Hot rolled Steel Plates, Sheets and Coils

Structural steels

Optim 700 QL

The high strength quenched and tempered steel Optim 700 QL is developed to improve performance, durability and safety of vehicles, lifting equipment and steel structures. Due to the high strength, structures can be designed lighter, payload increased and energy used more efficiently. The steel is easy to weld and bend. Ruukki's Optim 700 QL meets the requirements of EN 10025-6.

Applications

- Machine building
- Steel constructions
- Framework structures
- Lifting and mobile equipment
- Vehicles and transport equipment

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- **Designation**
  The letter “Q” refers to quenching and tempering, which is the manufacturing method and delivery condition for Optim 700 QL. The letter “L” refers to a low notch toughness testing temperature. The figure “700” refers to the yield strength class (690 MPa) of the steel.

- **Reference standard**
  Ruukki’s Optim 700 QL meets the requirements of the steel grade S690 QL EN 10025-6.

- **Delivery condition**
  Quenched and tempered.

- **Product shape**
  Hot rolled plate.

- **Chemical composition**
  Chemical composition is presented in table 1.

- **Carbon equivalent**
  Carbon equivalent CEV = 0.65 maximum.
  CEV = C + Mn / 6 + (Cr + Mo + V) / 5 + (Ni + Cu) / 15

- **Mechanical properties**
  Mechanical properties are presented in table 2.

- **Plate dimensions**
  Thickness 6 – 7.99 mm, width 2000 – 2500 mm.
  Thickness 8 – 20 mm, width 2000 – 3000 mm.
  Length: 2000 – 12000 mm.

- **Tolerances on dimensions and shapes**
  Thickness, width and length: EN 10029 Class A.
  Flatness: EN 10029 Class N.

- **Surface quality**
  EN10163-2 Class A 3.

- **Inspection documents**
  EN 10204:2004 Inspection certificate 3.1.

Flangeability
High-strength quenched and tempered steels have to be handled with special care during workshop processing, such as bending and flanging. The instructions given by the steel supplier and good engineering workshop practice form an essential part of work quality and safety.

Minimum recommended inside bend radii for flanging in room temperature are :
- Axis of bend transverse to the rolling direction: 3 x plate thickness.
- Axis of bend longitudinal to the rolling direction: 4 x plate thickness.

When working Optim 700 QL steel in the engineering workshop, high quality forming technology must be applied. Worn tools, insufficient lubrication, surface defects on plates, and cutting burrs may all reduce the quality. Plates taken from cold storage must be allowed to warm up to room temperature (+20°C) before being bent, as the formability may be considerably reduced at low temperatures.

- **Weldability**
  The steel can be welded using all common manual and automatic welding processes. The weldability is good. Welding is to be carried out in accordance with EN 10025-6:2004 and EN 1011-2 (Welding. Recommendations for welding of metallic materials. Part 2: Arc welding of ferritic steels.) Always make sure that moisture and other sources of hydrogen, such as grease, oil and other impurities, have been removed from the surface of the groove before welding.

- **Preparation of grooves**
  The welding grooves can be bevelled either by machining or thermal cutting. Flame, plasma or laser cutting may be used. The geometry of the groove primarily depends on plate thickness and the configuration of the joint.

- **Working temperature**
  The need for preheating is determined by the general instructions of EN 1011-2. The need for preheating is determined mainly by the chemical composition of the steel and the filler materials, i.e. their hardenability. Additionally, the combined plate thickness, heat input and hydrogen content of the welding consumables have to be taken into account. In normal engineering workshop conditions, the steel can be welded without preheating up to a plate thickness of 10 – 15 mm. According to long welding experience, a slight preheating of ~ +50°C has in many cases proven to be beneficial. Preheating is especially important when welding with low heat input, such as in tack welding or welding of root passes.

- **Welding consumables and avoidance of hydrogen absorption**
  Welding consumables should be selected according to the requirements of the application. Joint design, welding position and the requirements of the operating conditions affect the choice. To eliminate the risk of cold cracking, the hydrogen content of the filler metal must be kept as low as possible, which means that only low-hydrogen welding consumables (HD ≤ 5 ml/100 g) can be used. The welding consumables must be protected against moisture during transport, storage and use to avoid hydrogen absorption. If necessary, they must be dried according to the manufacturer’s instructions before welding. Examples of recommended consumables are given in Table 3. The consumables in the

table are matching, providing choices that lead to the same strength level as in the base material.

