdot Q}{c}$$
Figure 5. Quantity $a_F$
Influence of geometry and dimensions on variations of spring force and spring length for wire diameters from 1.1 to 16 mm.

Figure 6. Factor $K_f$
Influence of active coils on variations of spring force and spring length.
4.5. Permissible variations $e_1$ and $e_2$ of unloaded springs with ground spring seating surfaces

Values should only be specified for $e_1$ and $e_2$ (cf. Figure 1) if vital for the functioning of the spring.

Quality grade 1 can only be achieved with springs having a coil ratio $w$ ≤ 12 and a slenderness ratio $L_0/\pi d_0 ≤ 5$.

4.6. Production margin

The manufacturer needs a production margin in order to meet the loading conditions specified:

The numerical values of the quantities thus available as production margin are to be stated in the drawing and count only as reference values.

In the event of a production margin being utilised, care must be taken to ensure that the permissible shear stress is not exceeded (see DIN 2089 Sheet 1, Preliminary Standard).

<table>
<thead>
<tr>
<th>Quality grade</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation $e_1$ of generating line from the vertical</td>
<td>$0.03L_0$</td>
<td>$0.05L_0$</td>
<td>$0.08L_0$</td>
</tr>
<tr>
<td>(1,7°)</td>
<td>(2,9°)</td>
<td>(4,6°)</td>
<td></td>
</tr>
<tr>
<td>Variation $e_2$ from parallelism</td>
<td>$0.015D_n$</td>
<td>$0.03D_n$</td>
<td>$0.06D_n$</td>
</tr>
<tr>
<td>(0,9°)</td>
<td>(1,7°)</td>
<td>(3,4°)</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.

Quantities specified | Production margin provided by:
--- | ---
A given spring force and corresponding length of stressed spring | $L_0$
A given spring force, corresponding length of stressed spring and $L_0$ | $i_1$ and $d$ or $i_1$ and $D_n, D_m$ ($D_m$)
Two given spring forces and corresponding lengths of stressed spring | $L_0, i_1$ and $d$ or $L_0, i_1$ and $D_n, D_m$ ($D_m$)

5. Testing

5.1. Static load testing

The testing is carried out on the spring in the upright position in the direction of loading. It is recommended for this purpose that the given spring length $L$ should be attained and the corresponding force $F$ read off. Permissible variation in the force indication: ± 1%.

In the case of preset springs it is essential in all cases that prior to static testing they should be compressed to the solid length or to an agreed spring length; in the case of non-preset springs compression to the minimum length occurring in service or during installation is performed. This length must be stated.

Springs which are not resistant to buckling (see DIN 2089 Sheet 1, Preliminary Standard, February 1963 issue, page 7, Figure 8) must be tested on a mandrel or in a sleeve, the diameters of the mandrel or sleeve and the test method being agreed. In general, the test load should be taken as the mean value of the measuring results obtained from twice loading and unloading.

5.2. Characteristic

The characteristic (force-deflection curve) calculated according to DIN 2089 Sheet 1 (Preliminary Standard) is a straight line for the helical compression spring. In practice, the characteristic is not linear at the start and finish. If it is desired to test the spring rate $c$ by determining the spring characteristic, the testing must be carried out in the range from 0.3 $F_n$ to 0.7 $F_n$ to make sure of covering the linear portion, $F_n$ being associated with the smallest permissible test length $L_n$.

The spring rate $c$ is therefore:

$$c = \frac{\Delta F}{\Delta S} = \frac{F_2 - F_1}{S_2 - S_1}$$

where $\Delta F$ is the increase in force corresponding to a reduction in length $\Delta L$ or to the increase in deflection $\Delta S$ (see Figure 7).

5.3. Test load for pressing to solid length (settling testing)

Testing to solid length $L_{s1}$ shall be performed with not more than 1.5 times the theoretical spring force corresponding to the solid length $L_{s1}$.

Any testing of solid force is to be agreed. Figure 7. Test diagram
References to further standards

DIN 1757 Wire of copper and wrought copper alloys, drawn; dimensions
DIN 2076 Round spring wire; dimensions, weights, permissible variations
DIN 2089 Sheet 4 (Preliminary Standard) Helical springs made of round wire and rod; calculation and design of compression springs
DIN 2096 Helical springs made of round rod; quality specifications for compression springs quenched and tempered after coiling
DIN 2097 Helical springs made of round wire; quality specifications for cold coiled tension springs
DIN 2099 Sheet 1 Helical springs made of round wire and rod; data for compression springs; preprint
DIN 17223 Sheet 1 Round spring steel wire, quality specifications; patented drawn spring wire made of unalloyed steels
DIN 17223 Sheet 2 -; quenched and tempered spring wire and quenched and tempered valve spring wire made of unalloyed steels
DIN 17224 (Preliminary Standard) Stainless steel wire and strip for springs; quality specifications
DIN 17225 (Preliminary Standard) High-temperature steels for springs; quality properties
DIN 17672 Sheet 1 Rod, bar and wire of copper and wrought copper alloys; strength properties
DIN 17672 Sheet 2 -; technical conditions of delivery
DIN 17682 Round spring wire of wrought copper alloys; strength properties, technical conditions of delivery

Explanations

This Standard contains the agreements reached, in the present state of the art, between the branches of industry concerned regarding design, requirements and testing of cold coiled compression springs. The permissible variations have been so specified that the manufacture and acceptance of relatively small quantities can also be performed with economically acceptable effort. For compression springs the quality grades 1, 2 and 3 are specified, the permissible variations being, for quality grade 1, 0.63 times, and for quality grade 3, 1.6 times those of the medium quality grade 2. Compression springs with force and length variations corresponding to quality grade 1 can be made with an average 1 % reject rate by utilizing ordinary production facilities and applying the measuring methods prevailing at the present day. Springs of this kind must be 100 % tested and this entails increased expenditure in production. Quality grade 2 should therefore be specified as preferred because this quality grade can be guaranteed by adopting properly organised in-manufacture spot testing instead of 100 % testing. Quality grade 2 will usually yield the most favourable cost-quality ratio.

Over an extended period of time a joint operation has been conducted for the investigation and statistical evaluation of variations in spring force arising in production. According to this work, the permissible variation in spring force is a function of the spring dimensions Dm, d, ip and f. The mode of dependence established for compression springs applies similarly to tension springs (cf. DIN 2097). There is also a connection via the spring rate between spring force and length variations. The quality grades and permissible variations according to this Standard differ from those of the earlier issues. The quality grade designations 1, 2 and 3 have therefore been newly introduced.

In line with existing basic standards the following formula symbols have been amended:

\[ F \quad \text{Spring force (formerly} \quad P) \]
\[ L_{b1} \quad \text{Solid length (formerly} \quad L_g) \quad \text{and} \]
\[ \delta \quad \text{Deflection (formerly} \quad f) \]

The statutory unit of force Newton (N) has been specified instead of the kilopond (kp).

(Conversion:
- exact \( 1 \text{ kp} = 9.80665 \text{ N} \)
- rounded \( 1 \text{ kp} = 10 \text{ N} \)).

Further amendments compared with the earlier issue are the new provision of the determination of \( S_A \), \( A_p \) and \( e_i \).