

TAM[®] Plus

According to EN 10297-1



Tenaris around the world

Tenaris is a leading global manufacturer and supplier of steel pipe products and related services for the world's energy industry and other industrial applications. Our customers

include most of the world's leading oil and gas companies and our revenues amounted to US\$ 7.1 billion in 2015.



Employing around 21,700 people worldwide, we operate an integrated network of steel pipe manufacturing, research, finishing and service facilities

with industrial operations in the Americas, Europe, the Middle East, Asia and Africa and a direct presence in most major oil and gas markets.



TAM® Plus

REFERENCE NORM EN 10297-1
SEAMLESS STEEL TUBES WITH HIGH MACHINABILITY (HL)
AND CLOSE TOLERANCES FOR MECHANICAL APPLICATIONS

TAM® Plus is the new range of hot rolled mechanical tubes, designed by Tenaris to better meet the needs of industrial sector. The new product, which is part of the TAM® family Mechanical Application Tubes, is the result of an extended R&D experience and of a fully-integrated manufacturing process. Following a research carried out by the technical assistance area in various application fields, among which cylinders, rollers, bushing, connectors and gears, the need for a product featuring higher characteristics than the standard ones came to light.

Focus emerged in the following areas:

- Machinability (HL)
- Dimensional tolerances
- Straightness (upon request)

Objective of the project was to control:

- The metallurgical characteristics
- Production process for a family of steel suitable for machine tool working.

In our fully-integrated manufacturing process, from steelmaking to tube-rolling, coldrawing, heat treatments and tubular parts processing, we focus on designing tailor-made products to meet our customers' needs and ensure a longer product life, guaranteeing high mechanical properties and optimizing their operations. A highly skilled Tenaris team guarantees constant technical assistance during the different product development phases and after sales. We offer added value to each customers' request and a continuous product improvement in order to meet their needs.



Production technology

TAM® Plus is produced from fine grain alloy steel with guaranteed soluble aluminum and controlled sulfur contents (0.020-0.035).

The Electromagnetic Stirrer (EMS) allows to obtain an homogeneous structure of the bar and the lowering of the segregation index and central cavity porosity (Fig 1/Fig 2).

Furthermore, the automatic control of the continuous cast parameters allows better process control and steel quality.

In producing TAM® Plus tubes, the technology of the Arcore plant plays a key role:

- Piercer Mill
- Diescher Mill

The Piercer Mill is the machine that transforms – at high temperature – the primary material (round bar from continuous casting) into a hollow with heavy wall thickness and good concentricity.

FIG 1 - IMPRINT BAUMAN (NOT EMS)

FIG 2 - IMPRINT BAUMAN (WITH EMS)

TENARISDALMINE'S STEEL SHOP AERIAL VIEW



The diameter of the hollow is defined through the positioning of the rolling cylinders and the guiding discs; wall thickness is defined by the position of the cylinders and the internal mandrel. Arcore mill's process control and tube handling throughout the production lines are completely automatized. Radioisotopes devices monitor pipe wall thickness all along the tube body during the rolling phase.

ADVANTAGES OF THE DIESCHER MILL:

- Tube concentricity
- Wide wall thickness dimensional range

After the Diescher Mill, the finished diameter of the tube is defined:

- For the dimensional range 48.3 – 92.3. The tubes pass through an intermediate heating furnace; then to the Stretch Reducing Mill (SRM) that can also strictly control the variation of the wall thickness.
- For the dimensional range 95.4 – 219.1. The tubes are brought directly to the required diameter directly to the required diameter by a sizing mill, without any significant variation in wall thickness.

Diescher Mill, by means of transverse rolling, permits a hollow of lower wall thickness and the obtaining of a better concentricity.



