Dimensions and quality of conical disc springs

Tellerfedern; Maße und Qualitätsforderungen

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

Contents

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Scope and field of application</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Concept</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Symbols and units</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Classification</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Dimensions and designation</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Tolerances</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>6.1</td>
<td>Tolerances on diameter</td>
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</tr>
<tr>
<td>6.2</td>
<td>Tolerances on thickness</td>
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</tr>
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<td>6.3</td>
<td>Tolerances on free overall height, l₀</td>
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</tr>
<tr>
<td>7</td>
<td>Tolerances on spring load</td>
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</tr>
<tr>
<td>7.1</td>
<td>Single discs</td>
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<td>7</td>
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<td>7.2</td>
<td>Springs stacked in series</td>
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<tr>
<td>8</td>
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<td>10</td>
<td>Stresses in springs subject to static loading or moderate fatigue conditions</td>
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</tr>
<tr>
<td></td>
<td>Stresses in springs subject to fatigue loading</td>
<td>11</td>
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<tr>
<td>11.1</td>
<td>Minimum initial deflection to avoid cracking</td>
<td>11</td>
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</tr>
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<td>Stresses</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Materials</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Manufacturing process and surface quality</td>
<td>10</td>
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<tr>
<td>14</td>
<td>Heat treatment and surface treatment</td>
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<td>15.1</td>
<td>Check of dimensions and other spring characteristics</td>
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<td>15.2</td>
<td>Hardness testing</td>
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Dimensions in mm

1 Scope and field of application

This standard specifies requirements for the materials, dimensions, tolerances, and permissible stresses for conical disc springs. It includes graphs showing the permissible relaxation and the endurance life of such springs, as a function of stress. The minimum requirements specified here are intended to ensure the proper performance of conical disc springs, and may also be applied to non-standardized springs.

The three series specified here represent groups of spring sizes which have met with general acceptance in practice. Conical disc springs are not intended to be used with bolt/nut assemblies to counteract the effect of setting (as are DIN 6796 conical spring washers, for example).

2 Concept

Conical disc springs ('springs', for short) are annular coned elements that offer resistance to a compressive force applied axially. They may be designed as single discs or as discs stacked in parallel or in series, either singly or in multiples. They may be subjected to both static and fatigue loading, and may have ground end surfaces ('ground ends', for short).

Continued on pages 2 to 11
3 Symbols and units

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<thead>
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<th>Symbol</th>
<th>Unit</th>
<th>Term</th>
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<td>$D_e$</td>
<td>mm</td>
<td>Outside diameter of spring</td>
</tr>
<tr>
<td>$D_i$</td>
<td>mm</td>
<td>Inside diameter of spring</td>
</tr>
<tr>
<td>$D_0$</td>
<td>mm</td>
<td>Mean coil diameter</td>
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<tr>
<td>$E$</td>
<td>N/mm²</td>
<td>Modulus of elasticity</td>
</tr>
<tr>
<td>$F$</td>
<td>N</td>
<td>Spring load of a single disc (with or without ground ends)</td>
</tr>
<tr>
<td>$\Delta F$</td>
<td>N</td>
<td>Relaxation</td>
</tr>
<tr>
<td>$L_0$</td>
<td>mm</td>
<td>Length of springs stacked in series or in parallel, in the initial position</td>
</tr>
<tr>
<td>$L_c$</td>
<td>mm</td>
<td>Design length of springs stacked in series or in parallel, in the flattened position</td>
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<td>$N$</td>
<td>mm</td>
<td>Number of cycles to failure</td>
</tr>
<tr>
<td>$h_0$</td>
<td>mm</td>
<td>Initial cone height of springs without ground ends (equal to free overall height, $l_0$, minus $i$)</td>
</tr>
<tr>
<td>$i$</td>
<td>mm</td>
<td>Number of discs stacked in series, singly or in multiples</td>
</tr>
<tr>
<td>$l_0$</td>
<td>mm</td>
<td>Free overall height of spring in its initial position</td>
</tr>
<tr>
<td>$s$</td>
<td>mm</td>
<td>Deflection of single disc</td>
</tr>
<tr>
<td>$s_1, s_2, s_3, \ldots$</td>
<td>mm</td>
<td>Deflections associated with the spring loads designated $F_1, F_2, F_3, \ldots$</td>
</tr>
<tr>
<td>$t$</td>
<td>mm</td>
<td>Thickness of single disc</td>
</tr>
<tr>
<td>$t'$</td>
<td>mm</td>
<td>Reduced thickness of single disc in the case of springs with ground ends (group 3)</td>
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<tr>
<td>$\mu$</td>
<td></td>
<td>Poisson's ratio</td>
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<tr>
<td>$\sigma$</td>
<td>N/mm²</td>
<td>Design stress</td>
</tr>
<tr>
<td>$q_{II}, q_{III}, q_{OM}$</td>
<td>N/mm²</td>
<td>Design stresses at the points designated 0M, I, II, III and IV (see figure 1)</td>
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<tr>
<td>$q_h$</td>
<td>N/mm²</td>
<td>Mean fatigue stress associated with the deflection of springs subject to fatigue loading</td>
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<td>$q_U$</td>
<td>N/mm²</td>
<td>Minimum fatigue stress</td>
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<td>$q_H = q_0 - q_U$</td>
<td>N/mm²</td>
<td>Range of stress</td>
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4 Classification

