Autodesk Inventor Engineer s Handbook

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] قابل توجه خوانندگان عزیر: کلیه مطالب این هندبوک از سایت شرکت Autodesk کپی برداری شده است.[

هندبوک مهندسی نرم افزار Autodesk Inventor

**Spring Generator**

Tension Spring Generator

# Basic concepts

The extension spring is a helical cylindrical spring with coils adjoining each other capable of carrying the outer opposing forces actuating apart in its axis.



Dimensions

|  |  |
| --- | --- |
| d | wire diameter [mm, in] |
| D | mean spring diameter [mm, in] |
| D 1  | outside spring diameter [mm, in] |
| D 2  | inside spring diameter [mm, in] |
| H | working deflection [mm, in] |
| t | pitch of active coils in free state [mm, in] |
| o | eye height [mm, in] |
| s x  | spring deflection [mm, in] |
| L x  | spring length [mm, in] |
| F x  | working force exerted by the spring [N, lb] |
| W 8  | deformation energy [J, ft lb] |
| x | index responding with the spring state |

Coiling

1. Right (usually)
2. Left (must be notified in words)

States

1. Free: the spring is not loaded (index 0)
2. Preloaded: smallest working load is applied to the spring (index 1)
3. Fully loaded: maximum working load is applied to the spring (index 8)
4. Limit: the spring is depressed up to coil touching (index 9)

# Calculation of springs in metric units

General Calculation Formulas

[Utilization factor of material](file:///F%3A%5CINVENTOR%20BOOKS%5CLocal%20Help%202013%5Cautodesk_inventor_2013_help%5Cfiles%5CGUID-D69DA3D7-D178-4692-A951-D08751BF51B8.htm)

Outside spring diameter

D 1 = D + d [mm]

where:

|  |  |  |
| --- | --- | --- |
|    | D  | mean spring diameter [mm]  |
|    | d  | wire diameter [mm]  |

Inside spring diameter

D 2 = D - d [mm]

where:

|  |  |  |
| --- | --- | --- |
|    | D  | mean spring diameter [mm]  |
|    | d  | wire diameter [mm]  |

Working deflection

H = L 8 - L 1 = s 8 - s 1 [mm]

where:

|  |  |  |
| --- | --- | --- |
|    | L 8  | length of fully loaded spring [mm]  |
|    | L 1  | length of pre loaded spring [mm]  |
|    | s 8  | deflection of fully loaded spring [mm]  |
|    | s 1  | deflection of pre loaded spring [mm]  |

Height of spring eye



where:

|  |  |  |
| --- | --- | --- |
|    | L 0  | length of free spring [mm]  |
|    | L Z  | length of spring coiled part [mm]  |

Spring index

c = D/d [-]

where:

|  |  |  |
| --- | --- | --- |
|    | D  | mean spring diameter [mm]  |
|    | d  | wire diameter [mm]  |

Wahl correction factor



where:

|  |  |  |
| --- | --- | --- |
|    | c  | spring index [-]  |
|    | L Z  | length of spring coiled part [mm]  |

Initial tension



where:

|  |  |  |
| --- | --- | --- |
|    | d  | wire diameter [mm]  |
|    | τ 0  | free state stress [MPa]  |
|    | D  | mean spring diameter [mm]  |
|    | K w  | Wahl correction factor [-]  |

General force exerted by the spring



where:

|  |  |  |
| --- | --- | --- |
|    | d  | wire diameter [mm]  |
|    |   τ  | torsional stress is force per unit area. of spring material in general [MPa]  |
|    | D  | mean spring diameter [mm]  |
|    | K w  | Wahl correction factor [-]  |
|    | G  | modulus of elasticity of spring material [MPa]  |

Spring constant



where:

|  |  |  |
| --- | --- | --- |
|    | d  | wire diameter [mm]  |
|    | G  | modulus of elasticity of spring material [MPa]  |
|    | D  | mean spring diameter [mm]  |
|    | n  | number of active coils [-]  |
|    | F 8  | working force in fully loaded spring [MPa]  |
|    | F 1  | working force in minimum loaded spring [MPa]  |
|    | H  | working deflection [mm]  |

Spring Design Calculation

Within the spring design, wire diameter, number of coils and spring free length L 0 are set for a specific load, material and assembly dimensions.



