Product Datasheet

WearTuf 400

WearTuf 450

WearTuf 500

WEARTUF
Q&T Wear Steel

WearTuf 400

Revision:03

CHARACTERISTICS

WearTuf 400 is a fully martensitic Q&T abrasion resistant steel plate, having a hardness of average 400 Brinell. WearTuf 400 is a versatile wear plate that combines abrasion resistance with outstanding weldability and cold forming capabilities. The high impact toughness grants a very good crack resistance of the steel during fabrication and in service.

APPLICATIONS

WearTuf 400 has found its application base among the traditional earth moving, mining and transport equipment, such as buckets, dumpers, tippers, crushers, hammers, conveyors and other mineral feeding systems. Being supplied in the thin and wide dimension range, WearTuf 400 also focuses on light weight wear design concepts and applications.

DIMENSIONS

WearTuf 400 is supplied in the thickness range of 4.0 - 50.0 mm and in plate width of 900 – 3 100 mm. Supplied plate length from 4 000 to 18 000 mm.

HARDNESS GUARANTEE

Surface hardness: 370 – 430 Brinell

Guaranteed hardness range, measured on a milled surface at a depth of 0.5 – 2.0 mm below the plate surface, according to EN ISO 6506-1.

Min center hardness:

Plate thickness ≤ 20 mm : min 370 Brinell
Plate thickness > 20 mm: 95% of min guaranteed surface hardness (*)

IMPACT TOUGHNESS

Typical 45J/-40°C(-40°F)

The impact toughness is given as absorbed energy at temperature being the average of three full size Charpy-V test samples in longitudinal direction to rolling, according to EN ISO 148-1. (**)

CHEMICAL COMPOSITION

Ladle analysis:The steel is grain refined and fully killed, wt%

Thickness (mm)	C max	Si max	Mn max	P max	S max	Cr max	Ni max	Mo max	B max	CEV Typical	CET Typical
4.0 – 12.0	0.18	0.50	1.50	0.025	0.010	0.40	0.10	0.20	0.004	0.36	0.25
12.1 – 25.0	0.20	0.50	1.50	0.025	0.010	0.60	0.15	0.25	0.004	0.45	0.29
25.1 – 35.0	0.20	0.60	1.50	0.025	0.010	1.00	0.20	0.35	0.004	0.52	0.31
35.1 – 50.0	0.21	0.70	1.50	0.025	0.010	1.20	0.25	0.50	0.004	0.60	0.34

$$CET = C + \frac{Mn + Mo}{10} + \frac{Cr + Cu}{20} + \frac{Ni}{40}$$

$$CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Cu + Ni}{15}$$

QUALITY SYSTEM CERTIFICATION DNV·GL ISO 9001
ENVIRONMENTAL SYSTEM CERTIFICATION DNV·GL ISO 14001
SAFETY SYSTEM CERTIFICATION DNV·GL OHSAS 18001

MECHANICAL PROPERTIES TYPICAL VALUES

Yield strength Rp0.2	Tensile strength Rm	Elongation A5
1000 MPa	1250 MPa	10%

According to EN ISO 6892-1, uniaxial tensile testing is performed in transverse direction to Rolling.

ULTRASONIC TESTING

All plates delivered meets the Class E1, S1 requirement, according to EN 10160.

DELIVERY CONDITION

WearTuf 400 is delivered in the as quenched (Q) condition, and when found necessary in the condition of quenched and tempered (QT).
The plates are delivered with sheared or thermally cut edges.

TOLERANCES

The thickness tolerances of WearTuf 400 meets and exceeds the thickness tolerance of EN 10029 Class A (**). Tolerances on shape, length and width meets the requirements of EN 10029. Flatness tolerances conforms to EN 10029 Class S or closer. For more information, consult the Leong Jin catalogue: General Product Information.

SURFACE CONDITION AND PROPERTIES

The delivered surface finish meets and exceeds that of EN10163-2 Class A, Subclass 3.

The plates will be delivered as painted, using a low zinc silicate corrosion protective shop primer. Plates can also be delivered as unpainted.

HEAT TREATMENT

Since the properties in the as delivery condition cannot be retained after exposure at service temperatures above 250°C, WearTuf 400 is not intended for further heat treatment.

PROCESSING PERFORMANCE

More information on the steel processing performance of WearTuf 400 can be found by consulting the WearTuf Technical manuals on 1) Bending, 2) Welding, 3) Cutting and 4) Machining.

(*)The centre of plate hardness is defined as the mean hardness over the plate through thickness centre, corresponding to a width of 25% of the plate thickness.

