



FIRST X80 PIPELINE SECTION IN ITALY

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ABSTRACT

Snam Rete Gas decided for the first time to lay a pipeline section in L555MB (X80) steel in Italy as part of the TAP project on high strength steels, sponsored by ENI Group.

This pipeline trunk, 10 km long, will be placed on the Enna-Montalbano line which, for the remaining part, will be built in X65, the maximum steel grade used till now by Snam Rete Gas.

This paper presents information on the pipe and bend production and on the preliminary experimental activity performed for weldability and field bending items.

1 INTRODUCTION

ENI group is working on a gas transportation project aimed to develop and verify the technology for a "LD-HC-HP-HG" (Long Distance - High Capacity - High Pressure - High Grade) gas pipeline named TAP (Trasporto Alta Pressione [1]). Interest in high pressure and high grade pipe steels is due to the increasing necessity of economic gas transportation on long distances between upstream and downstream in an international context.

In the past ENI group has already studied long distance pipeline materials from the economic and pre-feasibility points of view. Now, with TAP project, ENI is going to do an "in field experience" with high grade steels to promote the "gas to market" with the "pipeline" option.

Snam Rete Gas role in the project is related to:

- the construction of a pipeline section in X80 in the Italian natural gas transportation network;
- contribution to the technical characterization of field welded joints for an X100 pilot pipeline;
- analysis of solutions for coating and cathodic protection especially dedicated to long distance pipelines [2].

The pipes and induction bends for this project were supplied by EUROPIPE and Mannesmann, respectively, whose references are:

- more than 20 years of experience in the production of high strength steel pipes and induction bends [3] [4];
- more than 500 km of line pipe and more than 1000 induction bends supplied in Grade X80 or L555MB [5];
- experience in the production of X100 and X120 pipes [5].

2 THE PIPELINE

The Snam Rete Gas transmission system (Figure 1) consists of 30,545 km of natural gas pipelines (as at 31/12/04) with a diameter from 25 to 1,200 mm with the maximum steel grade of X65 and a pressure between 0.5 and 75 bar.

Two 48"x16.1mm pipelines at 75 bar carry Algerian and Libyan gas across the Sicily Island from the off-shore approach of Mazara del Vallo to the North of Italy. A third line, with the same characteristics, is under construction in order to increase the transportation capabilities of the Italian gas network. The experimental section, about 10 km long, is included in the trunk from Enna to Montalbano of this new line (Figure 2). The steel grade is L555MB according to European Standard that is equivalent to X80, the thickness is 16.1 mm..

3 TECHNICAL FEASIBILITY

The X80 pipe laying and all the field activities will be carried on according Snam Rete Gas specifications reviewed in order to include L555MB X80 steel.

For this reason Snam Rete Gas needed a preliminary experience before laying the X80 pipeline to test the technical feasibility and so an experimental activity about weldability and field bending has been performed.

