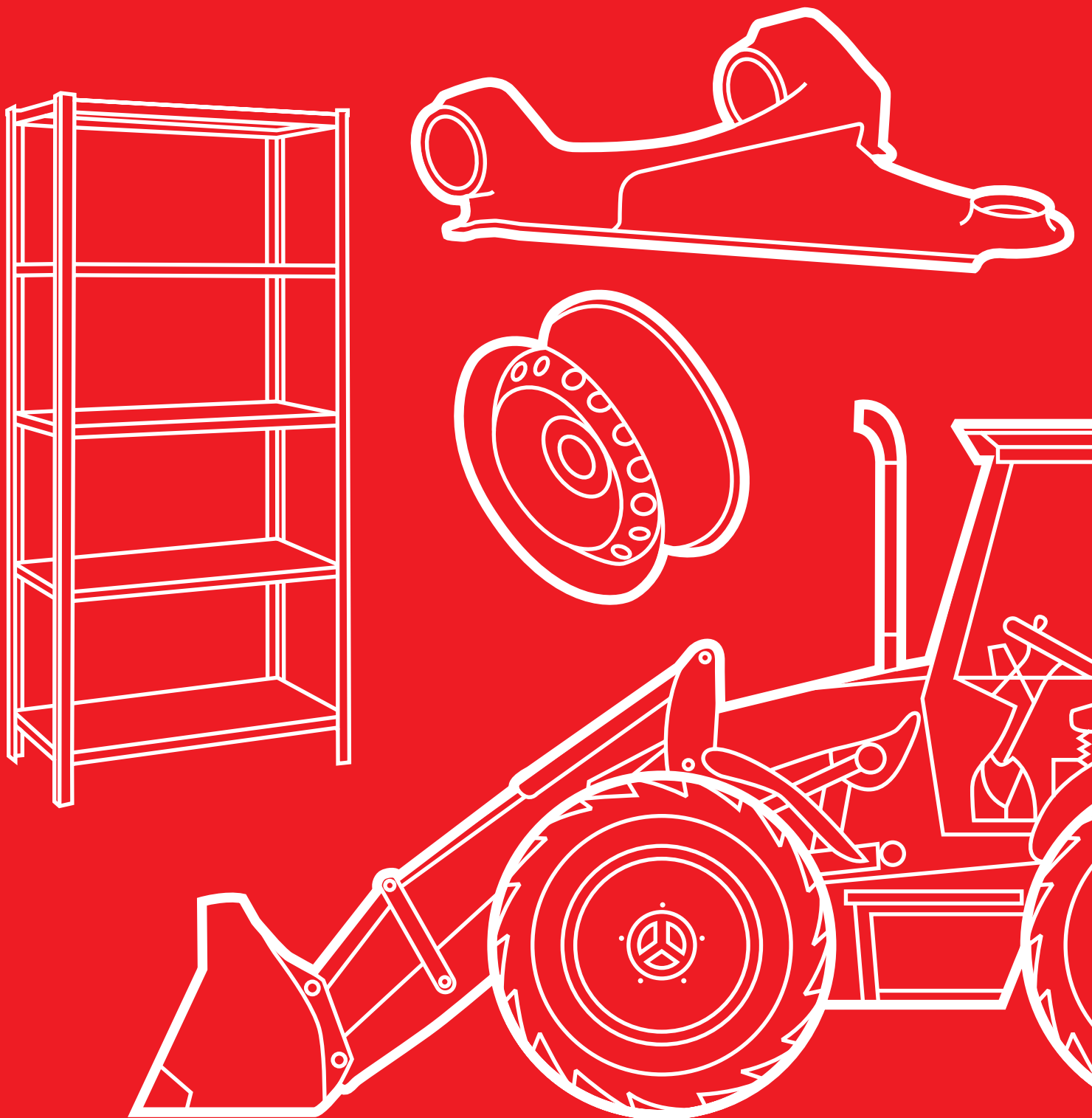


Corus Strip Products UK

# Tenform hot-rolled high-strength formable steels

Tenform XF, XK and CMN



# General

## Description

Tenform is hot-rolled high-strength formable strip steel available in a range of strengths, forming capabilities and steel characteristics. It has higher yield strengths than the forming qualities of standard mild steels.

