Hot rolled Steel Plates, Sheets and Coils

Steels resistant to wear and surface pressure

AR

Hardened steel resistant to abrasive wear cause by rolling contact and high surface pressure can be used to significantly lower the costs generated by wear and break -down of stuctural components. Despite its strength and hardness, weldability and formatibility of the steel grade are good.

Applications

- Ladles and lip plates of earth moving machines
- Wearing parts of mining machines
- Wearing parts of concrete Mixing plants and wood processing machines
- Platform structures
- Feeders, funnels

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- **Designation**
AR 400, AR 450 and AR 500 are hardened wear-resistant steel grades. The number of the designation indicates the average Brinell hardness value: 400 HBW, 450 HBW and 500 HBW, respectively.

- **Product shapes and dimensions available**
Cut lengths and heavy plates.

- **Supply condition**
Hardened.

- **Tolerances on dimensions and shapes**
Heavy plates: EN 10029 Class A
Cut lengths: EN 10051

- **Surface finish**
EN 10163-2 Class A3. Repair welding of plates is not permitted in plate production at the works.

- **Abrasion resistance and hardness**
The microstructure of abrasion resistant steel is martensitic, which guarantees high hardness and tensile strength. The hardness of AR 500 is over three times that of S355 structural steel, AR 450 is nearly three times, AR 400 is two and a times as hard as S355. High hardness and tensile strength give a steel high resistance to abrasion. Good abrasion resistance is the most important basis for choosing these steels.

- **Testing**
Brinell hardness HBW is measured in accordance with EN ISO 6506-1.

- **Inspection document**
A test report in accordance with standard EN 10 204-2.2 is issued. The test report verifies the chemical composition of the product in the hot rolled condition but not the result of mechanical tests. The test report includes an appendix in which the hardness of hardened plate is given.

- **Flanging**
Despite their high strength AR 400 can still be formed by free bending or flanging. However, the bending force, springback effect and the bending radius are greater than those for softer structural steels. When bending or flanging, workshop practices, condition of the tools and exact design must be taken in to consideration. Flangeability can be improved by raising the working temperature to 100 – 200 °C. AR 450 and 500 steel grades are not intended for bending.

- **Warning**
Hardened AR wear-resistant steels have to be handled with special care during bending. The instructions given by the steel supplier and the quality of the engineering workshop practice form an essential part of work safety.

- **Welding**
All the normal welding procedures can be used, provided that a professional welder pays special attention to the following factors:
- use of correct working temperature,
- correct choice of welding consumables,
- suitable arc energy.

A reserved attitude to post-weld heat treatments should be taken because they have a tendency to weaken the most important property of these steels i.e. wear resistance.

Working temperature
Increasing the working temperature slows the cooling of welded joints, which decreases the generation of a microstructure that is too hard and brittle and vulnerable to cracking in the heat affected zone (HAZ). It is advisable to increase the working temperature of AR 400 steels when the combined plate thickness exceeds about 40 mm. The respective thickness is about 30 mm for AR 450 and about 20 mm for AR 500. Generally a working temperature of 100°C is enough to ensure good result. However, when heavy and complicated structures are welded and when welding takes place under difficult circumstances, a higher, 150 – 200°C, working temperature is recommended. A higher working temperature than this may weaken the mechanical properties.

Welding consumables
Either conventional, so called non-alloyed filler materials or so called alloyed materials that produce higherstrength weld metals can be used as filler material. Generally non-alloyed filler materials are silicon and manganese alloyed and the strength of the weld metal they produce remains lower than the strength of the hardened base material. In this case we talk about “undermatching” filler materials. Correspondingly, we use the word “matching” when we talk about alloyed filler materials. An important advantage of non-alloyed filler material is that the softer weld metal they produce responds better to welding stresses. This is due to the better elongation and deformation ability of the soft weld metal in comparison with high-strength weld metal. It is highly advisable to use low-hydrogen, basic filler materials so that the amount of hydrogen will remain safely low.