If the calculated spring does not match any wire diameter for the τ 0 stress according to the formula, the spring calculation is repeated with the corrected stress value in a free state within the recommended range.



The spring without initial tension is designed for a mean recommended pitch value t = 0.35 D [mm].

If the calculated spring does not match with any wire diameter of a selected pitch, the spring calculation is repeated with the corrected pitch value within the recommended 0.3 D ≤ t ≤ 0.4 D [mm] range.

The spring design is based on the τ 8 ≤ u s τ A strength condition and the recommended ranges of some spring geometric dimensions: L 0 ≤ D and L 0 ≤ 31.5 in and 4 ≤ D/d ≤ 16 and n ≥ 2.

Specified load, material, and spring assembly dimensions

First the input values for the calculation are checked and calculated.

Next the spring length at the free state is calculated.



After the calculation, the wire diameter, number of coils and spring diameters are designed so that the spring hook height conforms to the selected hook type. The previously mentioned strength and geometric conditions also must be fulfilled. The spring design must conform to any spring diameter value limited in the specification. If not so, the limits of spring diameter are determined by the geometric conditions for minimum and maximum allowable wire diameter.

All spring wire diameters that conform to the strength and geometric conditions are calculated, starting with the smallest, and working to the largest. Spring hook height and number of coils are tested. If all conditions are fulfilled, the design is finished with the selected values, irrespective of other conforming spring wire diameters, and a spring is designed with the least wire diameter and the least number of coils.

The calculated spring hook height must be within the d ≤ o ≤ 30 d range. A combination of the wire diameter, number of coils, and spring diameter must result in a calculated spring hook with a height that corresponds with the height of a basic hook type. The basic hook type is selected by first investigating the full loop, then the full loop inside, and then other types of hooks.

Specified load, material, and spring diameter

First the input values for the calculation are checked.

After the check, the wire diameter, number of coils, spring free length, and assembly dimensions are designed, so that the spring hook height conforms to the selected hook type. The strength and geometric conditions also must be fulfilled. If an assembly dimension L 1 or L 8 is stated in the specification, or the working spring deflection value is limited, then the spring design must conform to this condition. If not, the limits of assembly dimensions and free spring length are determined by the geometric conditions for the specified spring diameter and minimum or maximum allowable wire diameter.

Formula for designing a spring with a specified wire diameter.



where the τ 8 = 0.85 τ A value is used for the value of torsion stress for the spring material, in the spring fully loaded state.

If no suitable combination of spring dimensions can be designed for this wire diameter, geometric investigations proceed on all suitable spring wire diameters. They are tested, beginning with the smallest and working to the largest, for coil numbers that result in the spring hook height that conforms with the conditions. The design is finished with the selected values, irrespective of other suitable spring wire diameters, and the spring is designed with the least wire diameter and the least number of coils.

The calculated spring hook height must be within the d ≤ o ≤ 30 d range. The corresponding hook type is selected for the hook height that is calculated in this way. A combination of the wire diameter, number of coils, free spring length, and assembly dimensions must result in a calculated spring hook with a height that corresponds with the height of a basic hook type. The basic hook type is selected by first investigating the full loop, then the full loop inside, and then other types of hooks.

Specified maximum working force, determined material, assembly dimensions, and spring diameter

First the input values for the calculation are checked and calculated.

Then the wire diameter, number of coils, spring free length, and the F 1 minimum working force are designed, so that the spring hook height conforms the selected hook type. The strength and geometric conditions also must be fulfilled.

Formula for designing a spring with a specified wire diameter.



where the τ 8 = 0.9 τ A value is used for the value of torsion stress for the spring material, in the spring fully loaded state.

If no suitable combination of spring dimensions can be designed for this wire diameter, geometric investigations proceed on all suitable spring wire diameters. They are tested, beginning with the smallest and working to the largest, for coil numbers that result in the spring hook height that conforms with the conditions. The design is finished with the selected values, irrespective of other suitable spring wire diameters, and the spring is designed with the least wire diameter and the least number of coils.