Filler metals that are clearly softer than the base material (undermatching) may be used on certain conditions. They are suitable for joints subjected to low loads. The benefit of undermatching welding consumables is that the formability and toughness of the weld metal is better than matching consumables.

- **Heat input**
Welding heat input depends on the strength and toughness requirements of the joint. The thermal cycle of the weld can handily be represented by the cooling time of the joint "$t_{8/5}$", which means the cooling time from 800 to 500°C. The recommended $t_{8/5}$ cooling time for the steel is approximately 8 – 20 seconds. This approximately corresponds with arc energies of 1.0 – 1.8 kJ/mm for plate thicknesses of 10 – 15 mm. The ideal heat input range in a given case depends on the plate thickness and the requirements for the joint. The longest permissible $t_{8/5}$ cooling time (corresponding to maximum permissible heat input) is determined by the impact toughness requirement of the HAZ (Heat Affected Zone) of the joint. Impact toughness is impaired if $t_{8/5}$ and/or heat input exceed their permissible values. The shortest recommended $t_{8/5}$ cooling time (corresponding to minimum permissible heat input) is determined by the susceptibility of the weld metal and the HAZ to cold cracking. If $t_{8/5}$ is too short and/or the heat input too low, the risk of cold cracking increases.

- **Post weld heat treatment (PWHT)**
PWHT is mainly used to reduce the residual stresses after welding and other workshop fabrication. PWHT is not recommended for quenched and tempered high strength steels. The steel grade Optim 700 QL should be post weld heat treated only when this is specified in the design rules of the steel construction.

- **Hot working**
The steel has obtained its mechanical properties by a quenching and tempering process. Optim 700 QL is not suited for applications requiring hot working at temperatures above 550°C since the material may lose its guaranteed mechanical properties.

- **Flame straightening**
Any flame straightening should be carried out under consideration of the mechanical properties of the steel, which have been achieved by quenching and tempering. In flame straightening, the hot spot temperature must not exceed 550°C, because this could lead to local softening and reduction of strength. Particular care must be exercised if the structure is subject to dynamic loads and thus fatigue damage.

- **Safety instructions**
High strength quenched and tempered steels have to be processed with special care in the engineering workshop. The instructions given by the steel supplier and good engineering workshop practice form an essential part of work quality and safety. Appropriate health and safety precautions must be taken when welding, cutting, grinding or otherwise working high strength Optim 700 QL steel. New employees must receive proper introduction to their duties.

Chemical composition

Table 1

	Content % (ladle analysis), maximum								
	C	Si	Mn	P	S	B	Cr	Cu	Mo
Optim 700 QL	0.20	0.80	1.70	0.020	0.010	0.005	1.50	0.50	0.70

Additionally, niobium (Nb), vanadium (V) or titanium (Ti) may be used as alloying elements either singly or in combination.

Mechanical properties

Table 2

	Yield strength R_{eH} MPa Minimum	Tensile strength R_m MPa	Elongation % A_5 Minimum	Impact strength J at -40°C Average minimum
Optim 700 QL	690	770 – 940	14	30

The tensile test is carried out in transversal direction to the rolling direction.
The impact test is carried out in longitudinal direction to the rolling direction.

Matching welding consumables

Table 3

Welding process	Filler metals [1]
Manual metal arc welding (MMAW)	OK 75.75 SH Ni 2 K 90 SH Ni 2 K 100 Fox EV 85 Fox U 100 N
Gas metal arc welding (GMAW)	OK Autrod 13.29/M21 [2] Union NiMoCr/M21 [2] Union x85/m21 [2] X70-IG/M21
Submerged arc welding (SAW)	OK Autrod 13.43+OK Flux 10.62 Union S 3 NiMoCr/UV 421 TT Fluxcord 42/OP 121 TT

[1] Corresponding welding consumables by other manufacturers are also usable.
[2] The shielding gas contains approximately 80% argon (Ar) and 20% carbon dioxide (CO_2). Shielding gases with CO_2 content of less than 20% may also be used.

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