ENDURA Dual

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Endura Dual is an advanced abrasion-resistant steel additionally alloyed with high titanium content (0.6%). This innovative grade is mainly dedicated to severe sliding wear conditions in service for applications where conventional water quenched steels (500HB, 550HB), hardfacing plates or hard-cast parts are traditionally implemented.

Compared to Endura , Endura Dual capita-lizes upon an innovative metallurgical concept, based on a specific chemical analysis. Furthermore, it is produced by Oil Quenching, which reduces the level of the residual stresses that is encountered within the plate after heat treatment (with more drastic quenching methods water quenching).

The outstanding extra wear resistance, severe abrasion combined with high impact cycle load, is mainly due to the contribution of the following hardening phenomena :

- an homogeneous precipitation of extra hard primary titanium carbides in the steel matrix leads to a significant improvement of the sliding wear resistance in extreme service conditions.

- a superficial hardening following a very efficient work hardening capability in service, governed by a metallurgic phenomenon called TRIP effect (**T**ransformation **I**nduced by **P**lasticity).

- in addition to a high stress grinding abrasion resistance, an ability of forming also remains within reasonable limits and allows the processing of curved parts (Fig 1, fig 2 : Endura Dual, 2000x300x10mm, R_{int}=1000mm)

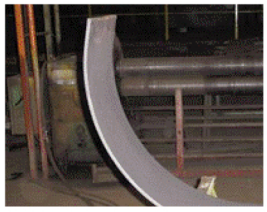


Fig 1: Rolling

Fig 2: Bending (successive folds)

No other competitor offers wear resistant steel at this level of hardness 500HB, with such high abrasion resistance combined with high resistance to cracking in service!

Standard

Endura Dual

Chemical analysis (indicative values weight %)

C	Mn	Ni	Cr	Mo	S	Ti
≈ 0.40	≈1.30	≈ 0.45	≈ 0.70	≤ 0.340	≤0.002	≈ 0.60

Mechanical properties (indicative values as delivered)

Hardness (HB)	Y.S. 0.2 MPa (KSI)	UTS MPa (KSI)	El 5.65 %	KCVL-20° (-4°F) J (ft.lbs)	E GPa
480	1200 (*174*)	1630 (*236*)	10	18 (*13*)	205

Hardness ≈ 450/490 HB (typical value)

Physical properties

Expansion coefficient (x 10^{-6}.°C^{-1})

20/100°C *68/212°F*	20/200°C *68/392°F*	20/300°C *68/572°F*	20/400°C *68/732°F*	20/500°C *68/932°F*
11.2	12.0	12.5	13.2	13.8

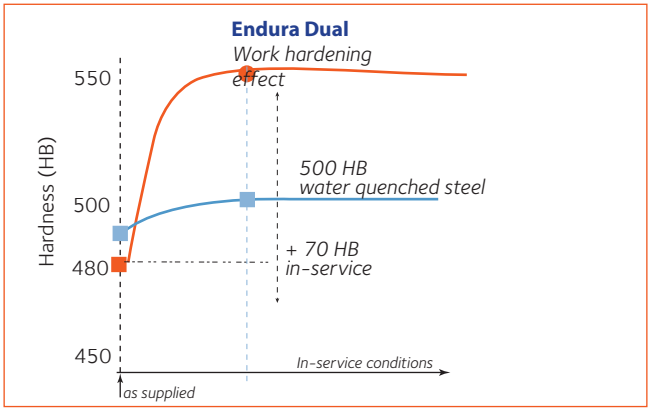
Density at +20°C (*68°F*) : 7.85 kg/dm^3

Metallurgical concept

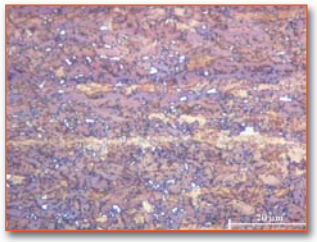
Wear resistance depends not only on the hardness of the steel at delivered state, but also on other properties, such as crack resistance, work hardening effect, strength, ductility, softening resistance, etc.
The performance in service of given wear resistant steel is strongly influenced by the microstructure obtained after thermal processing.
In the case of Endura Dual , a significant improvement of the wear resistance in service is mainly due to the following properties :

"TRIP effect" : TRansformation Induced by Plasticity.