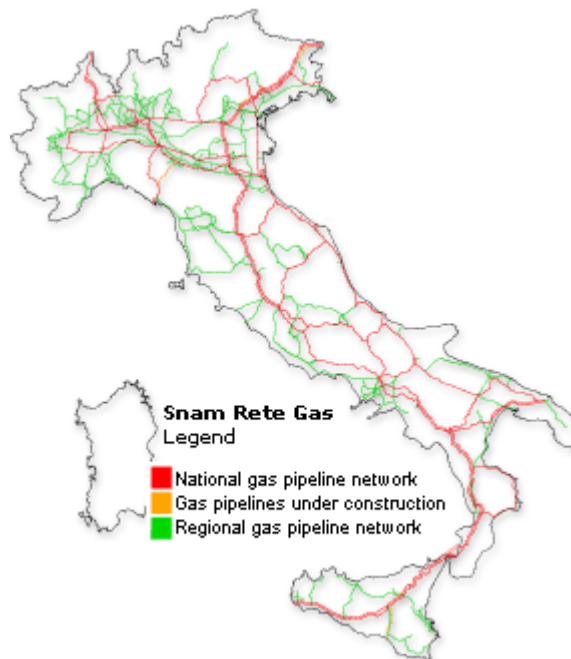


Figure 1: Snam Rete Gas transmission system

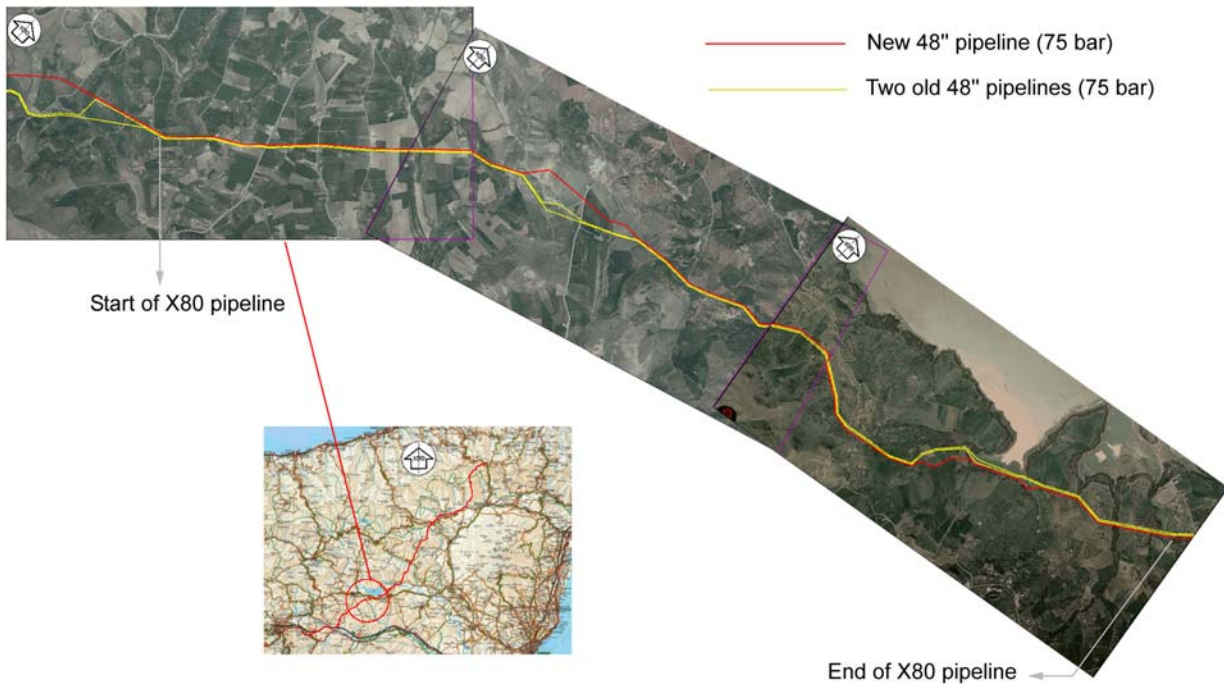


Figure 2: Panoramic view of the X80 pipeline

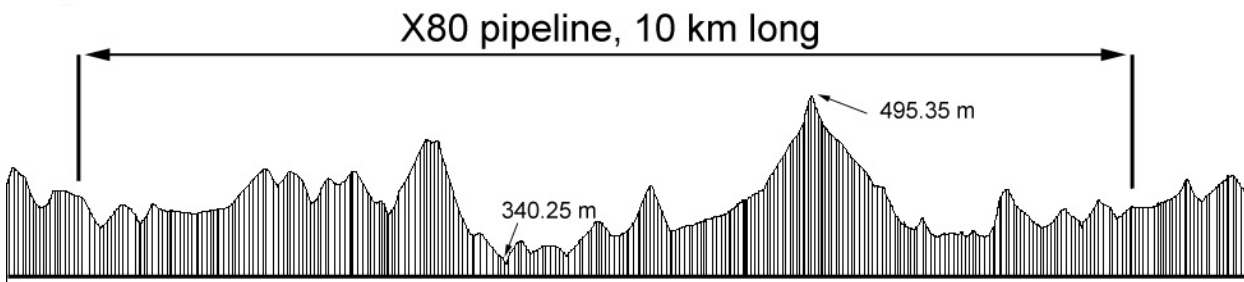


Figure 3: Pipeline profile

3.1 Weldability

Aim of this activity was to assess the manual and automatic weldability for L555MB/X80 pipes. The experimental campaign was executed on four joints between X80 48" x 15.1mm rings and one more joint between X80 48" x 15.1mm and X65 48" x 15.1mm rings. For the welders it was the first experience with a pipe of such a steel grade. The welding procedures and consumables have been chosen to investigate with few rings a scenario as rich and realistic as possible. We tested welding procedures suitable for line (GMAW- gas metal arc welding) and for connection and tie-in (SMAW – shielded metal arc welding) and we also tested internal, external and full thickness repairs on all these joints. Two joints were welded with GMAW procedure with different weld metals (one with mechanical characteristics similar to X80 and the other lower). Two other joints were welded with SMAW procedure with the root pass in cellulosic vertical up welding and with the fill passes in basic vertical up for one and basic vertical down for the other one.

