PRECISION STRIP

STAINLESS SPRING STEEL STRIP
ZAPP® 1.4310

New since 1701
Zapp Precision Metals GmbH

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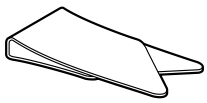
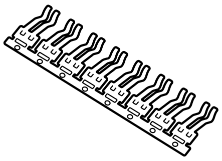
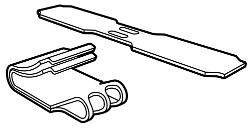
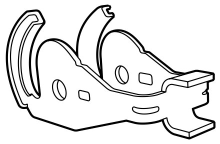





FOREWORD

The four versions of the Zapp® 1.4310 material are of major importance in Zapp's precision strip portfolio. The steel has earned a fixed place in the market for springs, punching and bending components. In fact, we can't imagine the marketplace without it!

For us, this was the occasion to devote a catalogue to "Zapp® 1.4310 Precision Strips". We are convinced that the information in the catalogue will help you find the right answers to a variety of questions. If you need any further information, we would be happy to help.

Of course, this also applies to questions related to other materials in our portfolio that are not covered in this catalogue.

Dr. Stefan Seng
Chief Executive Officer

Gerald Zwickel
Member of the Executive Board

THE COMPANY
Our 4th century – History

Progress in the steel industry in the last 300 years has had an impact on life, business and culture. The Zapp family is rooted in these developments:

1701-1869:	Initially, five generations produce wrought iron, and later steel.
1871:	Robert Zapp establishes a steel company in Düsseldorf with a focus on speciality steels.
1887:	Robert Zapp receives the exclusive sales rights to Krupp tool steels.
1913-1927:	Market introduction of Krupp materials Nirosta and Widia.
1926:	Acquisition of shares of the company Stahlwerk Ergste.
1955:	The enterprise operates under Robert Zapp Werkstofftechnik. The introduction of nickel- and cobalt-base materials, later distribution rights for CPM materials.
1961:	Stahlwerk Ergste focuses on stainless steels.
1991:	Stahlwerk Ergste acquires the company Westig.
1996:	Establishment of a first production plant in the United States, in Summerville, South Carolina. The plant produces wire and flat wire.
1998:	The companies of the Zapp group are combined under Zapp AG.
2000:	Construction of a second production facility in the United States in Dartmouth, Massachusetts, for precision strip products. Development of the West Coast Service Center.
2005:	Founding of the Zapp Medical Alloys and a Service Center for nickel-based alloys in Germany.
2007:	Creation of another service center in China, as well as on the east coast of the United States.
2008:	Acquisition of Ferd. Wagner GmbH
2011:	A major fire at the Ergste location destroys substantial parts of the precision strip manufacturing.
2012/2013:	Construction of the world's most modern factory for the production of precision strip in Unna. A concentration of the production of strip products in Unna follows, as well as the production of wire, rod and profile products in Schwerte-Ergste.
2013:	The Zapp Group unifies its presence; Stahlwerk Ergste Westig, Zapp Medical Alloys and Ferd. Wagner are combined under Zapp Precision Metals GmbH.

THE GROUP
The Zapp Group has production sites, consulting and service centers in Europe, United States and Asia. It also has a network of its own and third-party distributors. In Germany, Zapp is divided into the following business areas:

PRECISION STRIP, Unna, with the product areas:
_ Precision strip products and
_ Bimetals

PRECISION WIRE, Schwerte-Ergste, with the product areas:
_ Precision wire, bar and profile
_ MEDICAL ALLOYS: Fine wires, profiles, strips, sheets and tubes for medical technology

and

MATERIALS ENGINEERING, Ratingen/Unna, with the product areas:
_ SPECIALTY MATERIALS, Ratingen: High-performance materials
_ TOOLING ALLOYS, Ratingen and Unna: mainly powder metallurgical tool steel

MANUFACTURING FACILITIES
Zapp Precision Metals GmbH specialises in precision semi-finished, cold-formed products and operates plants for wire, bar and profile products in Schwerte-Ergste and Summerville, and for strip and bimetallic products in Unna and Dartmouth.

STRIP PRODUCTS
The material range includes rust-, acid- and heat-resistant stainless steels (ferritic, austenitic, martensitic and precipitation hardening steels), nickel and titanium alloys and high-carbon C-steel and bimetal. Depending on the alloy, we can supply products in the hardened, final-annealed or tempered conditions. Starting from cold-rolled wide strip, we produce precision strip products between 0.02 and 1.5 mm in thickness. Our U.S. production can manufacture strips can up to 1066 mm; in Europe we can make up to 750

mm in width. The strip is rolled on in a reversing mill with multiple rolls. Depending on thickness and desired properties, we can heat treat and roll several times in succession. We tension level annealed or cold-worked strip – such as spring steel – to improve the flatness and straightness and follow that with longitudinal and transverse finishing.
The core competency of PRECISION STRIP is creating products with tight shape and geometrical tolerances, special finishes, narrow mechanical and physical properties and special delivery forms (coil, spool, plate, multicoil).

INNOVATION AND TECHNOLOGY

The Zapp Group stands for sustainable innovations in the field of precision semi-finished products and high-performance materials. The construction of one of the world's most advanced factories for the production of precision strips in Unna is a testament to Zapp's aspirations of taking a leading position in an innovative market environment. The Zapp Group's innovative potential is a decisive success factor in the competitive marketplace and makes Zapp a sought-after partner, particularly in innovative industries such as medical technology as well as the automotive, aerospace and chemical industries.
Zapp faces increasing demands from industry and technology for the characteristics of the products and increasing cost pressure with a comprehensive research and development program. In doing so, Zapp is constantly able to develop customer-oriented, practical solutions in cooperation with research institutions and in close collaboration with customers.

QUALITY MANAGEMENT

The continuous improvement of processes and products with a comprehensive quality management system is a core element of the Zapp Group's corporate strategy. All locations are certified in accordance with ISO 9001 guidelines. The Schwerte-Ergste and Unna sites are certified as per ISO/TS 16949 for the additional requirements of the international automotive industry. The location in Rantingen is certified in accordance with EN 9120 and the Dartmouth, MA, USA site according to AS 9100 for the requirements of the international aviation industry.

SUSTAINABILITY

Sustainability forms the essential motor of innovation in a company. It also promotes the continuous process of improving economic, environmental and social performance, which in turn ensures the future viability of the company. This is the reason why sustainable and responsible business have characterized the culture of Zapp for more than 310 years.
Zapp is committed to the ten principles of the Global Compact of the United Nations. In this regard, environmental and climate protection is especially important for Zapp, as a company with high energy consumption. To this end, Zapp has implemented an environmental management system in throughout the company that is based on the requirements of the DIN EN ISO 14001. Having one of the most modern and energy-efficient cold rolling mills in Europe is a testament to our commitment to responsibility in this area. The same applies to investments made in new equipment at the Schwerte-Ergste site for profile, bar and wire production, in particular for the automotive industry and medical technology.
On the basis of evaluations and audits, we continuously identify potential for improvement with suppliers and customers in the area of sustainability and agree upon measures to realize this potential. Group-wide sustainability activities are controlled by corresponding representatives or functional units within the group, which ensure the inclusion of social and environmental requirements into everyday work processes.

COMPARISON OF THE MATERIALS

In addition to the standards for spring steel strip DIN EN 10151 and DIN EN ISO 9445-1, this Zapp spring steel strip catalogue provides an overview of the special properties of stainless spring steel precision strip Zapp® 1.4310 (X10CrNi18-8), as well as information for the selection and processing.
The demand for spring steel strip is rising among spring/punch and bending part manufacturers. This is due on the one hand to the required processing characteristics, and on the other to the function requirements for the manufactured components.
For these reasons, manufactures are increasingly turning to Zapp® 1.4310.

Due to its chemical composition, the material 1.4310 is a member of the austenitic steels group, according to the standards. Within this standard, Zapp has developed their own materials with tight analysis ranges:

_ Zapp® 1.4310FM
_ Zapp® 1.4310FC
_ Zapp® 1.4310FS
_ Zapp® 1.4310FF

Zapp® 1.4310FM and Zapp® 1.4310FC are more austenite-stable than Zapp® 1.4310FS and Zapp® 1.4310FF. With our technology and know-how, we can achieve high spring forces and great residual deformation capacity.

ZAPP® 1.4310FM

This version was originally developed for special membrane applications. Today, its use concentrates in the tensile strength range up to 1200 MPa at a simultaneous yield strength ratio of at least 75%. Temperature resistance depending on the type of load: up to 120 °C.

ZAPP® 1.4310FC

This spring strip version is suitable for stainless steel spring, punching and bending parts. It has good spring properties, particularly up to a tensile strength of 1500 MPa. Temperature resistance depending on the type of load: up to 200 °C.

ZAPP® 1.4310FS

This is the most commonly used grade of spring steel strip. The tensile strength can reach up to 2200 MPa. The material offers the user a unique combination of tensile strength/spring properties in conjunction with excellent formability. These strips can be processed into spring, punching or bending parts even at comparatively high tensile strengths.
Zapp® 1.4310FS is analytically compliant to the American material standard AISI 301 (US S30100). Temperature resistance depending on the type of load: up to 250 °C.

ZAPP® 1.4310FF

The material 1. 4310FF is a steel that has an improved corrosion resistance due to its increased molybdenum content. Zapp® 1. 4310FF can also reach strengths of up to 2200 MPa. The increased silicon and molybdenum content provide for increased tempering properties. Temperature resistance depending on the type of load: up to 250 °C.

Zapp® 1.4310 is used by many customers for various demanding applications. Zapp delivers the entire range of dimensions in different strength classes.
Specific treatment or processing requires different materials. We develop optimal solutions in close cooperation with our customers. Our specialists help us find the best material/processing combination for your application. Unique solutions to individual problems are often the beginning of a long-term, successful partnership. The tried-and-tested Zapp quality as well as fast and flexible ordering and delivery are guaranteed.

MATERIALS

TABLE 1 | Chemical composition (standard values)

Description	Mass fraction alloying elements in percent						
Zapp	C	Si	Mn	Cr	Ni	Mo	N
1.4310FM	0.06	0.60	1.20	18.10	8.20	-	0.040
1.4310FC	0.10	0.60	1.00	16.70	7.20	-	0.040
1.4310FS	0.10	0.90	1.20	16.70	6.60	-	0.070
1.4310FF	0.10	1.20	1.20	16.70	6.60	0.70	0.070

TABLE 2 | Corresponding standards

Description	EN 10151	EN 10151	EN 10088-2*	EN 10088-2*	ASTM A 666
Zapp	Material number	Abbreviation	Material number	Abbreviation	Abbreviation
1.4310FM	1.4310	X10CRNI18-8	1.4310	X10CrNi18-8	AISI 302
1.4310FC	1.4310	X10CRNI18-8	1.4310	X10CrNi18-8	AISI 301
1.4310FS	1.4310	X10CRNI18-8	1.4310	X10CrNi18-8	AISI 301
1.4310FF	1.4310	X10CRNI18-8	1.4310	X10CrNi18-8	**AISI 301

* EN 10088-2 replaces the national standards BS 1449-2, AFNOR A 35-573, UNI 8366-82 and SS 14

** Variation in silicon content

TABLE 3 | Corresponding global standards

Zapp	Europe EN	Europe EN	USA UNS	China GB	Russia Gost	India IS	Korea ST	Japan JIS
	Material number	Abbreviation	Abbreviation	Abbreviation	Abbreviation	Abbreviation	Abbreviation	Abbreviation
1.4310[1]	1.4310	X10CrNi18-8	S30100	1Cr17Ni7	12Ch18N9	X07Cr18Ni9	STS 301	SUS 301

[1] Except for Zapp® 1.4310FM

MECHANICAL PROPERTIES AND HARDNESS

TENSILE STRENGTH

Available tensile strength ranges for the four material versions of the stainless spring steel strip Zapp® 1.4310.

TABLE 4 | Tensile strength as per DIN EN 10151: Strip thickness 0.025 mm to ≤1.00 mm in the as-delivered condition C850 C1900 and T

Standard								
Tensile strength levels	C850	C1000	C1150	C1300	C1500	C1700[1)]	C1900[2)]	Increase in tensile strength by tempering (T) in MPa
Tensile strength range in MPa	850-1000	1000-1150	1150-1300	1300-1500	1500-1700	1700-1900	1900-2200	
Factory standard								
Zapp® 1.4310FM[3)]	■	■	■	on request		not available		up to 100
Zapp® 1.4310FC	■	■	■	■	■	on request		up to 200
Zapp® 1.4310FS	■	■	■	■	■	■	■	up to 250
Zapp® 1.4310FF	■	■	■	■	■	■	■	up to 300
Zapp® 1.4310 another RM range	Each individual tensile strength according to your specifications with a tolerance of ± 75 MPa Lower Rm ranges on request							see above
Zapp® 1.4310FS/FF from spring steel strip stock	In stock in these and other tensile strength classes. Actual values on request. For more information, see Chapter 3							up to 300

■ available

[1)] Strip thickness: max. 0.75mm

[2)] Strip thickness: max. 0.50 mm

[3)] available in level C700

TABLE 5 | Tensile strength as per DIN EN 10151: Strip thickness >1.00 mm to ≤2.00 mm in the as-delivered condition C850 to C1300 and T

Standard					
Tensile strength levels	C850	C1000	C1150	C1300	Increase in tensile strength by tempering (T) in MPa
Tensile strength range in MPa	850-1000	1000-1150	1150-1300	1300-1500	
Factory standard					
Zapp® 1.4310FM	■	■	on request		up to 80
Zapp® 1.4310FC	■	■	■	■	up to 130
Zapp® 1.4310FS	■	■	■	■	up to 150
Zapp® 1.4310FF	■	■	■	■	up to 170
Zapp® 1.4310 another RM range	Each individual tensile strength according to your specifications with a tolerance of ± 75 MPa Lower Rm ranges on request				see above
Zapp® 1.4310FS from spring steel strip stock	In stock in these and other tensile strength classes. Actual values on request. For more information, see Chapter 3				up to 170

■ available

For more information see Chapter 3.4

The difference in the tensile strength between the ends of a coil or a spool is regulated by the Section 7.2.2 as per DIN EN 10151. Narrower ranges of variation on request

MECHANICAL PROPERTIES AND HARDNESS

TABLE 6 | Elongation as per DIN EN 10151

Factory standard							
Elongations	A80%, min. (lengthwise) for the tensile strength levels						
Tensile strength levels	C850	C1000	C1150	C1300	C1500	C1700	C1900
Zapp® 1.4310[1)]	**25**	**20**	**15**	10	5	2	1
Zapp® 1.4310FM[2)]	**12**	**5**	**3**	**1**			

[1)] The values apply to the material Zapp® 1.4310FS/FF. For Zapp® 1.4310FC up to strength class C1500
[2)] The values for the material 1.4301 were used

TABLE 7 | Reference values for the elastic modulus as per DIN EN 10151

Factory standard	Elastic module in GPa	
	Cold rolled[1)] (C)	Cold rolled + heat treated (QT)
Zapp® 1.4310	185	195

[1)] measurements of longitudinal samples with a mean tensile strength of 1800 MPa; for a medium tensile strength of 1300 MPa the values are around 6 GPa lower. Intermediate values may be interpolated.

TABLE 8 | Reference values for Vickers hardness as per DIN EN 10151

Factory standard	Vickers hardness	
	Available HV[1)] ranges	Limiting deviation for HV target value
Zapp® 1.4310	250 – 450 451 - 600	± 25 ± 30

[1)]In these ranges, we can deliver steel in all HV target values depending on the strip thickness as per Tables 4 and 5. HV values must be determined as per DIN EN ISO 6507-1.

DIMENSIONS/ TOLERANCES

DIMENSIONS

Precision strip Zapp® 1.4310 is available in the following size ranges:

Thickness 0.020 – 1.50 mm
Width 2.00 – 750 mm

For thickness-width ratios larger than 1:10, we refer customers to our other product options in flat wire Zapp® 1.4310.

THICKNESS TOLERANCES

Uniform properties are a pre-requisite for highly productive and demanding processing by our customers. We achieve the tightest tolerances with the most modern equipment and control systems, as well as carefully selected raw materials. The precision tolerance as per standards is the Zapp standard tolerance. We can restrict it further on request.

TABLE 9 | Thickness tolerances as per DIN EN ISO 9445-1 for cold-rolled strip and cold-rolled bars for strip thickness ≥ 0.025 mm and rolling widths of up to 750 mm

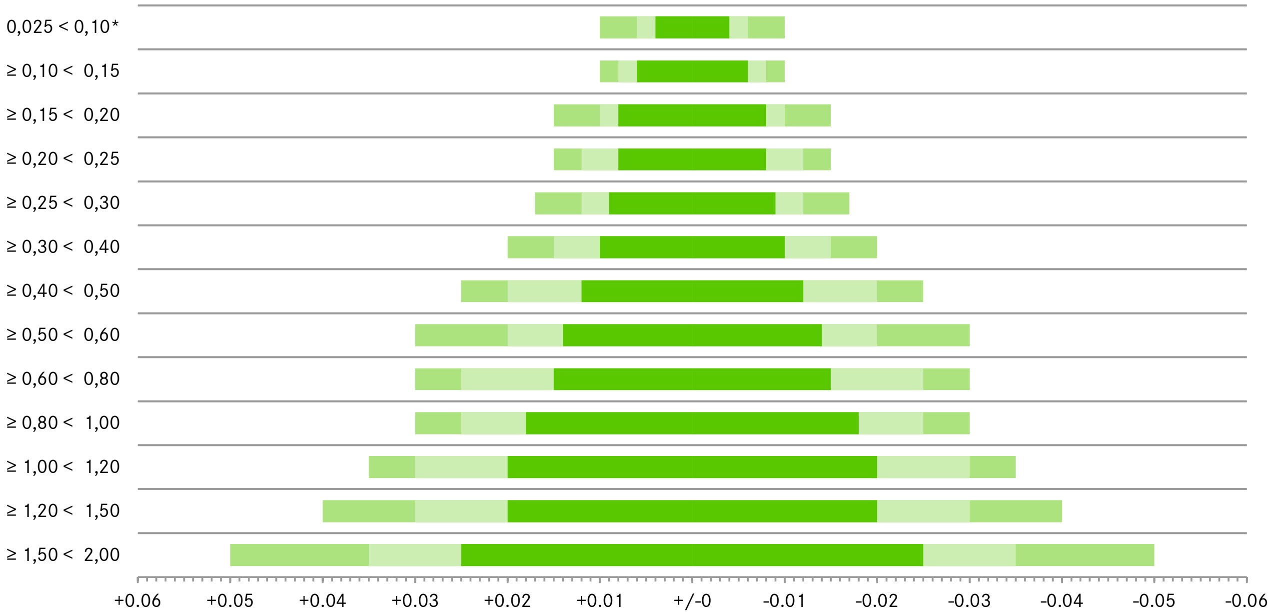
Thickness in mm		Limit deviations of nominal thickness for a nominal width of									Zapp factory standard for all widths
		Normal	Fine	Precision	Normal	Fine	Precision	Normal	Fine	Precision	Zapp
		w < 125			125 ≤ w < 250			250 ≤ w < 750			w < 750[1]
≥	<	+/- mm	+/- mm	+/- mm	+/- mm	+/- mm	+/- mm	+/- mm	+/- mm	+/- mm	+/- mm
0.025	0.10	10% of strip thickness	6 % of strip thickness	4 % of strip thickness	12 % of strip thickness	10% of strip thickness	8 % of strip thickness	15 % of strip thickness	10% of strip thickness	8 % of strip thickness	4 % of strip thickness
0.10	0.15	0.010	0.008	0.006	0.015	0.012	0.008	0.020	0.015	0.010	0.006
0.15	0.20	0.015	0.010	0.008	0.020	0.012	0.010	0.025	0.015	0.012	0.008
0.20	0.25	0.015	0.012	0.008	0.020	0.015	0.010	0.025	0.020	0.012	0.008
0.25	0.30	0.017	0.012	0.009	0.025	0.015	0.012	0.030	0.020	0.015	0.009
0.30	0.40	0.020	0.015	0.010	0.025	0.020	0.012	0.030	0.025	0.015	0.010
0.40	0.50	0.025	0.020	0.012	0.030	0.020	0.015	0.035	0.025	0.018	0.012
0.50	0.60	0.030	0.020	0.014	0.030	0.025	0.015	0.040	0.030	0.020	0.014
0.60	0.80	0.030	0.025	0.015	0.035	0.030	0.018	0.040	0.035	0.025	0.015
0.80	1.00	0.030	0.025	0.018	0.040	0.030	0.020	0.050	0.035	0.025	0.018
1.00	1.20	0.035	0.030	0.020	0.045	0.035	0.025	0.050	0.040	0.030	0.020
1.20	1.50	0.040	0.030	0.020	0.050	0.035	0.025	0.060	0.045	0.030	0.020
1.50	2.00	0.050	0.035	0.025	0.060	0.040	0.030	0.070	0.050	0.035	0.025

[1] The range is expanded compared to the standard.