(**) In plate thickness less than 12 mm, subsize Charpy test samples are used. The specified min value is then proportional to the cross section of the sample. According to EN 10025 -1, impact tests are not required for nominal thickness < 6 mm.

(***) In the range of 4.0 - 12.0 mm the Leong Jin thickness tolerances can be offered.

WearTuf 450

Revision:03

CHARACTERISTICS

WearTuf 450 is a fully martensitic Q&T abrasion resistant steel having a hardness of average 450 Brinell. WearTuf 450 combines wear resistant properties with excellent weldability and cold forming capability. Due to the high impact toughness, WearTuf 450 offers very good crack integrty.

APPLICATIONS

WearTuf 450 fits a vast number of different applications within earth moving, mining and transport equipment. WearTuf 450 is specially designed for applications focusing on light weight design concepts, such as on and off road dumper and tipper bodies, open top containers, concrete mixer and garbage trucks.

DIMENSIONS

WearTuf 450 is supplied in the thickness range of 3.0 - 60.0 mm and in plate width 900 - 3 100 mm. Supplied plate length from 4 000 to 18 000mm.

HARDNESS GUARANTEE

Surface hardness: 425 – 475 Brinell

Guaranteed hardness range, measured on a milled surface at a depth of 0.5 – 2.0 mm below the plate surface, according to EN ISO 6506-1.

Min center hardness:

Plate thickness ≤ 20 mm : min 425 Brinell
Plate thickness > 20 mm: 95% of min guaranteed surface hardness (*)

IMPACT TOUGHNESS

Typical 45J/-40°C(-40°F)

The impact toughness is given as absorbed energy at temperature, being the average of three full size Charpy-V test samples in longitudinal direction to rolling, according to EN ISO 148-1. (**)

CHEMICAL COMPOSITION

Ladle analysis:The steel is grain refined and fully killed, wt%

Thickness (mm)	C max	Si max	Mn max	P max	S max	Cr max	Ni max	Mo max	B max	CEV Typical	CET Typical
3.0 - 12.0	0.20	0.60	1.50	0.025	0.010	0.40	0.10	0.20	0.004	0.42	0.31
12.1 - 25.0	0.22	0.60	1.50	0.025	0.010	0.60	0.20	0.25	0.004	0.50	0.35
25.1 - 35.0	0.22	0.70	1.60	0.025	0.010	1.00	0.25	0.30	0.004	0.59	0.38
35.1 - 60.0	0.23	0.70	1.60	0.025	0.010	1.20	0.70	0.50	0.004	0.69	0.40

$$\mathbf{CET} = C + \frac{Mn + Mo}{10} + \frac{Cr + Cu}{20} + \frac{Ni}{40} \qquad \mathbf{CEV} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Cu + Ni}{15}$$

MECHANICAL PROPERTIES TYPICAL VALUES

Yield strength Rp0.2	Tensile strength Rm	Elongation A5
1100 MPa	1400 MPa	10%

According to EN ISO 6892-1, uniaxial tensile testing is performed in transverse direction to Rolling.

ULTRASONIC TESTING

All plates delivered meets the Class E1, S1 requirement, according to EN 10160.

DELIVERY CONDITION

WearTuf 450 is delivered in the as quenched (Q) condition, and when found necessary in the condition of quenched and tempered (QT).
The plates are delivered with sheared or thermally cut edges.

TOLERANCES

The thickness tolerances of WearTuf 450 meets and exceeds the thickness tolerance of EN 10029 Class A(***). Tolerances on shape, length and width meets the requirements of EN 10029. Flatness tolerances conforms to EN 10029 Class S or closer. For more information, consult the Leong Jin catalogue: General Product Information.

SURFACE CONDITION AND PROPERTIES

The delivered surface finish meets and exceeds that of EN10163-2 Class A, Subclass 3.

The plates will be delivered as painted, using a low zinc silicate corrosion protective shop primer. Plates can also be delivered as unpainted.

HEAT TREATMENT

Since the properties in the as delivery condition cannot be retained after exposure at service temperatures above 250°C, WearTuf 450 is not intended for further heat treatment.

PROCESSING PERFORMANCE

More information on the steel processing performance of WearTuf 450 can be found by consulting the WearTuf Technical manuals on 1) Bending, 2) Welding, 3) Cutting and 4) Machining.

(*)The centre of plate hardness is defined as the mean hardness over the plate through thickness centre, corresponding to a width of 25% of the plate thickness.

(**) In plate thickness less than 12 mm, subsize Charpy test samples are used. The specified min value is then proportional to the cross section of the sample. According to EN 10025 -1, impact tests are not required for nominal thickness < 6 mm.

(***) In the range of 4.0 - 12.0 mm the Leong Jin thickness tolerances can be offered.