## Applications

- Automotive components
- Tubes
- Structural sections
- Trench sheeting
- Shelving
- Bridges
- Silos and containers
- Earth moving and agricultural machines
- Hydroforming
- Roll forming

## Benefits

The relatively high yield strength of Tenform allows the user to increase the strength of the finished component or to reduce the steel thickness, or both. This can make products more profitable and competitive by increasing the output from each tonne of steel and by making them stronger, lighter and safer under load.

The strength and formability of Tenform expand the scope for design. For example, products can be manufactured by press forming rather than welding.

The close manufacturing tolerances that produce Tenform create a consistent, high-quality product which is already well established in the automotive, tube and other industries.

Corus has helped many companies convert successfully to high-strength steels and continues to develop these steels with properties and characteristics for specific applications.

## Products

The three hot-rolled high-strength formable strip steels offered by Corus are Tenform XF, Tenform XK and Tenform CMN, each with a range of guaranteed minimum strengths.

### Tenform XF

Tenform XF is hot-rolled micro-alloyed steel that gains its strength by precipitation hardening and grain refinement. Corus tightly controls residual elements such as sulphur to give Tenform XF its excellent formability.

With its combination of high-strength and excellent formability, Tenform XF is suitable for automotive applications such as cold-formed chassis and suspension components, brackets, side members and wheels. It is also used for cold-formed structural sections and trench sheeting in the construction industry, tubes and many other applications.

The grades available are XF300, XF350, XF400, XF420, XF450, XF460, XF500 and XF550.

### Tenform XK

Tenform XK is hot-rolled micro-alloyed steel that gains its strength by precipitation hardening and grain refinement. It combines high strength with good formability for cold-formed applications that have less demanding forming requirements. These include the less difficult parts among such items as cold-formed chassis components and brackets in the automotive industry, tubes, cold-formed structural sections and many other uses.

The grades available are XK300, XK350, XK400 and XK450.

### Tenform CMN

Tenform CMN is hot-rolled carbon-manganese steel with a two-phase microstructure that is tightly

controlled by Corus' modern manufacturing processes. The range is characterised by high tensile strengths, low yield strength to tensile strength ratios and excellent formability.

This product combines high strength with excellent formability for the most difficult cold-formed applications, including suspension housings, transverse links, wheel rims and discs in the automotive industry, tubes and general engineering uses.

The grades available are CMN250, CMN300 and CMN350.

## Standards

The nearest equivalent European specifications to the Tenform micro-alloyed steels are given in table 1 below. Corus also offers steels to the exact specification shown in EN 10149-2 : 1996.

**Table 1: Standards: Tenform XK/XF**

Corus	European	National		
	EN 10149-2 : 1996	UK	France	Germany
Grade		BS 1449	NFA 36-231	SEW 092
XK300	S315MC	HR40/30	E 315 D	QStE340TM
XK350	S355MC	HR43/35	E 355 D	QStE380TM
XK400	S420MC	HR46/40	E 420 D	QStE420TM
XK450	S460MC	HR50/45	-	QStE460TM
XF300	S315MC	HR40F30	E 315 D	-
XF350	S355MC	HR43F35	E 355 D	-
XF400	-	HR46F40	-	-
XF420	S420MC	-	E 420 D	QStE420TM
XF450	-	HR50F45	-	-
XF460	S460MC	-	-	QStE460TM
XF500	S500MC	-	E 490 D	QStE500TM
XF550 <sup>(see note)</sup>	S550MC	-	-	QStE550TM

**Note:** Consult Corus about the availability of XF550.

# Basic properties

## Mechanical properties

The values shown for strength and elongation in tables 2 and 3 below are for test pieces taken in the rolling direction; those for the bend test are for test pieces taken transverse to the rolling direction.