The thickness tolerance is an important factor in the spring design. Figure 1 (see Page 12) clearly shows the precision tolerances of different thicknesses of stainless Zapp spring steel strip steel.

DIMENSIONS / TOLERANCES

FIGURE 1 | Strip thickness tolerances in mm



Graphical representation of the thickness tolerances in mm for strip widths w < 125.00 mm

DIN EN ISO 9445-1 Normal Fine Zapp (precision)

WIDTH TOLERANCE
We offer tolerances in the following categories: normal, fine and precision.

In deviation from the standard, the tolerance range can be adjusted in the minus or plus/minus range on request. An agreement is required for each individual case. Closer tolerances may be possible upon request.

Table 10 | Width tolerances in mm as per DIN EN ISO 9445-1 for cold-rolled strip and cold-rolled strip in bars

Thickness in mm		w ≤ 40			40 < w ≤ 125			125 < w ≤ 250			250 < w < 750[1]		
≥	<	normal	fine	precision	normal	fine	precision	normal	fine	precision	normal	fine	precision
0.025	0.25	+ 0,17 − 0	+0.13 − 0	+ 0.10 − 0	+ 0,20 − 0	+ 0.15 − 0	+ 0.12 − 0	+ 0.25 − 0	+ 0.20 − 0	+ 0.15 − 0	+ 0.50 − 0	+ 0.50 − 0	+ 0.40 − 0
0.25	0.50	+ 0.20 − 0	+ 0.15 − 0	+ 0.12 − 0	+ 0.25 − 0	+ 0.20 − 0	+ 0.15 − 0	+ 0.30 − 0	+ 0.22 − 0	+ 0.17 − 0	+ 0.60 − 0	+ 0.50 − 0	+ 0.40 − 0
0.50	1.00	+ 0.25 − 0	+ 0.20 − 0	+ 0.15 − 0	+ 0.25 − 0	+0.22 − 0	+ 0.17 − 0	+ 0.40 − 0	+ 0.25 − 0	+ 0.20 − 0	+ 0.70 − 0	+ 0.60 − 0	+ 0.50 − 0
1.00	1.50	+ 0.25 − 0	+ 0.22 − 0	+ 0.15 − 0	+ 0.30 − 0	+ 0.25 − 0	+ 0.17 − 0	+ 0.50 − 0	+ 0.30 − 0	+ 0.22 − 0	+ 1.0 − 0	+ 0.70 − 0	+ 0.60 − 0
1.50	≤ 2.0	–	–	–	+ 0.40 − 0	+0.25 − 0	+ 0.20 − 0	+ 0.60 − 0	+ 0.40 − 0	+ 0.25 − 0	+ 1.0 − 0	+ 0.80 − 0	+ 0.60 − 0

Factory standard

[1] The range is expanded compared to the standard.

FLATNESS AND EDGE WAVINESS TOLERANCE

Different states of flatness in terms of evenness and edge waviness can occur on the rolled spring steel strip during cold forming. Edge waviness is defined in DIN EN ISO 9445-1 and is described by the ratio of wave height h to wave length l (see fig. 2). Although the standard defines these values for lightly re-rolled or tension-levelled cold-rolled strip, Zapp also applies them to spring steel strip. The test for flatness takes place as per DIN EN ISO 9445-1 and must be agreed upon. We are constantly optimizing our rolling and levelling technology by using the most up-to-date measuring equipment, for example. We use our acquired know-how to enable tighter limit values, even for the most challenging applications.

TABLE 11 | Flatness and edge waviness tolerances for cold-rolled strip

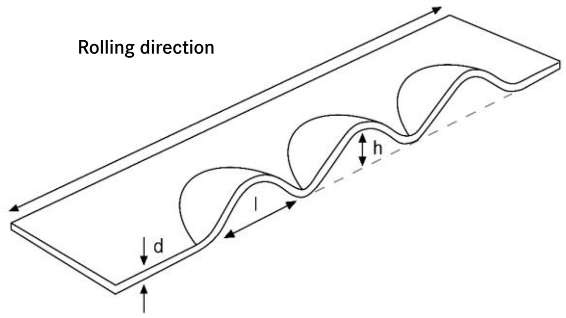
	Edge waviness				Flatness
	Zapp 1.4310		ISO 9445-1		DIN EN 10151
Strip thickness	h/l	h/l in %	h/l	h/l in %	By individual agreement
0.9 mm	≤ 0.015	≤ 1.5	≤ 0.03	≤ 3.0	
> 0.9 mm	≤ 0.015	≤ 1.5	≤ 0.02	≤ 2.0	

TABLE 12 | Flatness tolerances for cold-rolled strip in bars in accordance with DIN EN ISO 9445-1

Normal:	h ≤ 6 mm
Special tolerance (FS):	h ≤ 4 mm

The requirements do not apply for cold-rolled strip in a heat-treated condition

FIGURE 2 | Edge waviness



l = wave length
h = wave height
d = strip thickness

Advantage: For our products, we provide you with a significantly restricted edge waviness – for all strip thicknesses.

EDGE CAMBER TOLERANCE (SABRE)

TABLE 13 | Edge camber tolerances for cold-rolled strip and cold-rolled strip in bars as per DIN EN ISO 9445-1 and factory standard

	Width in mm		Edge camber tolerance in mm				
			Normal	Normal	Restricted[1]	Restricted[1]	DIN EN 10151
			Measurement length	Measurement length	Measurement length	Measurement length	By Individual agreement
	≥	<	1000 mm	2000 mm	1000 mm	2000 mm	
Zapp factory standard	2	10	≤ 5	≤ 20	≤ 2.5	≤ 10	
Standard	10	25	≤ 4	≤ 16	≤ 1.5	≤ 6	
Standard	25	40	≤ 3	≤ 12	≤ 1.25	≤ 5	
Standard	40	125	≤ 2	≤ 8	≤ 1.0	≤ 4	
Standard	125	400	≤ 1.5	≤ 6	≤ 0.75	≤ 3	

[1]Custom-made

FIGURE 3 | Camber (top view)

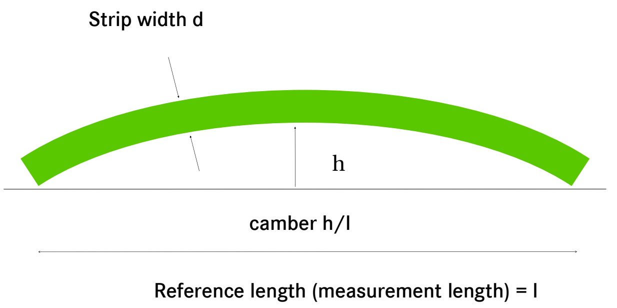
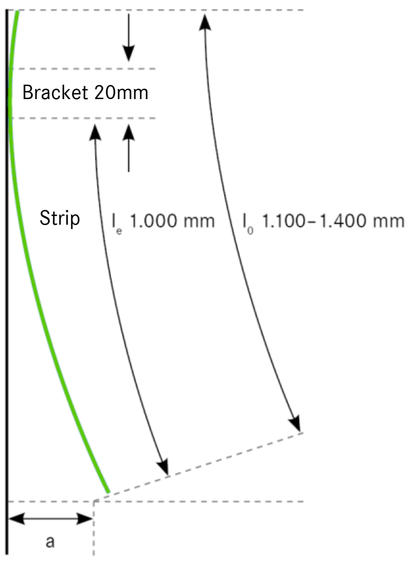


Figure 3. Illustrates: camber h is the maximum deviation between a straight edge and the curved formation of the strip d.

Advantage: Our custom processing technology enables the tightest edge camber tolerances for stainless spring steel strip. According to DIN EN ISO 9445-1, these tolerances apply only to soft strip, or the supplier and purchaser can agree on them as per this standard and DIN EN 10151.

FIGURE 4 | Coil set (side view)



a = coil set
l_0 = total sample length
l_e = test length

COIL SET (LONGBOW)

Depending on the process, coil diameter, thickness and mechanical properties have a large influence on coil set. DIN EN 10151 defines coil set as the displacement of the free end of a section of strip, that is fixed on one side, from the clamping plane.
Given the diversity of the factors of influence, DIN EN 10151 does not specify any limit values. We are able to restrict the formation of coil set through additional processing steps. Limit values are subject to agreement.

EFFECT OF SHAPE DEVIATION

Shape deviations on strips e.g. as per DIN EN 10251 include:

_ Deviations from flatness such as waviness, longitudinal and transverse curvature and torsion.
_ Deviations from straightness such as sabre shape/camber may occur in different ways, e.g
  _ Unsymmetrical strip thickness profile (cigar shape, wedge shape, bone shape), starting from hot-rolled wide strip, to cold-rolled wide strip and slit strip.
  _ In the roll gap
  _ During a redirect or the coiling or uncoiling of the strip
_ During the heat treatment of the strip

shape deviations are caused by various plastic deformations in the strip width and/or thickness that lead to internal stress differences in the strip.
Despite modern facilities and control technology, as well as a high level of development and experience in production technology for precision strip, shape deviations can occur. These are only visible in their entirety when the strip, placed under longitudinal tension, is released, e.g. after rolling or cutting.
According to today's standards, spring strips must meet ever-higher demands for precise shape along with the highest surface quality. For this reason, the handling of the strip through downstream levelling equipment after rolling, is of the utmost importance.
The following are available procedures for levelling the spring steel strip:

_ Tension annealing
_ Tension levelling at room temperature
_ Roller levelling

TENSION ANNEALING

The principle of tension annealing is the combination of stretching and heat input.
A tension levelling system generates a pull tension between a brake roller and a tension roller, which is required for the desired stretching in the plastic range.

In addition, strip heating also takes place. In this way, relaxation is generated along the width, thickness and length of the strip. Spring components produced from this type of treated strip do not demonstrate any increase in the mechanical values during tempering. In practice, tension annealing can create high levels of flatness and practically eliminate waviness and strip camber in particular. The removal and levelling of the internal stress in the strip follows as a next step.

TENSION LEVELLING

In tension levelling, strips are deformed alternately under tension at room temperature by way of three or more tension rollers of small diameter. Tension and bending stresses combine on the given tension roll. Spring strips can be formed with three, five or more rolls, whereby two or more rolls can used on the spring strip at variable depths. In the process, the yield strength in the area of the alternating bending is exceeded only minimally and the strip is extended permanently so that waviness is eliminated.

ROLLER LEVELLING

In roller levelling, the strip is bent in a decreasing amplitude between the working rolls of the levelling cassette and an existing bar and is levelled without the application of tension stress. Thus no extension of the strip takes place, which avoids internal stress induced by stretching.

FIGURE 5 | Straight waviness

Occurs when alternating plastic stretching and compression occur through the strip.

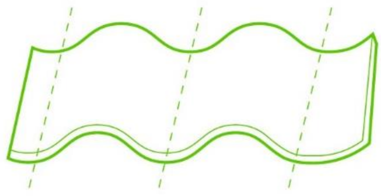


FIGURE 6 | Curvilinear waviness

Develops due to stretching of the longitudinal strip fibres at different lengths over the strip thickness. There is non-uniform stress distribution in the longitudinal and transverse directions.

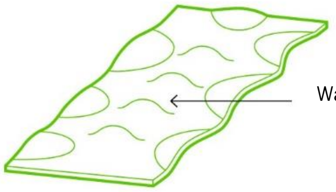


FIGURE 7 | Bows and torsion

Develops due to varying plastic stretching in longitudinal direction of the strip over the thickness of the strip.

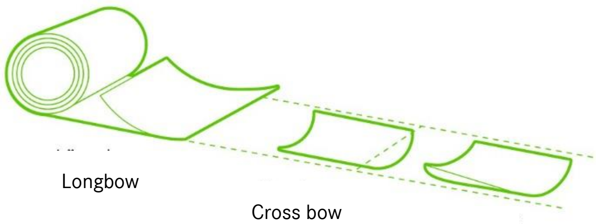
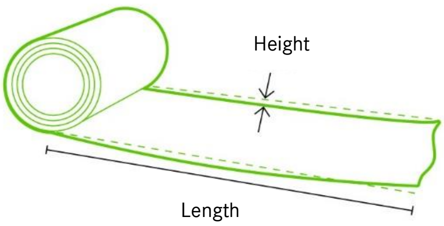


FIGURE 8 | Camber

Develops when an increasing or decreasing strip thickness (conicity) exists during the rolling of the strip and as a result differences in length occur.

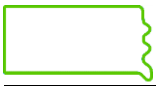


EDGES / SURFACES

EDGES

Spring steel strip is usually delivered with cut edges. These products have ridges as a result of the cutting. If there are particular requirements for these edges, it is necessary to make the corresponding agreements at the time of order.
In our factory standard, the limit for the burr height for cut products is restricted to 5%.

TABLE 14 | Edge finish

Edge shape	Edge finish	Zapp® 1.4310 burr height	ISO 9445-1 burr height	
	cut		≤ 10 %	Standard
	cut, low burr	≤ 5 %		Factory standard
	de-burred	0 %		Factory standard
	rounded in	0 %		Factory standard
	rounded off	0 %		Factory standard

SURFACES

We supply stainless spring steel strip Zapp® 1.4310 with a bright-rolled surface as standard.
The average roughness Ra as per DIN EN ISO 4287 determines the description of the surface.

Table 15 | Limits of the average roughness R_a

Strength classes	Zapp® 1.4310 Factory standard	DIN EN 10151
C850 and C1000	≤ 0.20 µm	≤ 0.50 µm
C1150-C1900	≤ 0.20 µm	≤ 0.30 µm

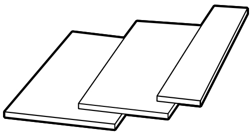
AVAILABLE SPECIAL DESIGNS

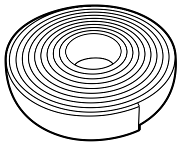
_ Degreased surfaces
_ Galvanic-compatible surfaces
_ Restricted roughness compared to our standard
_ High-gloss and different special surfaces with paper liner or protective film, if required. The type of special surface on request or as per the Zapp website:
https://www.zapp.com/en/products/strip/precision-strip/surfaces-of-stainless-steel-strip.html

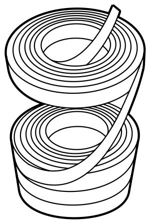
PASSIVE LAYER INFLUENCE

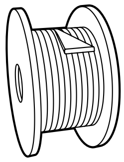
Our special surface treatment equipment is used for the degreasing and surface treatment of the strip. This is an electrolytic degreasing based on the neutral conductor procedure, where the strip runs horizontally through the system during the degreasing process.
Through targeted changes in the plant and process technology, the thickness and morphology of the passive layer is modified so as to impact the surface of the strip. This can for example lead to:
_ An improvement in the solderability as a consequence of improved flow of the solder
_ An increase in the service life of tools for punching

DELIVERY FORMS









COILS

The internal diameter of the coils is standardized at 300 or 400 mm. On request, we can supply a different internal diameter. To prevent the buckling of the coils, thin strip is wrapped around a core of cardboard or Pertinax.

TABLE 16 | Coil weights

Possible coil weights for different strip sizes

Strip width in mm		Weight[1] in kg/mm strip width	Restriction of the strip thickness
>	≤	Factory standard	Factory standard
2.0	2.8	1.2	≤ 0,30 mm[2]
2.8	4.0	2.0	≤ 0.45 mm[2]
4.0	6.0	3.0	-
6.0	10.0	4.0	-
10.0	15.0	4.0	-
15.0		10.0	≥ 0.15 mm

[1] Different weights on request [2] Different thicknesses available upon request

SPOOLS

For higher delivery weight for strips with widths between 2 mm and 45 mm, we offer oscillate wound spools, i.e. layer to layer, with marked weld points and burr location on the inside. Coil weight and type depend on the strip cross section and the quantities. We would be happy to meet your special requirements.

MULTICOIL

For longer machine run-times with less set-up time, we offer the multicoil option. Up to 13 individual coils, cut to specification and stacked on top of one another on a pallet, are welded together in the "endless strip", with the inside of one coil attached to the outside of the next. The welds are marked with coloured paint.

BARS/SHEETS

We also supply strips as straightened and cut bars/sheets. Lengths are available from 250 to 4000 mm and widths from 6 mm to 1060 mm (depending on thickness and tensile strength).

TABLE 17 | Length tolerance as per DIN EN ISO 9445-1

Nominal length (l) in mm	Tolerance in mm standard	Tolerance in mm special (S)
l ≤ 2000	+ 3.00	+ 1.50
	- 0	- 0
2000 ≤ l ≤ 4000	+ 5.00	+ 2.00
	- 0	- 0

Tighter tolerances on request

TABLE 18 | Squareness as per DIN EN ISO 9445-1

Cold-rolled strip width in mm	Deviation
≥ 250	≤ 0.5% of the actual width
< 250	on request

PACKAGING

INNER PACKAGING
For stability reasons, individual coils up to a strip thickness of ≤ 0.20 mm are wound on inner coils. The back of the strip is taped with crepe paper underneath. Coils stacked on top of one another are separated by means of cardboard, plastic or wood, depending on the coil geometry.
In the case of multicoils, the stacked individual coils are separated by special cardboard strips. The oscillate wound strip is on wooden spools, the ends are fixed with adhesive tape.

