Steel

perform®

Information on use and processing

thyssenkrupp

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Brief profile

perform® from thyssenkrupp is a micro-alloyed thermomechanically rolled cold-forming steel. Characteristic of the perform® steels are the particularly low sulphur content, the low carbon content and the micro-alloying of niobium, titanium, vanadium or molybdenum and their combination. perform® steels have excellent cold formability and weldability. The extremely fine-grained microstructure also leads to a very high good toughness with a low risk of cold cracking. thyssenkrupp offers the high-strength micro-alloyed steels in various yield strength levels from 300 to 700 MPa.

Instructions on processing

Forming

Micro-alloyed steels are ideal for structural and crash-relevant parts, such as beams. The selection of the steel grade to be used for a specific strength level should also be made with particular regard to the actual forming stress to be expected. In this way, the individual advantages can be optimally utilized and the steels can also be used for difficult drawn parts.

The steels are equally suitable for stretch forming and deep drawing operations, taking into account the existing yield strength and strength level. Due to their robust forming behavior, micro-alloyed steels enable the use of complex multistage forming processes. This enables the production of complex component geometries.

Content

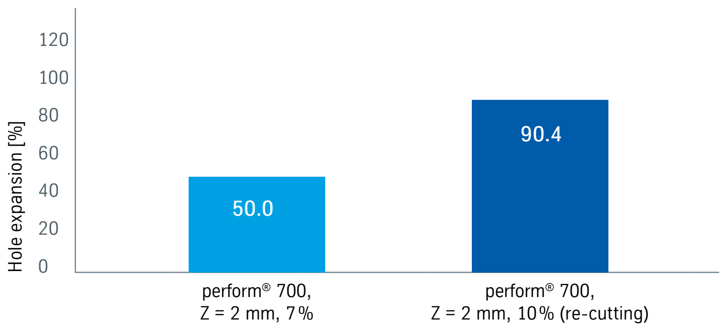
Local forming

With their particularly fine-grained microstructure and high degree of purity, the perform® steels offer a stable hole expansion capacity. The steels allow low bending radii for their respective strength class and therefore usually significantly exceed the standard requirements in accordance with DIN EN 10149-2. For 90° bends of thin perform® 700 sheets up to about 4 mm, minimum bend radii of only 0.5 times the sheet thickness can be achieved.

In all cutting processes, care must be taken to achieve the best possible quality of the cut edges, as this can greatly influence the performance of the material for further processing (e.g. for loads on the edge where good hole expansion capacity is required or for bending processes). For example, mechanical cutting causes deformation and the associated hardening in the area of the cut edge, which must be taken into account for subsequent forming steps.

For sheet thicknesses up to around 6 mm, it is generally advisable to use a cutting gap of 7 to 8 % in order to achieve optimum edge quality. For particularly high requirements in the upper strength range, the addition of a re-cutting operation has proven its worth. In this case of drawing collars, the cut edges are trimmed again in the range of approx. 60 to 80 % of the sheet thickness immediately before the forming process. The positive effect can be seen in significantly higher hole expansion values (see Figure 1).

Figure 1: Hole expansion conical punch 50°



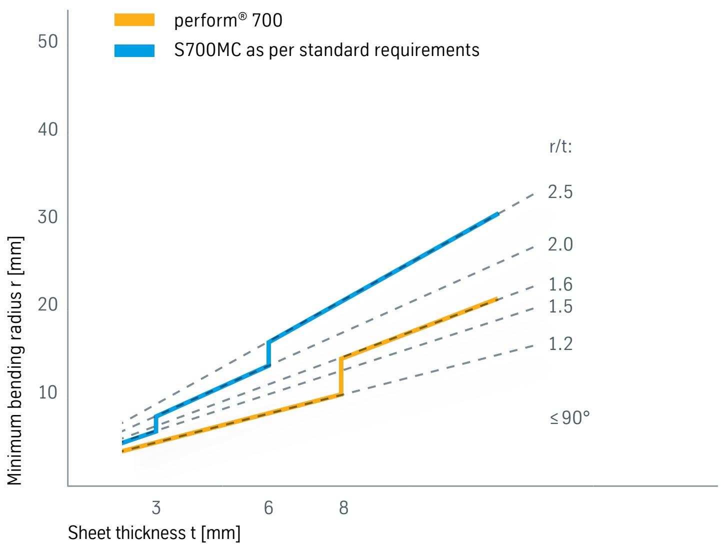
Hole expansion with 50° conical punch, D_0 = 20 mm; left reference (7 % cutting gap); right with re-cutting approx. 80 % of sheet thickness.

