Shot peening

After coiling, a spring contains stresses at the wire surface on the inside diameter of the spring. For dynamic loaded springs, these stresses do not allow the material properties to be fully exploited. By shot peening the spring, i.e. bombarding the spring with small, round, steel balls, the following improvements with regard to fatigue strength can be achieved:

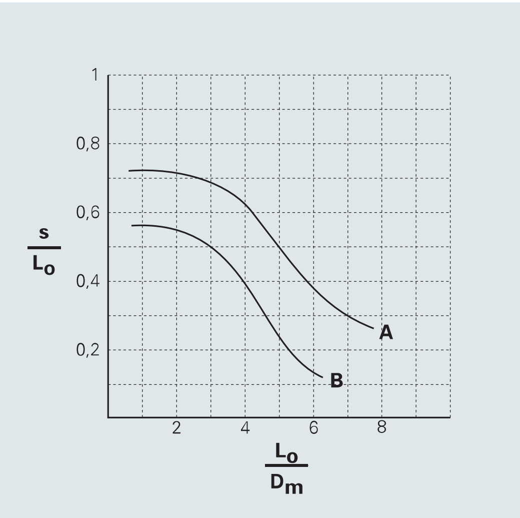
- Tension in the surface
- Reduction of notch fatigue factor as any small surface defects are closed up.
- Harder surface finish due to cold working by peening.

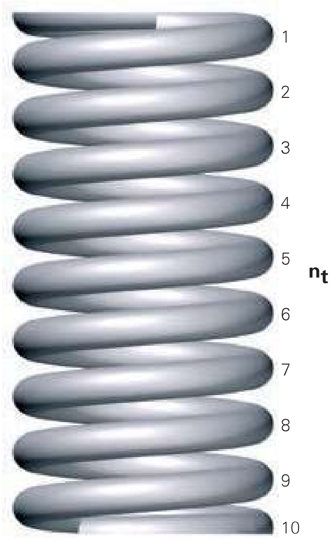
By shot peening, the life of the spring can be increased by more than 100%. Conversely, an increase in performance of up to 50% can be achieved with the same life. We particularly recommend this method of treatment for compression springs which are exposed to fatigue, where long life is required.

Close coiled extension and torsion springs are not normally shot peened, due to the practical difficulties (limited space for the shot inside the spring). Also, the advantages cannot be realized, compared with compression springs. Generally, compression springs should have a wire diameter of at least 1.5 mm. For thinner wire diameters, the effect is lower and there is a further risk of deformation.

Pre-setting

Pre setting is a plastic deformation, which is accomplished by loading the spring beyond the actual working range. In this way, tension in the surface is obtained in the opposite direction to the load tension. This leads to non or strongly reduced setting when the spring is working. We recommend pre-setting for highly stressed springs. Normally, pre-setting is carried out cold. Springs working in increased temperatures should be pre-set warm.





Breaking strength

This diagram is used to check that a compression spring will not break.

Values below curve B: No risk of breakage

Values between curves A and B: The spring should have internal location plus ground ends.

Values above curve A: There is a risk of breakage. The spring should have internal location.

Coil counting

This figure shows how the total number of coils (n_t) is counted. In this case, it is n_t 10. The number of active coils (n_V) is n_t - 1.5.

TOLERANCES

Due to the varying characteristics of the material it is impossible to make identical springs. Material hardness, dimension and physical properties can vary, which influences the consistency of the spring.

Tolerance table for coil springs

Diameter Dm (mm)	Tolerance (mm)
0,1 < Dm ≤ 2,5	± 0,12
2,5 < Dm ≤ 4	± 0,15
4,0 < Dm ≤ 6,3	± 0,2
6,3 < Dm ≤ 10	± 0,25
10 < Dm ≤ 16	± 0,3
16 < Dm ≤ 25	± 0,4
25 < Dm ≤ 40	± 0,5
40 < Dm ≤ 50	± 0,6
50 < Dm ≤ 63	± 0,8
63 < Dm ≤ 80	± 1
80 < Dm ≤ 100	± 1,2
100 < Dm ≤ 125	± 1,5
125 < Dm ≤ 160	± 2

For the end coil of the compression springs, the values should be doubled.