STANDARD AND SPECIAL PACKAGING

STANDARD PACKAGING
COILS
As a standard, we deliver our Zapp stainless spring steel strip on pallets that correspond to the external diameter of the material. Our shrink wrap consists of environmentally friendly polyethylene (PE).
_ Standard pallets: 600 – 1200 mm
_ Round pallets: max. 1250 mm
_ Weight per pallet: max. 1500 kg
_ Heavier weights available on request

MULTICOIL
Shipping on a circular pallet Ø 1250 mm and PE shrink wrap

SPOOLS
Spools are shipped on a transport stand with PE shrink wrapping

BARS/SHEETS
Shipped in wooden crates

SPECIAL PACKAGING
COILS
With an additional wooden cross and strap
_ in wooden crates (e.g. overseas)
_ standing on transport stands with the tightening strap
  with or without wooden crates

SPOOLS
_ Shipped in wooden crates

MULTICOILS
_ On pallets and crates

BARS/SHEETS
_ On pallets

Of course, other types of packaging are possible depending on your needs.

FIGURE 9 | Standard: Coils, inner - and outer packaging (without and with shrink wrap)

FIGURE 10 | Standard: Spools and multicoil, inner and outer packaging

FIGURE 11 | Special packaging: Coils and multicoil, inner and outer packaging and crate

FIGURE 12 | Standard and special packaging: Bars, inner and outer packaging

SPRING STRIP STOCK

SPRING STRIP FROM STOCK
Zapp® 1.4310FS and 1.4310FF spring steel strip is available rapidly from stock.

WELL-STOCKED WAREHOUSE
All standard thicknesses are available in almost all strength classes.

FROM OUR OWN PRODUCTION
The entire stock is from our own production.

PROVEN ZAPP QUALITY STANDARD
All Zapp® 1.4310FS und 1.4310FF deliveries, whether custom or from our service centre, meet our high quality standards.

CONTINUOUS STOCK ADDITIONS
In this way, we can deliver additional quantities at a moment's notice.

SHORTEST DELIVERY TIMES FOR OTHER PRODUCTS
From our Service Center: Cutting, deburring, rounding, tempering, coil division, cutting to length, spools, etc.

BENEFITS AT A GLANCE

_ You get tested products with a certificate.
We are happy to offer you the following tested values: Tensile strength, yield strength, elongation, Vickers hardness (reference values), formability.

_ Our standard thickness tolerances, regardless of the width, correspond to the "Precision" class as per DIN EN ISO 9445-1.

_ Any required amount is available quickly.

_ Intelligent logistics to meet your preferred delivery date.

_ Fastest quotation for projects and specific needs.

_ The long-term satisfaction of our customers is our goal.

If you are interested, request a brochure:
_ "Zapp Service Centre Stainless Spring Steel Strip from Stock". This brochure provides informative and detailed information about our spring steel strip from stock with our current stock program.

Contact information:
Tel +49 2304 79-508
Fax +49 2304 79-7979
E-mail: precisionstrip@zapp.com

MECHANICAL AND PHYSICAL PROPERTIES

EFFECT OF ALLOYING ELEMENTS

AUSTENITE STABILITY AND COLD WORKING

In addition to heat treatment and processing technology, the high hardening properties of austenitic Cr-Ni steel during cold forming have a significant impact on the static and dynamic properties of our Zapp® 1.4310 stainless spring steel strip.
Austenite stability, and with it the chemical composition, is a determining factor for the hardening capability.
The chemical composition of the chromium nickel steel, governed in particular by the elements carbon (C), chromium (Cr), nickel (Ni) and nitrogen (N), dictates the material properites in the annealed and significantly more in the cold-worked condition. These elements have the following effect:
The hardening tendency increases with decreasing nickel and chromium content and with increasing carbon content. (Fig. 13 and 14)
The assessment of the austenite stability of chromium-nickel steels can be particularly well performed on materials with relatively high carbon contents, such as 1.4310, by the Md30 temperature. This value is calculated from the chemical composition by means of an empirical formula (e.g. as per T. Angel). The value is the assumed deformation temperature at which after about 30% deformation approx. 50% α martensite forms. A rising Md30 temperature is a criterion for the reduction in the austenite stability and implies an increase in the ability to work harden. We have developed the Zapp® 1.4310 types with different levels of austenite stability to suit the different needs of our customers when it comes to the properties of spring steel.

INCREASING AUSTENITE STABILITY

Zapp® 1.4310FM

Zapp® 1.4310FC

Zapp® 1.4310FS/ 1.4310FF

For Zapp® 1.4310FS/ Zapp® 1.4310FF, the conditions exist to achieve high tensile strengths with simultaneously high residual deformation capacity.
Advantages of
_ high strength
_ high residual deformation capacity
_ good tempering properties
have a positive effect on the overall spring properties.

FIGURE 13 | Effect of carbon content

Influence of the carbon content on the ability to work harden of Cr-Ni steels with high austenite (18Cr/12Ni) and lower austenite stability (18Cr/8Ni).

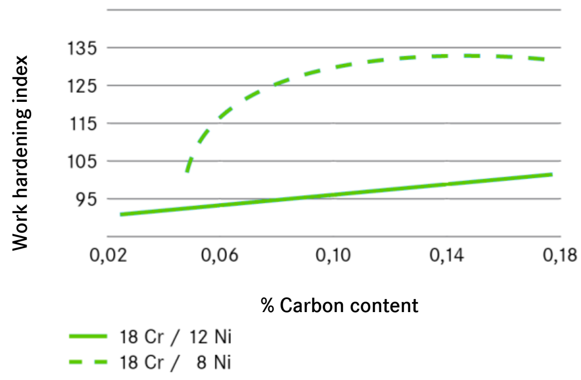
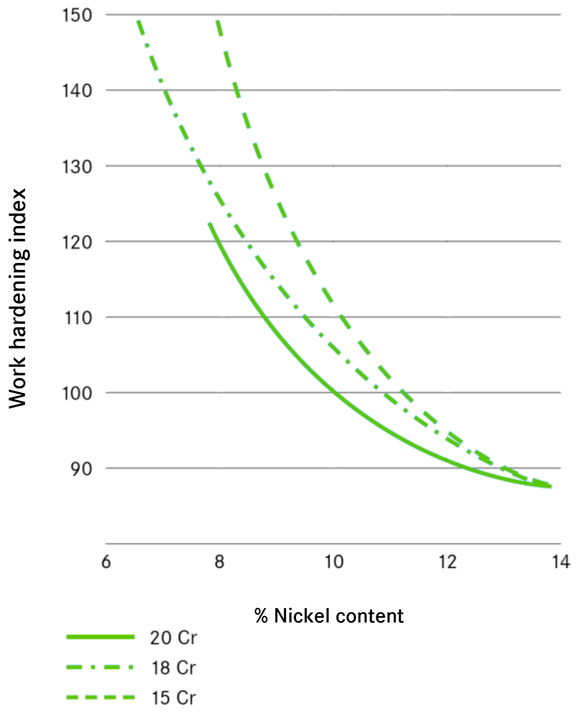


FIGURE 14 | Effect of nickel content

Effect of nickel and chromium content on the ability to work harden



EFFECT OF COLD FORMING

STRUCTURE

Zapp®1.4310 undergoes hardening during the cold rolling from the annealed, homogeneous austenitic structure (Fig. 15), via grain deformation on the glide planes typical to the austenitic lattice structure (FCC structure). The structure transforms into α- martensite (BCC structure) (see Fig. 16).
This process of α'-martinsite formation occurs without diffusion. As a result, the converted structure has the same chemical composition as the base material.
The capability of structure conversion and the extent of this conversion depend on the austenite stability. The quantity and hardness of the emerging martensite are of major significance to all properties of the spring strip or the components/products from it.

FIGURE 15 | Austenite structure

Solution annealed, homogeneous austenite structure of chromium nickel steel

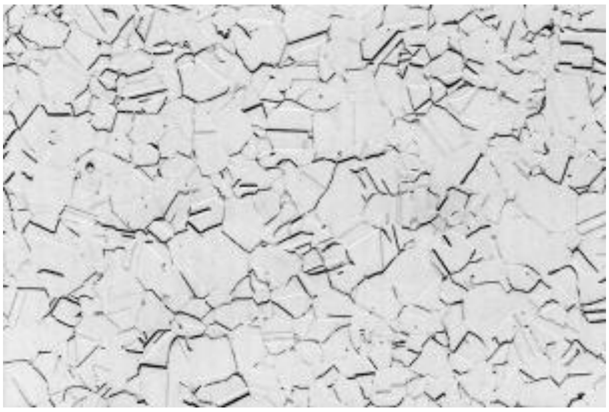


FIGURE 16 | Martensite structure

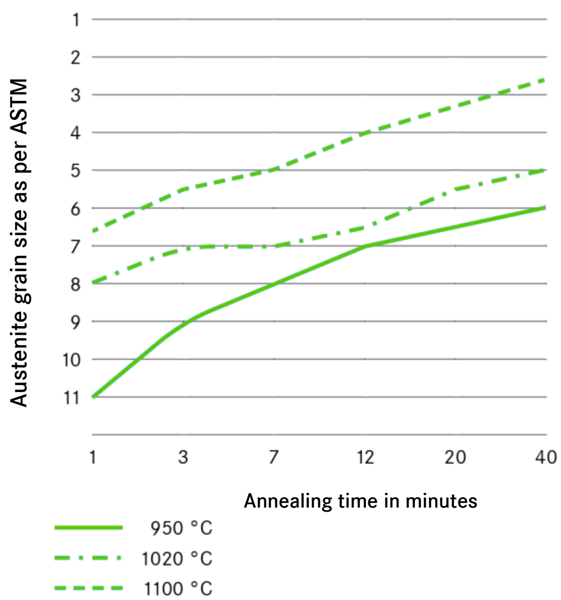
Structure after approx. 30 % cold forming with grain stretch and martensite

EFFECT OF SOLUTION ANNEALING

The annealed, homogeneous structure of austenitic chrome nickel steel (see Fig. 15) is heat-treated at high temperatures (1050-1100 °C) and then rapidly cooled (quenched) for example in water.
During this heat treatment, which is required to stop work hardening and to set up a homogeneous austenitic structure, the grains of the structure adapt. Depending on the temperature, time and product cross-section, different grain sizes can result.

FIGURE 17 | Effect of annealing time

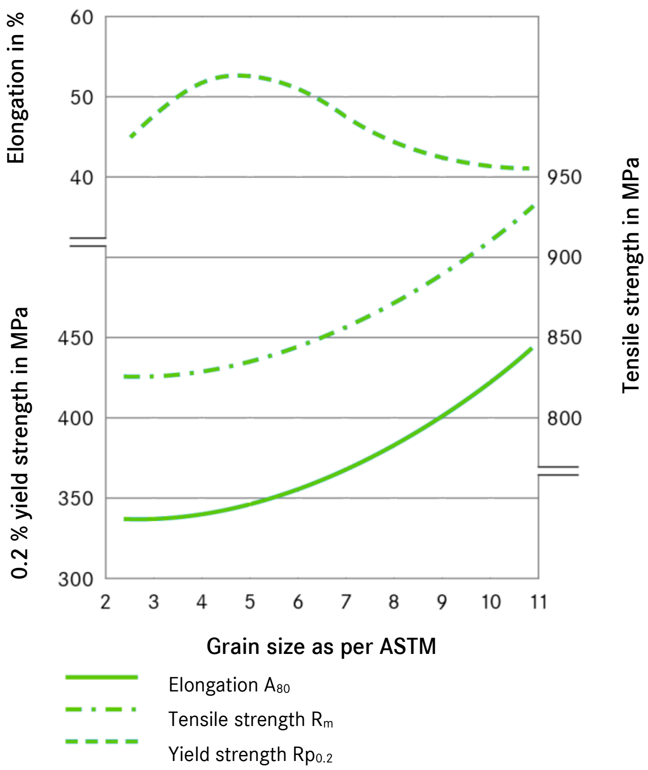
Influence of annealing time and annealing temperature on the grain size of the austenite



In the annealed condition, the grain size – in addition to the chemical composition – has an effect on the mechanical properties and hardness of chromium-nickel steels. This also applies to Zapp® 1.4310.

FIGURE 18 | Effect of austenite grain size

The effect of austenite grain size in the annealed condition on tensile strength, yield strength and elongation of Zapp® 1.4310FF.



EFFECT OF TEMPERING

TEMPERING

Suitable heat treatment after cold rolling or after the formation of components can significantly increase the spring properties. Such treatment although not mandatory, reduces the residual stress from the cold rolling and/or formation of the components.
The heat treatment of cold-formed austenitic chrome-nickel steels with temperatures up to max. 420 °C is often called "tempering". This treatment process results in no visible structural changes.
The following material properties can be affected positively by tempering:
_ Setting and relaxation behaviour
_ Tensile strength
_ Elasticity and yield strength
_ Spring bending limit
_ Elasticity modulus
The usefulness of such tempering treatment must be considered in each individual case. Certainly economic and equipment-related aspects are of importance to the decision making.

THE IMPROVEMENT OF THE PROPERTIES DEPENDS ON:

_ the chemical composition and the instability of the austenite
_ the initial tensile strength. The higher the tensile strength, the stronger the increase in tensile strength will be

The reason for this improvement of material properties: At temperatures of up to 300 °C, martensite forms from the highly-worked austenite, in addition to the existing strain-induced α'-martensite. Up until 420 °C fine iron chromium precipitation forms in the structure, which are favoured by silicon and molybdenum as a kind of catalyst. In contrast to the carbides that result from higher temperatures, these have no adverse effect on the mechanical properties and the corrosion resistance (Figure 19).

TABLE 19 | Tempering temperature

Recommended temperatures and holding times for tempering, taking economic considerations into account

Temperature	Holding time
80–120 °C	24h
330–370 °C	4h
400–420 °C	1h

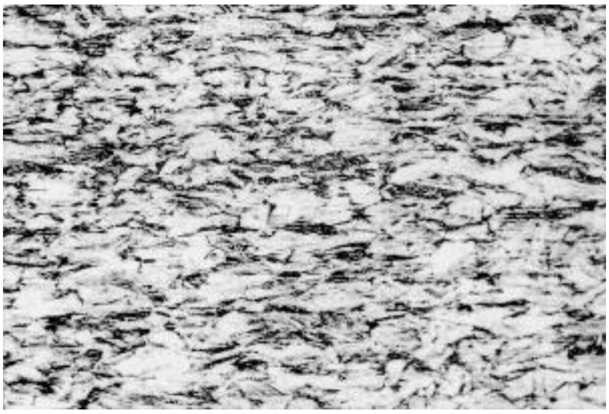
At temperatures above 420 °C, carbide precipitation occur at the grain boundaries (Figure 20). Such high temperatures should not be used, since this precipitation reduces the residual deformation capacity. In addition, the chromium in the structure depletes. This reduces the corrosion resistance, and can lead to intergranular corrosion.
To what extent tempering is applicable must be considered for each case individually.

FIGURE 19 | Structure without carbide precipitation

Structure after approx. 30% cold forming and tempering (400 °C/1h) without carbide precipitation

FIGURE 20 | Structure with carbide precipitation

Structure after approx. 30% cold forming and tempering (650 °C/1h) without carbide precipitation



REMOVAL OF TEMPERING COLOURS

The formation of tempering colours can be avoided only if the heat treatment takes place in a protective atmosphere or in a vacuum. Tempering colours that occur in a normal atmosphere (the colour varies from yellow-brown at 350 °C to brown at 420 °C) can be removed by a suitable treatment, e.g. for further processing or for cosmetic reasons.

The removal is easier if the material has been degreased before tempering. The treatment can be either mechanical – for example grinding – or light chemical or electrolytic pickling. The following methods have proven successful for chemical pickling (see Table 20). The subsequent passivation process restores the corrosion resistance.

TABLE 20 | Methods of treatment

		Treatment Methods	
		A	B
1.	**Immersion**		
	Bath composition	approx. 20 vol.-% HCl conc.	approx. 65 vol.-% H_3PO_4 conc. approx. 20 vol.-% H_2SO_4 conc..
	Temperature	Room temperature	Room temperature
	Duration	up to 10 s	up to 10 s
	Rinse	with sufficient quantity running water	with sufficient quantity running water
	Subsequent treatment		in hot water
2.	**Passivation**		
	Bath composition	about 20 vol.-% HNO_3 conc.	about 20 vol.-% HNO_3 conc.
	Temperature	Room temperature	Room temperature
	Duration	up to 5 min	up to 5 min
	Rinse	with sufficient quantity hot water	with sufficient quantity hot water
3.	**The final drying process can be carried out at room temperature in air**		

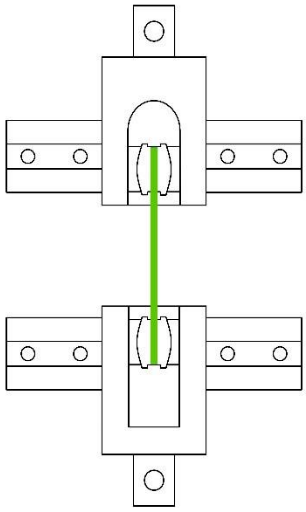
DETERMINATION OF MECHANICAL VALUES

The basic test method for determining the static mechanical characteristic values is the tensile test according to DIN EN ISO 6892-1, procedure B. Based on our factory standard, we determine the following values:

Parameter	Abbreviation	Unit
Tensile strength	R_m	MPa
0.2 % yield strength	$R_{p0,2}$	MPa
Elongation [%]	A_{80}	%

The required samples are taken from the spring steel strip in the rolling direction up to 60 mm in width according to DIN EN 10151 and greater than 60 mm strip width as per factory standard and prepared on the basis of DIN EN ISO 6892-1. Depending on the width of spring strip, the sample is proportional (form sample) or for widths of < 20 mm, parallel strips. With spring steel strip, our special procedure for sample preparation avoids any edge imperfections, that can influence the breakage mechanism of the specimen. During the tensile test the sample must not slip in the holding jaws.