Then the welded rings have been investigated by destructive and non-destructive tests. The radiographic examination didn't reveal any kind of defect on all joints and repairs. The destructive tests performed (hardness [6], Charpy-V transition curve on weld metal and on heat affected zone (HAZ) [7], ISO tensile test [8], weld metal cylindrical tensile test [9], bending test [10] and CTOD in weld metal and in HAZ [11]) are the same reported in the actual Snam Rete Gas specification (but with a more conservative temperature for the Charpy and CTOD tests in order to anticipate some future changes in the specification).

The only critical tests have been, for all the joints, the CTOD tests in HAZ at -10°C: this fact confirms a high grade steel (X80) decline in HAZ toughness.

Finally this activity confirmed a good weldability for pipes made in L555MB/X80 with both SMAW and GMAW techniques (with both traditional and high grade weld material) but it has also highlighted the importance of the welder experience in order to obtain the target value for toughness in HAZ.

3.2 Cold bending

Aim of this activity was to bend in field some X80 48" inch pipes with a traditional bending machine in order to verify the feasibility of this process and to highlight eventual critical aspects.

The experimental campaign was executed on four X80 pipes with 48" inches diameter, 15.1mm thickness and without coating (it has been considered marginal the effect of friction between pipe coating and bending machine).

The machine chosen is the same normally used for in field bending of X65 36" and 48" Snam Rete Gas pipes, but the chassis has been reinforced to sustain higher actions. For the machine operator this was the first experience with a pipe of such a steel grade.

We tried to obtain curves with the maximum angle (1,5° for each longitudinal length of one diameter) allowed from actual Snam Rete Gas internal specification leaving two straight pieces at the pipe ends with the minimum length of two diameters. At the end of each bending process has been performed a visual evaluation and a caliper pig test which gave always a good response. The bended pipes didn't show in any case unacceptable wrinkles or dents.

This experience demonstrates that it is possible to bend in field L555MB or X80 48" x 15.1mm pipes with the same machine used for lower grades .

As for traditional pipes, the machine operator has to increase the action on the pipe as he goes on with the beats and the actions needed at each beat are considerable higher than those on X65 pipes. So the operator has to give higher forces to obtain the target angle but he must also pay attention to not buckle the pipe. For these reasons new machine operator coaching is needed to increase experience on this new steel.

4 PRODUCTION RESULTS

4.1 Manufacture of L555MB/X80 Pipes

Project Information

EUROPIPE Large Diameter Pipe Mill Muelheim produced for X80 Pilot Project 705 SAW pipes of material grade L555MB in two items. The quantities are given in Table 1. The production was performed on 18 m line by the UOE process. The TMCP rolled plates of both items were delivered by the plate mills of Mannesmann (MRM) and Dillinger Hütte (DH). The slabs for the MRM plates were cast by Hüttenwerke Krupp Mannesmann (HKM) in Duisburg and the slabs for DH plates by DH steel works, respectively. The pipes have been produced according to EN 10208-2 and Snam Rete Gas specification GASD C 01.01.00 Rev. 1. They have been coated epoxy resin lining inside and 3-layer PE outside by Eupec Mülheim.

Table 1: Delivered quantities and pipe properties

a) Delivered quantities

Item	WT [mm]	OD [mm]	Grade	No. of pipes	Average Length [m]	Slab/Plate Supplier
001	16.1	1216.5	L555MB	504	14.4	DH / DH and HKM / MRM
002	18.9	1222.1	L555MB	201	14.3	

b) Chemical composition

	C	Si	Mn	P	S	Al	Cu	Cr	Ni	Mo	V	Nb	Ti	CE _{IW}
Max.	0.10	0.35	2.00	0.020	0.003	0.050	0.10	0.10	0.10	0.25	0.01	0.06	0.03	0.45

c) Mechanical properties (strip specimen in transverse direction)

		Specified Values	Production Results (average values)	
			Item 001	Item 002
YS (R _{10.5})		555-675 MPa	609 MPa	601 MPa
TS		625 MPa (min.)	709 MPa	700 MPa
Elongation		18 % (min)	20.3 %	19.3%
Y/T Ratio		0.90 (max.)	0.86	0.86
Impact Energy @ -10 °C	BM	135/180 Joule	275 Joule	262 Joule
	Weld	30/40 Joule	190 Joule	208 Joule
	HAZ	30/40 Joule	102 Joule	165 Joule

Mechanical Properties

The chemical composition (max values) and mean mechanical properties of the pipes are summarised in Table 1. Tensile and toughness properties will be discussed below in detail on the basis of statistical data of item 001 (WT: 16.1 mm; OD 1216.5 mm) because this was the larger quantity.