$D_m = D_y - D_t = D_i + D_t$

Tolerances for free length (L_O)

Ratio D_m / D_t	Tolerance
4 –12	±5%
(12) –15	±7,5%

Lowest tolerance for L_O = ±0.3 mm

Tolerances for spring force (F)

Ratio D_m / D_t	No of active coils 2-3.5	>3.5-5.5	>5.5-8.5	>8.5-12.5	>12.5+
4 – 5	±15%	±12%	±11%	±10%	±9%
(5) – 11	±13%	±11%	±10%	±9%	±8%

Tolerances for Die springs (page 50-67)

LENGTH Unloaded length, mm	Tolerance
L0 25-89	+/- 1mm
L0 102-305	+/- 1%

FORCE Springforce	Tolerance
General	+/- 10%

Tolerances for other wire and strip steel formations

Base dimension (mm)	Tolerance (mm) Linear dimensions
≤ 3	± 0,2
>3–6	± 0,3
>6–30	± 0,5
>30–120	± 0,8
>120–400	± 1,2
>400–1000	± 2,0

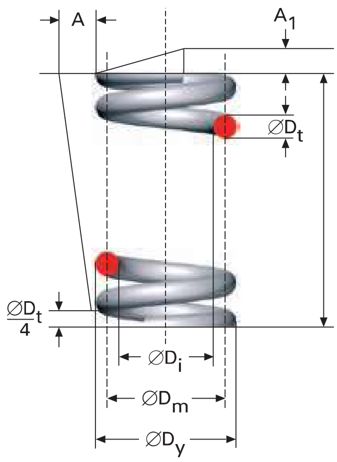
Base dimension (mm)	Tolerance (mm) Bending radius
≤ 3	± 0,2
> 3 - 6	± 0,3
> 6 - 30	± 1,0
> 30 - 60	± 2,0
> 60 - 120	± 4,0
> 120 - 300	± 10,0

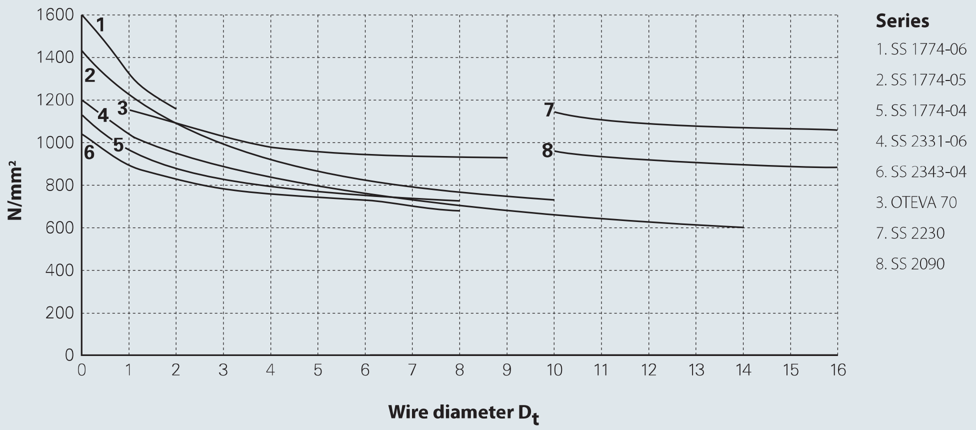
Base dimension (mm)	Tolerance (°) Bending angles
≤ 10	± 3
> 10 – 50	± 2
> 50	± 1

Base dimension = shortest leg length

Tolerance for angle deviation

The deviation (A) of the generating line from the vertical line must not be greater than 0.05 Lo (2.9°). Parallel misalignment (A1) must not be greater than 0.03 Dy (1.7°).





Permitted shear stress (τ) at static load

The material in wire springs is normally exposed to shear stress. When designing springs, the shear strength and modulus of shear of the wire is therefore of great importance. For a spring with established dimensions, the following applies:

– the higher the permitted shear stress, (t), the higher spring force

– the higher modulus of shear (G), the higher spring force for a given deflection.

The diagram above shows the highest permitted shear stress for a static loaded spring or one where the number of load oscillations during the expected life of the spring does not exceed 10 000.

The strength of an extension spring is determined largely by its loop design. With a normal loop, bent from the body of the spring, a strength loss of about 10–15% should be expected as the loop is weaker than the rest of the spring.

The life of a spring is significantly reduced by factors such as corrosion, increased working temperature, damage to the surface of the material, etc. Shot peening usually extends spring life considerably (See section on shot peening). Spring life is also dependent on the stress reversals in application, i. e. long deflection – shorter life and short deflection – longer life.

In order to estimate the life (N_C) of a spring exposed to a dynamic stress, the following reference values for maximum permitted shear stress may be used:

50 000 oscillations	Table value x 0.9
100 000 oscillations	Table value x 0.85
1 000 000 oscillations	Table value x 0.7
10 000 000 oscillations	Table value x 0.6

BRITISH WEIGHTS AND MEASUREMENTS

Measure

From	To	Multiplier
Metres	Inches	39,3701
Inches	Millimetres	25,4
Millimetres	Inches	0,0393

Forces

From	To	Multiplier
Newtons	Kilopond	0,102
Newtons	Pounds	0,22467
Newtons	Gram	102
Kilopond	Newtons	9,807
Kilopond	Pounds	2,2046
Kilopond	Gram	1000
Pounds	Newtons	4,448
Pounds	Kilopond	0,4536
Pounds	Gram	453,6
Gram	Newtons	0,009807
Gram	Kilopond	0,001
Gram	Pounds	0,0022046