This standard makes a distinction among three groups of springs, in accordance with table 1.

<table>
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<tr>
<th>Group</th>
<th>Thickness of single disc, $t$</th>
<th>Single disc with ground ends</th>
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<tr>
<td>1</td>
<td>Less than 1,25</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>From 1,25 to 6</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>Over 6 up to 14</td>
<td>Yes</td>
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</table>
5 Dimensions and designation

Conical disc spring of group 1 or 2

Conical disc spring of group 3

![Cross section of a single disc, including the relevant points of loading.](image)

Figure 1: Cross section of a single disc, including the relevant points of loading

Designation of a conical disc spring of spring series A with an outside diameter, $D_e$, of 40 mm:

Conical disc spring DIN 2093 – A 40

Where a particular manufacturing process is required for group 2 springs (cf. Table 10), the designation shall be amended as follows.

- In the case of springs produced by turning (G):
  Conical disc spring DIN 2093 – A 40 G

- In the case of springs produced by stamping (F):
  Conical disc spring DIN 2093 – A 40 F
Table 2: Conical disc springs of series A (with $\frac{D_e}{t} = 18; \frac{h_0}{t} = 0.4, E = 206,000$ N/mm$^2$, and $\mu = 0.3$)

<table>
<thead>
<tr>
<th>Group</th>
<th>$D_e$</th>
<th>$D_i$</th>
<th>$t$ or $(r)^1$</th>
<th>$h_0$</th>
<th>$l_0$</th>
<th>$F$</th>
<th>$s$</th>
<th>$l_0 - s$</th>
<th>$\sigma_{0M},^2$</th>
<th>$\sigma_{III},^3$</th>
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<td></td>
<td>N</td>
<td></td>
<td>N mm$^2$</td>
<td>N</td>
<td>N</td>
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$^1$ The values specified for $t$ are nominal values. In the case of group 3 springs, the values given in parentheses apply for $r'$ (reduced thickness). Limit deviations for thickness are specified in subclause 6.2.

$^2$ Design (compressive) stresses at the point designated 0M, i.e. on the conical surface of the spring.

$^3$ The values specified apply for the largest tensile stresses on the lower edges of the spring. The values specified with an asterisk (*) apply to the point designated II, those without an asterisk, to the point designated III.

In the case of springs with ground ends (cf. group 3 in clause 4), the desired spring load, $F$ (where $s$ is equal to approximately 0.75 $h_0$), is to be obtained by reducing the thickness of single discs, $t$, which then gives the value $r'$. In the case of spring series A and B, $r'$ shall be equal to approximately 0.94$t$, and in the case of spring series C, it shall be equal to approximately 0.96$t$. 