Bending and press braking

The predominant forming technique for cold forming steels is press brake bending. In most cases, bending with a defined inside radius in a die is limited by the rigid design of the die. The higher the strength of the steel, the greater the minimum press brake bending radius.

Figure 2 shows the press brake bending radii for perform® 700 compared with grade S700MC as per standard requirements independent of direction.

Figure 2: Press brake bending radii



perform® 700 is significantly better for press brake bending compared to the comparative grade according to DIN EN 10149-2.

Minimum bending radii during cold forming

	Recommended smallest bend radius for nominal thicknesses t in [mm] [1)]			
	t ≤ 3	3 < t ≤ 6	6 < t < 8	t ≥ 8
Thermo-mechanically rolled steel for cold forming				
Steel grade				
perform® 700	1.2 t	1.2 t	1.2 t	1.6 t
Reference grade DIN EN 10149-2				
S700MC	1.5 t	2.0 t	2.5 t	2.5 t

[1)] Values for bending angles ≤ 90°.

Thermal cutting

Thermal cutting is often used for non-automotive applications and thicker sheets. For perform® steels, plasma beam cutting, laser beam cutting and oxyfuel flame cutting are generally suitable.

For sheet thicknesses of less than 20 mm, laser beam cutting and plasma beam cutting are often used for thermal cutting of steel due to the higher cutting speed and lower heat input compared to oxy-fuel cutting. The latter results in a narrower heat-affected zone and less distortion.

Laser beam cutting has a higher dimensional accuracy compared to plasma beam cutting. Subsequent machining can therefore often be dispensed.

Joining

Micro-alloyed steels such as perform® are characterized by very good joining properties, both in pure and mixed bonds. The prerequisite is that the parameters are matched to the material.

Thermal joining

When welding, DIN EN 10149-1 section 7.5 "Technical properties" and STAHL-EISEN material sheet 088 must be observed. The choice of joining method should be made depending on the technical requirements and the sheet thickness. For use in the automotive sector, it is recommended that the steel-iron test sheet (SEP) 1220, parts 1 to 4, be used as a guide, above the thicknesses typical for vehicle construction, the steel-iron material sheet (SEW) 088.

Welding

When welding, the welding procedures specified in DIN EN 10149-2, section 7.5 "Technological properties" and STAHL-EISEN material sheet (SEW) 088 must be observed.

Instructions for welding processing can also be found in DIN EN 1011 Parts 1 and 2. In addition, it is recommended to consult the steel manufacturer before processing for the first time in order to make use of their experience in processing.

Resistance spot welding

Resistance spot welding is traditionally at the forefront, especially in car body construction. In particular, thin sheets with thicknesses of less than 3 mm can be joined economically and reliably using this process in mass production. However, this usually requires an adjustment of the joining parameters welding current, welding time and electrode force. Of particular interest here is the influence of the electrode force and welding time on the width of the welding area.

In principle, resistance spot welding can be used with perform® as with other ferritic materials. Restrictions on the suitability for welding may result from the presence of metallic coatings and/or coatings such as surface post-treatments. Due to the low alloying elements in the material, a low level of hardening and therefore ductile behavior of the joint is to be expected.

For a sufficiently wide welding area, higher electrode forces and longer current flow times are generally required with increasing sheet thickness and strength. Alternatively, the use of multipulse welding in accordance with SEP 1220-2 can have a positive effect on the width of the welding area. Recommendations for the use of other resistance welding processes such as projection or nut welding can be found in the DVS technical bulletins.

Gas metal brazing

Gas metal brazing or arc brazing is usually used for sheet thicknesses typical for automotive construction. The procedure for developing parameters is described in SEP 1220-4 and DVS 0938-2, for example. DVS 0938-2 "Arc brazing" describes the brazing of steels up to a tensile strength of approx. 500 MPa. If the material used is above this tensile strength, it is recommended that the properties of the joint be tested on a component-specific basis. In principle, arc brazing can be used with perform® as with other ferritic materials; however, there may be limitations due to additionally applied metallic coatings and/or coatings.

Arc welding

perform® is well suited for processing with common arc welding processes such as gas metal arc welding (GMAW), submerged arc welding (SAW), manual metal arc welding (MMAW) as well as their modifications and hybrid processes. A filler material should be used which, with the selected parameters, guarantees a weld metal whose yield strength is higher than that of the peform® grade used (overmatching).

