UHS 960 QC

Ultra high structural steels offers high strength and good workshop properties. In addition, UHS 960 QC combines excellent weather resistance and excellent surface quality, accurate dimensions and consistent properties. This means lighter structures, higher loads and lower energy consumption

MEKA steel distributes quenched (Q) and cold formable (C) ultra-high strength steels which are not directly compliant with any standards for structural steels. UHS 960 QC meets the highest requirements for applications, such as:

- Chassis and superstructures
- Booms for forest machinery
- Crane arms and other lifting equipment
- Load handling, support and fastening equipment
- Feeding and unloading hoppers
- Hook lifts and containers

UHS 960 QC **delivery program**

Cut lengths and coils can also be delivered as pickled, by separate agreement on a limited dimensional range:

Thickness:	2.50	–	8.0 mm
Width:	1000	–	1.600 mm
Length:	2000	–	13.000 mm

Tolerances, thickness, width and length: EN 10051. Flatness: EN 10029 Class N, steel type Plates are delivered with Mill-Flat guarantee.

UHS 960 QC **delivery condition**

Quenched. The average hardness of the quenched QC steel grades is slightly over 300 HBW; in other words, twice the hardness of S355 structural steels. The high hardness and tensile strength indicate good wear resistance. The 960 QC grades are tested according to EN 101491:1995. The tensile test and impact tests are carried out with test pieces longitudinal to the rolling direction.

Yield and tensile strength are tested longitudinal to the rolling direction, but guaranteed both in the longitudinal and transverse direction.

Elongation is tested longitudinal to the rolling direction. Impact strength is tested as Charpy V notch test in accordance with EN 100451. The impact strength value 34 J/cm2 corresponds to the value 27 J for a full size 10 x 10 mm standard test pieces. No impact tests are carried out for thicknesses less than 6 mm. The elongation is given as A80 value ≥ 6% for thickness < 3 mm.

UHS 960 QC **mechanical composition**

Yield strength Rp0,2	960 MPa
Minimum Tensile strength Rm	1000 MPa
Minimum Elongation A5 %	7
Minimum Strength longitudinally:	
- t	- 40
- °C Charpy V J/cm2 minimum	- 34

UHS 960 QC **chemical composition**

C	max. 0.11%
Si	max. 0.25%
Mn	max. 1.20%
P	max. 0.02%
S	max. 0.01%
P+S	max. 0.03%
Ti	max. 0.07%
CEV typical	0.52
CEV maximum	0.57

In addition, aluminium (Al), niobium (Nb), vanadium (V), chromium (Cr), molybdenum (Mo) or boron (B) may be used either singly or in combination. Carbon equivalent value (CEV) = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15. Ultra high strength steels have a dual-phase microstructure consisting of bainite and martensite.

The average grain size is in the order of magnitude of one micrometer (µm). The grades are classified according to the microstructure either as dual-phase (DP) or complex-phase (CP) steels, as the bainite consists of several metallographic phases.

UHS 960 QC **process instructions provided by steel producer**

Welding
Ultra-high strength steels can be easily welded by all conventional methods as long as general welding instructions for steels and the specific recommendations in this datasheet are followed. Preheating is not normally required, as the steel plates are thin and their CEV values are reasonable. The hydrogen content of the weld must be kept very low due to the ultrahigh strength of the steel. Groove surfaces must be dry and clean during welding. When welding ultra-high strength steels, particular attention must be paid to reasonable heat input values and proper selection of welding consumables.

Welding methods
The most commonly used welding method is gas shielded arc welding either with solid wire or a fluxcored electrode. Other recommended methods include laser welding and the combination method of pulse MAG and laser MAG, also known as laserhybrid welding. All of these allow high-quality welding with low, concentrated heat input. Metal arc welding with covered electrodes may be used, particularly for minor repairs.

Softened zone
Proper restriction of heat input is essential because high heat input in particular will create a zone softer than the parent metal in the welded joint. The zone is located in the heat affected zone (HAZ) of the joint. Even though this zone is narrow, it must be taken into account when designing the structure and welding. Welded joints must be avoided in the most stressed parts of a structure.

Selection of welding consumables
Welding consumables should be selected according to the requirements set by the structure to be welded. The type of joint and welding position also affect the selection. When welding ultra-high strength steels, either matching (high strength) or under matching (softer than the parent metal) consumables can be selected. Ultra-high strength steels require very low weld hydrogen content, HD ≤ 5 ml/100 g. Therefore, only low hydrogen type consumables may be used.