TENARISDALMINE - ARCORE ROLLING MILL



TAM® Plus offers technical characteristics above the standard for:

- Machinability (HL)
- Close tolerances on diameter and wall thickness
- Tight straightness (upon request)

MACHINABILITY

Machinability is determined by two factors:

1. Condition of materials

- Chemical and mechanical properties
- Heat treatment method and relevant microstructure
- Inclusion rate
- Surface condition

2. Working conditions

- Cutting speed
 - Cutting depth
 - Feed rate
 - Type of cutting edge, tool holder, machine
- The manganese sulphide present in the steel slows down the cutting edge wearing out and favors chip beaking (the opposite of using steel with calcium aluminate inclusions or other refractory materials, which are hard and abrasive).

Tenaris, in its R&D laboratories neutralized the undesirable alumina in the steel and added controlled quantities of sulfur, an element able to form manganese sulphide. Sulfur acts as a lubricant between tool and chip surface, facilitating machinability, while the high softening temperature of the manganese sulphide makes the steel suitable for use at high cutting speeds.

Machinability of Tenaris steel is measured by

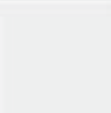
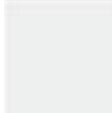
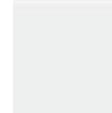
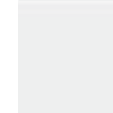
TOOL LIFE TESTS

With a tool life conventionally fixed at 10 minutes, laboratory tests have demonstrated that steel that has undergone re-sulfurisation is more machinable compared to the standard steel, thus permitting greater machining speeds.

CHIP FORMATION TESTS

Formation of short and detached chips is guaranteed by the use of re-sulphured steel that allows high machining speed with a consequent reduction in time and production costs.

CHIP SHAPES

1.	2.	3.	4.	5.	6.	7.	8.
Ribbon chip	Tubular chip	Spiral chip	Helical chip of conical type	Helical chip of conical type	Arc chip	Discontinuous chip	Needle chip
1.1 Long	2.1 Long	3.1 Flat	4.1 Long	5.1 Long	6.1 Attached		
							
1.2 Short	2.2 Short	3.2 Conical	4.2 Short	5.2 Short	6.2 Detached		
							
1.3 Tangled	2.3 Tangled		4.3 Tangled	5.3 Tangled			
							

Classification of chip types based on experimental observation according to the standard ISO 3685 (The ideal chip types are shown in green) TAM

Machinability economic advantages depend on two factors.

1. Tool life

Improvement in tool life is illustrated below by means of Taylor Curves for steel grades TAM® Plus E 470 HL compared to the same grade nonn re-sulfured steel.

With a tool life conventionally fixed at 10 minutes, the cutting speeds show an increase from 7 to 14%, allowing a considerable increase in the number of pieces produced with the same cutting edge.