Figure 4 shows the statistical distribution of tensile properties of the base material in transversal direction. The tests were performed on strip specimen at ambient temperature. The statistics are based on 56 individual test results. The histograms show usual distributions of all tensile properties in the specified limits for grade L555MB/X80. It can be concluded that the alloying concept and rolling technology of both plate suppliers are suitable for the production of L555MB (or similar steel grades) in big quantities for SAW pipes.

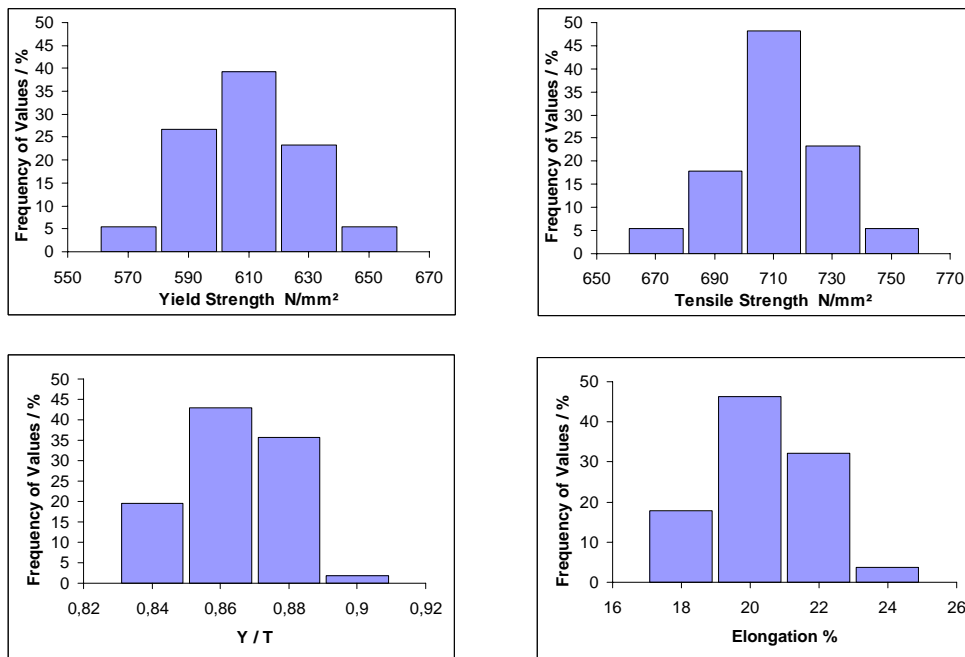


Figure 4: Statistical evaluation of tensile tests on strip specimen in transverse direction (WT: 16.1 mm; OD 1216.5 mm; L555MB)