Matching consumables for S 960 QC
Matching consumables must be used when a welded joint is to have strength properties close to those of the parent metal. Matching consumables have a standardised yield strength class of 89 (min. 890 MPa). For the S960 QC grades, the following matching consumables are recommended: covered electrodes as per EN 757 89 6 Z B 42 H5 and MAG consumables as per EN 12534 GMn4Ni2CrMo (mixed gas argon + CO2). For matching consumables in compliance with the standards, see table below:

S 960 QC, matching or nearly matching welding consumables

- Gas shielded arc (MAG): OK Autrod 13.31/M21(1), Union X90/M21 (1), X90IG/M21 (1) and X96/M21 (1)
- Fluxcored electrodes: PZ 6149 and Stein Megafil 1100 M
- Covered electrodes: OK 75.78, SH NNI 2 K 150 and Fox EV 90

1) M21: Shielding gas approx. 80% argon + 20% CO2. A lower CO2 content may also be used.

Similar welding consumables from other suppliers/manufacturers are equally recommended. The validity of any recommendations should be verified with the manufacturer before welding.

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Instructions for achieving strong welded joints for S 960 QC

When a welded joint is to have an equal strength with the parent metal, the tempering effect of the heat input caused by welding in the heat affected zone (HAZ) must be limited. The following measures are recommended to this end:

- Methods with a low heat input such as laser welding, pulse MAG and laser MAG are favoured.
- For a strip thickness of > 4 mm, the maximum arc energy should be 0.5 kJ/mm, and for a thickness of less than 4 mm it should be 0.4 kJ/mm.
- The designed cooling time from 800°C to 500°C (t8/5) should not exceed 4 seconds.
- The aim is to achieve as low a groove volume as possible. The lower the volume of molten material deposited in a single run the smaller the amount of heat and the resulting softening. For example, the bevel angle for a butt joint in single V and a single bevel (HV) grooves for thicknesses of > 4 mm should be a maximum of 50°.
- In multi-run welding, room temperature (+20°C) is used as the interpass temperature.
- Surfaces to be welded should be kept clean, dry and at least at room temperature to eliminate the need for preheating.
- For MAG welding, solid wire of the strength class 89 (min. 890 MPa) with a diameter of 1.0 mm as per EN 12534:2000 (Welding consumables. Wire electrodes, wires, rods and deposits for gas shielded metal arc welding of high strength steels. Classification) should be used.

Under matching consumables

The use of under-matching consumables produces a welded joint with a lower strength than that of the parent metal. Under-matching consumables may be used when, for example, the design allows this in terms of the location of joints and/or increase in the effective throat thickness. Under-matching consumables with a standardised yield strength class of 42 (min. 420 MPa) include the brands shown in the table below:

Welding process	Consumables
• MAG w/fluxcored	OK Tubrod 14.12, OK Tubrod 15.14, PZ 6102, PZ 6113, MXA 100 or DWA 50
• Submerged arc	OK Autrod 12.22 + OK Flux 10.71, L61+ FX860 or Union S 2 + UV 400
• Manual metal arc (MMA W)	OK 48.00 or P48 S or similar

The use of under-matched consumables produces a tough, deformable weld, which tolerates weld stress and impact loads better than a weld produced with high strength consumables. Longitudinal joints of crane arms, for example, are often welded with under-matching consumables to achieve a tough overall structure. The applicability of consumables and conformity of welded joints with the requirements are best ensured by a welding procedure test.

Handling welding consumables

Welding consumables are to be protected from moisture during transport, storage and use to prevent any condensation of water on them. If necessary, they should be dried according to the manufacturer's instructions before welding.

Joint preparation

It is recommended that the preparation of joints for welding, i.e. bevelling, is carried out by machining. Generally the best type of joint preparation for a butt joint for strip thicknesses of ≤ 3 mm is the square butt preparation. For thicker strips a single V-groove or a single V-groove with root face and a bevel angle of 40–70º is recommended, as shown in the figure on the next page.

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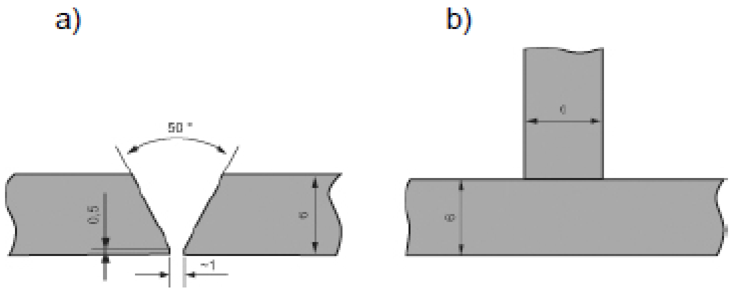

Welding of the ultra-high strength QC steels, examples of a butt joint (a) and a fillet joint (b)

The type of joint preparation to be used for a fillet joint and the bevelling of a web are to be determined according to the root penetration and weld thickness required of the welded assembly. Groove surfaces must be dry and clean before welding to prevent the harmful hydrogen having any contact with the welded joint.

