



TMK-ARTROM S.A.

Draganesti Str. 30, Slatina, jud. OLT, Romania 230119

Tel: +40 (249) 436862, 434640, 434641

Fax: +40 (249) 434330, 437288

E-mail: office.slatina@tmk-artrom.eu www.tmk-artrom.eu

EUID: ROONRC.J28/9/1991; J28/9/31.01.1991

VAT No. RO 1510210/1992

Subscribed and Paid Share Capital: 291.587.538,34 lei

TMK HYDRA ART INSIDE SKIVED AND ROLLER BURNISHED COLD FINISHED SEAMLESS STEEL TUBES and PISTON RODS TUBES FOR HYDRAULIC CYLINDERS

TMK is one of the world's leading producers of tubular products for the oil and gas industry. Since 2009 it has been ranked first in the world by volume of pipes shipped. The Company operates 28 production sites and 2 Research & Development centres around the world. TMK has the world's largest steel pipe production capacity, with the largest share of sales.

TMK-ARTROM, the main unit of TMK's European Division, it is a producer of steel tubes and pipes with 30 years of experience in producing and selling worldwide tubes mainly for industrial applications. The tubes production is integrated with the steel melting and billet casting performed under a common integrated management system and using up-to date technology in TMK-RESITA - the oldest steel producer from Romania.

Focused in production of seamless hot and cold finished tubes for mechanical applications, TMK-ARTROM has over 20 years of experience in production of Cold precision tubes suitable for Inside Skiving and Roller Burnishing (HPZ), being a major supplier for companies performing skiving operation as well for important companies producing Hydraulic Cylinders and Equipment.

Volumes for cold precision tubes for hydraulic cylinders have today a significant share in the total output of our cold finished production capacity.

TMK-ARTROM decides to develop cold finished product range in order to be closer to hydraulic cylinders producers by adding to the offer **Inside Skived and Roller Burnished (SRB)** tubes in lengths till 12 m. The state-of-the-art equipment special developed for this application and the partnership with one of the world most experienced producer for SRB tools is the premise for a high commitment for quality and flexibility.

The advantages TMK-ARTROM is offering to the customers are:

- **Fully integrated and controlled process from steel melting till final machining of the tubes**
- **High expertise in offering and developing steel grades with characteristics for most demanding applications**
- **Quick response, flexibility and full customer care and services** ➤ **Better cost control and optimization**

1. Standards

EN 10305-1	Steel tubes for precision applications
EN 10305-4	Steel tubes for precision applications
EN 10216-3	Seamless steel tubes for pressure purposes – Technical delivery conditions; Part 3 Alloy fine grain steel tubes
EN 10297-1	Seamless circular steel for mechanical and general engineering purposes – Technical delivery conditions – Part 1: Non-alloy and alloy steel tubes

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EN ISO 377	Steel and steel products – Location and preparation of samples and test pieces for mechanical testing
EN 10204	Metallic products – Types of inspection documents
EN ISO 286-2	ISO system of limits and fits –Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts
EN ISO 6892-1	Metallic materials - Tensile testing - Part 1: Method of test at room temperature

EN ISO 6892-2	Metallic materials - Tensile testing - Part 2: Method of test at elevated temperature
EN ISO 148-1	Metallic materials - Charpy impact test - Part 1: Test method
ASTM A370	Standard Test Methods and Definitions for Mechanical Testing of Steel Products
EN ISO 10893-5	Non-destructive testing of steel tubes - Part 5: Magnetic particle inspection of seamless and welded ferromagnetic steel tubes for the detection of surface imperfections
ASTM E709	Standard Practice for Magnetic Particle
EN ISO 10893-10	Non-destructive testing of steel tubes - Part 10: Automated full peripheral ultrasonic testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of longitudinal and/or transverse imperfections
ASTM E213	Standard Practice for Ultrasonic Testing of Metal Pipe and Tubing

2. Used for

Production of hydraulic cylinders.

3. TMK HYDRA ART Identification

TMK Hydra ArtH xxx OD x ID / TMK Hydra ArtH xxx OD x ID –IFR

TMK Hydra is the TMK-Artrom classification of Cold drawn inside skived and roller burnished (SRB) tubes.

Art H xxx is the grade identification, xxx being the minimum granted yield point in Mpa.

OD, ID are outside and inside diameters nominal values.

IFR - Improved Fatigue Resistance – is an optional finishing which increase the Fatigue resistance on cycling stress specific for hydraulic cylinders use.

4. Manufacturing process

- Manufactured from steel billets produced by EAF process using fine grain practice and advanced cleaning procedures.
- Seamless hot rolled hollows are obtained with controlled concentricity on an ASSEL rolling line and then drawn to precision tubes with significant cross-section reduction improving the geometry and strengthens of the tubes. The cold deformed tubes are then Inside skived and roller burnished (SRB) using state of the art equipment and tools supplied by well-known producers with extensive expertise for these processes.