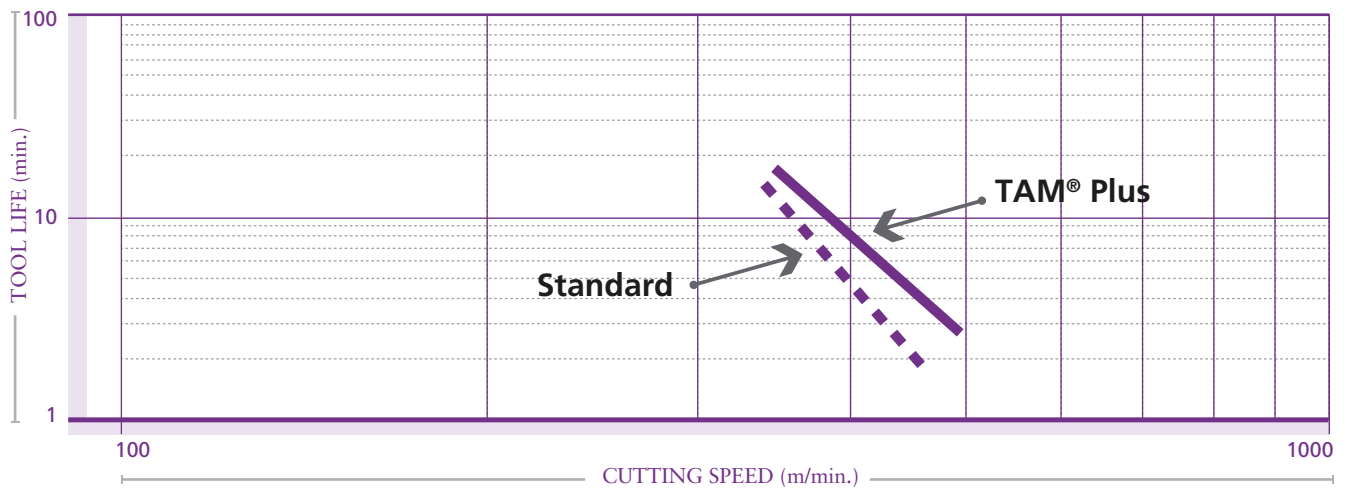
2. Chip formation

Experimental tests have shown that in severe working conditions, characterized by wide cutting depth intervals and low feeding rates, the re-sulphured TAM® Plus steel grades permit formation of detached chips.

ADVANTAGES

- Lower tool temperatures, for an equal number of working cycles, with consequent improvement in cutting speed
- Lower cutting edge wear
- Reduction in built-up edge
- Reduction in cutting force and consequent increase in tool life
- Reduction in the number of stops necessary to manually remove the chips and subsequent reduction in injuries associated with this operation
- Elimination of the number of irregular pieces caused by cutting edge wear
- Improvement in surface finish

TAYLOR CURVE E470 - 10297 NORM



CLOSE TOLERANCES ON WALL THICKNESS

Thanks to the Diescher transverse rolling process and the revamping of Piercer mill, Tenaris is able to guarantee close tolerances, continually measured, as shown in the table on page 11.

ADVANTAGES

- After mechanical working absence of unfinished areas
- Reduction in weight of the initial tube, since the production wall thickness necessary to obtain the finished dimension is the smallest possible

TIGHT STRAIGHTNESS

The process and product controls make it possible to obtain a straightness equal or inferior to 1‰ cumulative on the entire length of the tube.

ADVANTAGES

- Better centering with subsequent reduction in chips to remove
- Lower vibration/oscillation inside the machine
- Reduction in machine stops
- Increased productivity TAM

TENARISDALMINE'S STEEL SHOP AERIAL VIEW



APPLICATIONS

GRADE*	Applications
E355 HL	Steel for high machinability mechanical applications
E470 HL	Steel for high machinability and high yield mechanical applications
E420J2 HL	Steel for high machinability mechanical applications with guaranteed toughness
C45E HL	Steel for high machinability mechanical applications and tempering
42CrMo4 HL	Steel for high machinability mechanical applications for quench and tempering
16MnCrS5 HL	Steel for high machinability mechanical applications for quench and case hardening
20MnCrS5 HL**	Steel for high machinability mechanical applications for quench and case hardening

* HL = High machinability

** Chemical composition according to EN 10084-1

Note: C45E HL, 42CrMo4 HL, 16MnCrS5 HL e 20MnCrS5 HL can be provided rough (+AR), normalized (+N) and annealed (+A).

CHEMICAL ANALYSIS %

Grade	C	Si	Mn	P	S	V	Cr	Mo	Ni	Al Tot.	NB	TI
E355 HL	≤ 0,20	≤ 0,50	≤ 1,60	≤ 0,030	0,020 - 0,035	-	-	-	-	-	-	-
E470 HL	0,16 ÷ 0,22	0,10 ÷ 0,50	1,30 ÷ 1,70	≤ 0,030	0,020 - 0,035	0,08 ÷ 0,15	-	-	-	-	≤ 0,070	-
E420J2 H	0,16 ÷ 0,22	0,10 ÷ 0,50	1,30 ÷ 1,70	≤ 0,030	0,020 - 0,035	0,08 ÷ 0,15	≤ 0,30	≤ 0,80	≤ 0,40	≥ 0,010	≤ 0,070	≤ 0,050
42CrMo4 H	0,38 ÷ 0,45	≤ 0,40	0,60 ÷ 0,90	≤ 0,035	0,020 - 0,035	-	0,90 ÷ 1,20	0,15 ÷ 0,30	-	≥ 0,010	-	-
C45E HL	0,42 ÷ 0,50	≤ 0,40	0,50 ÷ 0,80	≤ 0,035	0,020 - 0,035	-	-	-	-	-	-	-
16MnCrS5 HL	0,14 ÷ 0,19	≤ 0,40	1,0 ÷ 1,30	≤ 0,025	0,020 - 0,040	-	0,80 ÷ 1,10	-	-	-	-	-
20MnCrS5	0,17 ÷ 0,22	≤ 0,40	1,10 ÷ 1,40	≤ 0,025	0,020 - 0,040	-	1,00 ÷ 1,30	-	-	-	-	-