Non-alloyed filler materials are used if the welded joints in the structures are not exposed during use to hard wear and load. Correspondingly, the use of alloyed filler materials is necessary if a welded joint is exposed to hard wear or the filler material is supposed to have the high strength level of the base material. When alloyed filler materials are used the need for increasing the working temperature is higher than welding with non-alloyed filler materials. Generally, when moderately thick plates are welded, it is enough that 1 – 3 final runs are welded with matching filler material and the fill up runs with undermatching filler material.

Arc energy

The maximum value of arc energy for AR 400, AR 450 and AR 450 steels has to be limited so that, on the one hand, we can limit the growth of austenite grain and, on the other hand, the tempering of martensite in the heat affected zone. Excessive growth of the grain size lowers toughness properties of a joint whereas a proportional increase of tempered martensite lowers hardness and strength. The minimum value of arc energy also has to be considered. It has to be high enough so that we can avoid excessive hardening of the HAZ. In this way we can achieve a parallel effect as by increasing the working temperature.

Achieving the optimal properties in welded structures requires the choosing of arc energy so that the cooling time $t_{8/5}$ for a welded joint is 10 s minimum but maximum of 20 s. For instance, for MAG welding a plate of thickness 10 mm this requirement corresponds to 1.2 – 1.7 kJ/mm arc energy. The dimension t 8/5 means the cooling time for a joint over the temperature range of 800 – 500°C, which is crucial from the point of view of the microstructure of HAZ.

Practical tips

- any distortion expected can be avoided by proper selection of welding parameters
- prehating is important, especially when tack welding
- a strong tack weld should be made in the middle of the plate to be welded
- the supplier's instructions for the storage and use of welding consumables should be followed carefully
- it is recommended that welding is commnenced in the middle of the plate and proceeds towards the edges
- the joint area should be kept at the correct temperature e.g. by welding without interruption
- when welding thick plates full penetration preparation should be used on both sides
- large plate areas and thick joints should be protected using, for example, mineral wool
- separate run off plates should be used on plate edges
- the root must be opened carefully
- the use of carbon arc gouging should be avoided
- in the case that carbon arc gouging is used the carbonised layer should be ground off thoroughly
- welding should be finished off by grinding all edges and corners smooth.

- **Heat treatment**

  The steels are not intended to be heat treated during or after fabrication. Tempering at moderate temperatures, 150 – 200°C, is the only heat treatment which will without fail allow the steel to retain its original wearing properties.

- **Flame cutting**

  A heat affected zone (HAZ) will build up on a thermally cut surface which is similar to the HAZ on a fusion welded steel surface. The surface hardens to a depth of 1 – 2 mm during flame cutting and post heat results in a soft tempered layer below this. When flame cutting, the pre-heating and working temperature instructions concerning welding can be used as a guideline. In practice it is advisable to preheat when cutting plates of the steel grades AR 400, AR 450 and AR 500, if the thickness is over 10 mm.

  Take note that the maximum allowable working temperature must be kept below 200°C in order that the wear resistance will meet requirements throughout the plate. The cooling of a cut surface must not be accelerated under any circumstances, on the contrary, the cooling of the plate surface can be slowed down if necessary e.g. by covering with mineral wool. A plate brought in from cold outside storage must be allowed to warm up sufficiently before cutting.

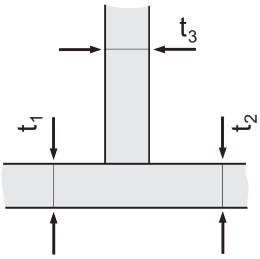
- **Mechanical cutting**

  The mechanical cutting of hardened wear-resistant steels is challenging, as the material to be cut is almost as hard as the cutting blade. AR 400 steels can be cut using heavy-duty cutting machines. The mechanical cutting of AR 450/500 can be recommended only with reservation, and then only at thicknesses of less than 10 mm. The hardness of the cutting blade must exceed 53 HRC (over 530 HBW).

- **Machining**

  AR steels can be machined using heavy-duty machines and hard metal tools. It is even possible to drill holes using tools made of high-speed steel, given proper tool geometry and using suitable cutting fluids.