171
Table 3: Conical disc springs of series B (with $D_e / t = 28$, $h_0 / t = 0.75$, $E = 206000$ N/mm$^2$, and $\mu = 0.3$)

<table>
<thead>
<tr>
<th>Group</th>
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<th>$D_i$</th>
<th>$t$ or $(r')^1$</th>
<th>$h_0$</th>
<th>$l_0$</th>
<th>$F$</th>
<th>$s$</th>
<th>$l_0 - s$</th>
<th>$\alpha_{3M}^2$</th>
<th>$\alpha_{1I}^3$</th>
<th>$N$</th>
<th>$N_{mm^2}$</th>
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<td>6.2</td>
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For $^1$, $^2$, and $^3$, see table 2.

In the case of springs with ground ends (cf. group 3 in clause 4), the desired spring load, $F$ (where $s$ is equal to approximately $0.75 h_0$), is to be obtained by reducing the thickness of single discs, $t$, which then gives the value $r'$. In the case of spring series A and B, $r'$ shall be equal to approximately $0.94 r$, and in the case of spring series C, it shall be equal to approximately $0.96 r$. 

172
### Table 4: Conical disc springs of series C (with $\frac{D_2}{t} = 40$, $\frac{h_0}{t} = 1.3$, $E = 206000 \text{N/mm}^2$, and $\mu = 0.3$)

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For $^1$, $^2$, and $^3$, see table 2.

In the case of springs with ground ends (cf. group 3 in clause 4), the desired spring load, $F$ (where $s$ is equal to approximately 0.75 $h_0$), is to be obtained by reducing the thickness of single discs, $t$, which then gives the value $r'$. In the case of spring series A and B, $r'$ shall be equal to approximately 0.94$r$, and in the case of spring series C, it shall be equal to approximately 0.96$r$. 

173
6 Tolerances
6.1 Tolerances on diameter
For all springs, tolerance class h12 shall apply for the outside diameter, \( D_e \).
The coaxiality tolerance for the outside diameter, where \( D_e \) does not exceed 50, shall be 2 \( \cdot \) IT 11 or, where \( D_e \) exceeds 50, it shall be 2 \( \cdot \) IT 12.
Tolerance class H12 shall apply for the inside diameter, \( D_i \).

6.2 Tolerances on thickness

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\(^4\) In the case of group 3 springs, the limit deviations specified apply to the reduced thickness, \( r' \) (cf. clauses 4 and 5).

6.3 Tolerances on free overall height, \( l_0 \)

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<tr>
<th>Group</th>
<th>( t )</th>
<th>Limit deviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Less than 1.25</td>
<td>+0.10 -0.05</td>
</tr>
<tr>
<td></td>
<td>From 1.25 to 2.0</td>
<td>+0.15 -0.08</td>
</tr>
<tr>
<td></td>
<td>Over 2.0 to 3.0</td>
<td>+0.20 -0.10</td>
</tr>
<tr>
<td></td>
<td>Over 3.0 to 6.0</td>
<td>+0.30 -0.15</td>
</tr>
<tr>
<td>3</td>
<td>Over 6.0 to 14.0</td>
<td>±0.30</td>
</tr>
</tbody>
</table>

7 Tolerances on spring load
7.1 Single discs
The static spring load, \( F \), of a single disc in the initial position \((l_0 - s)\) shall be determined for a spring in the loaded state, using a suitable lubricant. The flat plates between which the spring is to be compressed shall be hardened, ground, and polished.
Under normal circumstances, the values specified in table 7 shall apply.

<table>
<thead>
<tr>
<th>Group</th>
<th>( t )</th>
<th>Limit deviations for ( F ) at ( l_0 - 0.75 \cdot h_0 ), as a percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Less than 1.25</td>
<td>+25 -7.5</td>
</tr>
<tr>
<td>2</td>
<td>From 1.25 to 3.0</td>
<td>+15 -7.5</td>
</tr>
<tr>
<td></td>
<td>Over 3.0 to 6.0</td>
<td>+10 -5</td>
</tr>
<tr>
<td>3</td>
<td>Over 6.0 to 14.0</td>
<td>±5</td>
</tr>
</tbody>
</table>

To comply with the specified tolerances, it may be necessary to exceed the tolerance values specified for \( l_0 \) (cf. table 6).