Spring Check Calculation

Calculates corresponding values of assembly dimensions and working deflection for the specified load, material, and spring dimensions.

First, the input values for the calculation are checked. Then the assembly dimensions are calculated using the following formulas.

Length of preloaded spring



Length of fully loaded spring



where:

|  |  |  |
| --- | --- | --- |
|    | L 0  | length of free spring [mm]  |
|    | F 1  | working force in minimum loaded spring [mm]  |
|    | D  | mean spring diameter [mm]  |
|    | n  | number of active coils [-]  |
|    | G  | modulus of elasticity of spring material [MPa]  |
|    | d  | wire diameter [mm]  |
|    | F 8  | working force in fully loaded spring [MPa]  |

Working deflection

H = L 1 - L 8 [mm]

Calculation of Working Forces

Calculates corresponding forces produced by springs in their working states for the specified material, assembly dimensions, and spring dimensions. First the input data is checked and calculated, and then the working forces are calculated using to the following formulas.

Minimum working force



Maximum working force



Calculation of spring output parameters

Common for all types of spring calculation, and calculated in the following order.

Hook height factor



Spring constant



Length of coiled part

|  |
| --- |
| Spring without initial tension  |
|    | L z = t n + d [mm]  |
| Spring with initial tension  |
|    | L z = 1.03 (n + 1) d [mm]  |

Pre loaded spring deflection

s 1 = L 1 - L 0 [mm]

Total spring deflection

s 8 = L 8 - L 0 [mm]

Torsional stress of spring material in the preloaded state



Torsional stress of spring material in the fully loaded stress



Spring limit force



Deflection in limit state



where:

|  |  |  |
| --- | --- | --- |
|    | k  | spring constant [N/mm]  |
|    | F 9  | working force of spring loaded at limit [N]  |
|    | F 0  | spring initial tension [N]  |

Limit spring length

L 9 = L 0 + s 9 [mm]

Spring deformation energy



Developed wire length

|  |
| --- |
| l = 3.2 D n + l 0 [mm]  |
|    | Where the developed hook length l 0 :  |
|    |    | for half hook  |
|    |    |    | l 0 = π D + 4 o - 2 D - 2 d [mm]  |
|    |    | for full loop  |
|    |    |    | l 0 = 2 (π D - 2 d) [mm]  |
|    |    | for full loop on side  |
|    |    |    | l 0 = 2 (π D - 2 d) [mm]  |
|    |    | for full loop inside  |
|    |    |    | l 0 = 2 (π D - d) [mm]  |
|    |    | for raised hook  |
|    |    |    | l 0 = π D + 2 o - D + 3 d [mm]  |
|    |    | for double twisted full loop  |
|    |    |    | l 0 = 4 π D [mm]  |
|    |    | for double twisted full loop on side  |
|    |    |    | l 0 = 4 π D [mm]  |
|    |    | for non-specified hook type  |
|    |    |    | l 0 = 0 [mm]  |

Spring mass



Natural frequency of spring surge



Check of spring load

τ 8 ≤ u s τ A

Overview of used variables:

|  |  |
| --- | --- |
| d  | wire diameter [mm]  |
| k  | spring constant [N/mm]  |
| D  | mean spring diameter [mm]  |
| D 1  | spring outside diameter [mm]  |
| D 2  | spring inside diameter [mm]  |
| F  | general force exerted by the spring [N]  |
| G  | shear modulus of elasticity of spring material [MPa]  |
| H  | working deflection [mm]  |
| c  | spring index [-]  |
| K w  | Wahl correction factor [-]  |
| l  | developed wire length [mm]  |
| L  | spring length in general [mm]  |
| L Z  | length of coiled spring part [mm]  |
| m  | spring mass [N]  |
| n  | number of active coils [-]  |
| o  | spring hook height [mm]  |
| t  | pitch of active coils in free state [mm]  |
| s  | spring deflection (elongation) in general [mm]  |
| u s  | [utilization factor of material](file:///F%3A%5CINVENTOR%20BOOKS%5CLocal%20Help%202013%5Cautodesk_inventor_2013_help%5Cfiles%5CGUID-D69DA3D7-D178-4692-A951-D08751BF51B8.htm)  |
|   ρ  | density of spring material [N/mm 3 ]  |
|   τ  | torsional stress is force per unit area. of spring material in general [MPa]  |
| τ A  | allowable torsion stress of spring material [MPa]  |