Rates

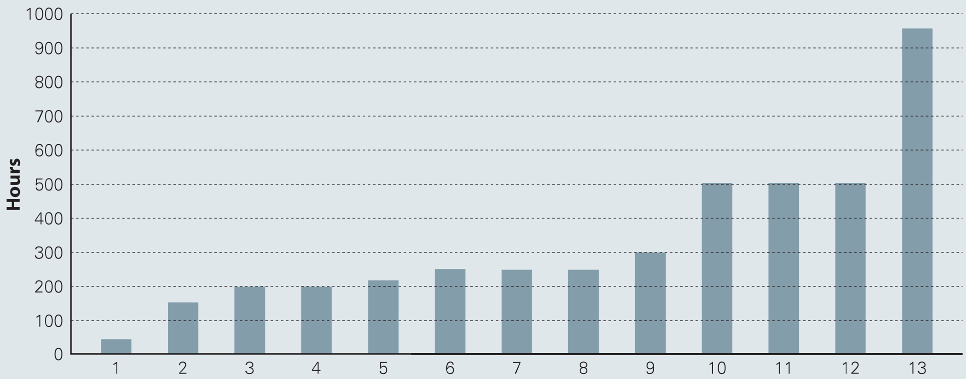
From	To	Multiplier
Kp/mm	lb/in	55,998
Kp/mm	N/mm	9,807
Kp/mm	kN/m	9,807
lb/in	Kp/mm	0,017858
lb/in	N/mm	0,175133
N/mm	Kp/mm	0,101968
N/mm	lb/in	5,7099

Torque

From	To	Multiplier
Kp mm	lb in	0,086796
Kp mm	N m	0,009807
lb in	Kp mm	11,52125
lb in	N m	0,1129889
N m	Kp mm	101,968
N m	lb in	8,850413

SURFACE TREATMENT OVERVIEW

Type of surface treatment	Appearance	Thickness of coating, micron	Risk of hydrogen embitterment	Wear resistance
Bezinal zinc coating	Grey semi bright	20–30	No	Not recommended
Delta-seal	Grey matt	8–12	No	Recommended
Delta-protect	Various	8–12	No	Very good
Electrolytic polishing	Silver ultra bright	0	No	Recommended
Epoxy paint	Various	50–100	No	Recommended
Gold plating	Gold matt / bright	2–5	Yes	Not recommended
Chromium plating	Silver/bright silver	8–12	Yes	Very good
Nickel plating, electrical	Silver/bright silver	5–10	Yes	Recommended
Nickel plating, chemical	Bright silver	5–10	Yes	Recommended
Silver-plated	Bright silver	4–10	Yes	Not recommended
Tin plating	Matt silver/silver	8–1	Yes	Not recommended
Electro-galvanising	Silver semi matt/bright	8–12	Yes	Not recommended
Mechanical galvanising	Greyish matt	12–25	No	Not recommended
Phosphating	Grey matt / semi bright	10–15	No	Not recommended
Painting	Various	50–150	No	Not recommended
Black oxidisation	Bright black	0,5–2	No	Not recommended
Teflon	Large selection	15–100	No	Very good
Zinc coated wire	Greyish matt	20–30	No	Recommended



1. Black oxide + oiled
2. Mechanical galv. + yellow chrome > 12 µ
3. Painting, incl. zinc priming coat
4. Teflon, incl. phosphating
5. El galv. + yellow chrome > 12 µ
6. Zinc coated wire
7. Epoxy varnish, incl. phosphating
8. Delta-Seal
9. Tin plating > 12 µ
10. Bezinal zinc coating
11. El. nickel plating 15 µ
12. Chem. nickel plating 15 µ
13. Magni 565

Corrosion resistance to salt spray test

It is not possible to give a general comparison of the corrosion resistances of different coatings, as the result very much depends on the thickness of the coating whether it is homogenous, its adhesion, its porosity or combinations of all of these etc. If the material has been pre-treated, this also influences the result. The values in the diagram above must therefore only be regarded as general values.

SURFACE TREATMENT OVERVIEW

Fields of application and characteristics

Zinc coatings

Electro-galvanising is the most popular surface treatment for springs and gives a smooth and even coat. To improve corrosion resistance, springs are also treated with either bright chrome (FZB) or yellow chrome (FZG). However, there is a risk of hydrogen embrittlement. In recent years, an alternative to electro-galvanizing, mechanical galvanising (also called Rotalyt), has emerged. The coating, which has a very low propensity for hydrogen embrittlement, is applied mechanically by letting zinc powder, glass balls and the components to be coated rotate in a tumbler. The balls act as powder carriers and are removed once treatment is complete.