FIGURE 21 | Tensile testing machine



MECHANICAL AND PHYSICAL VALUES

SOLUTION ANNEALED CONDITION

TABLE 21 | Solution annealed condition

Mechanical values for the soft, solution annealed condition in the rolling direction

Zapp	0.2 % yield strength $R_{p0.2}$ in MPa	Tensile strength R_m in MPa	Elongation at break: A_{80} in %
1.4310FM	230-330	650-750	45-60
1.4310FC	250-350	700-800	42-57
1.4310FS	300-430	800-950	38-55
1.4310FF	300-430	800-950	38-55

COLD-FORMED STATE

The progression of the mechanical characteristics, which are dependent on the degree of cold deformation, are illustrated in the following typical consolidation charts for Zapp 1.4310 stainless spring steel strip:
(Fig. 22 to Fig. 24)

FIGURE 22 | Mechanical values 1.4310FM
Progression of the mechanical characteristics for Zapp® 1.4310FM

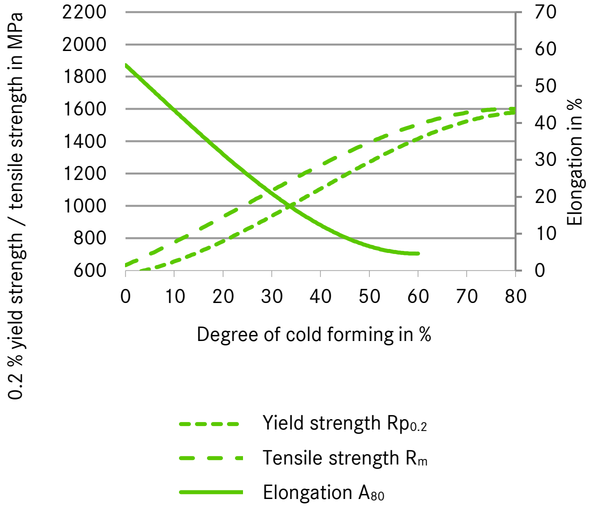


FIGURE 23 | Mechanical values 1.4310FC
Progression of the mechanical characteristics for Zapp® 1.4310FC

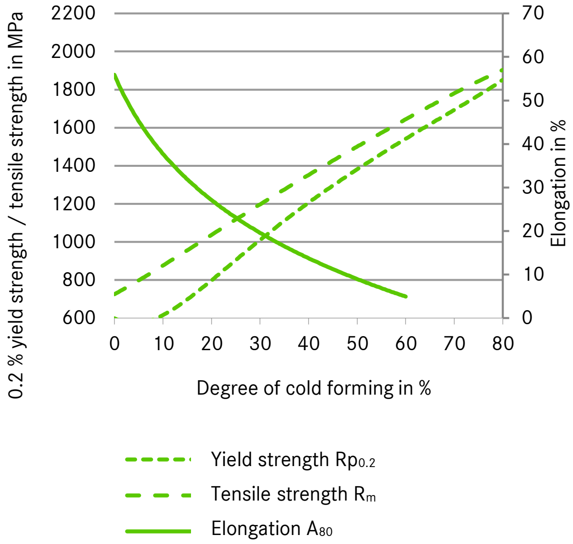
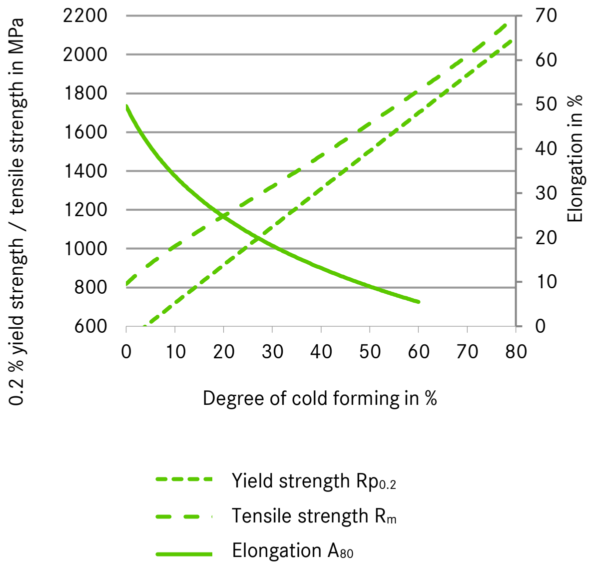


FIGURE 24 | Mechanical values 1.4310FS / FF
Progression of the mechanical characteristics for Zapp® 1.4310FS and 1. 4310FF



INCREASE IN TENSILE STRENGTH AND YIELD STRENGTH BY TEMPERING

Tempering increases the tensile strength and yield strength of our stainless spring steels Zapp® 1.4310 to varying degrees.
Depending on the selected boundary conditions cf. 4.4) the steel reaches tensile strength values of up to 300 MPa.

FIGURE 25 | Tensile strength with / without tempering

Tensile strength R_m with/without tempering for Zapp® 1.4310

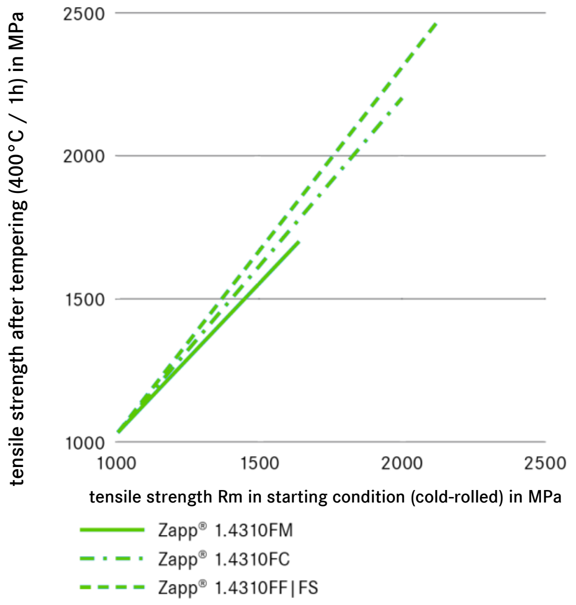
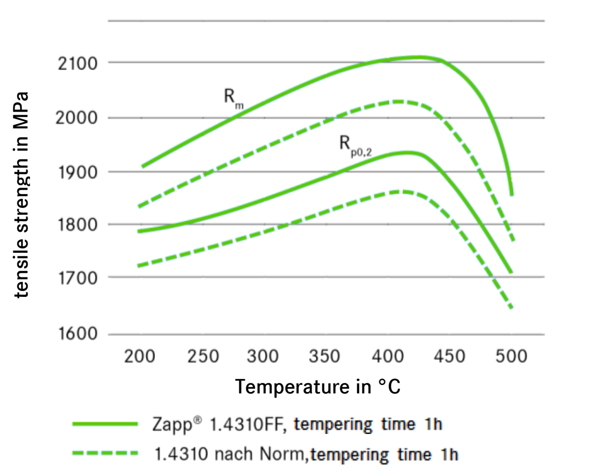


FIGURE 26 | Comparison of tempering behaviour 1.4310

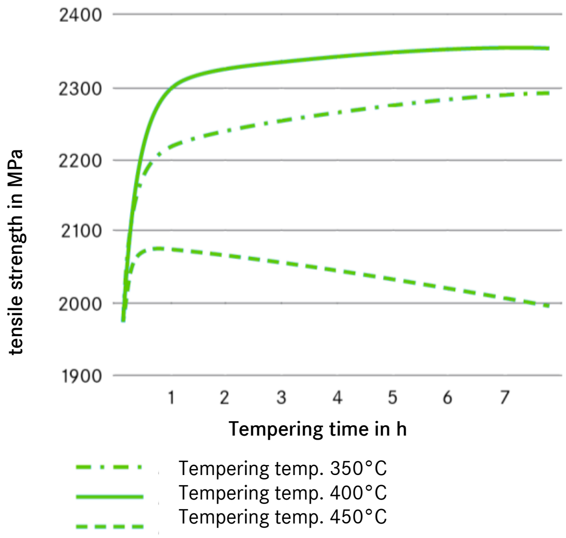
Tempering behaviour: Zapp® 1.4310FS and 1 4310FF compared to 1.4310 as per the standard with higher austenite stability



This increase in tensile strength and yield strength of Zapp® 1.4310FS and 1. 4310FF is superior to the 1.4310 over the entire tempering temperature range according to the standard.

FIGURE 27 | Effect of tempering temperature

Effect of tempering temperature and time on the tensile strength of Zapp® 1.4310FF with a starting tensile strength of approx. 2000 MPa



In addition to the described structure effects (see 4.4) at temperatures from approx. 500 °C, Fig. 27 clearly shows the reduction in tensile strength after one hour (for the tensile strength class C 1900).

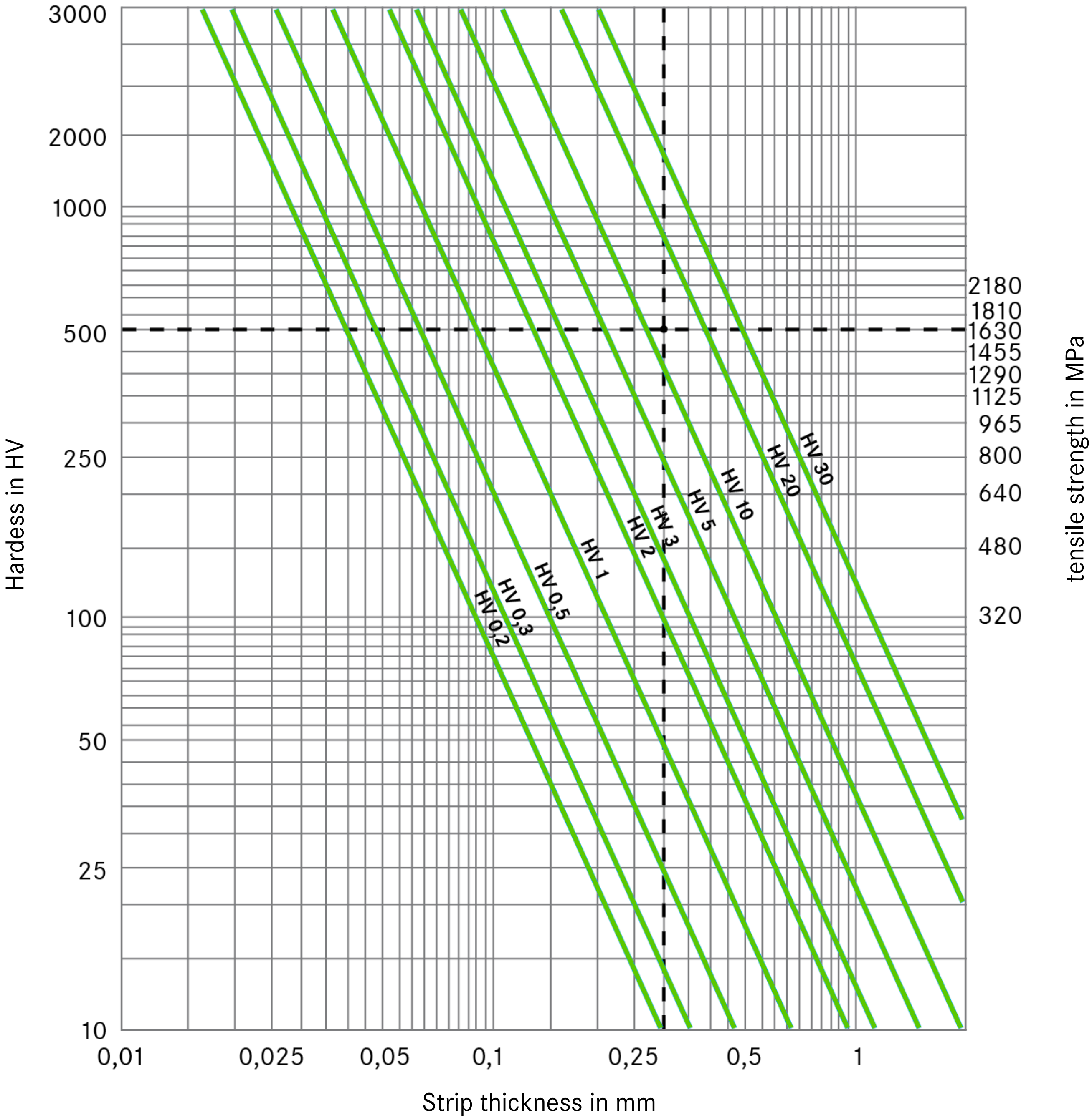
TENSILE STRENGTH AND HARDNESS

The tensile strength of spring strip and components can be converted to hardness values according to Brinell, Vickers or Rockwell. These simpler test methods demonstrate significantly higher spread compared to the conventional tensile testing. For chromium-nickel steels, the "Vickers" method is used as per ISO 6507-1.l In hardness testing, the thickness of the sample to be measured plays an important role.
A general rule is that the test with the highest possible permitted load for the respective strip thickness is the test that should be carried out.

FIGURE 28 | Minimum thickness of samples

Minimum thickness of samples as a function of test force and hardness
(HV 0.2 to HV 30), according to DIN EN ISO 6507-1.

Example:
RM = 1630 MPa, according to the conversion table in DIN EN ISO 18265, corresponds to HV500 at a thickness of 0.3 mm and the hardness test HV10 will be used.



The "working point" is determined by the ordinate values of the thickness and the expected hardness. The load to be applied corresponds to the level to the left of the working point. The correlation between the tensile strength and the hardness values determined, according to the various hardness test methods is not explicit, but rather empirical.

In practice, the comparison tables as per DIN EN ISO 18265 for tensile strength above 1100 MPa can be used for Zapp® 1.4310.

TABLES

The standard DIN EN ISO 18265 defines the basics for the conversion of hardness values. The scope of the standard does not include stainless steels. Since no adequate standard exists for these steels at the present time, the tables in the aforementioned standard serve as reference values. The tables provide guideline values for the comparison of tensile strength with the different hardness types, but also between the hardness types themselves.

In practice, the comparison tables as per ISO 18265 for tensile strengths above 1100 MPa can be used for Zapp® 1.4310. At this level of strength there is a relatively high proportion of α'-martensite in the structure, so that this structure can be compared with the structure of hardened low-alloy steels. Increasing tensile strength narrows the range of hardness values.

TABLE 22 | Conversion table for hardness

Conversion for hardness and hardness in tensile strength for low-alloy steels

Tensile strength	Vickers hardness	Brinell hardness	Rockwell hardness							
MPa	HV10	HB[a]	HRB	HRF	HRC	HRA	HRD	HR15N	HR30N	HR45N
1095	340	323	-	-	34.4	67.6	51.1	77.4	54.4	36.5
1125	350	333	-	-	35.5	68.1	51.9	78.0	55.4	37.8
1155	360	342	-	-	36.6	68.7	52.8	78.6	56.4	39.1
1190	370	352	-	-	37.7	69.2	53.6	79.2	57.4	40.4
1220	380	361	-	-	38.8	69.8	54.4	79.8	58.4	41.7
1255	390	371	-	-	39.8	70.3	55.3	80.3	59.3	42.9
1290	400	380	-	-	40.8	70.8	56.0	80.8	60.2	44.1
1320	410	390	-	-	41.8	71.4	56.8	81.4	61.1	45.3
1350	420	399	-	-	42.7	71.8	57.5	81.8	61.9	46.4
1385	430	409	-	-	43.6	72.3	58.2	82.3	62.7	47.4
1420	440	418	-	-	44.5	72.8	58.8	82.8	63.5	48.4
1455	450	428	-	-	45.3	73.3	59.4	83.2	64.3	49.4
1485	460	437	-	-	46.1	73.6	60.1	83.6	64.9	50.4
1520	470	447	-	-	46.9	74.1	60.7	83.9	65.7	51.3
1555	480	456	-	-	47.7	74.5	61.3	84.3	66.4	52.2
1595	490	466	-	-	48.4	74.9	61.6	84.7	67.1	53.1
1630	500	475	-	-	49.1	75.3	62.2	85.0	67.7	53.9
1665	510	485	-	-	49.8	75.7	62.9	85.4	68.3	54.7
1700	520	494	-	-	50.5	76.1	63.5	85.7	69.0	55.6
1740	530	504	-	-	51.1	76.4	63.9	86.0	69.5	56.2
1775	540	513	-	-	51.7	76.7	64.4	86.3	70.0	57.0
1810	550	523	-	-	52.3	77.0	64.8	86.6	70.5	57.8
1845	560	532	-	-	53.0	77.4	65.4	86.9	71.2	58.6
1880	570	542	-	-	53.6	77.8	65.8	87.2	71.7	59.3
1920	580	551	-	-	54.1	78.0	66.2	87.5	72.1	59.9
1955	590	561	-	-	54.7	78.4	66.7	87.8	72.7	60.5
1995	600	570	-	-	55.2	78.6	67.0	88.0	73.2	61.2
2030	610	580	-	-	55.7	78.9	67.5	88.2	73.7	61.7
2070	620	589	-	-	56.3	79.2	67.9	88.5	74.2	62.4
2105	630	599	-	-	56.8	79.5	68.3	88.8	74.6	63.0
2145	640	608	-	-	57.3	79.8	68.7	89.0	75.1	63.5
2180	650	618	-	-	57.8	80.0	69.0	89.2	75.5	64.1
-	660	-	-	-	58.3	80.3	69.4	89.5	75.9	64.7
-	670	-	-	-	58.8	80.6	69.8	89.7	76.4	65.3
-	680	-	-	-	59.2	80.8	70.1	89.8	76.8	65.7
-	690	-	-	-	59.7	81.1	70.5	90.1	77.2	66.2
-	700	-	-	-	60.1	81.3	70.8	90.3	77.6	66.7
-	720	-	-	-	61.0	81.8	71.5	90.7	78.4	67.7
-	740	-	-	-	61.8	82.2	72.1	91.0	79.1	68.6

[a] The Brinell hardness values up to 450 HB were determined with the steel ball as a penetrator; the values above that were determined with the tungsten carbide ball.

MECHANICAL AND PHYSICAL VALUES

FIGURE 29 | Vickers hardness HV 1.0

Statistical evaluation of Vickers hardness HV 1.0 and tensile strength for work-hardened or spring-hard rolled strips of our stainless steel spring steel strip Zapp® 1.4310FF/FS.

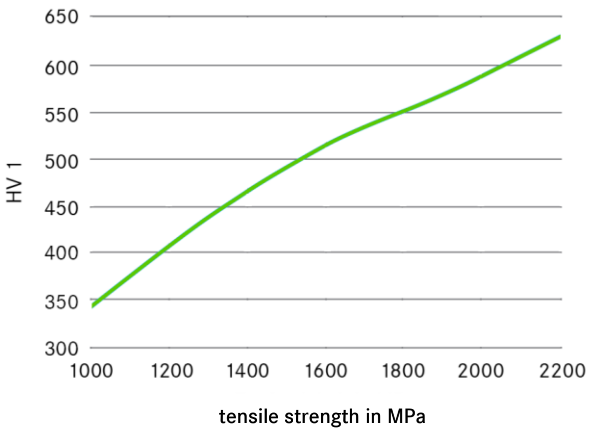
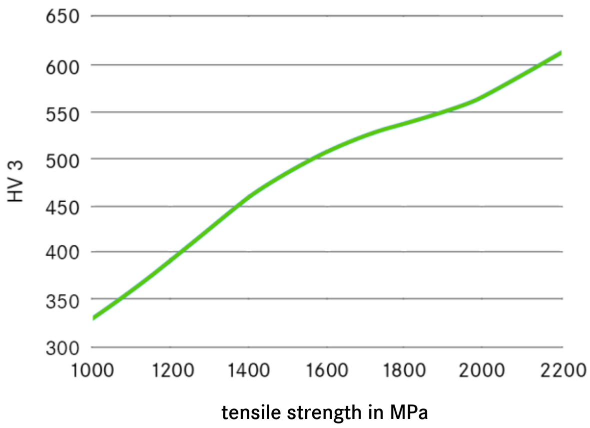


FIGURE 30 | Vickers hardness HV 3.0

Statistical evaluation of Vickers hardness HV 3.0 and tensile strength for work-hardened or spring-hard rolled strips of our stainless steel spring steel strip Zapp® 1.4310FF/FS.