Example of the determination of combined plate thickness



Combined plate thickness:

T joint $t = t_1 + t_2 + t_3$

Bult joint: $t_3 = 0$

Dimensional ranges

Table 1

Cut lengths

	Thickness mm	Width range mm [1]	Max length mm
AR 400	3 – 6	1200 – 1560	12 000
AR 400	(6) – 12	1200 – 1524	6 000
AR 450	3 – 6	1200 – 1560	12 000
AR 450	(6) – 12	1200 – 1524	6 000
AR 500	3 – (4)	1200 – 1295	6 000
AR 500	4 – 12	1200 – 1524	6 000

[1] The exact values depend on thickness.

Heavy plates

	Thickness mm [1]	Width range mm [2]	Max length mm
AR 400/450/500	5 – 60	1750 – 2500	6 000

[1] Plates thicker than 60 mm by special agreement only.
[2] The exact values depend on thickness.

Chemical composition

Table 2

	Thickness mm		Content %, maximum (ladle analysis)									
	Cut lengths	Heavy plates	C	Si	Mn	P	S	Al	Cr	Ni	Mo	B
AR 400	3 – 12	5 – 30	0.20	0.70	1.70	0.030	0.015	0.060	1.50	0.40	0.50	0.004
	–	(30) – 60	0.24	0.70	1.70	0.030	0.015	0.060	1.00	0.70	0.50	0.004
AR 450	3 – 12	5 – 60	0.26	0.70	1.70	0.030	0.015	0.060	1.00	0.70	0.50	0.004
AR 500	3 – 12	5 – 60	0.30	0.70	1.70	0.030	0.015	0.060	1.00	0.80	0.50	0.004

Aluminium (Al) and/or titanium (Ti) is used for binding nitrogen (N).

Mechanical properties

Table 3

	Thickness mm Cut lengths	Heavy plates	Yield strength $R_{p0,2}$ N/mm²	Tensile strength R_m N/mm²	Elongation A_5 %	Hardness range HBW	Impact strength t °C	KV J
AR 400	3 – 12	5 – 15	1000	1250	10	360 – 420	-40	40
	–	(15) – 30	1000	1250	10	380 – 450	-40	20
	–	(30) – 60	1100	1400	8	380 – 480	-40	20
AR 450	3 – 12	5 – 60	1200	1450	8	425 – 475	-40	20
AR 500	3 – 12	5 – 60	1250	1600	8	450 – 530	-30	20

Values are directive.

Limiting directive values for free bending

Table 4

	Thickness mm	Free bending < 90° Mandrel radius/plate thickness R/t Bend line vs. rolling direction Transverse	Longitudinally	Width of clear opening/plate thickness W/t Transverse	Longitudinally	Bending to 90° V-channel W/t
AR 400	3 – 6	3.0	3.0	9	9	≈ 15
AR 400	(6) – 20	3.0	4.0	9	11	≈ 15
AR 450	3 – 20	4.0	5.0	11	13	≈ 15
AR 500	5 – 20	≈ 10.0	≈ 12.0	23	27	–

Instructions related to bending of plates thicker than 20 mm are available from our Technical Support.

Carbon equivalent (CEV)

Table 5

	Thickness mm	CEV	Product shape
AR 400	3 – 12	0.49	Cut lengths
AR 400	5 – 12	0.45	Heavy plates
AR 400	(12) – 30	0.50	Heavy plates
AR 400	(30) – 60	0.56	Heavy plates
AR 450	3 – 12	0.49	Cut lengths
AR 450	5 – 30	0.50	Heavy plates
AR 450	(30) – 60	0.58	Heavy plates
AR 500	3 – 12	0.54	Cut lengths
AR 500	5 – 60	0.64	Heavy plates

Typical values.

$$CEV = C + Mn / 6 + (Cr + Mo + V) / 5 + (Ni + Cu) / 15$$

Recommended working temperatures for flame cutting

Table 6

	Thickness mm	Temperature °C
AR 400	15 – 30 (30) – 60	50 – 75 75 – 125
AR 450	15 – 60	75 – 125
AR 500	10 – 60	125 – 175

Our Customer Service is happy to give you further information

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