WEARTUF
Q&T Wear Steel

WearTuf 500

Revision:01

CHARACTERISTICS

WearTuf 500 is a fully martensitic Q&T abrasion resistant steel having hardness of average 500 Brinell. WearTuf 500 combines very high wear resistant with excellent weldability and bending performance. In respect to the hardness WearTuf 500 offers very good impact toughness granting good crack resistance.

APPLICATIONS

WearTuf 500 is mainly used within the mining and recycling industry. Common applications are: heavy dumper and tipper bodies, buckets, cutting edges, hammers, shredders, crushers, sieves and various lining parts.

DIMENSIONS

WearTuf 450 is supplied in the thickness range of 4.0 - 50.0 mm and in plate width 900 - 3 100 mm. Supplied plate length from 4 000 to 18 000mm.

HARDNESS GUARANTEE

Surface hardness:
470 – 530 Brinell

Guaranteed hardness range, measured on a milled surface at a depth of 0.5 – 2.0 mm below the plate surface, according to EN ISO 6506-1.

Min center hardness:

Plate thickness ≤ 20 mm : min 470 Brinell
Plate thickness > 20 mm: 95% of min guaranteed surface hardness (*)

IMPACT TOUGHNESS

Typical 35J/-40°C (-40°F)

The impact toughness is given as absorbed energy at temperature, being the average of three full size Charpy-V test samples in longitudinal direction to rolling, according to EN ISO 148-1. (**)

CHEMICAL COMPOSITION

Ladle analysis:The steel is grain refined and fully killed, wt%

Thickness (mm)	C max	Si max	Mn max	P max	S max	Cr max	Ni max	Mo max	B max	CEV Typical	CET Typical
4.0 - 12.0	0.27	0.60	1.20	0.02	0.01	1.00	0.50	0.30	0.004	0.48	0.34
12.1 - 25.0	0.29	0.60	1.50	0.02	0.01	1.30	0.70	0.50	0.004	0.61	0.41
25.1 - 50.0	0.29	0.60	1.60	0.02	0.01	1.30	0.90	0.60	0.004	0.66	0.44

$$\mathbf{CET} = C + \frac{Mn + Mo}{10} + \frac{Cr + Cu}{20} + \frac{Ni}{40} \qquad \mathbf{CEV} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Cu + Ni}{15}$$

QUALITY SYSTEM CERTIFICATION DNV·GL ISO 9001
ENVIRONMENTAL SYSTEM CERTIFICATION DNV·GL ISO 14001
SAFETY SYSTEM CERTIFICATION DNV·GL OHSAS 18001

MECHANICAL PROPERTIES TYPICAL VALUES

Yield strength Rp0.2	Tensile strength Rm	Elongation A5
1250 MPa	1600 MPa	8%

According to EN ISO 6892-1, uniaxial tensile testing is performed in transverse direction to Rolling.

ULTRASONIC TESTING

All plates delivered meets the Class E2, S2 requirement, according to EN 10160.

DELIVERY CONDITION

WearTuf 500 is delivered in the as quenched (Q) condition, and when found necessary in the condition of quenched and tempered (QT).
The plates are delivered with sheared or thermally cut edges.

TOLERANCES

The thickness tolerances of WearTuf 500 meets and exceeds the thickness tolerance of EN 10029 Class A (***). Tolerances on shape, length and width meets the requirements of EN 10029. Flatness tolerances conforms to EN 10029 Class S or closer. For more information, consult the Leong Jin catalogue: General Product Information.

SURFACE CONDITION AND PROPERTIES

The delivered surface finish meets and exceeds that of EN10163-2 Class A, Subclass 3.

The plates will be delivered as painted, using a low zinc silicate corrosion protective shop primer. Plates can also be delivered as unpainted.

HEAT TREATMENT

Since the properties in the as delivery condition cannot be retained after exposure at service temperatures above 250°C, WearTuf 500 is not intended for further heat treatment.

PROCESSING PERFORMANCE

More information on the steel processing performance of WearTuf 500 can be found by consulting the WearTuf Technical manuals on 1) Bending, 2) Welding, 3) Cutting and 4) Machining.

(*) The centre of plate hardness is defined as the mean hardness over the plate through thickness centre, corresponding to a width of 25% of the plate thickness.

(**) In plate thickness less than 12 mm, subsize Charpy test samples are used. The specified min value is then proportional to the cross section of the sample. According to EN 10025 -1, impact tests are not required for nominal thickness < 6 mm.

(***) In the range of 4.0 - 12.0 mm the Leong Jin thickness tolerances can be offered.