As its initial structure not fully martensite (a mix of martensite, bainite and retained austenite), Endura Dual has the ability to work-harden when submitted to local plastic deformation in service. Plastic deformation induces a surface hardening phenomenon by transformation of retained austenite into fresh and very hard martensite while the material remains ductile underneath, making it most effective to withstand both abrasion and heavy impact in service.



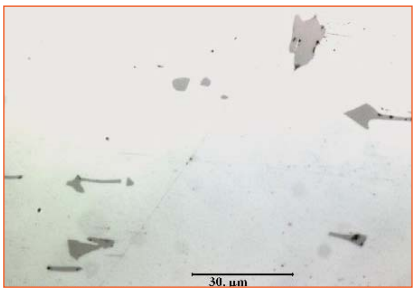
In addition, the super ductility of the retained austenite contributes to improve the lifetime in service by allowing larger micro shearing and thus delays the ultimate tearing of metal particles from the surface of the material exposed to the abrasive.



On this typical microstructure of Endura grades, the retained austenite grains revealed by means of Klemm reactive etching appear in white. When subjected to plastic deformation in service (impact or high pressure), Endura Dual takes advantage of a surface hardening about 70 HB, whatever the applied strain level.

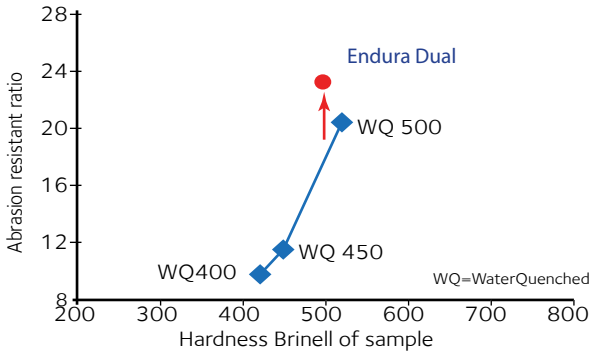
Titanium carbides

The extreme abrasion resistance versus the conventional wear resistant steels (500HB, 550HB...) is gained by the presence of the primary titanium carbides which are precipitated during the first stage of the solidification (already present within the semi-products, slab or ingot, before rolling and heat treatment). These titanium carbides exhibit an average hardness of 3000HV (Vickers hardness) and therefore create numerous hard spots in the steel matrix like crushed gravel in concrete.



Extremely hard primary titanium carbides homogeneously embedded in the steel matrix

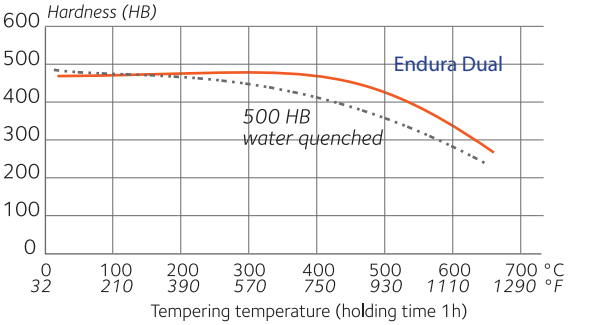
Abrasive wear test results



Abrasive test followed ASTM G65 standard

Properties at high temperature

Chemical composition of Endura Dual, and specially chromium, molybdenum and huge titanium contents, give a high softening resistance to the material. This property allows using Endura Dual in hot service conditions, at a maximum of 450°C (*840°F*) while conventional 500 HB water quenched steels are limited to 250°C (*480°F*).



Softening resistance according to tempering temperature

Service life

Whatever service conditions are, the original metallurgical concept of Endura Dual gives the material an improve of its performance in terms of wear resistance and process ability, compared to other conventional
500 HB water quenched steels, especially for extreme applications, where severe abrasion conditions are combined with huge impact, heat or moderate corrosion.

Processing

Cutting

All classical thermal processes (gas-plasma-laser) can be used. Plasma/laser processes are specially recommended. They provide increased precision and cutting aspect and induce a thinner Heat Affected Zone (HAZ).

Welding

Endura Dual can be welded with all classical processes : manual (SMAW), semi-automatic under gas protection (GMAW), automatic under flux (FCAW). Welded areas shall be clean, free of grease, water, oxides...

Electrodes and flux shall be dried according to supplier's recommendations.
For welds without preheating, an austenitic welding wire shall be used.