FATIGUE STRENGTH

The dynamic fatigue test with the Wöhler curve are materials engineering concepts that relate to the operational stability in mechanical engineering. For many spring components, the dynamic strength or fatigue is a decisive factor for durability. The classic method to evaluate the endurance strength and fatigue strength is the Wöhler curve (DIN 50100). Test pieces are put under stress σ on multiple load horizons in a cyclic, most often sine-shaped stress-time function, for a determined load time or until a breakage occurs. The values recorded in this way are presented in a stress-cycle digram; known as the Wöhler lines. Since the results of these tests are statistically spread, an array of curves generally results. From these, the median with 50% rupture probability is used for assessment.

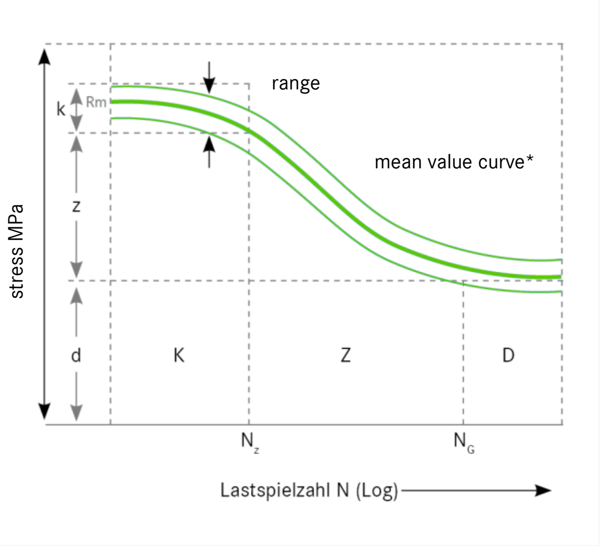
_ Test bodies that reach the cycle limit without visible failure are known as passed components.
_ For a load that leads to a failure within ¼ cycle, this is referred to as a static strength, which is also determined in the tensile test.
_ The range of the low-cycle fatigue is < 5 x 10^4 load cycles.
_ The range of endurance strength lies between 10^4 and 10^6 load cycles
_ The subsequent range > 10^6 load cycles, in which the Wöhler line is practically horizontal, is known as the fatigue strength. For austenitic steels, this is typically 10^6 to 10^8 cycles. Fatigue strength is approx. ¼ of the tensile strength for spring steel strip made from 1.4310.

A low level of impurities in the material, high tensile strength and – as far as possible – defect free surface of the component are beneficial to the fatigue strength. The number of sustained load cycles of a spring component failure under operating load to can be predicted in the framework of statistical accuracy with the help of the S-N curves and additional methods. This is the operating measurement (operational stability) of a component.

The fatigue strength can be determined for different types of stress. For example, for bending, tensile, pressure, shock or torsional stress. In practice, the bending fatigue strength of the material is used for the design of a spring component. In addition, knowledge of the fatigue strength can be necessary for tension-related stress. Figures 32-39 depict the the Wöhler curves for bending stresses and tension-related stress for our stainless spring steel strip Zapp® 1.4310FC and Zapp® 1.4310FF/FS. The values are valid at room temperature and in a normal dry atmosphere.

The diagrams contain guidelines that assist the designer in the selection of dimensions, load, etc. Where doubt remains, we recommend a specific fatigue strength test tailored to the usage load spectrum for the finished component. Given the comprehensive and cost-intensive measurement methods, the Wöhler curves are not a part of our standard testing.

FIGURE 31 | S-N diagram / principle



* 50 % probability up to rupture

Rm: Static tensile strength
Range: 2x standard deviation, i.e. approximately 95% of the distribution are within these limits
Stress σ_d: Fatigue strength
Stress σ_z: Highest endurance strength
Stress σ_k: Highest low-cycle fatigue
D Fatigue strength range
Z: Endurance strength range
K: Low-cycle fatigue range
N_Z: Load cycles, endurance strength start
N_G: Load cycles, fatigue strength start

MECHANICAL AND PHYSICAL VALUES

PULSATING TENSILE STRESS WITH LOW STRESS = 0

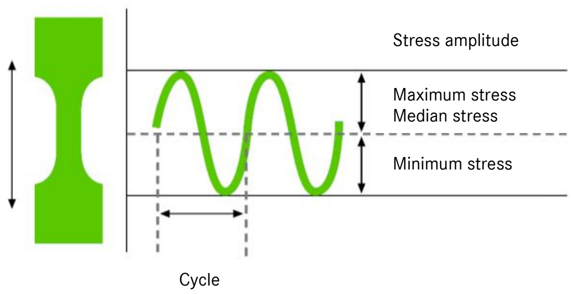


FIGURE 32 | Pulsating tensile stress

Zapp® 1.4310FC, strip thickness 0.40 mm, cold-rolled,
tensile strength 1650 MPa in rolling direction
S-N curve: Maximum stress as a function of the number of load cycles

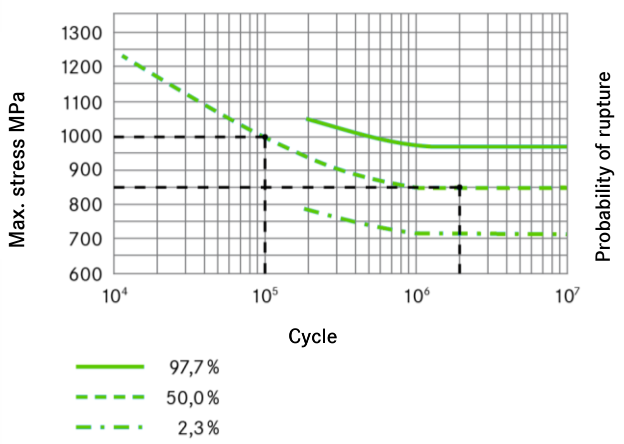
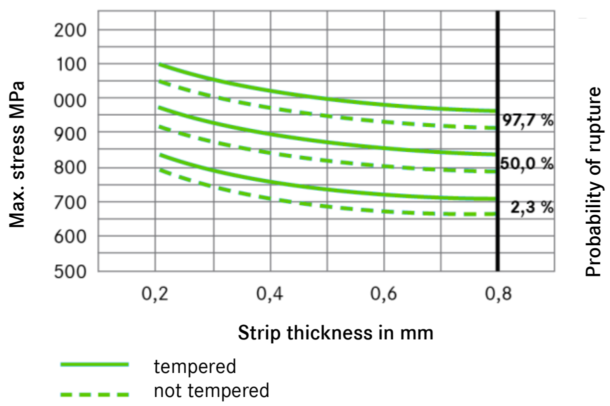


FIGURE 33 | Pulsating tensile stress

Maximum stress after 2 x 10^6 load cycles as a function of strip thickness and the influence of tempering 400°C for 1 h.



Example in Figure 32: When a spring is expected to be exposed to 10^5 load cycles, the maximum stress of 1000 MPa is taken from the middle curve. This means that, at a load of median stress of approx. 500 MPa and a stress amplitude of ± 500 MPa, 50% of springs will break before reaching 10^5 load cycles (endurance strength). After 2 x 10^6 load cycles, the maximum stress is constant at approx. 850 MPa, i.e. a fatigue strength of 425 ± 425 MPa under pulsating tensile stress
(Minimum stress 0).

FIGURE 34 | Pulsating tensile stress

Zapp® 1. 4310FF and 1.4310FS, strip thickness 0.40 mm, cold-rolled, tensile strength 1850 MPa in the rolling direction

S-N curve: Maximum stress as a function of the number of load cycles, low stress = 0

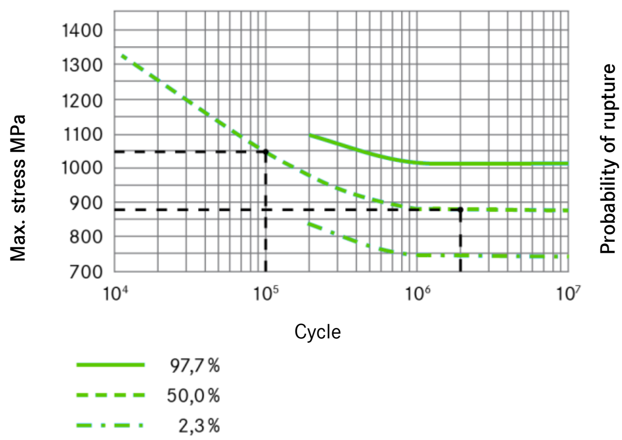
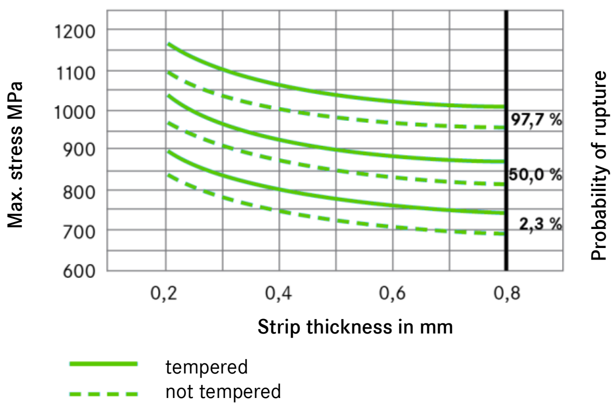
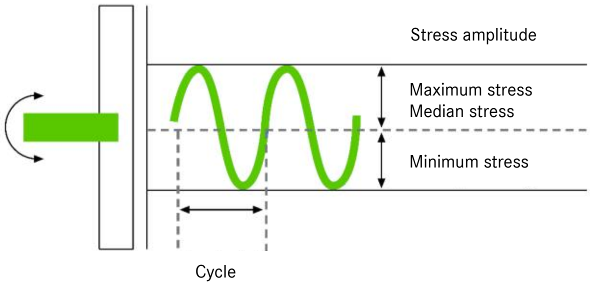


FIGURE 35 | Pulsating tensile stress

S-n curve:
Maximum stress after 2 x 10^6 load cycles as a function of strip thickness and influence of the tempering process at 400°C for 1h.



ALTERNATING BENDING STRESS
WITH MEDIAN STRESS = 0



Example in Figure 36: When a spring is expected to be exposed to a max. of 10^5 load cycles, an alternative bending stress of approx. ± 700 MPa is to be read from the middle curve. This means that 50% of springs break at a stress of ± 700 MPa before reaching the 10^5 load cycles (endurance strength). After 2 x 10^6 load cycles, the stress amplitude remains constant at ± 550 MPa. This is equivalent to a fatigue strength of ± 550 MPa under alternating bending stress (median stress 0).

FIGURE 36 | Alternating bending stress

Zapp®1.4310FC, strip thickness 0.40 mm
cold-rolled, tensile strength 1650 MPa in the rolling direction
S-N curve:

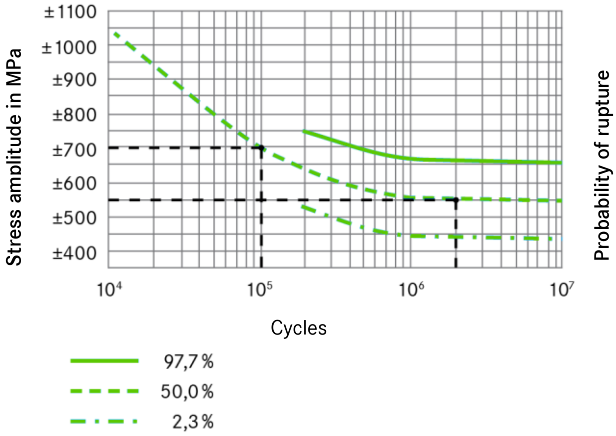


FIGURE 38 | Alternating bending stress

Zapp ® 1.4310FS and 1 4310FF, strip thickness 0.40 mm
cold-rolled, tensile strength 1850 MPa in the rolling direction
S-N curve

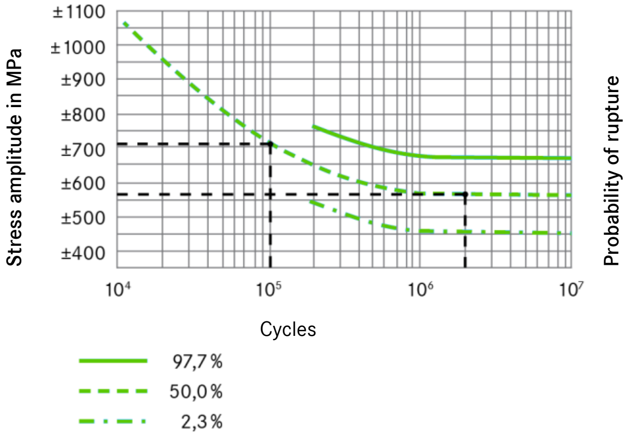


FIGURE 37 | Alternating bending stress

Maximum stress after 2 x 10^6 load cycles as a function of strip thickness and influence of the tempering process at 400°C for 1h.

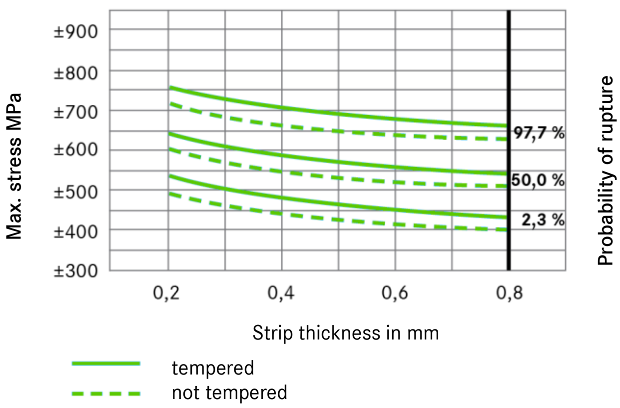
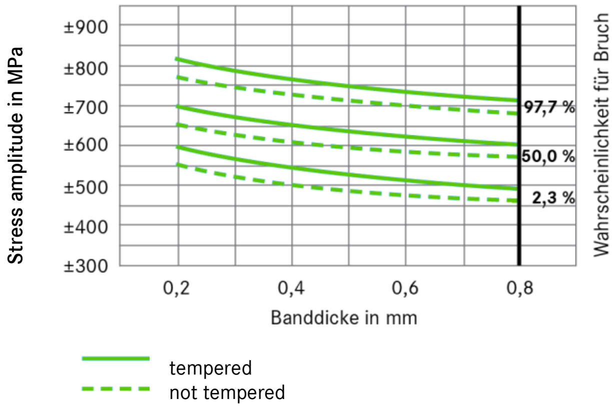


FIGURE 39 | Alternating bending stress

Maximum stress after 2 x 10^6 load cycles as a function of strip thickness and influence of the tempering process at 400°C for 1h.



THE FATIGUE STRENGTH OF A COMPONENT COMPOSED OF ZAPP® 1.4310 STAINLESS SPRING STEEL STRIP CAN BE INFLUENCED POSITIVELY:

_ Tempering increases the fatigue strength in general
_ Low levels of non-metallic inclusions, particularly near the surface, are favourable for high fatigue strength
_ Compressive stresses in the surface (for example, by shot peening) improve the fatigue strength
_ A smooth surface finish increases the fatigue strength
_ The fatigue strength longitudinal to the rolling direction tends to be higher than the corresponding transverse values
_ A smoothing of the edges improves the fatigue strength
_ The higher the tensile strength, the higher the fatigue strength. As a guideline, the bending strength reaches about 30-50% of the level of tensile strength.
_ A limitation in the fatigue strength results from the simultaneous increase of the notch sensitivity of the component.

FIGURE 40 | Alternating bending stress

Wöhler curves for stainless spring steel Zapp ® 1.4310 in the annealed and hard spring condition under alternating bending stress

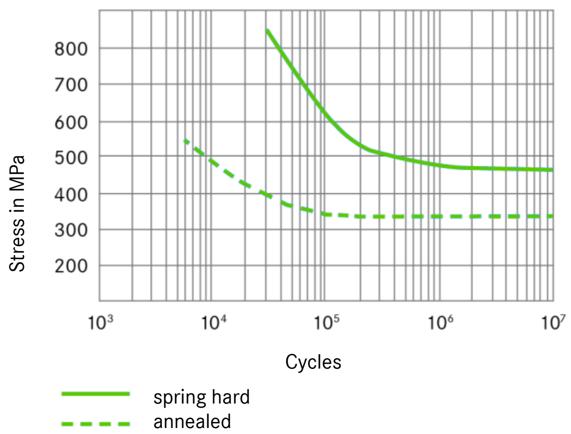
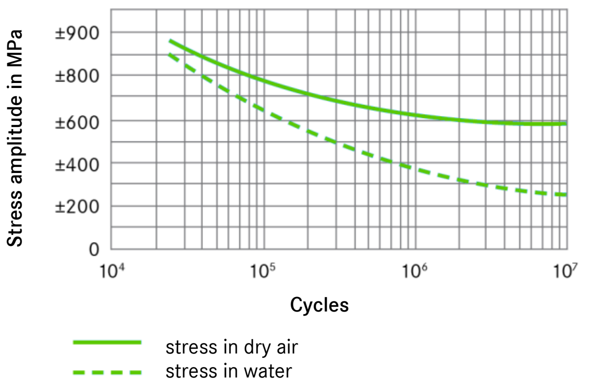


FIGURE 41 | Impact of corrosion on fatigue strength

Influence of corrosion on the fatigue strength of stainless spring steel Zapp®1.4310
Type of load: Alternating bending stress with medium stress = 0



Fracture probability 50%

Corrosion adversely affects the fatigue strength. For this reason, components exposed to extended stress loads should be protected from contact with corrosive media through appropriate design measures. The effects of corrosion processes are only partially predictable because of their complexity. In extreme cases, spring components that are exposed to fatigue loading can even fail in weak corrosive media without visible external attack.
Given its higher molybdenum and nitrogen content, the corrosion resistant Zapp® 1.4310FF offers higher fatigue strength in corrosive media.

SETTING AND RELAXATION

The permanent plastic deformation of a spring component after applying a load at room temperature is generally referred to as setting. At a higher temperature, it is known as relaxation. This behaviour in a spring component can be determined as follows: After production, a spring is loaded statically for the first time. After a defined period of exposure at room temperature, or at a higher temperature, the load is released. The resulting loss in length, which reduces with the number of repetitions, is the setting or relaxation. The progression of the cumulative curve of the loss with load time is characterized by a high initial loss, which reduces as the load time reduces.

THE HEIGHT OF THE SETTING OR THE RELAXATION DEPENDS ON ...

_ the version of Zapp® 1.4310 used
_ the shape of the spring component
_ the applied stress
_ the application temperature
_ the duration of the temperature exposure
_ the tensile strength of the spring strip

Figure 42 and Figure 43 show setting or relaxation losses as a function of time at room temperature and at elevated temperatures. These values illustrate the magnitude of the effect.
Figure 42 shows the influence of tensile strength and the Zapp® 1.4310 types.
Figure 43 shows the significant influence of temperature and stress for the same material condition.