TECHNICAL MANUAL

Bending | Welding | Cutting | Machining

Bending

BENDING

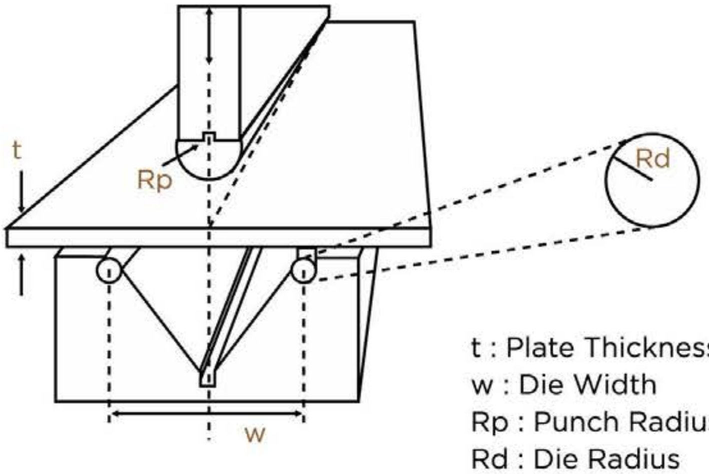
WearTuf abrasion resistant steel is produced to meet the high customer demands on formability, accuracy and productivity. The steel compositions and processing procedures used when manufacturing WearTuf have been carefully applied to obtain the very best performance in terms of cold forming. Close thickness tolerances, consistence of the through - thickness properties, together with an excellent surface finish, promotes a reproducible spring back, bending to narrow radius and having a high crack resistance during forming operation.

TOOL GEOMETRY

To secure a complete plate and punch tool contact throughout the entire bending operation, it is recommended that the head of the punch tool is designed to have a semicircular geometry. The punch tool radius chosen should comply with the minimum radius given in Table 1.

DIRECTION OF ROLLING

Due to the texture effect of the steel from rolling of the plate, the bending performance differs, depending on the orientation relative to the rolling direction. The bending property transverse the rolling direction is always more favorable compared to bending in a longitudinal direction. Thus, the bending recommendation shows 2 sets of radius figures representing minimum radius for bending in both transverse and longitudinal directions.



t : Plate Thickness
w : Die Width
Rp : Punch Radius
Rd : Die Radius

Table 1. WearTuf Bending Recommendation					
Thickness (mm)		Direction	Min Tool Radius, R (mm)		
Min	Max		WearTuf 400	WearTuf 450	WearTuf 500
3.0	7.9	Transversal Longitudinal	2.5 x t 3.0 x t	3.0 x t 3.5 x t	4.0 x t 4.5 x t
8.0	19.9	Transversal Longitudinal	3.0 x t 4.0 x t	3.5 x t 4.0 x t	4.5 x t 5.0 x t
20.0	60.0	Transversal Longitudinal	4.0 x t 5.0 x t	4.5 x t 5.0 x t	5.5 x t 6.0 x t

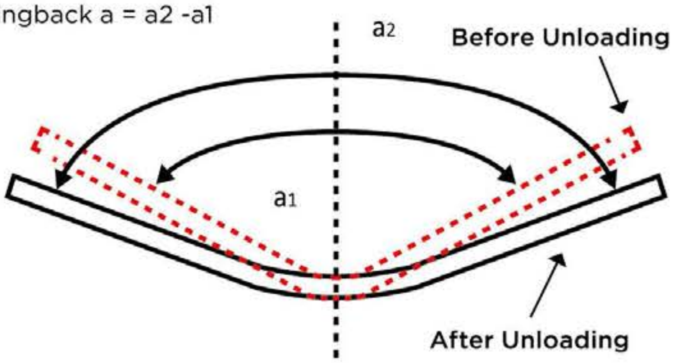
Min recommended punch tool radius (R) when bending to an angle of 90° in either the transverse direction or the longitudinal direction to rolling.

DIRECTION OF ROLLING

Table 2. Recommended Die Opening (W) in respect to Plate Thickness (t) when Bending 90°	
Steel Grade	Die Opening (W)
WearTuf 400	> t x 14
WearTuf 450	> t x 14
WearTuf 500	> t x 16

The spring back increases by the steel strength and the width of die (W). Other factors influencing the spring back are the punch tool radius, actual thickness of plate and friction between plate and bending tools.

Springback a = a2 -a1



By having a narrow spread in tensile properties (or hardness) and thickness tolerance, the consistency in springback is improved, boosting the bending reproducibility.