# Material

Material of spring wire for metric

|  |  |  |  |
| --- | --- | --- | --- |
| Wire type  | G [MPA]  | Allowable limit torsion stress τ A  | Density ρ [kg.m 3 ]  |
| Draw patented from carbon steel | 80 500 | 0.5 σ ult  | 7.85 10 3  |
| Heat treated from carbon steel | 78 500 | 0.6 σ ult  |
| Heat treated or annealed from alloy steel (Si-Cr, Mn-Cr-V) 14260 and 15260 | 78 500 | 0.6 σ ult  |
| Hardened by drawing from chrome-nickel stainless austenitic steel 17242 | 68 500 | 0.5 σ ult  |
| Hardened by drawing from tin-bronze 423016 and 423018 | 41 500 | 0.45 σ ult  | 8.8 10 3  |
| Hardened by drawing from brass 423210 and 423213 | 34 500 | 0.45 σ ult  | 8.43 10 3  |

Material of spring wire for English

|  |  |
| --- | --- |
| Wire type  | Modulus of Elasticity in Shear [psi]  |
| Hard drawn steel wire QQ-W-428 | 11 200000 |
| Music wire QQ-W-470 | 11 200000 |
| Oil-tempered steel wire QQ-W-428 | 11 200000 |
| Chrome-silicon alloy wire QQ-W-412 | 11 200000 |
| Corrosion-resisting steel wire QQ-W-423 | 11 200000 |
| Chrome-vanadium alloy steel wire | 11 200000 |
| Silicon-manganese steel wire | 11 200000 |
| Valve-spring quality wire | 11 200000 |
| Stainless steel 304 and 420 | 11 600000 |
| Stainless steel 316 | 11 600000 |
| Stainless steel 431 and 17-7 PH | 11 600000 |

Allowable limit torsion stress τ A [10 3 psi]

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wire diameter [in]  | Hard drawn steel wire QQ-W-428  | Music wire QQ-W470  | Oil-tempered steel wire QQ-W-428  | Chrome-silicon alloy wire QQ-W-412  | Corrosion-resisting steel wire QQ-W-423  | Chrome-vanadium alloy steel wire  | Silicon-manganese steel wire  | Valve-spring quality wire  | Stainless steel 304 and 420  | Stainless steel 316  | Stainless steel 431 and 17-7 PH  |
| 0.010 | 150 | 176 | 157 | 176 | 145 | 175 | 158 | 175 | 138 | 131 | 158 |
| 0.012 | 149 | 171 | 154 | 175 | 143 | 174 | 157 | 174 | 129 | 154 | 158 |
| 0.014 | 148 | 167 | 152 | 174 | 141 | 173 | 156 | 173 | 134 | 127 | 150 |
| 0.016 | 147 | 164 | 150 | 174 | 139 | 172 | 155 | 172 | 132 | 125 | 148 |
| 0.018 | 146 | 161 | 148 | 173 | 137 | 171 | 154 | 171 | 130 | 123 | 145 |
| 0.02 | 145 | 159 | 146 | 173 | 135 | 170 | 153 | 170 | 128 | 121 | 143 |
| 0.024 | 143 | 155 | 142 | 172 | 131 | 168 | 151 | 168 | 124 | 118 | 140 |
| 0.026 | 142 | 153 | 141 | 171 | 129 | 167 | 150 | 167 | 123 | 116 | 138 |
| 0.028 | 141 | 151 | 140 | 171 | 128 | 166 | 149 | 166 | 122 | 115 | 136 |
| 0.030 | 140 | 149 | 139 | 170 | 127 | 165 | 148 | 165 | 121 | 114 | 134 |
| 0.032 | 139 | 147 | 138 | 170 | 126 | 164 | 147 | 164 | 120 | 113 | 132 |
| 0.034 | 138 | 145 | 137 | 169 | 125 | 163 | 146 | 163 | 119 | 112 | 130 |
| 0.036 | 137 | 143 | 136 | 169 | 124 | 162 | 145 | 162 | 118 | 112 | 129 |
| 0.038 | 136 | 142 | 135 | 168 | 123 | 161 | 144 | 161 | 117 | 111 | 128 |
| 0.041 | 135 | 141 | 133 | 167 | 122 | 160 | 144 | 160 | 116 | 110 | 127 |
| 0.0475 | 132 | 138 | 130 | 166 | 119 | 156 | 140 | 156 | 113 | 107 | 124 |
| 0.054 | 138 | 136 | 128 | 165 | 117 | 152 | 137 | 152 | 111 | 105 | 122 |
| 0.0625 | 123 | 132 | 125 | 162 | 115 | 149 | 134 | 152 | 109 | 104 | 119 |