7.2 Springs stacked in series
Ten single discs stacked in series shall be used to determine the deviation in load between the loading curve and the unloading curve of springs stacked in series. The individual discs shall be centred about a mandrel in compliance with clause 16. The flat plates between which the spring is to be compressed shall be hardened, ground, and polished.
Prior to testing, the spring shall be compressed to twice its design load, \( F \) (where \( s \) is approximately 0.75 \( h_0 \)).
At \((l_0 - 7.5 \cdot h_0)\), the spring load determined for the unloading curve shall make up at least the minimum percentages specified in table 8 of the spring load determined for the loading curve (cf. figure 2).

<table>
<thead>
<tr>
<th>Group</th>
<th>Minimum spring load (unloading), as a percentage, for spring series</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>92,5</td>
</tr>
<tr>
<td>3</td>
<td>95</td>
</tr>
</tbody>
</table>

Within certain tolerances, the form of the actual individual discs will deviate from the geometrically ideal form of the stack. Together with the effect of friction, this results in a load/deflection curve for the stack that differs from that established for the sum of the results for the individual discs (cf. subclause 7.4 of DIN 2092).
Stacks of springs shall normally be tested with the arrangement used in practice.

Figure 2: Measuring points for loading and unloading curves
8 Play between spring and centring element

Means shall be provided to keep the spring in position, these being preferably internal, such as a mandrel. In the case of external positioning, a sleeve is preferred. The recommended amount of play between the spring and such a centring element is specified in table 9, as a function of the outside or inside diameter of the spring.

<table>
<thead>
<tr>
<th>$D_1$ or $D_2$</th>
<th>Approximate play</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 16</td>
<td>0.2</td>
</tr>
<tr>
<td>Over 16 up to 20</td>
<td>0.3</td>
</tr>
<tr>
<td>Over 20 up to 26</td>
<td>0.4</td>
</tr>
<tr>
<td>Over 26 up to 31.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Over 31.5 up to 50</td>
<td>0.6</td>
</tr>
<tr>
<td>Over 50 up to 80</td>
<td>0.8</td>
</tr>
<tr>
<td>Over 80 up to 140</td>
<td>1</td>
</tr>
<tr>
<td>Over 140 up to 250</td>
<td>1.6</td>
</tr>
</tbody>
</table>

9 Permissible set

See DIN 2092 for relevant concepts.

Following heat treatment, each spring shall be prestressed in such a manner that the values specified in table 7 are complied with when the spring is compressed to twice its design load, $F$ (where $s$ is equal to approximately 0.75 $h_0$).

In the case of springs subject to static loading, the guideline values for relaxation illustrated in figures 3 and 4 should not be exceeded.

![Figure 4: Illustration of permissible relaxation for springs made from high-grade chromium alloy steel or chromium-vanadium alloy steel in accordance with DIN 17 221 and DIN 17 222](image)

Where the service temperature will exceed 100 °C, the spring manufacturer shall be consulted.

10 Stresses in springs subject to static loading or moderate fatigue conditions

In the case of springs made from DIN 17 221 or DIN 17 222 steel that are subject to static loading or to moderate fatigue conditions, the design stress at the point designated $\sigma_{OM}$, shall be approximately equal to the yield strength, $R_y$, of the material used (i.e. 1400 to 1600 N/mm²).

Where used at higher stresses, it is likely that the springs will suffer from creep or relaxation (cf. clause 9).

11 Stresses in springs subject to fatigue loading

11.1 Minimum initial deflection to avoid cracking

Springs subject to fatigue loading shall be designed and installed in such a way that the initial deflection, $s_{II}$, is from about 0.15 $h_0$ to 0.20 $h_0$ in order to avoid cracking at the upper inner edge (point I; cf. figure 1) as a result of residual stresses from the setting process.