## Comparisons

Tables 4 and 5 on the opposite page compare the properties of one of the Tenform micro-alloyed steels (XF) with Tenform CMN. The two final pages of this leaflet contain a brief summary of the main differences between all three products at similar strengths.

## Chemical composition

The chemical compositions of Tenform micro-alloyed and carbon-manganese steels are shown in table 6 on the opposite page.

## Dimensions

The overall thickness and width limits for Tenform micro-alloyed and carbon-manganese steels are shown in table 7 on the opposite page. These dimensions are limits and therefore not all combinations of thickness and width will be available. For specific combinations of thickness and width, please consult Corus.

**Table 2: Mechanical properties: Tenform XK/XF**

Grade	R <sub>eL</sub> (N/mm <sup>2</sup> )	R <sub>m</sub> (N/mm <sup>2</sup> )	A (%)	Bend test mandrel diameter
	Min	Min	Min	Min
			L <sub>0</sub> = 80mm	
XK300	300	400	24	2t
XK350	350	430	21	2t
XK400	400	460	18	3t
XK450	450	500	18	3t
XF300	300	400	26	0t
XF350	350	430	23	0.5t
XF400	400	460	20	0.5t
XF420	420	480	20	0.5t
XF450	450	500	20	1t
XF460	460	520	18	1t
XF500	500	550	18	1t
XF550	550	600	12	1t

**Notes:**

1. Minimum impact energy at -20°C is 27 Joules, based on a 10mm x 10mm notched sample.
2. Material thickness, t, is in millimetres.

**Table 3: Mechanical properties: Tenform CMN**

Grade	R <sub>eL</sub> (N/mm <sup>2</sup> )	R <sub>m</sub> (N/mm <sup>2</sup> )	A (%)	Bend test mandrel diameter
	Min	Min	Min	Min
			L <sub>0</sub> = 80mm	
CMN250	250	360	28	0t
CMN300	300	440	26	0t
CMN350	350	540	20	0t

**Note:** Material thickness, t, is in millimetres.

**Table 4: Typical properties: Tenform CMN300 and XF350**

Tenform	R <sub>eL</sub>	R <sub>m</sub>	R <sub>eL</sub> :R <sub>m</sub>	A <sub>80</sub>	Hole expansion	Fatigue limit	CEV
	(MPa)	(MPa)	(%)	(%)	(%)	(MPa)	(Wt%)
CMN300	320	470	68	28	50	0.4R <sub>m</sub>	0.30
XF350	392	471	83	27	55	0.4R <sub>m</sub>	0.19

Note: The values shown in the table above are for test pieces taken in the rolling direction.

**Table 5: Typical properties: Tenform CMN350 and XF450**

Tenform	R <sub>eL</sub>	R <sub>m</sub>	R <sub>eL</sub> :R <sub>m</sub>	A <sub>80</sub>	Hole expansion	Fatigue limit	CEV
	(MPa)	(MPa)	(%)	(%)	(%)	(MPa)	(Wt%)
CMN350	431	568	76	23	40	0.4R <sub>m</sub>	0.34
XF450	486	550	88	22	40	0.4R <sub>m</sub>	0.26

Notes:

1. The values shown in the table above are for test pieces taken in the rolling direction.
2.  $CEV = (C + Mn/6) + (Cr + Mo + V)/5 + (Cu + Ni)/15$

**Table 6: Chemical composition**

Grade	C	Mn	P	S	Si	Micro-alloying elements (e.g. Nb)
	Max	Max	Max	Max	Max	Max
Tenform XK/XF						
XK300/350/400/450	0.10	1.20	0.030	0.020	0.04	0.300
XF300/350/400/420	0.10	1.20	0.025	0.010	0.04	0.300
XF450/460/500	0.10	1.50	0.025	0.010	0.35	0.300
XF550	0.12	1.50	0.020	0.020	0.30	0.300
Tenform CMN						
CMN250	0.12	0.90	0.035	0.010	0.10	-
CMN300	0.15	0.90	0.035	0.006	0.10	-
CMN350	0.15	1.50	0.035	0.006	1.00	-

Note: Values are in weight percentages.