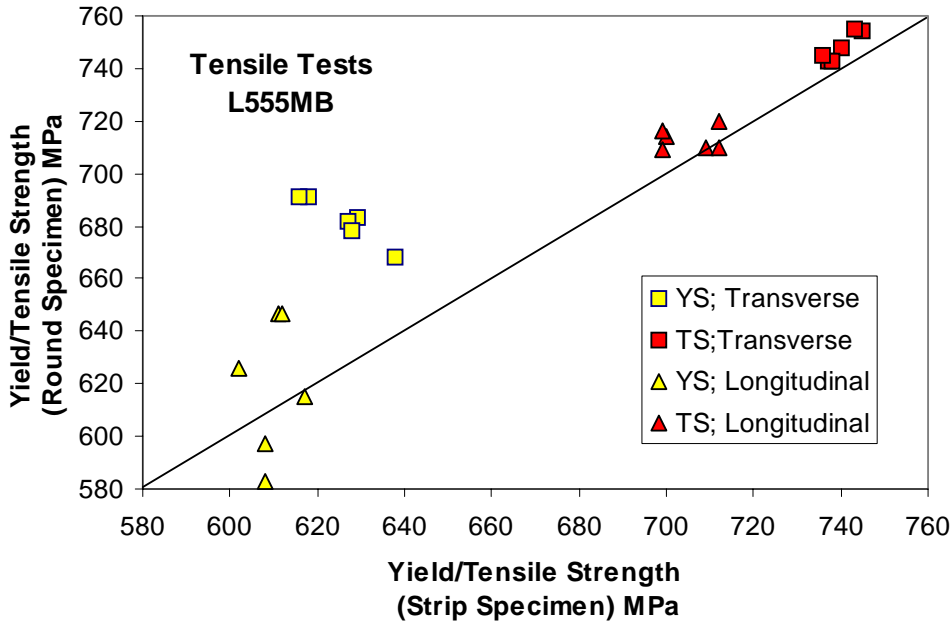


Figure 5: Correlation of yield strength (YS) and tensile strength (TS) between strip and round specimens in longitudinal and transverse directions (WT: 16.1 mm; OD 1216.5 mm; L555MB)

The release criteria for tensile properties is described in line pipe specifications as tensile test in transverse direction on flattened strip specimen. However, the flattening during specimen preparation leads to a distinctive decrease of yield strength because of the well-known Bauschinger-effect in transverse direction. This phenomenon does not exist in longitudinal direction because there is no flattening for longitudinal samples. Fig. 5 shows the correlation of yield and tensile strengths between strip specimen and round specimen in both directions.

The necessity to fulfil the tensile requirements on flattened transverse specimen lead to produce a base material that is actually stronger than required. This effect is more distinctive in case of high strength steel grades in comparison to lower grades. Fig. 6 shows the correlation between round and strip specimens of L555MB and X65.

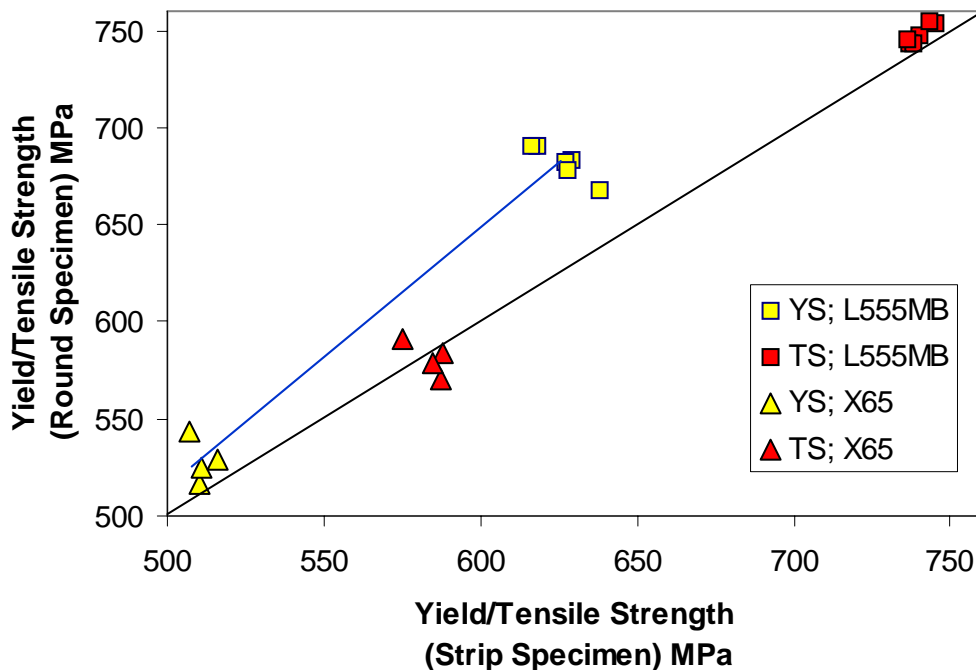


Figure 6: Correlation of yield strength (YS) and tensile strength (TS) between strip and round specimens in longitudinal and transverse directions