CALCULATION OF BENDING FORCE

Based on plate thickness, bending length, steel tensile strength and bending tool geometry, the requested bending force can easily be estimated by using the formula below.

$$P = \frac{b \times t^2 \times R_m}{(W - R_d - R_p) \times 9800}$$

P	=	Bend Force, tons (metric)
t	=	Plate Thickness, mm
w	=	Die Width, mm
b	=	Bend Length, mm
Rm	=	Tensile Strength, MPa (table 3)
Rd	=	Die Entry Radius, mm
Rp	=	Punch Radius, mm

Table 3. Tensile Strength	
Steel Grade	Typical Tensile Strength, MPa
WearTuf 400	1250
WearTuf 450	1400
WearTuf 500	1600

WELDING

WELDING

WearTuf abrasion resistant steel is based on a low-alloy steel concept, granting an excellent weldability. By this, the carbon equivalents (CEV/CET) can be kept low in respect to the plate hardness. Combined with the excellent impact toughness of the steel, a very high resistance to weld cracking can be secured.

Important considerations when welding WearTuf abrasion steel are as follows:

- Use electrodes of low hydrogen style, granting low hydrogen pick up
- Position the Weld in low stressed areas
- Use preheating if required (according to recommendations in Table 1)

To obtain a proper weld quality, it is recommended to apply good weld hygiene by keeping the joint clean from moisture, oil and scale from cutting (according to EN 1011). To secure this, always perform bevel preparation by milling the edge and respect the guidelines given in this manual.

HYDROGEN CRACKING

When welding fully martensitic Q&T steel, it is important to eliminate the risk of developing hydrogen cracking (cold cracking).

Hydrogen cracking in welds is caused by either one or a combination of several factors given below:

- The hydrogen content in the weld deposit is too high
- The stress concentration in or around the weld is too high
- The carbon equivalent of the steel is too high

To prevent hydrogen cracking in welds, the following actions must be considered:

- Always select weld electrodes that grant a low hydrogen pick up, not exceeding 5 ml/100 g weld metal deposit
- Try to position the weld in low stressed areas and secure good fitting of the parts to be welded
- Always consult the preheat recommendation as shown in Table 1, to verify if preheating of the welded area prior to welding is required or not

PREHEAT REQUIREMENTS

Preheating prior to welding depends mainly on:

1) Steel Composition (CET)
2) Thickness of Plate
3) Weld Metal Hydrogen Content
4) Heat Input Applied
5) Weld Stress Conditions

Preconditions determining the preheat requirements on WearTuf grades are:

- Weld metal hydrogen content ≤ 5 ml/100g weld metal
- Ambient temperature > 0℃ and air humidity max 70%

In Tables 1, the recommended preheat temperatures are given as function of WearTuf grade, plate (single) thickness and Heat Input.

Table 1. Heat Input: ≤ 1.7 kJ/mm ; Weld Metal Hydrogen Content: ≤ 5 ml/100g

	Single plate thickness,mm										
Steel Grade	3	12	20	25	30	35	40	45	50	55	60
WearTuf 400	25°C			100°C			125°C			N/A	
WearTuf 450	25°C		125°C				150°C			175°C	
WearTuf 500	25°C	150°C			175°C					N/A	

Recommended max interpass temperature for multipass welding WearTuf 400/450/500 : 250℃

The preheat recommendations, given in the tables above, have been established by using the Tekken test, according to ISO 17642, conducted in a controlled laboratory environment.

Depending on air humidity and/or the location where the plates are stored, it is recommended to dry off the area that is to be welded using a flame torch or similar. This is to allow dampness and moisture that is stuck on the plate surface to be released prior to start welding.

If the ambient temperature when welding is subzero degrees (< 0℃), the recommended preheat temperatures in Table 1 should be increased by 25℃.

If preheating needs to be applied, the temperature given in the Table states the minimum temperature of the welded area throughout the entire welding sequence.

If preheating is required, preheating must also be applied when performing the initial tack welding operation.

If the carbon equivalent of the electrode exceeds that of the plate, the recommended preheat temperature in the Tables should be increased by 25℃.

If the weld to be welded is considered to be located in heavily constrained areas, the recommended preheat temperature in the Tables should be increased by 25℃.

HEAT INPUT RECOMMENDATIONS

Calculation of Welding Heat Input:
Q(kJ/mm) = [U x I x 60 x k] / [v x 1000]

The maximum recommended Heat Input (Q) in relation to plate thickness (t) for welding WearTuf is given by the expressions below:

Plate Thickness: 4 - 25 mm
Q Max = 0.12 x t

Plate Thickness: > 25 mm
Q Max = 3 kJ/mm

Q - Heat Input (kJ/mm)
U - Voltage (V)
I - Current (A)
v - Welding Speed (mm/min)
k - Thermal Efficiency Factor

Thermal Efficiency Factor, k

Manual Metal Arc (MMA)	k=0.8
Gas Metal Arc (GMAW)	k=0.8
Flux Cored Arc (FCAW)	k=0.9
Metal Cored Arc (MCAW)	k=0.9
Submerge Arc Welding (SAW)	k=1.0

If a too high Heat Input is applied, there is a risk that the hardness in the adjacent area to the weld (HAZ) will be affected in a way, reducing the wear resistant compared to the rest of the plate.