**Table 7: Dimensions**

	Thickness		Width	
	>	≤	Min	Max
Tenform XK/XF				
Mill finish	1.50	8.00	710	1830
Pickled	1.50	5.00	735	1550
Tenform CMN				
Mill finish	1.50	8.00	710	1830
Pickled	1.50	5.00	735	1550

Note: Dimensions are in millimetres.

## Advanced properties

### Blanking

The force required to shear Tenform CMN and Tenform XF and XK depends on the tensile strength and thickness of the product being cut. Figure 1 (right) shows the average blanking forces expected for these products.

### Formability

#### Elongation

Tenform XF and Tenform CMN have similar levels of formability for a given tensile strength. With its relatively higher sulphur level, Tenform XK has a slightly lower minimum elongation value than Tenform XF at the same strength. The typical elongation levels of all three products decrease with increasing tensile strength.

#### Ratio of yield stress to tensile strength ( $R_{eL}:R_m$ )

This ratio is a measure of the separation between yield stress and tensile strength determined from the uniaxial tensile test. In general, lower  $R_{eL}:R_m$  gives an improved strain distribution during press forming, enabling more complex parts to be formed. The typical  $R_{eL}:R_m$  for Tenform XF and XK is 80-85%, whereas for Tenform CMN it is significantly lower at 70-75%. For example, the tensile strengths of CMN300 and XF350 are similar (table 4), but the typical yield stress of CMN300 is approximately 70MPa lower than XF350.

The three Tenform products are suitable for similar applications, but they will perform differently in pressing operations, which is an important factor in choosing the right product. That choice will also depend on the minimum yield stress or tensile strength required by the design of the component.

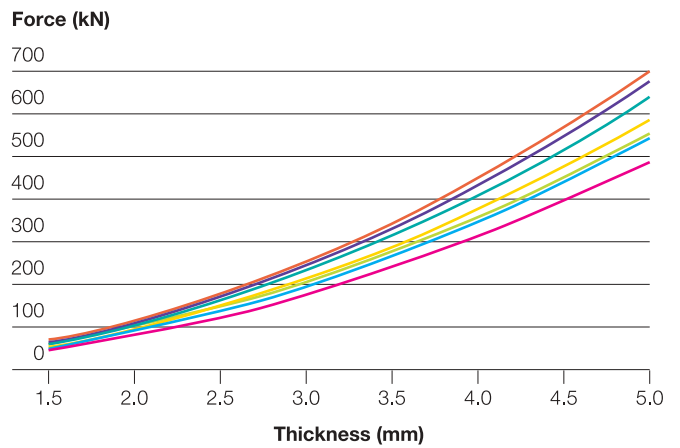
#### Hole expansion

The hole expansion ratio is a measure of the material's ability to withstand either plunged hole formation or flange stretching without cracking. It is measured in the laboratory by expanding a punched hole using a flat-nosed punch until a visible crack is observed on the circumference of the hole. It is defined in the formula below.