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- Tubes with **IFR (Improved Fatigue Resistance)** are tested with high sensitivity ultrasonic methods and additionally machined on outside surface using a center-less grinding process in order to remove any surface imperfection which can be potential fatigue cracking sources.
- Adequate steel chemistry as well as suitable heat treatments performed before and after cold working are used in order to obtain the mechanical properties for TMK HYDRA ART grades described in Paragraph 6.
- The last heat treatment before delivery is listed for each grade:
 - +SR – Stress relieved
 - +N – Normalized
- Selection of the tests for TMK HYDRA ART precision tubes:
 - Mandatory according to standards: Chemical analysis, Charpy test, Tensile test, Dimensional inspection, Visual inspection, Roughness measurement, NDT as per Paragraph 8;
 - Upon agreement with customer: NDT for other grades than standard offered, Flattening test or drift expanding test.

5. SRB Tubes Dimensions & Tolerances

Size program according to Tab. 1. Other sizes can be produced by agreement but this can be subject of minimum ordered quantities or other commitments.

Size tolerances:

- Outside Diameter (OD) in accordance with EN 10305-1.
- Inside Diameter (ID) in accordance with ISO H8 – EN ISO 286-2, Ra – 0.3 µm or better (please see Tab. 1).

Note: On request, OD can be supplied only on agreed positive tolerances suitable for future machining (for example for telescopic cylinders). For such purpose the tubes can be pre-machined using a centerless grinding process, the final OD value and OD variation being necessary to be agreed.

Straightness: max 0.5 mm/1000 mm.

- Total deviation for tubes with length 6 m: max. 3.5 mm/length.
- Total deviation for tubes with length > 6 m: for each meter over 6 m the tolerance must be increased by 0.5 mm.

Roundness and eccentricity:

- OD and ID roundness deviation shall be within the limits of the OD and ID tolerances.
- Eccentricity shall be maximum 5%.
- Eccentricity calculated by formula:

$$\text{Eccentricity} = \frac{100 \cdot (Wt \max - Wt \min)}{(Wt \max + Wt \min)}$$

Where Wt max, Wt min are maximum and minimum measured wall thickness in same crosssection.

6. Piston Rods Tubes Dimensions & Tolerances

The tubes are cold drawn having OD machined by center-less grinding to final piston rod size plus an agreed small over metal suitable for last grinding operation before chroming.

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Steel grades and dimension range for grinding				
Grade	Delivery Condition	OD	WT	Length
ART H355	+N	25 - 140 mm	3 - 20 mm	6 - 12m
ART H460	+N	25 - 140 mm	3 - 20 mm	6 - 12 m
Tolerance				
OD	+/-0.05 mm for OD <100 mm and +/-0.10 mm for OD >=100 mm			

Final surface finish, Ra: 0.40 µm or better.

Straightness: max 0.35 mm/1000mm.

The tubes are suitable for chroming.

7. Chemical composition – cast analysis, % by mass

Grade	Delivery condition	Correspondent steel grade	C	Mn	Si	P	S	N	V	Ceq
			max.	max.	max.	max.	max.	max.	max.	
ART H355	+N	E355 +N (acc. EN 10305-1)	0.22	1.6	0.55	0.025	0.02	0.009		≤0.49
ART H450	+SR	E355 +SR (acc. EN 10305-1)	0.22	1.6	0.55	0.025	0.02	0.009		≤0.49
ART H460	+N	P460NL +N (acc. EN 10216-3)	0.2	1.00-1.70	0.6	0.025	0.005	0.0075	0.2	≤0.56
ART H525	+SR	E355 +SR (acc. EN 10305-1)	0.22	1.6	0.55	0.025	0.02	0.009		≤0.49
ART H560	+SR	E355 +SR (acc. EN 10305-1)	0.22	1.6	0.55	0.025	0.02	0.009		≤0.49
ART H620	+SR	E410 +SR (acc. EN 10305-1)	0.16-0.22	1.30-1.70	0.10-0.50	0.03	0.02	0.0075	0.08 - 0.15	≤0.56
ART H690	+SR	E410 +SR (acc. EN 10305-1)	0.16-0.22	1.30-1.70	0.10-0.50	0.03	0.02	0.0075	0.08 - 0.15	≤0.60

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Note

1. For grade showing sulfur content up to 0.020%, the sulfur can be added at manufacturer discretion to support machinability. The sulfur will be controlled added after a deep desulfurization.
2. C_{eq} is calculated by formula : $C_{eq} = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$
3. For grades ART H460, ART H620, ART H690 at manufacturer's discretion the elements Nb, Ti and V can be added in order to obtain fine grain structure. The sum of these elements will be maximum 0.20%.
4. Steel grade ART H460 is fully comply also with EN 10216-3- P460NH.
5. Other chemical elements such Cr, Mo, Ni, Al, Cu not included here will be reported in MTR.