Following welding conditons have been used in our weld tests

	Solid Wire	Gas
Trademark	LNM 307	ATAL 5A
Standard name	ER307 / G18-8-Mn	M21
Supplier	Lincoln	Air Liquid
Diameter/Composition	Ø 1.2 mm	82% Ar+18% C02
Automatic/Manual	automatic	
Welding position	PB	
Heat Input (KJ/cm)	12 - 18	
Voltage (V)	26 - 28	
Amperage (A)	220-270	
Travel speed (cm/min)	25 - 35	
Polarity	DC+	
Wire feed rate (m/min)	10 - 12	
Gas flow rate (l/min)	18 - 24	
Stick-out (mm)	10 - 20	
Preheating (°C)	20°C	
Interpass temp. (°C)	40°C	

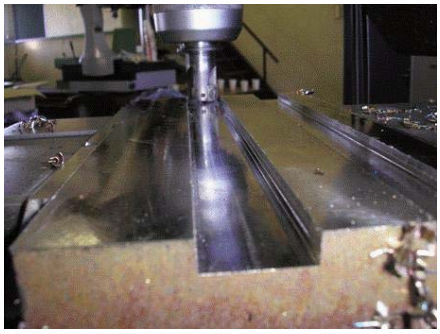
If you are using a ferritic welding product, preheating is strongly recommended in order to avoid cold cracking defects...

The following welding conditions have been used in our weld tests

	Solid Wire	Gas
Trademark	Nertalic 70A	ARCAL 12
Standard name	A5.18 / G3Si1	M12
Supplier	SAF	Air Liquide
Diameter/Composition	Ø 1.2 mm	98% Ar+2% C02
Automatic/Manual	automatic	
Welding position	PB	
Heat Input (KJ/cm)	12 - 18	
Voltage (V)	26 - 28	
Amperage (A)	220-270	
Travel speed (cm/min)	25 - 30	
Polarity	DC+	
Wire feed rate (m/min)	7.5	
Gas flow rate (l/min)	18 - 24	
Stick-out (mm)	10 - 20	
Preheating (°C)	160°C	
Interpass temp. (°C)	180°C	

Forming and Machining

Refer to the Endura Dual guideline



Applications

The properties of Endura Dual clearly indicate that this steel has many potential applications where an extreme abrasion resistance combined with high resistance to cracking is required in service, such as:

- Bucket liners for excavator, shovel, loader, dozer, ...
- Cutting edges, stiffeners... for different types of buckets
- Truck tray body liners
- Wear parts for primary and secondary crushers
- Vibratory feeder liners
- Chute liners
- Hopper liners
- Screens
- Trommels
- Pipe elbows
- Cyclones
- Deflectors
- Grinder liners (SAG Mill)
- Demolition tools (recycling)
- Pipes for dredging
- Blade liners for heavy duty fans...

Examples of three areas of industry where Endura Dual can make the different versus the conventional solutions...

Counter-Blades
Mines & Quarries

Extra large fans (XXL), extreme service conditions (blade protection)

- cement plants
- incineration plant (waste treatment technology)
- ore processing
- iron making plants

Screens
(hot working conditions)

- iron making plant (blast furnace)
- sintering plant
- coking plant

In general, for complex applications where the wear phenomenon is combined with high temperature or corrosion, the service conditions should be carefully investigated in order to provide adequate solution...

Dimensional programme

Sizes - mm (inch)	**Thickness - mm (inch)** **6 to 50 mm** *(0.236 to 1.968)*
2000 x 6000 *(78.740 x 236.220)*	xx
2500 x 8000 *(98.425 x 314.960)*	xx

xx = optimum sizes

Indicative dimensional programme

Others dimensions available on request.

1. This technical data and information represents our best knowledge at the time of printing. However, it may be subject to some slight variations due to our ongoing research programme on abrasion resistant grades. We therefore suggest that information be verified at time of enquiry or order.

   Furthermore, in service, real conditions are specific for each application.
   The data presented here is only for the purpose of description, and may only be considered as guarantees when ou company has given written formal approval.

2. ENDURA Dual has been developed specifically for its abrasion resistance.

   Customer's usage of ENDURA Dual for any other purposes, not directly resulting from its abrasion resistance, is his own prerogative but won't, in any way, engage TITUS STEEL's responsability. In addition to the recommendations given in this document, customer will have to follow the industry standard quality rules for any processing operation performed on this material.