It should be noted that the tendency to cold cracking increases with the yield strength of the weld metal, so that a weld metal with excessive strength can also have a detrimental effect. However, this is generally only relevant for sheet thicknesses above the typical automotive range. Table 1 provides an overview of recommended filler materials for GMA and MMA welding as well as wire-powder combinations for submerged arc welding.

Table 1: Filler materials und wire-powder combinations

	Filler material GMA welding	Filler material MMA welding	Wire-powder combinations submerged arc welding
Steel grades			
perform® 300 to perform® 380	G 42 4 M21 3Si1 according to EN ISO 14341-A	E 42 5 B 4 2 H5 according to EN ISO 2560-A	S 38 4 AB S2 according to EN ISO 14171-A
perform® 420 to perform® 460	G 46 4 M21 4Si1 according to EN ISO 14341-A	E 50 4 B 4 2 H5 according to EN ISO 2560-A	S 46 2 AR S2Mo H5 according to EN ISO 14171-A
perform® 500 to perform® 550	G 62 5 M21 Mn3Ni1Mo according to EN ISO 16834-A	E 62 6 Mn2NiCrMo B 4 2 H5 according to EN ISO 18275-A	S 55 6 FB S3Ni1Mo H5 according to EN ISO 26304-A
perform® 600 to perform® 700	G 69 6 M21 Mn4Ni1,5CrMo according to EN ISO 16834-A	E 69 6 Mn2NiCrMo B 4 2 H5 according to EN ISO 18275-A	S 69 6 FB SZ3Ni2,5CrMo H5 according to EN ISO 26304-A

Heat conduction during welding has a significant influence on the mechanical properties of welded joints. In practice, this can be described by the temperature-time curve $t_{8/5}$. thyssenkrupp has carried out extensive welding tests to determine processing windows within which the best possible properties are achieved in the area of welded joints. The $t_{8/5}$ windows of perform® are summarized in table 2.

Table 2: $t_{8/5}$ window of perform®

	$t_{8/5}$min [s]	$t_{8/5}$max [s]
Steel grades		
perform® 300 to perform® 600	5	20
perform® 650 to perform® 700	5	15

Greater care must be taken with perform® with a higher yield strength than with lower-strength variants. Above a yield strength of 600 MPa, we recommend aiming for a cooling time $t_{8/5}$ between 5 s and 10 s, among other things to make optimum use of the strength potential of the filler materials. In many cases, the cooling time cannot be calculated with sufficient accuracy, for example in the case of complex geometries or the use of modified arc welding processes.

In these cases, it is advisable to measure the cooling time by inserting a thermocouple into the liquid weld metal. The relationship between the welding conditions and the mechanical properties of the welded joints is described in detail in SEW 088. Further information on the application of the cooling time concept in practice can also be found there.

Due to their low alloying element content, preheating before welding perform® can often be dispensed. Of course this should be checked on a case-by-case basis. It is generally recommended to limit the preheating and intermediate layer temperature for perform® to 150°C, whereby the sensitivity increases with increasing yield strength. Details on heat conduction during welding and the calculation of the minimum preheating temperature during welding can be found in SEW 088. To simplify the calculation, thyssenkrupp has developed the ProWeld software, which is available free of charge after registration on the Internet at https://online.thyssenkrupp-steel.com/ecmlogin/proweld_register.do.

Laser beam welding

Laser beam welding is frequently used, particularly for thicknesses typical of the automotive industry. This is characterized, among other things, by the application of relatively low energy per unit length and therefore a high cooling rate of the joining zone. Due to the low content of carbon and other alloying elements, a low level of hardening is also to be expected with perform® laser beam welding compared to higher alloyed steels.

For reasons of occupational safety, the high welding speed due to the process and the small weld pool, it is difficult to measure the $t_{8/5}$ time, so it is advisable to determine the properties of the joint using geometries close to the component. Laser-welded joints are generally characterized by high quality and strength, this also applies to joints made from perform®.

Fatigue strength and crash behavior

Compared to deep-drawing steels, increased minimum values for yield strength and tensile strength are assured for micro-alloyed steels. These key data enable a reliable and practiceoriented fatigue strength assessment. Micro-alloyed steels are offered in various strength levels. The higher the yield strength and tensile strength, the higher the fatigue strength level.

Parallel to the increase in strength, the formability tends to decrease, so that a sensible optimum must be found at this point by the designing engineer and the production planner. Micro-alloyed steels are the conventionally used materials for shell components and structural components.

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