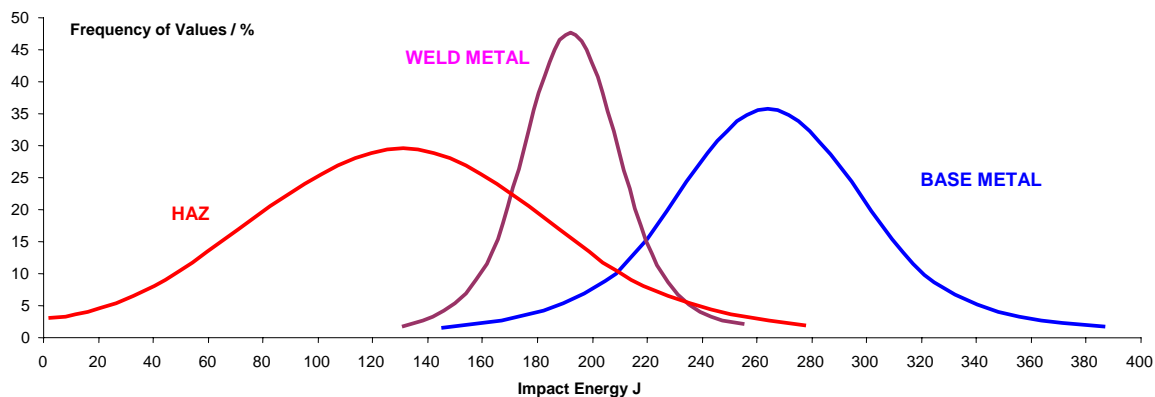


Figure 7: Statistical distributions of impact energy values at -10°C for base metal, weld seam and HAZ (mid wall position; WT:16.1 mm; OD 1216.5 mm; L555MB)

The level of carbon equivalent (CE) in TMCP rolled heavy plates usually does not lead to problems regarding the base metal toughness because of the extremely fine grain size of this material. L555MB usually consists of predominantly bainitic microstructure. Due to the special welding concepts of EUROPIPE the weld seam toughness is also on an adequate level and fulfils the toughness requirements. However, higher CE and the grain coarsening because of the twofold heat input by the inside and the outside welding in the root position of the Heat Affected Zone (HAZ) may lead to formation of local brittle zones in the HAZ. Figure 7 shows statistical distributions of impact energy values for base metal, weld seam and HAZ. These distributions are based on 56 mean values of item 001 (WT: 16.1 mm; OD 1216.5 mm). The tests have been performed at -10°C on specimens of mid wall position which is similar to root position at this wall thickness.

EUROPIPE performs intensively R&D activities and investments regarding base material and welding technology to reduce the size and the probability of local brittle zones. Nevertheless, the above mentioned physical phenomena both the Bauschinger-effect and the local brittle zones in root position of the HAZ must be taken into consideration for the description of specified requirements on X80 and higher grades.

4.2 Manufacture of L555MB Induction Bends

Mannesmann Bending Plant fabricated for the project described above in total 46 induction bends of size 48" x 25.9 mm min. wt. in Material Grade L555 MB/X80. Mother Pipes for bending differ from normal line pipe regarding the chemical composition to be suitable for the induction bending process and wall thickness in order to guarantee the mandatory minimum wall thickness requirements after bending. Therefore TMCP rolled plates from Mannesmann Plate Mill in Muelheim with special designed analysis were used as pre-material. The Mother Pipes were fabricated at EUROPIPE 18 m line in Muelheim. Plate and Mother Pipe fabrication followed the requirements of EN 10208-2 and SNAM-Specification GASD C 01.01.00 Rev. 1. The bending radius was 7D, bending angles between 20° up to 60° . All bends with straight tangents of 600 mm length.

Hot Bend Production

Induction bending is a largely automated process. The "transformation" of straight pipe to pipe bend takes place only in the heated narrow annular zone which moves continuously along the length of the bend as the bending process advances (Figure 8 and 9). The heating of this zone is effected by means of an induction ring. An alternating current passes through the inductor and induces a potential which causes an eddy current in the material to be bent.



Figure 8: Hot induction bending of 48" line pipe at Mannesmann Bending Plant



Figure 9: Detailed view on induction coil and heated zone during bending

To avoid high ovalisation in the bend body the width of the bending area must be limited. The formed material, immediately behind the inductor, is cooled by water spray. During bending, the temperature of the bending zone is measured continuously and held constant, at a predetermined value above Ac3. The front end of the pipe is clamped to a pivoted arm, the bending force acts axially on the pipe. Set to the desired bending radius, the bending arm then describes a circular arc around its pivot point. As a result of the radial thrust, applied to it, the pipe automatically follows this curve.

Bending was followed by full body tempering heat treatment in a gas fired bogie hearth furnace. This in order to achieve the specified mechanical properties for grade L 555 MB material.