* All steel grades are completely calmed

MECHANICAL PROPERTIES

GRADE	DELIVERY CONDITION*	TENSILE PROPERTIES							IMPACT TEST**	
		Rp 0.2 (MPa) min			Rm (MPa) min			A %	Charpy KV long	
		Wall thickness mm			Wall thickness mm			long.	T °C	J MIN
		≤16	>16≤40	>40≤65	≤16	>16≤40	>40≤65	min		
E355 HL	G	355	345	335	490-650	490-650	490-650	20	-	-
E470 HL	G	470	430	430	650	600	600	17	-	-
E420J2 HL	N	420	400	390	600	560	530	19	20	27

* G = as rolled (not treated) - N = normalized - Normalization can be done online or in the furnace.

** The impact test values indicated are meant to be calculated as the average of the three samples of width W = 10 mm. One individual value may be below the minimum, but not less than 70% of that value.

The certificate reports the dimension of the sample and the values measured in the test in J. If the sample width W is less than 10 mm, the minimum requested KV10 values are reduced in the new KVW value according to the formula: KVW=KV10 x (W/10)



DIMENSIONAL TOLERANCES

Outside Diameter and Wall Thickness tolerances are highlighted in the table.

OPTION A

Straightness: better or equal to 1‰ cumulative.

LENGTHS

Tubes are supplied in commercial lengths.

OPTION B

Different lengths from the standard foreseen can be agreed at the time of the order.

SERVICE CENTER

Tenaris Service Center can supply tubes cut fixed lengths with tolerances of $-0 / +3$ mm. Cut Squareness: 1,5 mm.

CHECKS

The product is subjected to the following tests:

- Mechanical tests in accordance with reference standards
- Electromagnetic test according to EN 10893-

LIV.F3 longitudinal

- Visual and dimensional check on each tube
- Anti Mixing control

OPTION C

Specific additional tests can be agreed at the time of the order.

SURFACES

The product is supplied with hot finished surfaces, as rolled.

CERTIFICATION

The product is supplied with 3.1 Inspection Certificate, in conformity with EN 10204. Tenaris operates with complete product traceability.

IDENTIFICATION AND MARKING

“TAM® PLUS” mechanical tubes are identified as follows:

Continuous paint marking (white colour):

- Manufacturer's trade mark
- TAM PLUS
- Steel grade
- Reference norm
- OD x WT
- S (production process)
- Heat
- Internal mill order number

Die stamping:

- Manufacturer's trade mark
- TAM PLUS
- Steel grade
- S (production process)
- Mill inspector.

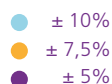
Painting (pink Tenaris color) on cross sections of both tube ends

PACKAGING

In bundles fasted with strap

Tenaris offers technical assistance for customized applications of its product.