11.2 Stresses

Figures 5 to 7 illustrate the endurance life of conical disc springs subject to fatigue loading that have not been shot peened. They specify guideline values for the range of stress, $\sigma_{II}$, as a function of the minimum stress, $\sigma_{OM}$, at three different numbers of stress cycles, $N$, namely where $N$ is less than or equal to $2 \times 10^5$, equal to $10^6$, and equal to $5 \times 10^6$.

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 endurance life. The test pieces were ten single discs with hardened surfaces, stacked in series, designed for use at ambient temperature, provided with an internal or external centring element with a
smooth finish, having a minimum initial deflection, \( s_1 \), from about 0.15 \( h_0 \) to 0.20 \( h_0 \).

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

![Graphical representation of endurance life of springs where \( t \) is less than 1.25 mm](image)

**Figure 5: Graphical representation of endurance life of springs where \( t \) is less than 1.25 mm**

![Graphical representation of endurance life of springs where 6 mm < \( t \) < 14 mm](image)

**Figure 7: Graphical representation of endurance life of springs where 6 mm < \( t \) < 14 mm**

It should be noted that stress cycles in practice are generally not sinusoidal in form. Where additional types of loading (e.g. sudden dynamic loading or that which results from resonance) act on the spring, it may be assumed that their endurance life will be shorter. Where such is the case, the values given in the above figures shall be converted by appropriate factors of safety, the spring manufacturer being consulted where necessary.

**NOTE:** Reliable information regarding the endurance life is not available for springs made from materials other than those specified here, for springs consisting of more than ten single discs stacked in series, for other 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 springs which exhibit a highly degressive load/deflection curve (springs of series C consisting of a large number of single discs stacked in series), an uneven distribution of total applied load from the single discs can be expected due to the friction between the discs and the centring element and to dimensional deviations. In this case, the end of the spring subject to deflection receives the higher portion of loading, which results in an endurance life that is shorter than can be read from figures 5 to 7.

**12 Materials**

Springs in accordance with this standard shall be made from high-grade steel with a modulus of elasticity, \( E \), of 206,000 N/mm², as specified in either DIN 17 221 or DIN 17 222, it being noted that Ok steel shall only be used for the manufacture of group 1 springs.

**NOTE:** Other materials shall be the subject of agreement (e.g. stainless steel for springs in accordance with DIN 17 224, copper alloys (spring bronze) in accordance with DIN 1777), since their moduli of elasticity and strength properties will likely be different. The values given for \( F \) and \( \sigma \) in Tables 2 to 4 then cease to apply. It is therefore recommended to consult with the spring manufacturer.
13 Manufacturing process and surface quality

<table>
<thead>
<tr>
<th>Group</th>
<th>Manufacturing process</th>
<th>$R_a &lt; 3.2$</th>
<th>$R_a &lt; 12.5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stamped, cold formed, edges rounded</td>
<td>$R_a &lt; 6.3$</td>
<td>$R_a &lt; 6.3$</td>
</tr>
<tr>
<td>2*)</td>
<td>Stamped, cold formed, $D_e$ and $D_i$ turned, edges rounded</td>
<td>$R_a &lt; 6.3$</td>
<td>$R_a &lt; 3.2$</td>
</tr>
<tr>
<td>3</td>
<td>Cold or hot formed, turned on all sides, edges rounded</td>
<td>$R_a &lt; 12.5$</td>
<td>$R_a &lt; 12.5$</td>
</tr>
</tbody>
</table>

*) Unless otherwise specified, the particular manufacturing process shall be up to the manufacturer (cf. clause 5).

**) The values specified do not apply to shot peened springs.

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

14 Heat treatment and surface treatment

14.1 Heat treatment

After quenching and tempering, the spring shall not exhibit a depth of decarburization exceeding 3% of its thickness. To ensure good strength with as little relaxation as possible, the hardness of springs shall lie within the range of 42 to 52 HRC. For group 1 springs, the Vickers hardness is to be determined.