Surface treated wire

Surface treated wire is in many cases a very good and value-for-money alternative to stainless material where the weight/component is large and corrosion resistance requirements are moderate. With the material already having been "hot dip galvanized" and post-annealed before production, there is no risk of hydrogen embrittlement. The only drawback tends to be the narrow choice of coated wire, which is largely restricted to zinc coated SS1774 and zinc/aluminium (Bezinal) coated SS1774.

Nickel plating

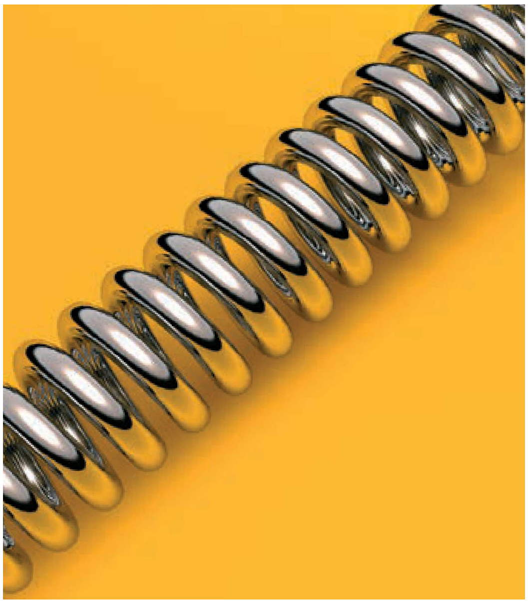
Used for decorative and anti-corrosion purposes. It should not be used on springs where the wire is exposed to large angular rotations, as the nickel plate is very hard and will crack under load. Nickel plating is usually used as the primer prior to tin, silver, gold, etc.

Chromium plating

Chrome with nickel coating beneath can be polished to a very bright apperance and is therefore primarily used for decorative purposes. The surface is very hard and wear-resistant. It should not be used for springs with high loads.

Tin plating

Used primarily to facilitate welding. Tin plate also provides good protection against corrosion. Springs that are tin plated are usually pre-treated with nickel.



SURFACE TREATMENT OVERVIEW

Fields of application and characteristics

Silver plating / gold plating
Used for decorative and corrosion protection purposes and for components used in the electrical and electronic industry. Electrolytic silver plating is chosen for a lot of applications due to its excellent electrical conductivity.

Phosphating
Phosphating is used for decorative purposes. It provides minimal protection against corrosion and is usually finished by oiling. Phosphating is also a primary treatment used prior to painting, where the phosphate coating prevents corrosion and gives a good adhesion.

Black oxide
Used for decorative purposes and consists of an iron oxide layer which does not protect against corrosion. Usually oiled afterwards.

Electrolytic polishing
This surface treatment, which polishes and gives a smooth surface, is only carried out on stainless and acidproof materials and is primarily used for decorative purposes, due to the resultant surface being bright. The surface finish increases the spring's relaxation limit.

Painting
A large variety of paints, prime coatings and zinc chromium colours are available and used mainly on heavier springs. Usually not suitable for springs with no space between coils.

Epoxy paint
A very good surface treatment for springs. The paint is applied by spraying an electrostatically charged powder on the components, which are then furnace heated. The resultant surface is even and very tough.

Delta-Seal

An organic surface treatment method where zinc particles are applied on the surface, which provides good basic protection against corrosion.
Delta-Seal is the pre-treatment for Magni 565.

Magni 565

A surface treatment system consisting of the organic pre-treatment Delta-Seal and the non-organic Delta-Protect. Provides high-class anti-corrosion protection and is particularly suited for springs where there is zero risk of hydrogen embrittlement.

Teflon

Suitable surface treatment for applications requiring low friction, good insulation and chemical resistance properties.

Operating temperature range -190 – +260 °C.

Hydrogen embrittlement

Hydrogen inclusion in steel can lead to the steel breaking at a much lower tensile than normal, even though the steel under short cycle tests, e.g. impact tests, exhibits normal durability values. This phenomenon is called hydrogen embrittlement. Hydrogen inclusion occurs in all instances where hydrogen can develop on the surface of the steel. Surface treatment processes that involve soaking in non-oxidised acids, cathodic cleaning and cathodic coating may cause embrittlement. Oil hardened spring wire and leaf springs that have been hardened after shaping are particularly sensitive.

The propensity to become brittle decreases as the tensile strength and hardness decreases. Normally, there is no brittleness in steel with a tensile limit < 1000 N/mm^2 or hardness below 30 Vickers.

Most of the hydrogen can be removed by heat treatment (soaking) in accordance with the following:

Material thickness < 3 mm	170 °C	5 hours
Material thickness < 12 mm	190–210 °C	4 hours