FIGURE 42 | Setting as a function of time

Setting as a function of time at room temperature.
Load 1000 MPa

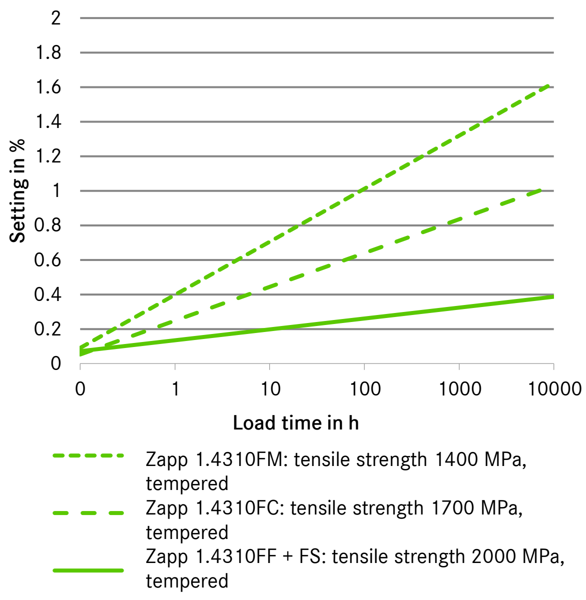
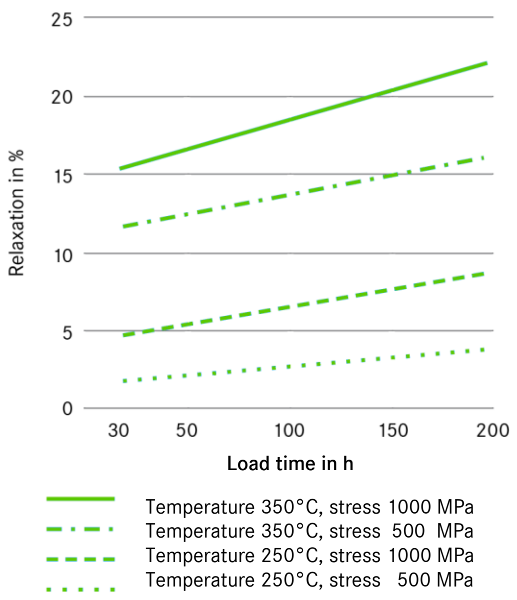


FIGURE 43 | Relaxation as a function of time

Relaxation as a function of time at elevated temperatures without initial progression: Zapp® 1.4310FS and 1.4310FF



ELASTICITY PROPERTIES

The elasticity properties of stainless spring steels are characterized by the spring bending limit, the elasticity limit (here: 0.01% yield strength) and the elastic modulus. The procedure for determining the values of spring bending limit and the elastic modulus is carried out in accordance with in DIN EN 12384. The tensile test according to DIN EN ISO 6892-1 provides the values of the elastic limit.

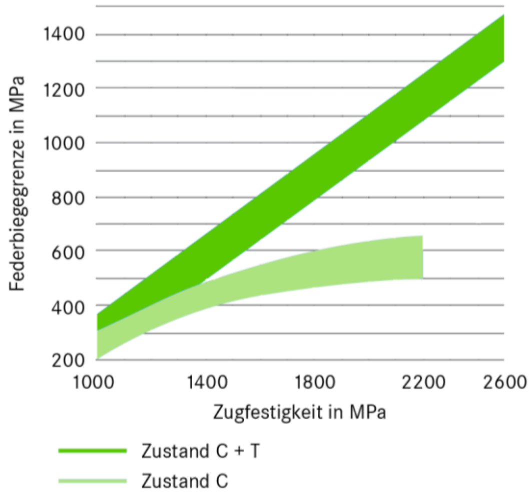
SPRING BENDING LIMIT

The spring bending limit is an elastic bending stress. It specifies the stress value that results in a deformation of 50 µm in a test sample after the release of load, taking into account the support distance.
The test strip is gradually bent by 0.667 mm and then the load is removed again.

Spring steel strip with greater thickness has equal values of tensile strength in the lower limits as those specified in Table 23 for the spring bending limit. The differences of chemical composition of the four Zapp versions are only slightly noticeable at equal tensile strength. The material Zapp® 1.4310FM tends to have higher values in the tensile strength, comparatively speaking. The spring bending limit is higher in the direction transverse to the rolling direction than in the longitudinal direction. This anisotropy should be considered in the design of springs. Residual stress reduces the spring bending limit. The stress can be reduced by a suitable thermal treatment (tempering).

FIGURE 44 | Spring bending limit

Spring bending limit dependent on the tensile strength in cold-formed condition (condition C) or after cold forming and tempering (condition C + T) for Zapp® 1.4310, tempering: 400 ° C / 1 h



Advantage: Over the many years of cooperation with our customers, the spring bending limit for specific uses has become a decisive parameter for the spring action of a component. If necessary, we determine the spring bending limit of the Zapp® 1.4310 spring steel strip and confirm the values on our test certificate.

TABLE 23 | Spring bending limit

Allocation of benchmarks for the spring bending limit of cold-formed + tempered stainless spring steels in Zapp 1.4310 grades at the tensile strength levels as per DIN EN 10161
Strip thickness 0.05 mm to 1.00 mm

Tensile strength level	C 1000	C 1150	C 1300	C 1500	C 1700	C 1900
Condition C + T Spring bending limit MPa	approx. 350	approx. 500	approx. 600	approx. 750	approx. 950	approx. 1150
Zapp® 1.4310FM	■	■	on request		not available	
Zapp® 1.4310FC	■	■	■	■	on request	
Zapp® 1.4310FS/FF	■	■	■	■	■	■

■ = in stock

ELASTICITY PROPERTIES

ELASTIC MODULUS

The elastic modulus (or Young's modulus) as it is commonly known is the slope of the Hookean line in the stress-strain curve of the tensile test. It identifies the relationship between stress and strain during a deformation in the elastic range. A three-point bending test based on DIN EN 12384 can be used to determine this value for stainless steel spring strip. The more resistance a material has against elastic deformation, the higher the elastic modulus.
The charts show that spring components should be designed transverse to the rolling direction, as a matter of preference. If this is not possible – for manufacturing reasons – the positive influence of tempering should be used.

SPRING CONSTANT

In practical application, the spring constant of a straight rod results mathematically from its cross-sectional area, its length and its elastic modulus.

FIGURE 46 | Elastic modulus - range

Dependence of the scattering range of the elastic modulus on the tensile strength of the cold-rolled and cold-rolled/tempered Zapp® 1.4310FS and FF stainless spring steel strip longitudinally to the direction of rolling.
Despite the overlapping values, the positive impact of tempering on the increase in the elastic modulus is visible. Values from the tensile test.

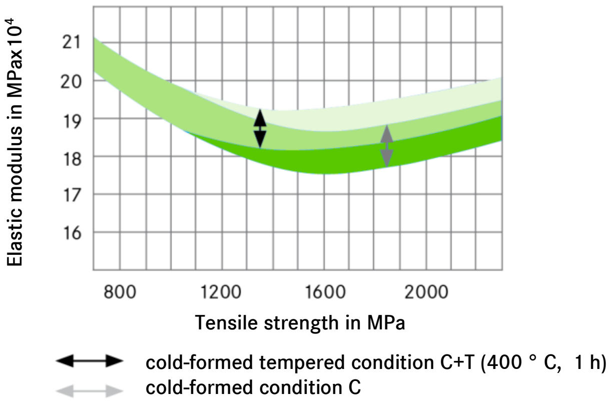
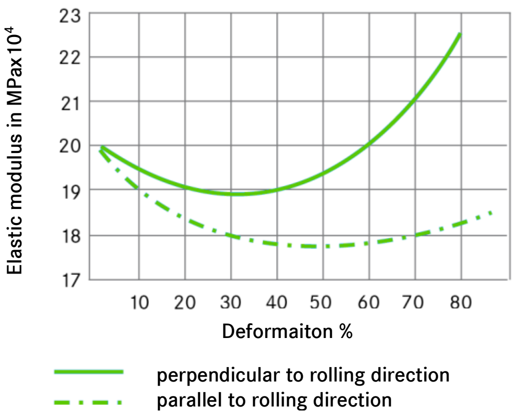


FIGURE 45 | Elastic module - tensile strength

Zapp® 1.4310 Dependence of the elastic modulus on the degree of cold formation and the rolling direction
Values from the tensile test.



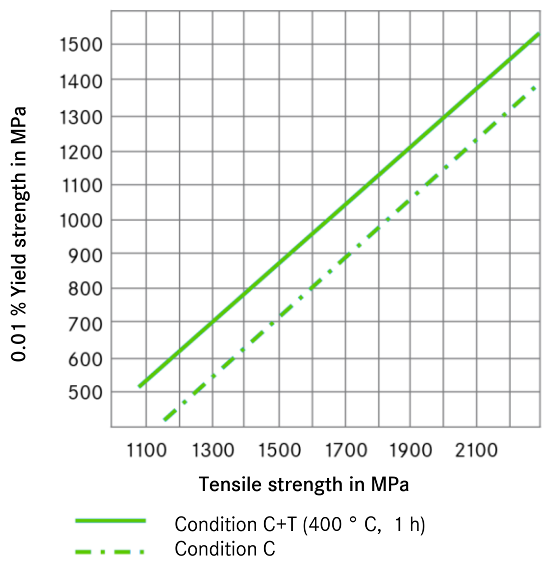
ELASTIC LIMIT

The elastic limit of a material refers to the extent of the mechanical stress above which non-reversible compression and/or plastic deformation occurs in the elastic range. In the stress-strain diagram, it is the point at which the stress curve deviates from a linear progression.

In addition to other material values, the elasticity values are used for the calculation and determination of the strength and stability of mechanical structures. Of the various identifiable stresses in the chart, we have highlighted the stress for the elastic limit that causes a permanent elongation of 0.01% ($RP_{0.01}$). A higher elastic limit improves the spring properties of the component.

FIGURE 47 | Dependence $RP_{0.01}$ - limit

Dependence of the Rp0.01- limit on the strength in the cold-rolled and cold-rolled + tempered condition of Zapp® 1.4310FS and 1.4310FF stainless spring steel strip (tempering 400°C/1 h).



Conclusions from Figures 47-50:

_ The positive influence of tempering temperature and time

_ The maxima of the limits of elasticity and strength result from temperatures / times

_ Increased strengths increase the maxima of the values at higher temperatures

_ Increased strength and $RP_{0.01}$-limit in the cold-rolled condition leads to higher values after tempering.

Influence of tempering temperature and time on tensile strength and elastic limit.

FIGURE 48 | Effect of tempering temperature

Zapp 1.4310FM Rm=1250 MPa cold-rolled.

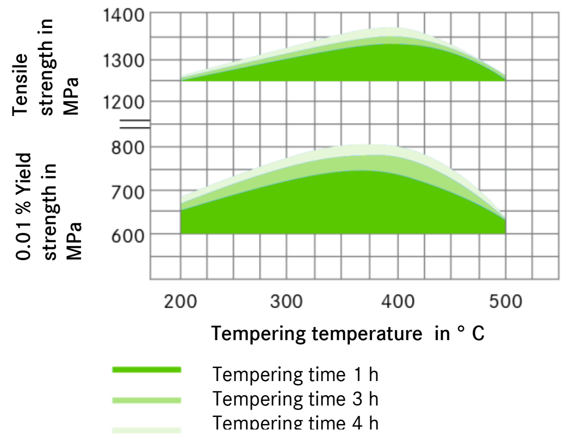


FIGURE 49 | Effect of tempering temperature

Zapp 1.4310FC Rm=1650 MPa cold-rolled.

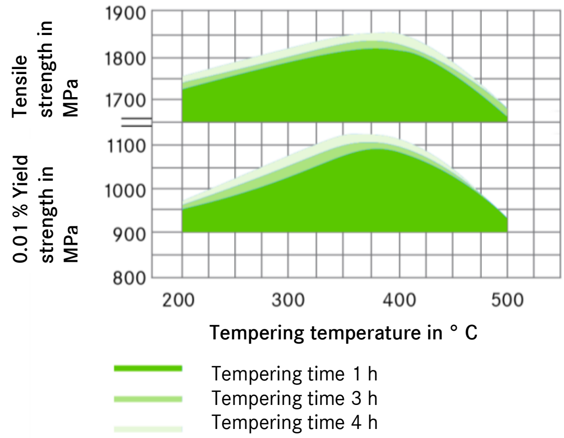
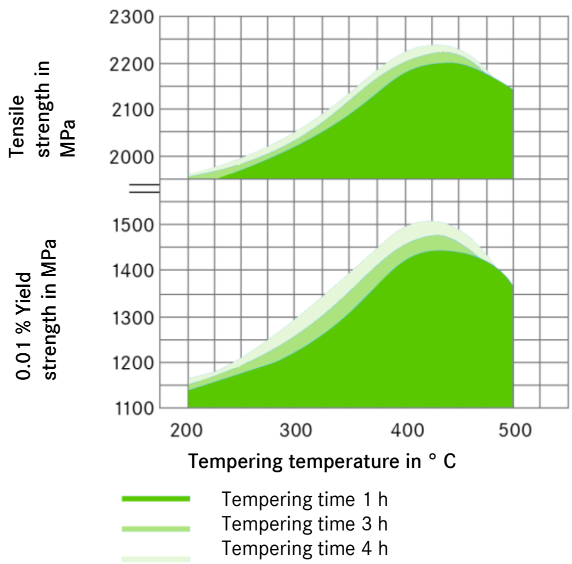


FIGURE 50 | Effect of tempering temperature

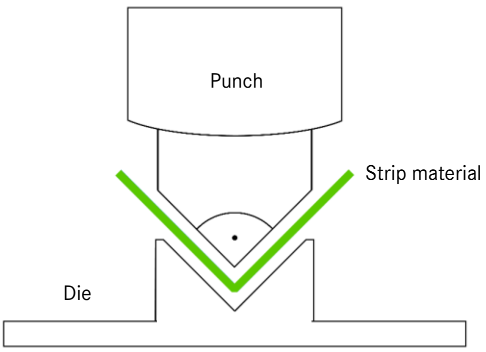
Zapp® 1. 4310FF/FS: Rm=1950 MPa cold-rolled.



DEFORMATION CAPACITY

Knowing the residual deformation capacity of the stainless steel strip is critical to determining the bending radii for a component. Often, the yield values and/or the yield ratio ($Rp_{0.2}/R_m$) are not enough to describe the residual deformation capacity of the spring steel strip. The press brake test and/or the fold test offers further information for the design of the spring components. Austenitic chrome nickel steels are classified as flow sluggish. For this reason, the forming speed should be adjusted accordingly during the production of the components.

FIGURE 51 | Press brake tool



FORMABILITY

The bend test and accompanying tests are based on DIN EN 10151, taking into account the general requirements according to DIN EN ISO 7438.
The test to demonstrate the formability is analogous to the production of springs. A test strip with smooth sides and, as far as possible, approx. 20 mm width is bent by 90°in a press with a bending mandrel radius specific to to the sample thickness (Fig. 51).
Bending transverse to the rolling direction determines the transverse values and bending parallel to the rolling direction the longitudinal values.
The minimum radius to which a material can be bent by 90° without visible cracking on the surface is taken as the measure of the formability. The ratio of the bending radius (r) to the strip thickness (t) is called the bend formability r/t. A higher value for the ratio r/t implies a deterioration in the residual deformation capacity. The selection of a suitable material variant can counteract this.

THE FOLLOWING APPLIES:

_ The formability decreases with increasing tensile strength.
_ The formability in the transverse direction is considerably better than in the direction of rolling and has a lower scatter range.
_ The formability improves at the same tensile strength with decreasing thickness.

RESIDUAL DEFORMATION CAPABILITY

TABLE 24 | Formability

Formability of stainless spring steel strip Zapp® 1.4310 as per DIN EN 10151

Tensile strength level	Formability (r/t)[1] for strip thicknesses in mm							
	0.05 ≤ 0.25 <0.05 on request		> 0.25 ≤ 0.50		> 0.50 ≤ 0.75		> 0.75 ≤ 1.00[2]	
	Position of the bending axis to the rolling direction							
	transverse	longitudinal[3]	transverse	longitudinal[3]	transverse	longitudinal[3]	transverse	longitudinal[3]
C 850[4]	≥ 0.5	≥ 1.0	≥ 0.5	≥ 1.5	≥ 0.5	≥ 2.5	≥ 1.0	≥ 3.0
C 1000[4]	≥ 0.5	≥ 2.0	≥ 0.5	≥ 2.5	≥ 1.0	≥ 3.0	≥ 2.0	≥ 4.0
C 1150[4]	≥ 0.5	≥ 2.5	≥ 1.0	≥ 3.0	≥ 2.0	≥ 4.0	≥ 2.5	≥ 5.0
C 1300[4]	≥ 1.5	≥ 3.0	≥ 2.0	≥ 4.0	≥ 2.5	≥ 5.0	≥ 3.0	≥ 7.0
C 1500	≥ 2.0	≥ 4.5	≥ 2.5	≥ 5.0	≥ 3.0	≥ 7.0	≥ 3.5	≥ 9.5
C 1700	≥ 2.5	≥ 9.0	≥ 3.0	≥ 9.5	≥ 3.5	≥ 11.0	-	-
C 1900	≥ 3.0	≥ 12.0	≥ 3.5	≥ 13.0	-	-	-	-

1) r = bend radius, t = strip thickness
2) Data on the formability of strips with thicknesses above 1 mm must be determined separately.
3) Unless otherwise agreed, these values are to be seen as an indication only.
4) The values for the material 1.4301 apply to 1.4310FM as per DIN EN 10151 Table 5.

The formability of the grades Zapp® 1.4310FS and 1 4310FF can be improved significantly as a custom production through targeted technical production measures.

TABLE 25 | Formability

Formability of stainless spring strip Zapp® 1. 4310FF and 1.4310FS according to factory standard (custom production)

Tensile strength level	Formability (r/t)[1] for strip thicknesses in mm							
	0.05 ≤ 0.25 < 0.05 on request		> 0.25 ≤ 0.50		> 0.50 ≤ 0.75		> 0.75 ≤ 1.00[2]	
	Position of the bending axis to the rolling direction							
	transverse	longitudinal[3]	transverse	longitudinal[3]	transverse	longitudinal[3]	transverse	longitudinal[3]
C 1000	0	≥ 1.5	0	≥ 2.0	0	≥ 2.5	≥ 1.5	≥ 3.0
C 1150	0	≥ 2.0	≥ 0.5	≥ 2.5	≥ 1.5	≥ 3.0	≥ 2.0	≥ 4.5
C 1300	≥ 1.0	≥ 2.5	≥ 1.5	≥ 3.0	≥ 2.0	≥ 4.5	≥ 2.5	≥ 6.0
C 1500	≥ 1.5	≥ 4.0	≥ 2.0	≥ 4.5	≥ 2.0	≥ 6.0	≥ 3.0	≥ 8.5
C 1700	≥ 2.0	≥ 9.0	≥ 2.5	≥ 9.5	≥ 3.0	≥ 11.0	-	-
C 1900	≥ 3.0	≥ 12.0	≥ 3.5	≥ 13.0	-	-	-	-

1) r = bend radius, t = strip thickness
2) Data on the formability of strips with thicknesses above 1 mm must be determined separately.
3) Unless otherwise agreed, these values are to be seen as an indication only.

