

Coil springs —

Part 1: Guide for the design of helical compression springs

UDC 621 – 272.272

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The preparation of this British Standard was entrusted by the General Mechanical Engineering Standards Committee (GME/-) to Technical Committee GME/15, upon which the following bodies were represented:

- British Railways Board
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- National Federation of Scale and Weighing Machine Manufacturers
- Railway Industry Association of Great Britain
- Royal Ordnance
- Spring Research and Manufacturers Association

This British Standard, having been prepared under the direction of the General Mechanical Engineering Standards Committee, was published under the authority of the Board of BSI and comes into effect on 29 May 1987

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First published March 1951
First revision January 1964
Second revision May 1987

The following BSI references relate to the work on this standard:
Committee reference GME/15
Draft for comment 86/70353 DC

ISBN 0 580 15850 0

Amendments issued since publication

Amd. No.	Date of issue	Comments
5921	October 1989	
6218	April 1990	Indicated by a sideline in the margin

Contents

	Page
Committees responsible	Inside front cover
Foreword	ii
Section 1. General	
1 Scope	1
2 Definitions	1
3 Symbols	5
4 General	5
Section 2. Compression springs made from circular section material	
5 Methods of calculation	6
6 Tolerances	7
Section 3. Compression springs made from rectangular (including square) section material	
7 Limitation on material section dimensions	10
8 Methods of calculation	10
9 Tolerances	14
Appendix A Methods of specifying springs for general purposes	17
Appendix B Methods of testing	23
Appendix C Modulus of rigidity of some materials	25
Appendix D Typical tolerances on rectangular section material	26
Figure 1 — End fixation factor H for various end conditions	6
Figure 2 — Critical values $H/(L_0/D)$	7
Figure 3 — Rectangular section: design chart for stress	11
Figure 4 — Rectangular section: design chart for rate	12
Figure 5 — Critical relative deflection for $m = 1.0$ to 2.5	13
Figure 6 — Critical relative deflection for $m = 0.4$ to 1	14
Figure 7 — Hand of coiling	17
Figure 8 — End coil form	18
Figure 9 — Coil end formed from tapered bar	18
Figure 10 — Data sheet 1	20
Figure 11 — Data sheet 2	22
Figure 12 — Measurement of free length and parallelism	23
Figure 13 — Measurement of squareness	24
Figure 14 — Measurement of bow	24
Table 1 — Calculated tolerances for group A springs made from circular section material, with more than 3.5 and less than 5 total coils	9
Table 2 — Calculated tolerances for group B springs made from circular section material, with more than 3.5 and less than 5 total coils	9
Table 3 — Calculated tolerances for group A springs made from rectangular section material, with more than 3.5 and less than 5 total coils	15
Table 4 — Calculated tolerances for group B springs made from rectangular section material, with more than 3.5 and less than 5 total coils	16
Table 5 — Modulus of rigidity values	25
Table 6 — Typical tolerances on rectangular section material	26
Publications referred to	Inside back cover

Foreword

BS 1726-1 was first published in 1951 and revised in 1964 to incorporate much of the essential information from ADE Design Data Sheets, which were no longer available from HM Stationery Office and for which copyright permission to republish was obtained.

This revision has been prepared to take account of current manufacturing processes. It supersedes BS 1726-1:1964, which is withdrawn. Part 2¹⁾ of the standard deals with helical extension springs and Part 3¹⁾ with helical torsion springs.

NOTE There are numerous methods of calculating the parameters necessary for the design of springs and initially the designer is free to use any one of these.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 26, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

¹⁾ In preparation.

Section 1. General

1 Scope

This Part of BS 1726 provides guidance on the design of parallel sided helical compression springs manufactured from either:

- a) circular section material, or
- b) rectangular and square section material.

NOTE 1 It should be borne in mind that, in general, the surface quality of rectangular material is inferior to that obtainable on round material due to problems in wire drawing. For this reason it is recommended that rectangular section springs should be used in static applications only.

Two grades of tolerances, 1 and 2, are given for circular section springs and one grade, 2, for rectangular or square section springs.

NOTE 2 These tolerances are based on experience gained within the spring industry, but no process control capability is implied. Where process control capability is required there will need to be agreement between the customer and the supplier.

Three types of end coils are provided for, i.e. open end, closed end and closed and ground end, the last of these being applicable only to springs where the diameter or axial dimension of material is 0.5 mm or greater.

This Part of BS 1726 differentiates between springs that have or have not been stress relieved (see 2.66) after forming (hereinafter designated group A springs [see 2.31]), and springs, the material of which has undergone a structural change by heat treatment after forming (hereinafter designated group B springs [see 2.32]).