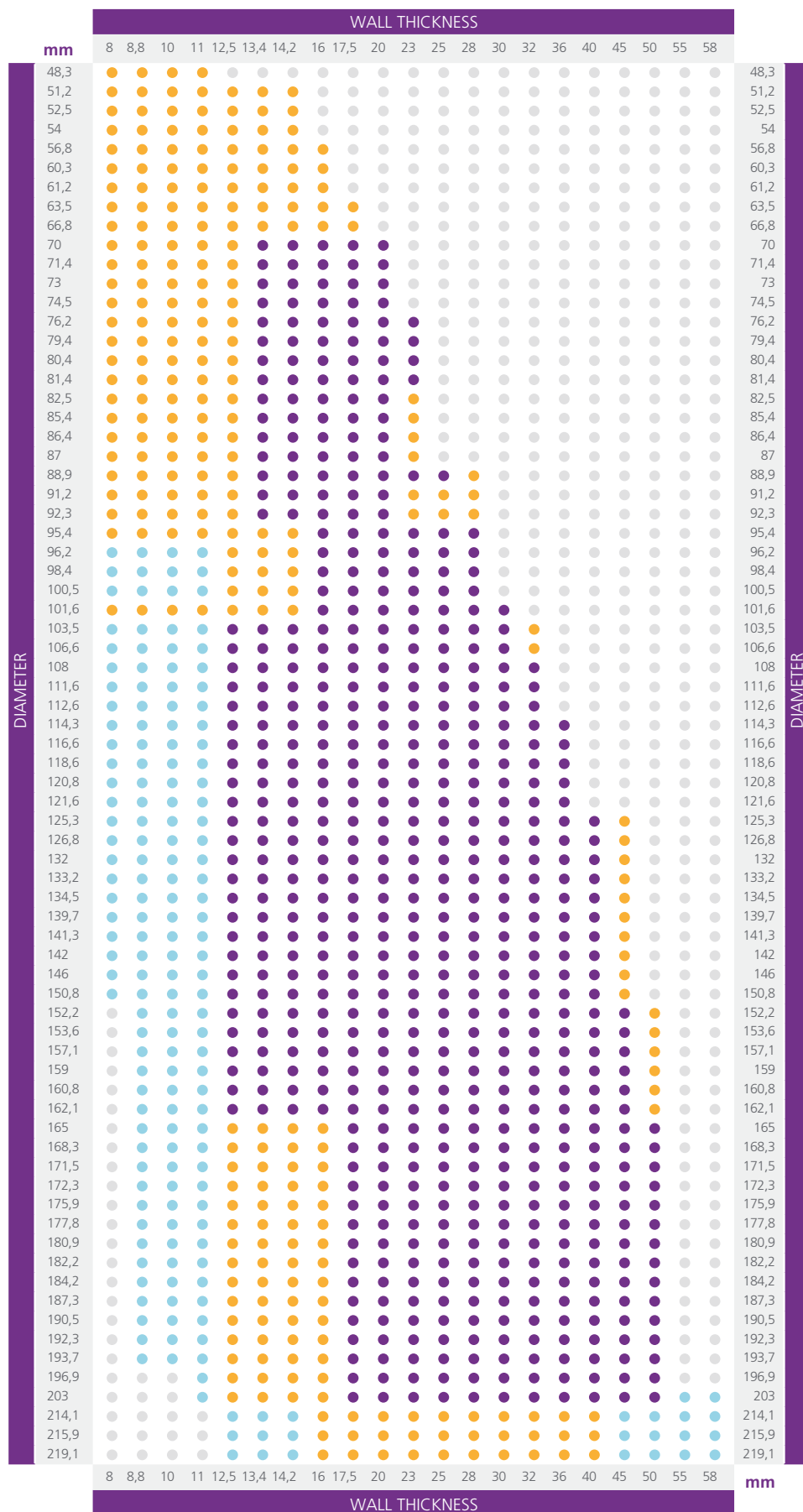
Dimensional Tolerances



Tolerance O.D.

 $\leq 80 \pm 0,4 \text{ mm}$

$>80 \pm 0,5\%$



Tenaris technicians are at your disposal in order to point the dimension of initial tube that guarantees achievement of finished size after mechanical working. All thicknesses can be continuously produced.



For further information

www.tenaris.com

For assistance please contact

standardmechanical@tenaris.com