FOLDABILITY

DIN EN ISO 7438 also describes the test of foldability. This residual deformation capacity is better characterized by the practical values (Table 26) in our factory standard. A test sample of approx. 20 mm in width and approx. 150 mm in length, with smoothed edges and taken parallel to the the rolling direction, is bent by 180° transverse to the rolling direction and placed between the clamping jaws of the testing equipment. The clamping jaws close slowly and evenly until ruptures appear on the surface of the sample. The ratio of the remaining jaw distance (d) to the strip thickness (t) is measured. We can positively influence the foldability of Zapp® 1.4310 through targeted, technical production measures as a custom production.

TABLE 26 | Folding test

Guideline values for the folding test for Zapp ®1. 4310FF and 1.4310FS (Factory standard for custom production)

	Condition	Strip thickness 1 mm	Tensile strength MPa	Folding test d/t
Zapp® 1.4310FF and Zapp® 1.4310FS	EN 10151	-	-	-
	C	≤ 0.40	1900-2200	≤ 20
	C + T	≤ 0.40	approx. 2200-2500	≤ 15

[1] Values for thicknesses > 0.4 mm on request

TEMPERATURE DEPENDENCE

To this point, the values for mechanical properties have related to room temperature. Temperature has an enormous influence on these properties, however.

CHANGES AT LOW TEMPERATURES

Tensile strength and hardness increase in all steels with decreasing temperature. At the same time, the elongation and with it the plasticity decrease. The amount of the increase or decrease depends on the material.

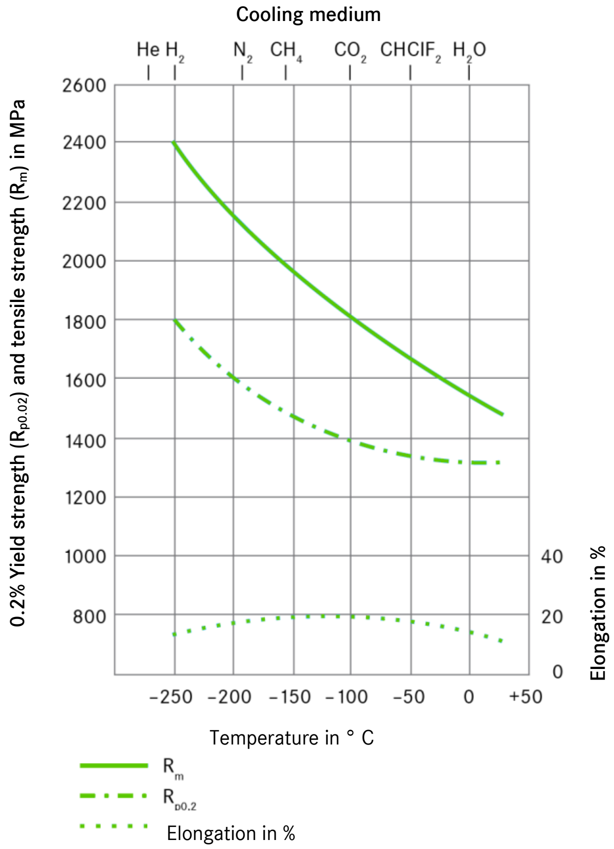
In contrast, austenitic chromium-nickel stainless steels remain tough and ductile at very low temperatures due to their granular structure at increasing tensile strength and 0.2% yield strength levels. Due to the given austenite stability of the Zapp® 1.4310 types, these changes are more pronounced than in other austenitic steels, such as such as 1.4303.

So, as the fatigue strength increases with increasing tensile strength, under alternating bending stress at room temperature, it also increases at reduced temperatures. For example the fatigue strength increases by about 20% at -40 °C, for example, compared to room temperature.

The elastic modulus also increases with decreasing temperature; for example, in the tensile strength grades C1150 and C1300, it decreases by about 12% and 8%, respectively.
Figure 52 shows the favourable behaviour of stainless steel spring strip 1.4310 at low temperatures.
The spring steel strip grade Zapp® 1.4310 shows a sufficient yield strength ratio $R_{p0.2}/R_m$ at -250 °C, such that the desired spring characteristics and functionality of the component remain.

FIGURE 52 | Tensile strength / low temperatures

Change in tensile strength, 0.2% yield strength and elongation of stainless spring steel strip Zapp® 1.4310 at low temperatures



CHANGES AT HIGH TEMPERATURES

Increases in temperature are associated with changes in mechanical and physical values for all steels. The austenitic chrome-nickel steels demonstrate significantly better properties in this regard compared to ferritic chrome steels. This is due to their good levels of scaling resistance, which results from the high alloy content of chrome, together with high tensile strength and elongation. The thermal resistance of the stainless steel spring strip for longer exposure to temperature is about 250 °C. If there is low mechanical stress, the same value for the 1.4310FS/FF material types can be assumed to be around 300 °C. Under longterm loads, particularly dynamic, the mentioned temperatures are lower and dependent on the extent of the load.
To reduce these effects, spring components that will be exposed to high temperatures during use should be treated with a tempering process.
The properties of the stainless spring steel strip or spring components made of Zapp® 1.4310 at higher temperatures are characterized by their short- and longterm performance.

SHORT-TERM PERFORMANCE

The following changes result for the typical values of spring strip:

_ Reduction in the tensile strength and the 0.2% yield strength
_ Reduction in the elasticity due to the reduction in elastic modulus, the spring bending and elastic limits
_ Increase in elongation

Figure 53 shows the hot strength chart for the stainless steel spring strip Zapp® 1.4310 in the rolled and in the tempered condition.
The same behaviour as observed with the tensile strength and 0.2% yield strength can be expected with the elastic limit.
The significant value drop at temperatures above 450 °C indicates an increase in grains and recrystallization.

FIGURE 53 | Hot strength chart

Hot strength chart for stainless spring steel strip Zapp® 1.4310

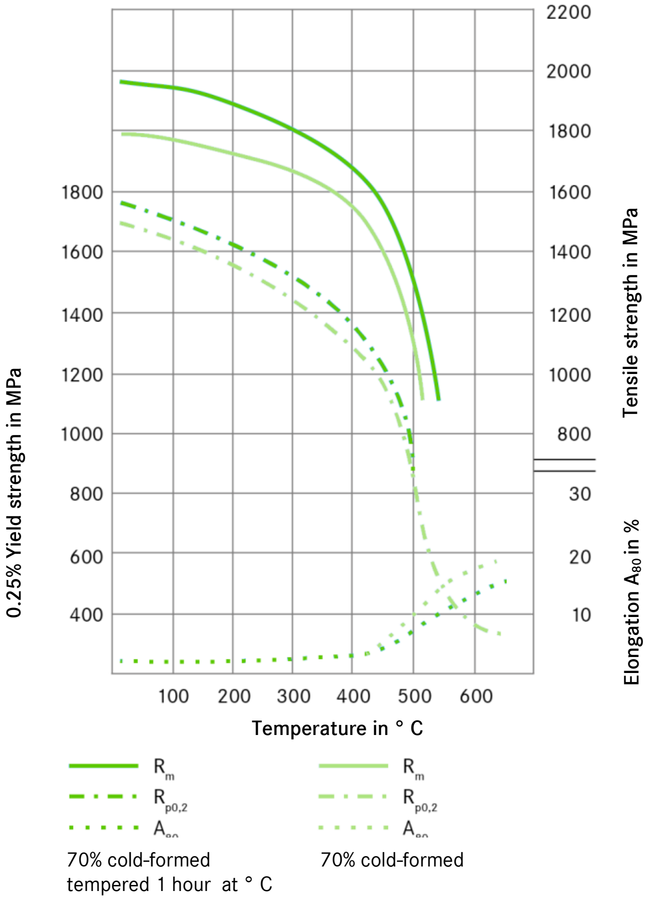
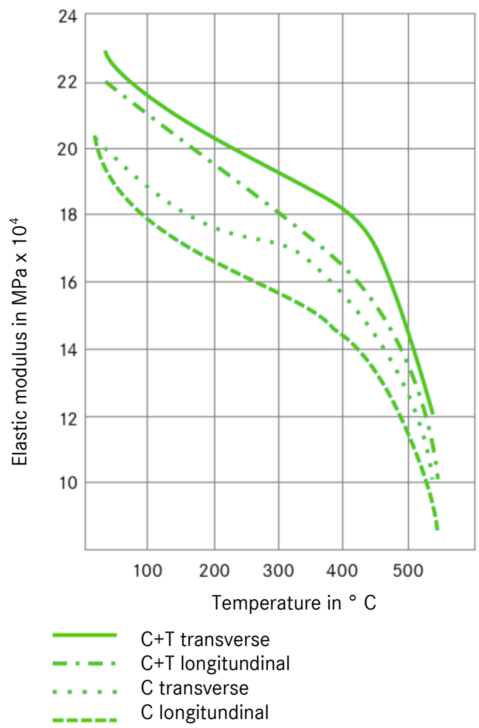


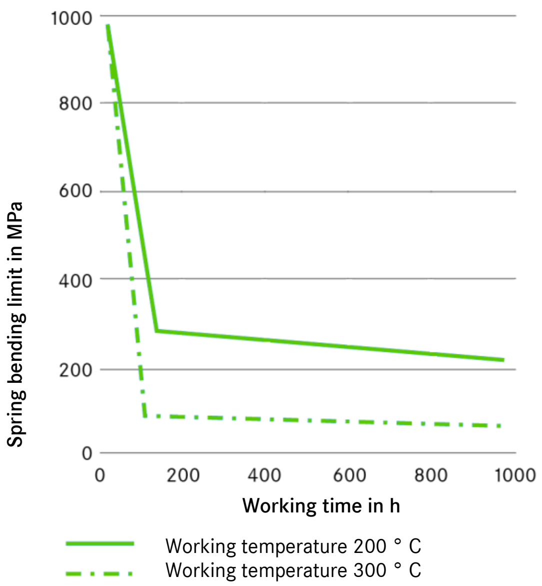
FIGURE 54 | Effect of increased temperature on the e-modulus

Effect of elevated temperature on the elastic modulus of stainless spring steel strip Zapp 1.4310, tensile strength in the tempered condition 2000 MPa (400 °C/1h)



TEMPERATURE DEPENDENCE

FIGURE 55 | Effect of temperature on spring bending limit
Influence of temperature on the spring bending limit of stainless spring steel strip Zapp® 1.4310FF, 0.50 mm thickness, tensile strength 1850 MPA, tempered condition (400 °C/ 1h)



LONG-TERM PERFORMANCE

The permanent deformation at elevated temperatures depends on the applied load and its duration. The stress is expressed either as the value of the force that causes a prescribed degree of deformation in a specified period (= creep stress), or as the value of the force that leads to a rupture in a specified period of time (creep resistance).

CREEP BEHAVIOUR

Creep resistance decreases significantly with increasing temperature for all steels. With increasing tensile strength, the drop is faster and more evident, as is visible in the example in Fig. 56. With the 400 °C curve, the temper effect results in relatively constant creep values up to 10h test period. This behaviour speaks volumes for the tempering process of spring steel strip, particularly for spring components.

CREEP PROPERTIES

Figure 57 specifies the creep stress for 1% elongation in 10,000 h and 100,000 h.
A rapid drop in the creep stress occurs in the temperature range between 400-500 °C. Above 700 °C, applied stress at a low level remains nearly constant.

FIGURE 56 | Creep behaviour

Creep behaviour of stainless spring steel Zapp® 1.4310 in different output tensile strengths

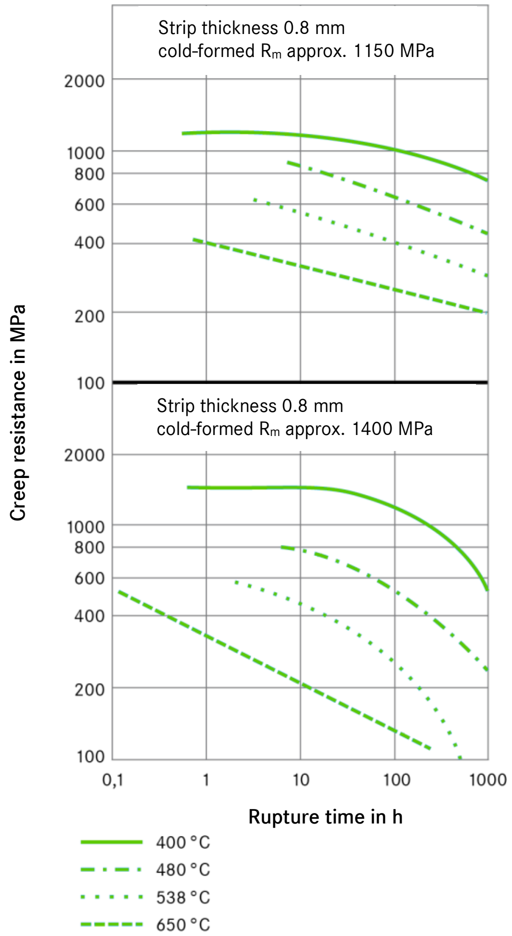
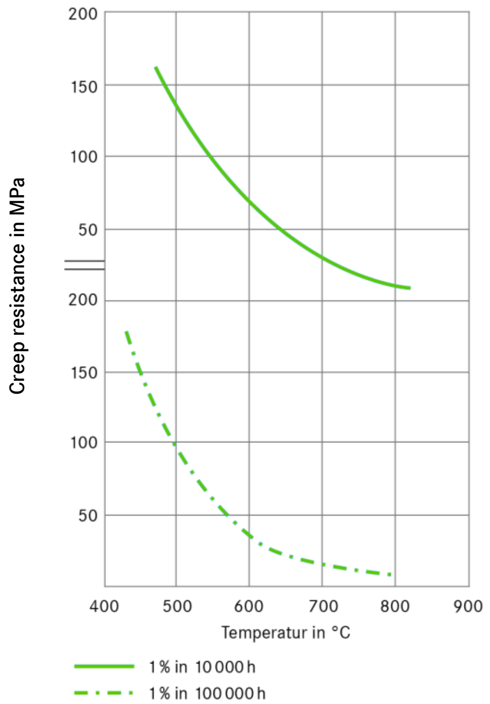


FIGURE 57 | Dependence of time-yield strength

Dependence of the time-yield strength on the temperature in ealed stainless spring steels Zapp® 1.4310.



MAGNETIC PROPERTIES

Non-alloy, low-alloy and stainless ferritic and martensitic chromium steels are known to be ferromagnetic. In contrast, pure austenitic chromium-nickel stainless steels in the soft, solution-annealed condition at room temperature are paramagnetic (in everyday parlance, "non-magnetic"). Depending on the alloy elements and the material condition (e.g. deformation), they can have mixed paramagnetic and ferromagnetic properties. During cold forming, a partial conversion of austenite into α'-martensite (deformation-induced martensite) takes place (cf. Chapter 4.1 and ff.), which then has ferromagnetic properties. In addition to the degree of deformation, the chemical composition (by way of the austenite stability) has an impact on the tendency to form α'-martensite.
The more unstable the austenite, the higher the ferromagnetic portion in the structure after cold forming.

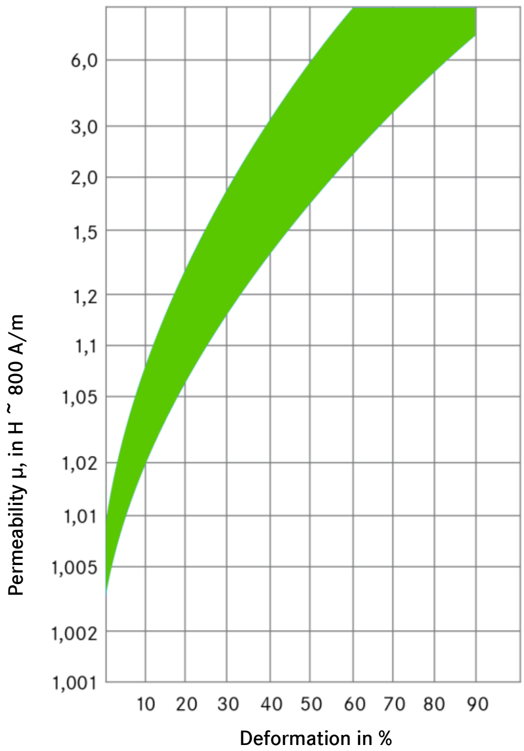
PERMEABILITY

The material permeability can be used to evaluate the magnetic properties of austenitic chrome-nickel steels such as Zapp® 1.4310. In the non-deformed and annealed condition, spring strip is non-magnetic at permeability values from 1,002 to 1,004.

Figure 58 shows the increasing permeability values (i.e. stronger magnetic properties) with increasing deformation.

FIGURE 58 | Dependence of permeability

Dependence of the permeability on cold forming for spring steel strip Zapp® 1. 4310FF and 1.4310FS



OTHER PHYSICAL PROPERTIES

OTHER PHYSICAL PROPERTIES

With decreasing temperature, the specific heat, the thermal conductivity and the thermal expansion as well as the specific electrical resistance of austenitic steels decreases, in contrast to density. With increasing temperatures, these ratios are inverse.

The numbers reflect values for stainless spring steels Zapp® 1.4310 in the annealed condition. We can provide the values for the cold-formed condition on request.

TABLE 27 I Physical properties

Density ρ

T in °C	-150	-75	20	100	200	300	400	550
g/cm^3	7.99	7.96	7.91	7.88	7.84	7.80	7.75	7.69

Specific heat capacity c_p

The average specific heat between 0 °C and 100 °C for Cr-Ni-steels is 502 J / (kg K)

T in °C	-150	-75	20	100	200	300	400	550
J/(kg K)	335	402	456	494	532	557	569	586

Thermal conductivity λ

T in °C	-150	-75	20	100	200	300	400	550
W/ (m K)	8.8	12.6	14.7	16.3	18.4	20.5	21.4	22.2

Average linear thermal expansion coefficient αm

T in °C	-150 to 20	-75 to 20	20 to 100	20 to 200	20 to 300	20 to 400	20 to 500
$10^{-6}/K$	14.2	15.0	16.3	17.0	17.2	17.8	18.2

Specific electrical resistance ρel

T in °C	-150	-75	20	100	200	300	400	550
$\Omega\ mm^2/m$	0.50	0.58	0.68	0.74	0.83	0.90	0.95	1.02

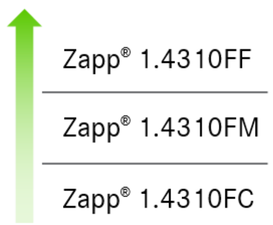
CORROSION RESISTANCE

CORROSION RESISTANCE
Stainless steels owe their high corrosion resistance to a naturally occurring, homogeneous passive layer. It is formed when there are adequately high levels of free chromium and oxygen at the surface. If this passive surface layer is damaged, it renews itself when exposed to air.