After heat treatment manual NDE, dimensional control and final inspection were carried out. All inspection was in accordance with Snam Rete Gas Specification GASD-C.02.04.00 Rev.2 in connection with "Nota Tecnica per curve X80". The specified maximum ovality for the bend body was 2.0% and for the bend ends 0.7%. The actual values measured were all below these requirements. The decrease of wall thickness in the extrados after bending was measured to 5-6 %.

All Bends got PU-coat (Iamsub) from outside and epoxy resin lining from inside (Figure 10).



Figure 10: Iamsub coated 7D-bends with epoxy resin lining inside, size 48" in Grade L 555 MB

Mechanical Properties

Destructive Testing was performed on 1 off qualification test bend and 2 production bends. The chemical composition and mechanical properties of the bends are listed in Table 2.

Table 2: Hot induction bend properties

a) Chemical Composition of the Base Material in Weight %

	C	Si	Mn	P	S	Al	Mo	Ni	Nb	CE_{IIW}
average	0.08	0.26	1.75	0.011	0.0005	0.03	0.27	0.22	0.070	≤ 0.47

b) Mechanical Properties

		Specified Values	Production Results (average values)
Yield Strength (R_{t0.5})		555 MPa (min.)	594 MPa
Tensile Strength		625 MPa (min.)	695 MPa
Elongation		18 % (min.)	20 %
Y/T Ratio		90 % (max.)	86 %
Impact Energy (CVN, mid-wall, @ - 10°C)	BM	105 / 140 Joule	265 / 324 Joule
	Weld	30 / 40 Joule	59 / 138 Joule
	HAZ	30 / 40 Joule	263 / 302 Joule

Figure 11 is showing the strength properties of base material in the different zones of the bends in comparison with the values of the original mother pipe tested before bending.

Due to the process related heating during induction bending the yield strength and tensile strength of the mother pipe, produced from TMCP rolled plate, is reduced by 50 MPa to 100 MPa. The analysis of the pre-material is specially designed in order to guarantee the minimum specified requirements after bending. Therefore the strength level of the mother pipe needs to be on a significant higher level than the specified minimum values for Grade L555 MB. The single values measured along the bend from bend start to bend stop in the extrados, intrados and neutral zone are all in a small scatter band, showing the homogeneity of the entire bend. Also the elongation A5 is on an excellent level of 20% for base material and weld metal. The toughness properties are shown in Figure 12 as transition curves for extrados, intrados, HAZ and Weld Metal. All samples were taken transverse at mid-wall thickness. Due to the heat treatment during bend fabrication, the toughness of the HAZ is clearly improved compared to the HAZ toughness in the as-welded condition on the line pipes. For the weld metal the transition temperature seems to be at -10 / -20°C after bending, where first single values deviate from the upper shelf energy values.