Appendix A gives two methods of specifying springs for general purposes. Methods of testing springs are described in Appendix B. Values of the modulus of rigidity of some materials are given in Appendix C, and typical tolerances on rectangular section material are given in Appendix D, for information purposes.

NOTE 3 The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this Part of BS 1726 the following definitions apply.

2.1

active coils (effective coils, working coils)

the coils of a spring that at any instant are contributing to the rate of the spring

2.2

angle of grind

the angle subtended by the ground end surface of the spring at the intersection of the plane of the ground surface with the major axis of the spring

2.3

bow

the measurement established by laying the spring on a datum surface or straight edge and measuring the maximum deviation between any coil and the surface with a feeler gauge

NOTE See B.2.13.

2.4

buckling

the unstable lateral distortion of the major axis of a spring when compressed

2.5

chamfering

the removal of a corner on the inside and/or outside diameter of the ground face of a spring to clear any radius on the spring seat

2.6

closed end

the end of a helical spring in which the helix angle of the end coil has been progressively reduced until the end coil touches the adjacent coil

2.7

compression spring

a spring whose dimension, in the direction of the applied force, reduces under the action of that force

2.8

compression test

a test carried out by pressing a spring to a specified length a specified number of times

2.9

coning

an operation in which the diameter of the ends of an extension or compression spring is reduced

2.10

countersink

an internal chamfer

2.11

cramp test

a test carried out by compressing a spring to a specified length for a defined period

2.12

creep

the change in length of a spring with time when subjected to a constant force

2.13

damper coils

coils that are active at the free length but inactive at the normal operating length

2.14**dead coils**

the coils of a spring that do not affect the rate of the spring

2.15**deflection**

the relative displacement of the ends of a spring under the application of a force

2.16**edge dressing**

the removal of material from the outside edge of the end coils where they protrude beyond the outside diameter of the spring

2.17**elastic deformation**

the deformation that takes place when a material is subjected to any stress up to its elastic limit. On removal of the force causing this deformation the material returns to its original size and shape

2.18**elastic limit (limit of proportionality)**

the highest stress that can be applied to a material without producing permanent deformation

2.19**end fixation factor**

a factor used in the calculation of buckling to take account of the method of locating the end of the spring

2.20**extension spring**

a spring whose length, in the direction of the applied force, increases under the application of that force

2.21**fatigue**

the phenomenon that gives rise to a type of failure which takes place under conditions involving repeated or fluctuating stresses below the elastic limit of the material

2.22**fatigue limit**

the value, which may be statistically determined, of the stress condition below which material may endure an infinite number of stress cycles

2.23**fatigue strength (endurance limit)**

a stress condition under which a material will have a life of a given number of cycles

2.24**fatigue test**

a test to determine the number of cycles of stress that will produce failure of a component or test piece

2.25**finish**

a coating applied to protect or decorate springs

2.26**fitted length**

the length of a spring when assembled into position within a mechanism from which it is required to function

2.27**free length**

the length of a spring when it is not loaded

NOTE In the case of extension springs this may include the anchor ends.

2.28**gauge**

a device against which a dimension or form can be compared

2.29**gauging**

the comparison of a dimension by the use of gauges

2.30**grinding**

the removal of metal from the end faces of a spring by the use of abrasive wheels to obtain a flat surface which is square with the spring axis

2.31**group A springs**

springs that have or have not been stress relieved (2.66) after forming

2.32**group B springs**

springs, the material of which has undergone a structural change by heat treatment after forming

2.33**hand**

the direction in which the helix of a spring is formed, i.e. right or left.

2.34**heat stabilization**

the process of removing primary creep and inducing beneficial stresses into a spring, so that, when the spring is subjected to an operating stress and temperature, it will exhibit improved stress temperature relaxation properties

2.35**helical spring**

a spring made by forming material into a helix

2.36**helix angle**

the angle of the helix of a helical coil spring

2.37**hysteresis**

the lagging of the effect behind the cause of the effect. A measure of hysteresis in a spring is represented by the area between the loading and unloading curves produced when the spring is stressed within the elastic range

2.38**index**

the ratio of the mean coil diameter of a spring to the material diameter for circular sections or radial width of cross section for rectangular or trapezoidal sections

2.39**initial tension**

the part of the force exerted, when a close coiled spring is axially extended, that is not attributable to the product of the theoretical rate and the measured deflection

2.40**inside coil diameter of a spring**

the diameter of the cylindrical envelope formed by the inside surface of the coils of a spring

2.41**linearity**

the degree by which the force-deflection curve of a spring approaches a straight line

2.42**load test**

a test on a spring to determine either the force at a given length or the length under a given force

2.43**loop (eye, hook)**

the formed anchoring point of a helical spring or wire form. When applied to an extension spring, it is usually called a loop. If closed, it may be termed an eye and if partially open may be termed a hook

2.44**modulus of elasticity**

the ratio of stress to strain within the elastic range

NOTE The modulus of elasticity in tension or compression is also known as Young's modulus and that in shear as the modulus of rigidity.