14.2 Shot peening

It is recommended that shot peening be carried out on springs subjected to severe loading, which enables the values given in figures 5 to 7 to be increased. This procedure shall be the subject of agreement.

14.3 Corrosion protection

Whether and which corrosion protection is to be provided shall be a function of the particular spring application. Suitable corrosion protection measures include phosphating, black finishing, and the application of protective metallic coatings such as zinc or nickel.

Electroplating processes using aqueous solutions that are currently available may not preclude the risk of hydrogen embrittlement. 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 of springs (cf. DIN 50 969). Where springs are to be electroplated, it is recommended that the manufacturer be consulted, and that this procedure not be used for springs subject to fatigue loading.

15 Testing

Determination of the properties covered in subclauses 15.1 and 15.2 shall be the subject of agreement between purchaser and manufacturer.

15.1 Check of dimensions and other spring characteristics

The specifications given in DIN 267 Part 5 shall apply in addition to the characteristics and quality levels specified in table 11.

<table>
<thead>
<tr>
<th>Spring characteristics</th>
<th>AQL value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major characteristics</td>
<td></td>
</tr>
<tr>
<td>Spring load, $F$ (where $z = 0.75 h_0$)</td>
<td>1</td>
</tr>
<tr>
<td>Outside diameter, $D_e$</td>
<td></td>
</tr>
<tr>
<td>Inside diameter, $D_i$</td>
<td></td>
</tr>
<tr>
<td>Minor characteristics</td>
<td>1,5</td>
</tr>
<tr>
<td>Free overall height in initial position, $l_0$</td>
<td></td>
</tr>
<tr>
<td>Spring thickness, $t$ or $r$</td>
<td></td>
</tr>
<tr>
<td>Surface roughness, $R_a$</td>
<td></td>
</tr>
</tbody>
</table>

15.2 Hardness testing

Rockwell hardness testing shall be carried out as specified in DIN 50 103 Part 1, and Vickers hardness testing (for group 1 springs), as in DIN 50 133. The indentation shall be made on the upper surface of the spring, at a point that lies centrally between the inner and outer edges.

16 Other relevant requirements

Where possible, the centring element and the seat shall be made from case-hardened materials, with a case depth of about 0.8 mm, and have a hardness of 55 HRC. The surface of the centring element shall be smooth and, where possible, polished.

It shall be permitted to use unhardened centring elements where the spring is subject to static loading.
Standards referred to
DIN 267 Part 5  Fasteners; technical delivery conditions; acceptance inspection (modified version of ISO 3269:1984)
DIN 1777  Wrought copper alloy strip for springs; technical delivery conditions
DIN 2092  Design of conical disc springs
DIN 6796  Conical spring washers for bolt/nut assemblies
DIN 17 221  Hot rolled steel for springs suitable for quenching and tempering; technical delivery conditions
DIN 17 222  Cold rolled steel strip for springs; technical delivery conditions
DIN 17 224  Stainless steel wire and strip for springs; technical delivery conditions
DIN 50 103 Part 1  Rockwell hardness testing of metallic materials; C, A, B, F scales
DIN 50 133  Vickers hardness testing of metallic materials; HV 0.2 to HV 100
DIN 50 969  Heat treatment of chemically and/or electrochemically treated high-strength steel components to prevent hydrogen embrittlement

Other relevant standards
DIN 1016  Hot rolled steel sheet and strip; tolerances on size, form and mass
DIN 1544  Steel flat products; cold rolled steel strip; dimensions, limit deviations and form tolerances
DIN 8201 Part 1  Abrasives; classification and designation
DIN 50 942  Phosphating of metals; methods of test
DIN 59 200  Hot rolled wide steel flats; dimensions and tolerances on size, form and mass

Previous editions
DIN 2093: 05.57, 04.67, 04.78, 09.90.

Amendments
In comparison with the September 1990 edition, the following amendments have been made.
  a) In table 4, the value specified for $D_t$ where $D_s$ is equal to 50 has been corrected.
  b) In table 5, the limit deviation specified for group 2 springs has been corrected.

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