THE DEGREE OF CORROSION RESISTANCE IN STAINLESS STEEL DEPENDS ON A NUMBER OF FACTORS:
_ Level and type of alloying elements
_ Product surface
_ Operating conditions of the steel

If the chromium content of steel is at least 12% (as with ferritic and martensitic materials) it is generally considered chemically stable under normal atmospheric conditions and in fresh water. Austenitic Cr-Ni steels have improved corrosion resistance. As a result of their higher molybdenum and nitrogen contents Zapp® 1.4310FF spring steel strip has better corrosion resistance.

CORROSION RESISTANCE



In the following sections you'll find specific information about the common types of corrosion in stainless steels. In the design of components, it is possible to reduce corrosion problems in advance by, among other things, choosing the right material.

ZAPP® 1.4310 DEMONSTRATES RESISTANCE
_ in all non-halide salt solutions
_ in strong oxidizing acids (e.g. nitric acid, sulphuric acid)
_ in reducing, but aerated weak acids (e.g. low concentration sulphuric acid or oxalic acid)
_ in weak acids like carbonic acid, Hydrocyanic acid or acetic acid
_ in alkaline solutions
_ organic acids (food)
_ fresh water
_ industrial atmosphere

Chemical resistance tables provide more detailed information about the behaviour of Zapp® 1.4310 at different temperatures and concentrations of individual media. If required, we would be happy to provide consultation.

GENERAL CORROSION (EROSION CORROSION)
In this, the most widely known type of corrosion, the degradation of the steel takes place evenly over the entire surface.

INTERGRANULAR CORROSION
This type of corrosion is an attack in acidic media along the grain boundaries. The grains are not eroded, but can be removed from the structure. As a result, the steel loses its cohesion locally. Intergranular corrosion is caused by precipitates of chromium-rich carbides at grain boundaries, brought about by heat stress between 450 and 850 °C (see Chapter 4.4).
This form of carbide formation leads to a chromium depletion of the structure close to the grain boundary and thus an increased susceptibility to corrosion. The test for intergranular corrosion takes place as per DIN EN ISO 3651, Part 1, Procedure A (Strauss test: sulphuric acid copper sulphate solution).

CORROSION RESISTANCE

PITTING CORROSION

Pitting corrosion is point-shaped corrosion that occurs especially from an attack by media containing halide (chlorine, bromine and iodine ions). These ions activate the originally passive surface of stainless steel which results in the formation galvanic micro-elements. The subsequent pits or holes may vary in size from 1 μm^2 up to multiple mm^2. Since the surface remains largely unaffected in this type of corrosion, no significant material loss takes place. However, the life of a spring component decreases severely, since the pitting corrosion increasingly penetrates the strip once it starts.

TO AVOID OR REDUCE PITTING CORROSION, WE RECOMMEND...

_ adequate oxygenation and, with it, the maintenance of the passive layer, e.g. through the movement of inactive, halide-containing media (flow rate at least 2 m/s)
_elimination of residues and deposits on the components
_ electropolishing of the surfaces
_ addition of inhibitors (alkalis, chromates) to the triggering media
_ temperature reduction and application of higher flow rates

GALVANIC CORROSION

The risk of galvanic corrosion exists if different metals in an aqueous solution (electrolyte) form a conductive connection.

THE BASE MATERIAL IS ATTACKED EVEN MORE INTENSELY,

_ The greater the difference of the metals in the potential series
_ The smaller the surface of the base metal is in comparison to that of the noble metal
_ The lower the ohmic resistance of the electrolyte is in the existing combination of materials

This type of corrosion can be avoided with certainty by using the same materials.

STRESS CORROSION CRACKING

This type of corrosion can occur when steel, under internal or external tension, is exposed to certain corrosive media. Characteristic of this type of corrosion is a non-deformed material separation with an inter- or (most commonly) transgranular course. Often there is no visible build-up of corrosion products.
Stainless steel spring strips obtain their spring characteristics from cold rolling. The internal stress generated in this process generally creates an increased susceptibility to this type of corrosion. Use in chloride and alkali hydroxide solutions > 50° C, for example, must be avoided for this reason.

CORROSION FATIGUE

Spring components that are subject to dynamic mechanical stress and, simultaneously, the action of a corrosive medium can suffer from corrosion fatigue. As a result, the fatigue strength is not reached and the maximum cyclic stress declines. Zapp® 1.4310 is resistant to corrosion fatigue when the alternating tension is kept low.

CREVICE CORROSION

This type of corrosion occurs in crevices where the mobility of a medium is reduced. For this reason, no or little oxygen can penetrate for passivation. Alloys in which the corrosion resistance is due to the formation of a passive layer are particularly vulnerable to this type of corrosion.
It can be observed that crevice and pitting corrosion occur mostly at the same time. The type of corrosion can be avoided by designing components in such a way that there no unventilated crevices.

CORROSION ILLUSTRATIONS

FIGURE 59 | Erosion corrosion

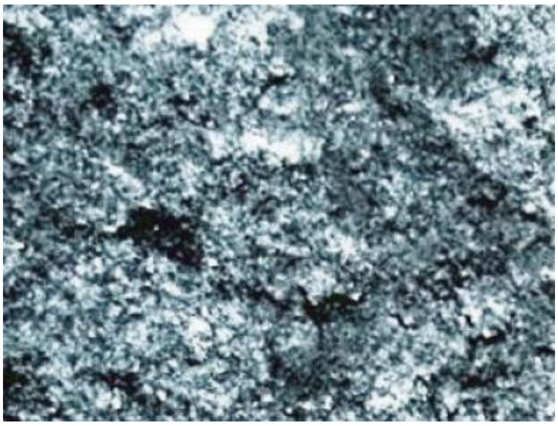


FIGURE 62 | Welding corrosion

FIGURE 60 | Pitting corrosion

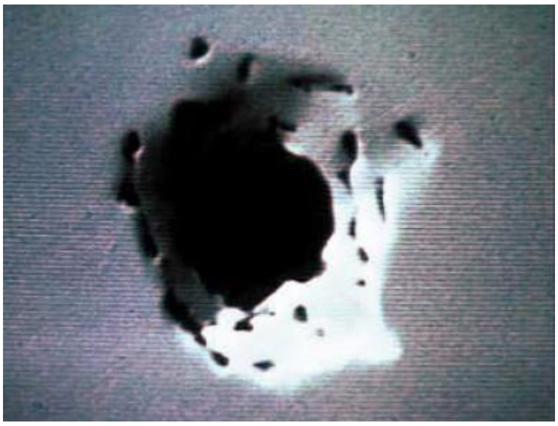


FIGURE 63 | Intergranular corrosion

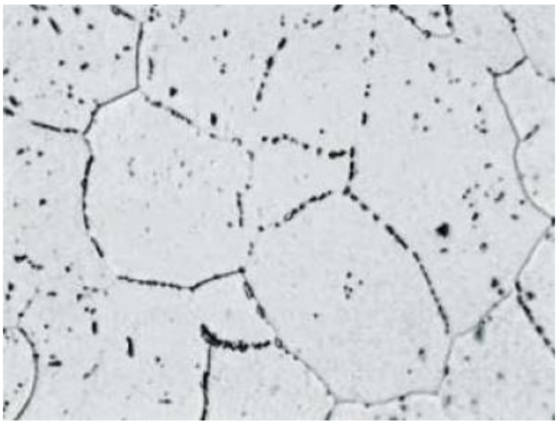


FIGURE 61 | Galvanic corrosion

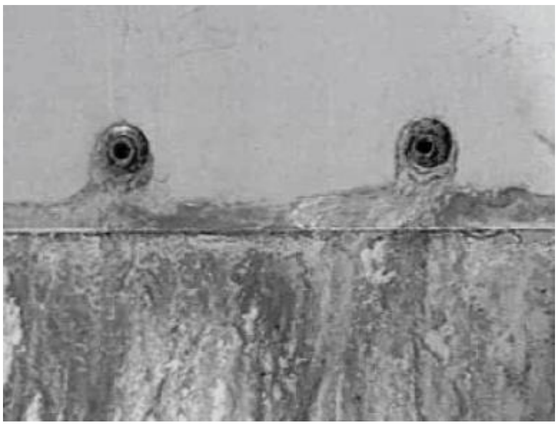
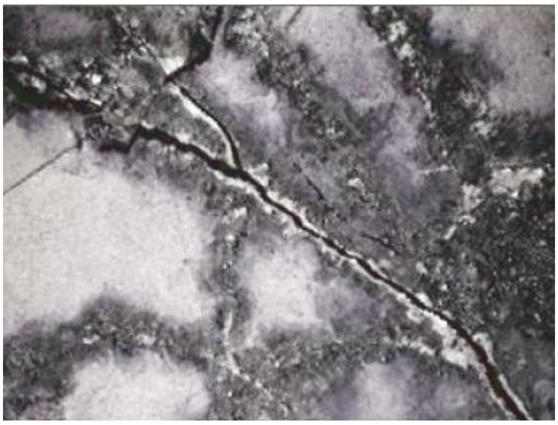


FIGURE 64 | Stress corrosion



OTHER GRADES AND DELIVERY FORMS

FLAT SPRING WIRE

Flat spring wires from Zapp stainless materials and coated flat wire in carbon steel are available with specific width/thickness ratios, such as for spring clamps or spring rails in windscreen wipers in the automotive industry.

Flat-rolled profiles are made from solid round wires. This manufacturing process enables the maintenance of particularly tight tolerances and guarantees shiny, dense surfaces with optimum surface roughness values. You can receive our flat wires with the tightest straightness and pretension on request.

TABLE 28 | Other grade compositions

Description	Mass fraction alloying elements in %								
Zapp	Standard/ SEL[1]	AISI/UNS	C	Si	Mn	Cr	Ni	Mo	N
1.4310FB	1.4310	302	0.10	0.90	1.25	17.25	8.20	0.30	0.020
1.4310FD	1.4310	301	0.10	0.50	1.25	17.00	7.25	0.30	0.070
1.4310FI	1.4310	301[2]	0.09	1.20	1.25	17.25	7.00	0.30	0.110
1.4301PA	1.4301	302	0.04	0.50	1.50	18.50	9.25	0.30	0.030
1.0611	1.0611	G106400	0.62	0.20	0.70	0.100	0.100	0.03	-
1.0617QC	1.0617	G107400	0.73	0.20	0.70	0.100	0.100	0.03	-

1) Steel iron list

2) Deviation in Si content

TENSILE STRENGTH

The level of the tensile strength is determined based on the dimension and material, as well as the processing techniques.
Tensile strength: up to 2100 MPa

DIMENSIONS

Width: 0.50 mm to 15.0 mm
Thickness: 0.20 mm to 2.00 mm

TABLE 29 | Tolerances

Thickness [mm]	Standard	Fine	Precision
≤ 0.30	± 0.025	± 0.010	± 0.008
≤ 0.80	± 0.030	± 0.012	± 0.008
≤ 2.00	± 0.030	± 0.015	± 0.008

Width [mm]	Standard	Fine	Precision
≤ 3.00	± 0.080	± 0.050	± 0.030
≤ 8.00	± 0.100	± 0.080	± 0.030
≤ 15.00	± 0.100	± 0.080	± 0.030

Other dimensions and tolerances available on request

SURFACE FINISH

_ Matte
_ Blank
_ Glossy
_ Galvanized
_ Galvanized, powder coated (black)

DELIVERY FORMS

_ Reusable wooden spools
_ Reusable plastic spools

DESIGN

Defined coil curvature on request

CAMBER

Standard: ≤ 2.0 mm / 500 mm measuring length
Special: ≤ 2.0 mm / 1000 mm measuring length
Specific requirements on request

EDGE FINISH

Due to the production process, flat-rolled sections have uniform, burr-free edges. Different edge designs are possible:

Flat rolled round edges

Flat rolled, rounded edges

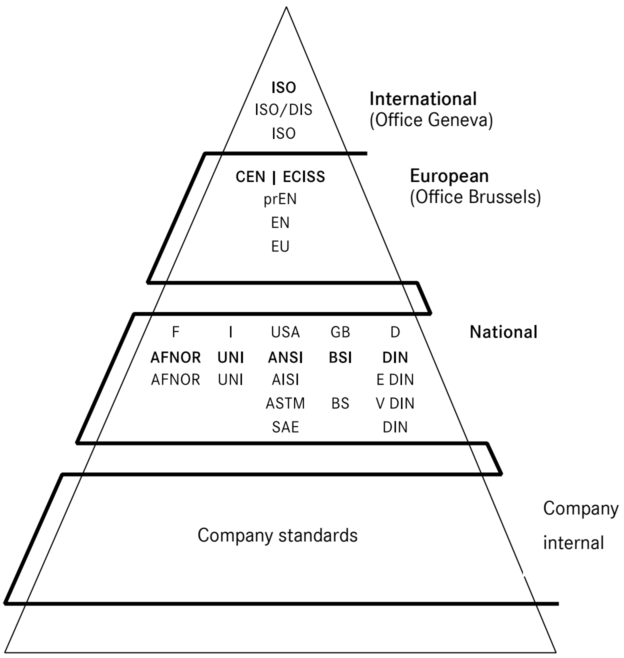
Flat rolled, rounded corners

More information about our flat spring wires is available in our information sheets and/or from our qualified professionals.

HIERARCHY OF STANDARDS

Standardization is the systematic unification of tangible and intangible items for the benefit of the general public. Standards are created collaboratively by parties of experts and promote implementation and quality assurance in, for example, production and development. The standards have the character of recommendations in the sense of their creation, ownership, content and areas of application. Legally, the user can rely on them as the recognized rules of the industry.
Figure 65 depicts the levels of standardization, from factory up to international standards.

FIGURE 65 | Standardization level



ISO	International Organization for Standardization
ISO/DIS	Draft International Standard
CEN	European Committee for Standardisation
ECISS	European Commitee for Iron and Steel Standardisation
prEN	Draft of an EN
EN	European Standard
EU	Euronorm
DIN	German Institute for Standardization (Berlin)
E DIN	Draft of a DIN
V DIN	DIN Prestandard
DIN	German standard

The following figures show an overview of the national and international standards applicable to stainless spring steel strip. According to the hierarchy, the international standards apply before the European standards and these in turn before the national standards.
ISO standards can be applied in European (EN standards) or German standards (DIN standards). EN standards have to be converted into national standards.

FIGURE 66 | Spring strip standards

International → **ISO 6931-2**
Stainless steel for springs
Part 2 Strip

European → **EN 10151**
Spring strip made of stainless steel
Technical terms of delivery

National (D) → **DIN EN 10151**
Spring strip made of stainless steel
Technical terms of delivery

FIGURE 67 | Product standards

International → **ISO 9445-1**
Continuously cold-rolled stainless steel - Tolerances on dimensions and form - part 1 cold-rolled strip and cold-rolled strip in bars

European (EN) → **EN ISO 9445-1**
Continuously cold-rolled stainless steel - Tolerances on dimensions and form - part 1 cold-rolled strip and cold-rolled strip in bars

National (D) → **DIN EN ISO 9445-1**
Continuously cold-rolled stainless steel - Tolerances on dimensions and form - part 1 cold-rolled strip and cold-rolled strip in bars

FIGURE 68 | Inspection certificate

International → **ISO 10474**
Steel and steel products
Inspection documents

European → **EN 10204**
Metallic products
Inspection certificates

National (D) → **DIN EN 10204**
Metallic products
Inspection certificates

PROCESSING PROCEDURES

WELDING
Since spring steel strip is used primarily for the manufacture of springs, there is little call for welding. Should this be the case, however, the material can be welded with or without filler metal. If a welding filler must be used, use for example 1.4316. To avoid embrittlement by grain coarsening and/or chromium carbide precipitation at the grain boundaries in the welding zone and/or temperature-influenced zones, the materials must be cooled from the welding heat quickly. In general, heat treatment after welding is not necessary. Note that, during welding, the mechanical values in the welding zone are greatly reduced in comparison to the remaining part, due to the influence of heat on the cold-formed components. The Zapp® 1.4310 spring steel strip is easily weldable using all conventional methods, with the exception of oxygen-acetylene flame.

SOLDERING
Generally, stainless spring steel strip in Zapp® 1.4310 solders well. The soldering temperature must be adjusted to:
_ The relatively poor thermal conductivity of stainless austenitic materials.
_ The reduction in the tensile strength at temperatures > 450 °C and the associated decline in the spring properties.
_ The chromium carbide precipitation on the joint grain boundaries at temperatures between 450° - 850 °C and the associated higher corrosion as a result of local chromium depletion.

BRAZING
Brazing connections are possible with low-melting silver solders (35% - 56% silver according to DIN EN ISO 17672) and associated flux according to DIN EN 1045. Only cadmium-free silver solder may be used for the food industry. It is processed with a low flame; point overheating must be avoided. Working in sections may be required. Check whether or not high-temperature soldering is necessary.
Roughen the surfaces chemically or mechanically. The soldering gap should be at least 0.01 mm and the overlap at least 2.00 mm. Also joint solder wire must be used with larger gap distances (approx. 0.50 mm - 1.5 mm). After completing the soldering seam, flux residue must be removed with plenty of water and, if necessary, a cleaner, otherwise discolourations may occur. Any heat tint can be removed by pickling or brushes.

SOFT SOLDERING
Austenitic stainless steels are good for soft soldering, for example when 30% tin solder is used according to DIN EN ISO 9453 with a phosphoric acid based flux as per DIN EN 29454-1. Fluxes containing muriatic acid chloride may not be used.
The surfaces to be joined must be metallically clean; where possible, the soldering seams must have 10.0 mm - 15.0 mm of coverage.

MACHINABILITY
Like all austenitic stainless steels, Zapp® 1.4310 is difficult to machine. Essentially, the machinability is adversely affected by the high capacity for cold working, the low thermal conductivity and the toughness of the material. Increasing tensile strength tends to improve the machinability of the spring steel strip. While sulphur alloying improves the machinability significantly, it is not recommended due to the formation of sulfide stress cracking. The formability would deteriorate significantly as a result.

ELECTROPOLISHING
The 1.4310 spring steel strips can be electropolished. The treated surfaces provide the following benefits:
_ Metallically pure and thus improved corrosion resistance.
_ Levelling the surface and deburring
_ Shiny appearance with a diffuse reflection
_ The micro-roughness is reduced, which makes it more difficult for soiling to adhere.

PROCESSING PROCEDURES

PUNCHING AND BENDING

In recent decades, punching technology has developed into one of the most widespread mass component production methods. Today, many products are produced using punching technology. Consequently, the demands for the qualitative performance of punching / bending parts have increased.

The selection of the precise spring strip takes into account the influence of steel production and hot rolling. The product- and material-specific properties of the cold-rolled strip also play a role. Zapp Precision Metals can optimize and vary these properties in collaboration with you, the customer.

Particularly when multiple processes take place in succession, e.g.: **Punching – fine blanking – bending – turning**, the cold-rolled strip has a significant influence on the quality and economics of your project. The spring-back of a component, cracking, inferior cutting performance and tool wear all hinder the production of smooth, crack-free, installation-ready parts with a long tool life.

DIRECTORY OF TABLES AND ILLUSTRATIONS

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