ELECTRODE SELECTION

Welding WearTuf grades should be performed using low alloy ferritic electrodes, granting low hydrogen pick up.

Always select electrodes where the supplier guarantees weld metal hydrogen content of ≤ 5 ml/100g weld metal in the weld deposit.

To secure low hydrogen content in flux based electrodes, it is important that the electrode handling instructions given by the electrode supplier are respected.

If using either of the welding methods MMA, FCAW or SAW, it is recommended to choose consumables that have a basic flux system.

The yield strength (Re) of the electrode/weld metal is recommended not to exceed 500 MPa.

Welding Designation	Welding Method	Electrode Type
MMA	Manual Metal Arc Welding	Stick electrodes, coated electrodes
GMAW,MAG	Gas Metal Arc Welding	Solid wire + shielding gas Ar/CO_2-mix
FCAW	Flux Cored Arc Welding	Tubular wire with flux inside + shielding gas
MCAW	Metal Cored Arc Welding	Tubular wire with metal powder + shield gas
SAW	Submerged Arc Welding	Solid wire + flux

In Tables 2 and 3, the corresponding EN ISO and AWS classification have been given of the electrodes recommended for welding of WearTuf.

Table 2. Ferritic Electrodes for Welding WearTuf					
Class	MMA (Manual Metal Arc)	GMAW (Gas Metal Arc)	FCAW (Flux Cored Arc)	MCAW (Metal Cored Arc)	SAW (Submerged Arc)
EN ISO	2560- E 42X	14 341 - G 42X	17632 - T 42X	17632 -T46X 100	14171-S 42X
AWS	A5.5 E70x	A5.28 ER80x	A5.29 E7XT-x	A5.28 E110C-x	A5.23 F7x

X – Substitutes one or several additional digits of the class.

If preheating is required, according to Tables 1 , but cannot be performed, austenitic (stainless steel) electrode can be utilized. These electrodes can dissolve much more of the harmful hydrogen compared to ferritic electrodes, preventing hydrogen cracks to develop in the weld. The only drawback utilizing austenitic electrodes is the higher cost of consumable.

Table 3. Austenitic Electrodes for Welding WearTuf					
Class	MMA (Manual Metal Arc)	GMAW (Gas Metal Arc)	FCAW (Flux Cored Arc)	MCAW (Metal Cored Arc)	SAW (Submerged Arc)
EN ISO	1600 E188 Mn	14343 B 188 Mn	17633 T 188 Mn	17633 T 188 Mn	14343 B 188 Mn
AWS	5.4 E307-X	5.9 ER307	5.22 E307T-X	5.9 EC307	5.9 ER307

X – Substitutes one or several additional digits of the class.

Shielding Gas : When using either of the welding methods
GMAW, FCAW or MCAW, a shield gas mix of Ar + 15-25% CO_2 is recommended.

CARBON EQUIVALENT

The carbon equivalent should be calculated based on the actual steel composition, given by the plate certificate. When calculating the carbon equivalent (CET or CEV), either of the equations shown below can be used.

Eq.1

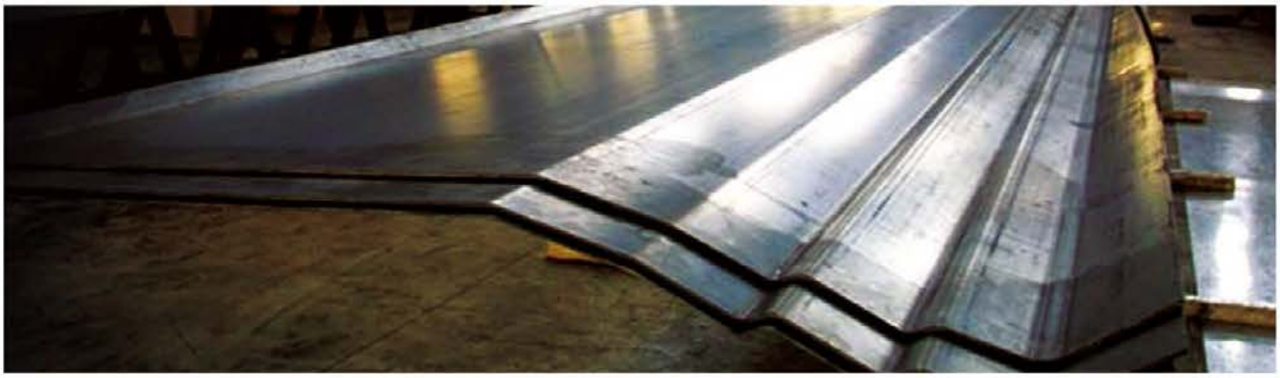
CEV=C%+Mn%/6 +[Mo%+Cr%+V%]/5+[Ni%+Cu%]/15