$$((D_f - D_i) / D_i) \times 100$$

$D_f$ =final hole diameter     $D_i$ =initial hole diameter

Figure 1: Average theoretical shearing force



#### Key

— XF300      — CMN300      — XF450      — XF500  
— XF350      — XF400      — CMN350

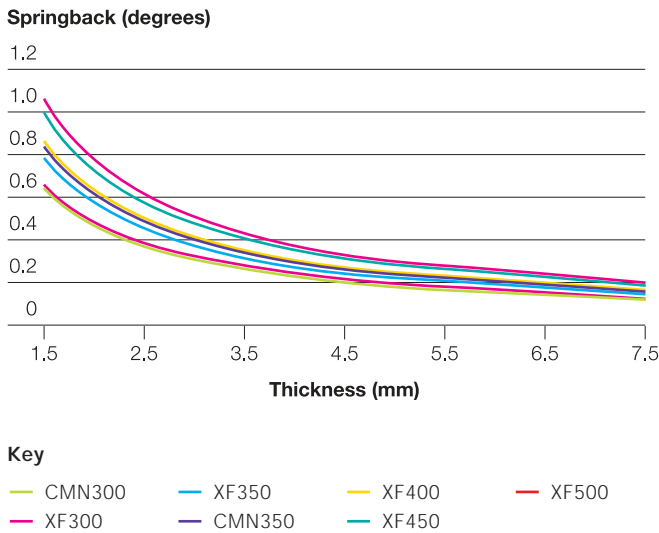
In general, for all three products, the hole expansion ratio decreases as the tensile strength increases. However, the ratio differs slightly between products of a given tensile strength. Tenform XK has a lower hole expansion ratio than Tenform XF at the same strength level owing to its higher sulphur content. The hole expansion ratio of Tenform CMN300 is slightly lower than that of Tenform XF350. Tenform CMN350, with its two-phase ferrite-bainite microstructure, has a hole expansion ratio similar to that of Tenform XF450.

For all products, the condition of the sheared edge has a significant influence on the hole expansion ratio. Therefore, when producing components with stretched flanges or plunged holes, or both, take care to optimise the edge condition of the blank and of any punched holes intended for plunging operations.

#### Springback

Springback is the characteristic of strip steel to take a shape that is slightly different from that defined by the forming process, i.e. the steel 'springs back'. The amount of springback depends primarily on the yield stress and material thickness of the product. Springback is normally determined by measuring the difference

**Figure 2: Comparison of theoretical springback for a bending angle of 90°**



between the angle at which a channel section is formed and the larger angle reflected in the finished section. Figure 2 above shows the theoretical amount of springback for various Tenform products.

### Weldability

The three Tenform products can be readily spot welded, laser welded or fusion welded. However, the ranges of current for acceptable weld quality will differ for each product.

The levels of elements such as carbon, manganese, silicon and phosphorous are important parameters in determining the optimum currents and electrode forces when resistance spot welding. However, fusion welding tolerates higher levels of these elements than resistance spot welding.

The strengthening mechanisms for the three Tenform products are based on the use of different steel compositions—in particular, carbon, manganese and niobium. Tenform XF and XK use less carbon and manganese than Tenform CMN and make use of niobium additions to achieve the required strength. Tenform CMN contains relatively more carbon and

manganese and no niobium. The carbon and manganese values of Tenform CMN are correspondingly higher than Tenform XF and XK of similar strength.

### Fatigue

The fatigue test is a measure of the ability to withstand an alternating applied stress. This is normally expressed in the form of an S-N curve, where the number of cycles to failure (N) is plotted against the applied stress range (S).

For all three Tenform products, a fatigue limit exists where applied stresses below that limit will not lead to failure. The fatigue limit is normally expressed as a ratio of the tensile strength and is typically 0.4R<sub>m</sub>.

Corus can also provide information on XF, XK and CMN products tested under strain-life conditions.

In welded components, the position of welds needs to be carefully considered to avoid adversely affecting the fatigue life of the component.

### Post-galvanising

Tenform XF, XK and CMN250 are suitable for post-galvanising.

### Painting

Tenform's characteristics for painting are equivalent to those of conventional mild steels.

### Health and safety

The three Tenform products in this brochure are covered by *Product health and safety data sheets 2 and 16*.

### More information

For more information about these products, contact Corus at the address on the back cover.

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# www.corusgroup.com

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