# Utilization factor of material uS

The factor gives a relationship between the torsion stress of a spring in the fully loaded state and the allowable torsion stress, such as u S ≈τ 8 / τ A . If a greater value is selected, less material is needed for spring production. The spring dimensions and the space for mounting are less, but the securing of spring stability during its function is lower, and vice versa. This factor is a reciprocal value of the safety rate. For common operational conditions, the value of the utilization factor of the material is recommended to be within the u S = 0.85 ... 0.95 range. Lower values can be used for springs working in aggressive surroundings, at high temperatures or loaded with impacts.

# Hooks of extension springs

Height of an extension spring hook



where:

|  |  |
| --- | --- |
| L 0  | length of free spring [mm] |
| L Z  | length of spring coiled part [mm] |

Most frequently used hooks of extension springs

|  |  |
| --- | --- |
| Hook type and dimension instructions  | Image  |
| Half hook, o = 0.55 to 0.8 D 2  |   F:\INVENTOR BOOKS\Local Help 2013\autodesk_inventor_2013_help\images\GUID-F014783C-B523-40DC-9ED1-A420038F5C05-low.gif |
| Usually: d ≤ 6.3 mm, D >= 3.15 mm, i >= 9  |
| Full loop, o = 0.8 to 1.1 D 2  |   F:\INVENTOR BOOKS\Local Help 2013\autodesk_inventor_2013_help\images\GUID-7771B12B-4198-4845-A442-8B80F390A7B8-low.gif |
| Used generally |
| Full loop on side, o ≈ D 2  |   F:\INVENTOR BOOKS\Local Help 2013\autodesk_inventor_2013_help\images\GUID-626051DD-997A-4D8E-A930-47EAEF3C68DB-low.gif |
| When moving the force out of spring axis does not matter |
| Full loop inside, o = 1.05 to 1.2 D 2  |   F:\INVENTOR BOOKS\Local Help 2013\autodesk_inventor_2013_help\images\GUID-AE34E4DF-F7D8-4600-8225-1D4C613A8B78-low.gif |
| Usually: d ≤= 10 mm, i >= 7  |
| Raised hook, o = 1.2 D 2 to 30 d  |   F:\INVENTOR BOOKS\Local Help 2013\autodesk_inventor_2013_help\images\GUID-8CF9D71B-90DC-4498-BE34-C61E5ED6D015-low.gif |
| Usually for: d = 0.5mm to 4 mm, o ≤ 100 mm  |
| Double twisted full loop, o ≈ D  |   F:\INVENTOR BOOKS\Local Help 2013\autodesk_inventor_2013_help\images\GUID-474A9834-357D-4B3B-8063-37C866E38B68-low.gif |
| Used generally |
| Double twisted full loop on side, o ≈ D 2  |   F:\INVENTOR BOOKS\Local Help 2013\autodesk_inventor_2013_help\images\GUID-021E55CA-DA44-476A-9C95-969F6FE8E53F-low.gif |
| When moving the force out of spring axis does not matter |

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