2.45**natural frequency**

the frequency at which a spring will freely vibrate once it has been excited

2.46**open end**

the end of an open coiled helical spring in which the helix angle of the end coil has not been progressively reduced

2.47**outside coil diameter**

the diameter of the cylindrical envelope formed by the outside surface of the coils of a spring

2.48**parallelism**

the degree to which the two ground ends of a spring are parallel to each other

2.49**permanent set (set)**

the permanent deformation of a spring after the application and removal of a force

2.50**pitch**

the distance from any point in the section of one coil to the corresponding point in the next coil when measured parallel to the axis of the spring

2.51**prestressing (scragging)**

a process during which internal stresses are induced into a spring

NOTE It is achieved by subjecting the spring to a stress greater than that to which it is subjected under working conditions and higher than the elastic limit of the material. The plastically deformed areas resulting from this stress cause an advantageous redistribution of the stresses within the spring. Prestressing can only be performed in the direction of applied force.

2.52**rate (stiffness)**

the force that has to be applied in order to produce unit deflection

2.53**relaxation**

loss of force of a spring with time when deflected to a fixed position

NOTE The degree of relaxation is dependent upon, and increases with, the magnitude of stress, temperature and time.

2.54**residual range**

the residual range of a spring is the deflection available beyond the maximum working position up to the solid position

2.55**safe deflection**

the maximum deflection that can be applied to a spring without exceeding the elastic limit of the material

2.56**screw insert**

a plug screwed into the ends of a helical extension spring as a means of attaching a spring to another component. The plug has an external thread, the diameter, pitch and form of which match those of the spring.

2.57**shot peening**

a cold working process in which shot is impacted on to the surfaces of springs thereby inducing residual stresses in the outside fibres of the material

NOTE The effect of this is that the algebraic sum of the residual and applied stresses in the outside fibres of the material is lower than the applied stress, resulting in improved fatigue life of the component.

2.58**solid length**

the overall length of a helical spring when each and every coil is in contact with the next

2.59**solid force**

the theoretical force of a spring when compressed to its solid length

2.60**space (gap)**

the distance between one coil and the next coil in an open coiled helical spring measured parallel to the axis of the spring

2.61**spring seat**

the part of a mechanism that receives the ends of a spring and which may include a bore or spigot to centralize the spring

2.62**squareness**

the measurement established by standing the spring on a datum surface, placing an engineer's square against it and measuring the largest deviation between the top end coil and the square with a feeler gauge

NOTE 1 See B.2.11.

NOTE 2 Since squareness includes the effects of bow it should be noted that squareness, as defined for a spring, is different from that given in BS 308-3.

2.63**stress (bending stress, shear stress)**

the force divided by the area over which it acts. This is applied to the material of the spring, and for compression and extension springs is in torsion or shear, and for torsion springs is in tension or bending

2.64**stress correction factor**

a factor that is introduced to make allowance for the fact that the distribution of shear stress across the wire diameter is not symmetrical

NOTE This stress is higher on the inside of the coil than it is on the outside.

2.65**stress range**

the difference between the stresses induced by the minimum and maximum applied forces in a component subjected to cyclic loading

2.66**stress relieving**

a low temperature heat treatment carried out at temperatures where there is no apparent change in the metallurgical structure of the material. The purpose of the treatment is to relieve stresses induced during manufacturing processes

2.67**stroke (range)**

the distance between the minimum and maximum working positions of a spring

2.68**swivel hook**

a loop (hook or eye) fitted to the end of an extension spring so that it is capable of rotating about the axis of the spring

2.69**vapour blasting**

a process by which the surface of a component is modified by the action of a stream of liquid carrying solid particles of abrasive energized by compressed air

NOTE The results of this process can be to remove scale, produce a clean matt surface finish and induce compressive stresses into the outer fibres of the material.