Need for an elevated working temperature
Preheating is a common way to elevate working temperature for welding. The need for an elevated working temperature is primarily determined on the basis of the chemical composition, i.e. hardenability, of the steel and welding consumables. The combined strip thickness, heat input by welding and the hydrogen content in the weld caused by welding consumables must also be taken into account. In normal workshop conditions, ultra-high strength steels can be welded without preheating thanks to the low CEVs relative to the high strength and small strip thicknesses.

Heat input
A low heat input will minimise the impact of the welding heat cycle on the mechanical properties of the HAZ of the joint. The table below shows heat input values for butt and fillet joints, which will provide good mechanical properties for a welded joint. Softening of the HAZ will be pronounced if a large heat input value is used. Thanks to the relatively low alloying and hardenability, ultra-high strength steel will lend itself well to welding by methods with low heat input and a short cooling time t8/5. Methods that provide a cooling time t8/5 of less than 4 seconds include laser welding. It should be noted that in fillet welds made by metal arc welding with covered electrodes, the maximum heat input value may be easily exceeded. This happens, f.e. with 6mm thick strips when the effective weld thickness exceeds 4–5 mm.

Approximate arc energies for welding

Strip thickness mm	Arc energy (1) Butt joint	Fillet joint
• 2.5 – 4.0mm	0.25 – 0.60 kJ/mm	0.40 – 0.70 kJ/mm
• 4.5 – 6.0mm	0.35 – 0.80 kJ/mm	0.50 – 1.10 kJ/mm
• 6.5 – 8.0mm	0.45 – 0.10 kJ/mm	0.60 – 1.40 kJ/mm

1) Arc energy = E = 60 x U x I / 1000 x v, in which E = (kJ/mm), U = arc voltage (V), I = welding current (A) and welding speed v = (mm/min).

As cooling times of a welded joint through the temperature range 800 – 500 ºC, the heat input recommendations shown in table above comply with the following cooling times: t8/5 = 4 – 15 seconds
N.B: Cooling times shorter than these t8/5 values can also be used in welding.

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Forming

The cold formability (i.e. at +20°C) of ultra-high strength steels is good, in regard to their high strength. They can be formed in any chamfering direction and the bend can be located independently from the rolling direction. Bending force, spring-back effect and the bending radius are greater than those for softer structural steels due to the higher strength.

Minimum bending radii for cut lengths of various thicknesses, bending angle 90°

Strip thickness mm	Radii
• – 3.0mm	10.5
• 3.1 – 4.0mm	14.0
• 4.1 – 5.0mm	17.5
• 5.1 – 6.0mm	22.0
• 6.1 – 8.0mm	28.0

There are no restrictions for the location of the bend. To obtain full advantage of the formability good engineering workshop techniques and careful design must be used. Worn tools, poor lubrication, surface defects and burrs on cut edges may all impair forming quality. Plates taken from a cold storage must be allowed to warm up to room temperature (+20°C) before being formed.

Cutting

Ultra-high strength steels are well suited for thermal cutting. The cut surface will be smooth, which provides good fatigue resistance. Flame, plasma and laser cutting will leave a softened zone at the strip edge due to the heat, but selecting the proper cutting method will make this zone very narrow. When cutting high strength steels mechanically, particular attention must be paid to the stiffness of the cutting equipment, blade condition and clearance and supporting of the work piece. Strips taken from a cold storage must be allowed to warm up to room temperature (+20°C) before cutting.

Hot-dip zinc coating

Due to an optimised chemical composition, ultra-high strength steels provide a good substrate for hot-dip zinc coating. Proper control of the galvanising parameters will produce an aesthetically pleasing, bright and durable coating. The coating thickness is regulated by controlling the galvanising time and temperature. Unnecessarily long immersion should be avoided to ensure reasonable coating thickness and good adherence of the coating.

Heat treatment

Ultra-high strength steels are not intended for heat treatment after welding or any other workshop operation. If stress relieving is required, however, it may be carried out in the temperature range 400–450°C. The soaking time is determined according to the material thickness and the structure of the steel product. Slow cooling in the furnace is recommended. Annealing or working at a temperature above 450°C is not recommended because it may considerably reduce the strength of the steel.

Occupational safety

Special care must be taken in all stages of handling ultra-high strength steels. Safe working methods are particularly important in bending, flanging and cutting. The handling instructions of the steel supplier and safety instructions of the workshop must be adhered to in detail. New employees must receive appropriate training before they are allowed to process hardened steels.