Eq.2

CEV=C%+[Mn%+Mo%]/10+[Cr%+Cu%]/20+Ni%/40

The CEV formula is traditionally used for commercial structural carbon steel grades while the CET formula has been adapted to better correspond to Q&T steel grades.

The carbon equivalent is traditionally used for judging the need of preheating prior to welding and to rank the steel weldability. The lower carbon equivalent the better weldability.



Cutting

CUTTING

WearTuf abrasion resistant steel can be cut by any means of thermal cutting or cold cutting* methods.

* shear, saw or abrasive water jet

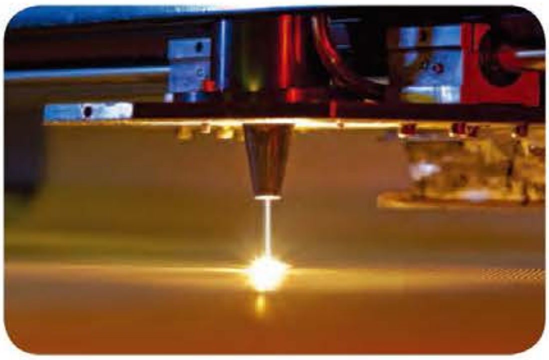
The most common way to cut steel is by using any of the thermal methods like: Oxy-fuel(flame) cutting,Plasma cutting or Laser cutting.

PLASMA CUTTING

When cutting WearTuf steel grades by plasma cutting, there are no restrictions . The same cutting parameters can be utilized for cutting commercial steel grades (mild steel).

LASER CUTTING

WearTuf steel grades are most suitable for laser cutting. Laser cutting is normally utilized when cutting steel of thickness up to 30 mm. To reach an optimal cut edge quality when laser cutting WearTuf that has been primer coated, it is recommended to reduce the cutting speed by 5 - 10% compared to laser cutting on a non-primer coated surface.



OXYGEN FUEL CUTTING

Oxy fuel cutting can be used for cutting WearTuf steel grades in any thickness, but due to the high thermal impact on the steel, it is recommended to only use Oxy fuel cutting for cutting gauges > 30 mm.

GENERAL RECOMMENDATIONS ON THERMAL CUTTING WEARTUF

- Independent of which thermal cutting method is used, the cut parts should always be allowed to cool slowly after cutting. Do not use accelerated cooling for cut parts.
- Before starting thermal cutting for WearTuf steel grades, allow the plate to reach an ambient temperature of min 0°C.

PREHEATING WHEN OXYGEN FUEL CUTTING OF WEARTUF

When utilizing Oxy fuel cutting for WearTuf grades, attention should be placed on the thickness of the plate being cut. If the plate thickness exceeds the minimum plate thickness, according to Table 1, it is recommended to apply preheating of the plate prior to cutting. The preheating recommendations of WearTuf are given in Table 1.

Table 1. Preheating Recommendations Prior to Oxygen Fuel Cutting WearTuf

Steel Grade	Plate Thickness, mm	Pre-Heating,
WearTuf 400	≥ 50	100 - 125
WearTuf 450	≥ 40	100 - 125
WearTuf 500	≥ 30	100 - 125

If preheating is not applied, according to Table 1, there is a risk of developing hydrogen cracks (cold cracks) in the cut edges. If hydrogen cracking occurs, these cracks will be visual about 48 hours or up to several weeks after cutting.

THERMAL IMPACT ON STEEL HARDNESS WHEN CUTTING

Surface Hardness Gradients

Depending on the cutting method used, the hardness will be affected in different ways, corresponding to a certain distance away from the cutting edge. With the exception of cutting methods, the extension of softening depends on plate thickness and steel composition.

According to Figure 1, laser cutting has the lowest impact on softening while Oxy-Fuel cutting has the highest impact on the extension of softening.