2.70**variable pitch spring**

a helical spring in which the pitch of the active coils is not constant

2.71**variable rate spring**

a helical spring whose load deflection curve is intentionally made non-linear

3 Symbols

Symbol	Term	Unit
b	radial dimension of rectangular section material	mm
c	spring index	—
D	mean coil diameter	mm
D_o	outside diameter of spring	mm
$D_{H\text{ (min)}}$	minimum diameter of pocket into which spring has to fit	mm
D_i	inside diameter of spring	mm
$D_{s\text{ (max)}}$	maximum diameter of spigot over which spring has to fit	mm
d	material diameter	mm
d_{max}	maximum material diameter allowing for material diameter tolerance	mm
f	natural frequency of unloaded spring	Hz
F	spring force	N
F_s	theoretical solid force	N
ΔF	change in spring force	N
G	modulus of rigidity (see Appendix A)	N/mm ²
h	axial dimension of rectangular section material	mm
h'	axial dimension of rectangular section material after coiling	mm
h'_{max}	maximum axial dimension of rectangular section material after coiling allowing for section size tolerance (see Appendix D)	mm
H	end fixation factor	—
k	material constant for calculation of upset height of rectangular section material after coiling	—
K	stress correction factor	—
L	spring length	mm
L_o	free length of spring	mm
L_s	theoretical solid length of spring	mm
$L_{s\text{ (max)}}$	maximum allowable solid length of spring	mm
ΔL	change in spring length	mm
m	shape factor for rectangular section material	—
n	number of active coils in spring	—
N	total number of coils in spring	—
R_i	inside radius to clear on spring seat	mm

Symbol	Term	Unit
R_o	outside radius to clear on spring seat	mm
S	spring rate	N/mm
t	thickness of any surface coating	mm
δ	deflection from nominal free length to loaded length	mm
λ	stress factor for rectangular section material	—
μ	rate factor for rectangular section material	—
ρ	density of material	kg/mm ³
τ	shear stress in spring	N/mm ²
τ_s	theoretical solid stress in spring	N/mm ²

4 General

4.1 When designing a spring, certain characteristics have to be determined, e.g. shear stress, rate, natural frequency, buckling and the tolerances that can be permitted to ensure that it functions as required, but which will allow it to be produced economically. These characteristics are dealt with in section two, for springs made from circular section material, and in section three, for springs made from rectangular (including square) section material.

4.2 Two methods of specifying springs for general purposes are given in Appendix A.

Method one (see **A.2**) deals with the complete specification of a spring when all the relevant information is available for the spring manufacturer to produce the spring required. The information can be provided to the manufacturer by the customer completing data sheet 1 (see Figure 10). Advice on the completion of this data sheet is given in **A.2**.

When the customer does not have the information to complete data sheet 1, he may use method two (see **A.3**) by completing data sheet 2 (see Figure 11), which is an application for spring design. This is passed to the manufacturer who will then complete data sheet 1 and submit it to the customer for approval. Advice on the completion of data sheet 2 is given in **A.3**.

4.3 Methods of testing springs to determine dimensional characteristics, properties and performance are given in Appendix B.

Section 2. Compression springs made from circular section material

NOTE Unless otherwise indicated, this section applies both to group A and group B springs (see 2.31 and 2.32).

5 Methods of calculation

5.1 Equations

The various characteristics attributable to springs can be calculated by using the equations given in 5.2 to 5.8.

5.2 Stress correction factor

The stress correction factor, K , is given by the equation

$$K = \frac{c + 0.2}{c - 1}$$

where

$$c = \frac{D}{d}$$

NOTE In the case of springs with an index less than 5 this correction factor will lead to conservative results and when such springs are subject only to static operating conditions the spring designer may make allowance for this fact.

5.3 Shear stress

The shear stress, τ , is given by the equation

$$\tau = \frac{8FDK}{\pi d^3}$$

5.4 Rate

The rate, S , is given by the equation

$$S = \frac{\Delta F}{\Delta L} = \frac{Gd^4}{8nD^3}$$

5.5 Natural frequency

The natural frequency, f , is given by the equation

$$f = \frac{d}{2\pi n D^2} \sqrt{\left(\frac{G \times 500}{\rho}\right)}$$

5.6 Buckling

A compression spring will buckle if the deflection under maximum force, as a proportion of the free length of the spring, exceeds a critical value of $H/(L_0/D)$. A range of values of H for various spring end conditions is given in Figure 1 and critical values of $H/(L_0/D)$ in Figure 2.

There are two main reasons why a range of values for H has been given for each end condition. First, the exact end conditions shown in Figure 1 are rarely met in actual practice and, secondly, buckling is affected to a large extent by the end squareness of the spring under load. For the purposes of this Part of BS 1726 the minimum value of H should be used.

5.7 Number of coils

In practice it is possible to determine only the total number of coils. Not only does the number of active coils change during deflection, but the supplier occasionally needs to vary the number of inactive coils to meet other requirements (e.g. solid length). It is therefore impossible to state a specific relationship between the number of active coils, n , and the total number of coils, N .