8. Mechanical Properties

Grade	Delivery condition	Correspondent steel grade	Upper Yield Strength or Proof Strength R_{eH} or $R_{p0.2}$	Tensile Strength R_m ,	Elongation A,
			min	[MPa]	min
ART H355	+N	E355 +N (acc. EN 10305-1)	min 355	490-650	22
ART H450	+SR	E355 +SR (acc. EN 10305-1)	min 450	min 580	10
ART H460	+N	P460NL +N (acc. EN 10216-3)	min 460	560-730	19
ART H525	+SR	E355 +SR (acc. EN 10305-1)	min 525	min 600	10
ART H560	+SR	E355 +SR (acc. EN 10305-1)	min 560	min 620	10
ART H620	+SR	E410 +SR (acc. EN 10305-1)	min 620	min 690	12
ART H690	+SR	E410 +SR (acc. EN 10305-1)	min 690	min 750	12

9. Impact test

Grade	Delivery condition	Correspondent steel grade	KV min		KV min	
			[Joules]		[Joules]	
			Longitudinal		Transversal*	
ART H355	+N	E355 +N (acc. EN 10305-1)	40 J / - 30°C	Option 1, 3	27J/-30°C	Option 1
ART H450	+SR	E355 +SR (acc. EN 10305-1)	27J / - 20 °C			Option 2
ART H460	+N	P460NL +N (acc. EN 10216-3)	40 J / - 30 °C	Option 3	27J/-30°C	
ART H525	+SR	E355 +SR (acc. EN 10305-1)	27J / - 20 °C			Option 2
ART H560	+SR	E355 +SR (acc. EN 10305-1)	40J / - 20 °C			Option 2

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ART H620	+SR	E410 +SR (acc. EN 10305-1)	40J / - 40 °C		27J/-40°C	
ART H690	+SR	E410 +SR (acc. EN 10305-1)	40J / - 40 °C		27J/-40°C	

*Transversal impact test is possible for the sizes where standard test specimens can be machined from nominal wall.

Impact test values are the minimum granted average absorbed energy for 10x10 mm specimen with Vnotch.

The following impact test options can be provided:

Option 1 - Longitudinal impact test: 40J and 27J transversal at - 40°C

Option 2 – Transversal impact test: 27J at - 20°C

Option 3 - Longitudinal impact test: 40J at - 50°C

Upon request other values/temperatures for impact test can be agreed.

10. Non – destructive testing

SRB tubes (before ID machining) and Piston Rod tubes (before OD grinding) are Non-destructive tested as follows:

- SRB tubes, grades ART H355, ART H450, ART H460, ART H525, ART H560 and all grades for piston rods tubes are UT tested, if Option 4 is selected.
- All **IFR (Improved Fatigue Resistance)** SRB tubes and all grades ART H620, ART H690 are full length Ultrasonic tested, using as reference standard notch disposed in longitudinal and transversal direction, on both External and Internal surface, 3 % Wt depth (with a minimum 0.20 mm), notch length maximum 25 mm, notch width maximum 0.50 mm.

Option 4 - full length Ultrasonic testing, using as reference standard notch disposed in longitudinal and transversal direction, on both External and Internal surface, 3 % Wt depth (with a minimum 0.20 mm), notch length maximum 25 mm, notch width maximum 0.50 mm.

The SRB or Piston Rod tubes having indications over the acceptance level are dressed and re-inspected. The dressed area shall conform to specifications tolerances, contrary the tubes are rejected.

11. Tube ends preparation

- Square cut to the longitudinal axis of the tubes with a slight bevel on outside surface.
- Protected with plastic caps.

12. Lengths

- Minimum and maximum manufacturing lengths according to Table 1. Usually, the tubes shall be supplied in random lengths within 2 m variation.
- As an option fix lengths or multiple of fix length are available with cutting tolerance of -0/100 mm as well as cut to length pieces in range 0.4 - 4 m, cutting tolerance of -0/+3 mm.

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13. Surface protection

SRB Tubes:

Inside and outside surface oiled by immersion in corrosion preventive oil in order to ensure temporary protection against corrosion during about 6 months storage in covered area, out of excessive humidity and/or direct water contact.

Piston Rods Tubes:

Unprotected for last grinding operation before chroming.

14. Marking

Continuous marking along the length of the tube with following information: manufacturer's logo, dimension (OD x ID), steel grade, heat number and the number of standard or other data as per the customers' request.

15. Packaging

Packed in bundles with circular or hexagonal cross-section, bundle weight of maximum 2000 kilograms. The bundles are tied with protected metallic straps to provide protection against mechanical damage and corrosion during storage and in transit.

16. Mill test report

Mill test reports are issued to customer requirements. Usually it comply with EN 10204 – 3.1

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