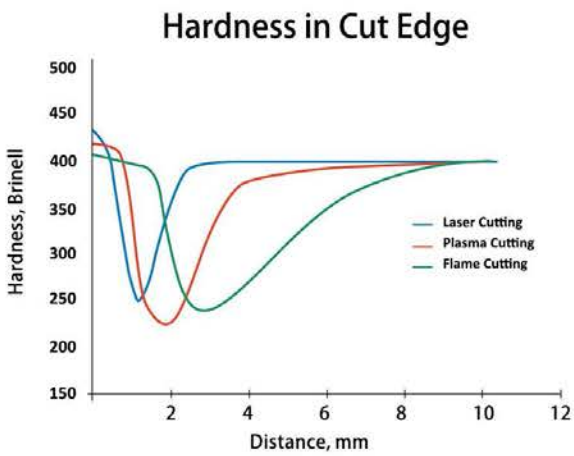


Figure 1. Hardness variation at the cut edge of WearTuf 400, using different cutting methods

CUTTING SMALL COMPONENTS IN WEARTUF

When cutting small components from WearTuf plates, special attention must be given to how the cutting process is performed. When cutting small components, the heat generated from the cutting process will be accumulated. Therefore, the temperature of the part that has been cut must not exceed the temperature resistance of the steel. If it does, mechanical properties of the cut component will be affected. Overall, a higher risk will be imposed on the components if they are being cut into smaller sizes or have larger plate thickness.

Depending on the maximum temperature reached for the plate or component, the hardness of the steel will be reduced according to Figure 2. Reduced hardness results in reduced wear resistance of the component.

To minimize or eliminate softening when cutting small components, the following recommendation should be considered:

- Use a cutting method that has a low thermal impact on the steel
- Perform plasma or oxy fuel cutting while having the plate submerged in water (under water cutting)

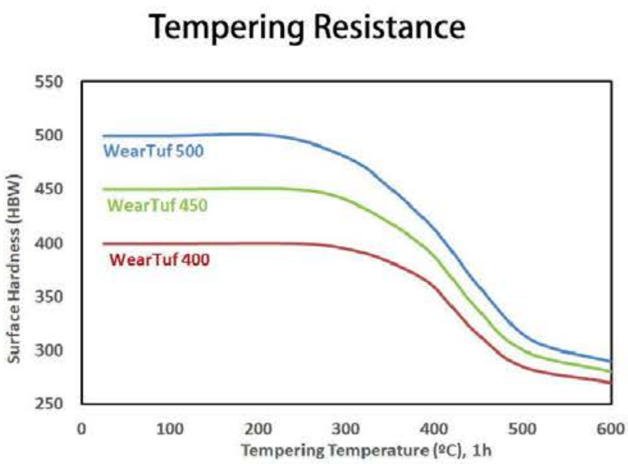


Figure 2. Tempering Resistance of WearTuf Grades

Machining

DRILLING

WearTuf can be drilled using either High Speed Steel (HSS) or cemented carbide drills.

The kind of drills to use depends on the drilling machine stability and drill diameter.

Usually radial or column drilling machines allow substantial vibrations, that is why drills made of High Speed Steel (HSS) are recommended to be used.

When using HSS-drills in the diameter range from 5 mm to 30 mm, either micro alloyed (HSS-E) drills or 8%-Cobalt containing drills (HSS-Co) should be selected, having a small helix which can withstand high torques.

Due to the high re-grinding frequency of HSS-drills, the productivity becomes low when processing Q&T steels. To reach high productivity machining, modern and stable drilling/milling machines (CNC-type) have to be used, as well as the use of cemented carbide types of drills/milling tools.

For high productivity drilling operation, the most economical type of drill to use is a tool that has cemented carbide inserts. This drill consists of cemented carbide cutting edges mounted into a tool. The hole diameter of this kind of tools stays in the range from 12 mm and up.

Cemented Carbide Tool with Indexable Inserts

For smaller hole diameters (ø < 12mm), solid cemented carbide drills must be used.

Solid Cemented Carbide Drills

MILLING

Depending on the kind of milling operation to be conducted, the following recommendations are given:

• For face milling: Use a tool that has round cemented carbide inserts.
• For finish milling: Use a tool that has cemented carbide inserts with a 45° cutting angle.
• For end milling: Use either a solid cemented carbide tool or a tool with cemented carbide inserts.

Face Milling

End Milling

Counterboring and **countersinking** are best performed using tools equipped with cemented carbide inserts and rotating pilot.

Mechanical Properties of WearTuf			
	Hardness	Yield Strength, Typical	Tensile Strength, Typical
WearTuf 400	400 Brinell [370-430]	1000 MPa	1250 MPa
WearTuf 450	450 Brinell [425-475]	1100 MPa	1400 MPa
WearTuf 500	500 Brinell [470-530]	1250 MPa	1600 MPa

GENERAL RECOMMENDATIONS

- For all machining operations, proper clamping of work piece is required.
- Cooling lubricants should always be used when machining WearTuf grades.
- For best performance, always try to use cemented carbide tools with internal cooling.