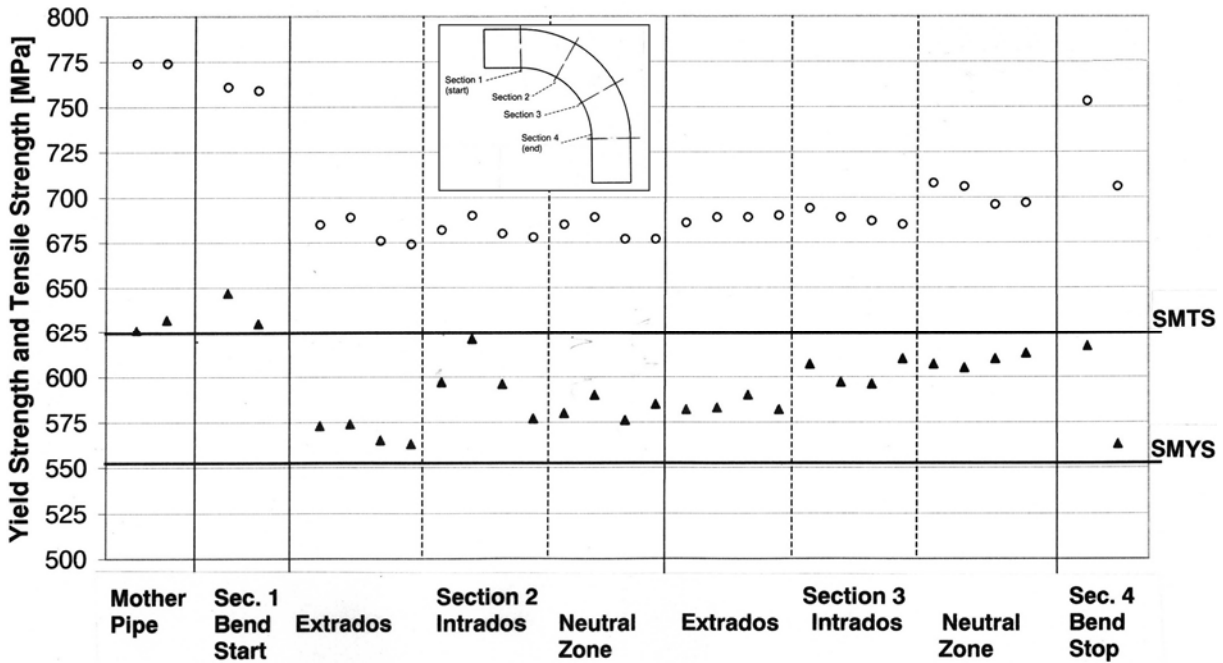


Figure 11: Strength Properties of 7D-Induction Bends, Grade L 555 MB (single values, flat-transverse), tested in different sections of the bend

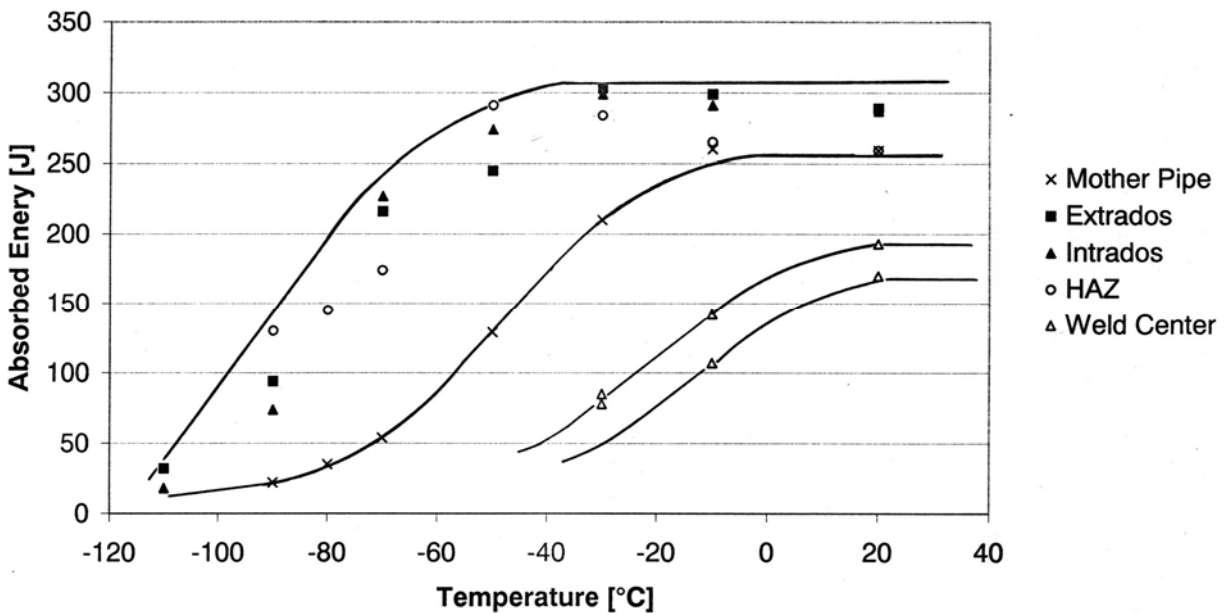


Figure 12: Toughness Properties of 7D-Induction Bends, Grade L 555 MB (average values, transverse)

5 CONCLUSION

Inside TAP project, sponsored by ENI Group, Snam Rete Gas decided to lay for the first time a small pipeline section in L555MB/X80 in Italy. This pipeline trunk, 10 km long, will be placed in Sicily island on the Enna-Montalbano line. The pipe laying is starting on 21st March of this year and will end in 2006. At that time all the information about the first laid line in Italy with this high grade steel will be available.

At this moment the activities of preliminary feasibility study and the production of pipes and hot bends are finished.

The weldability and cold bending experimental activities gave both good results. The weldability with both SMAW and GMAW techniques has been confirmed and it has been highlighted the importance of the welder experience in order to obtain the target value for toughness in HAZ (where CTOD testing could be

critical). Some tests have demonstrated that it is possible to bend in field L555MB/X80 pipes with the same machines used for lower grades.

The L555MB/X80 EUROPIPE production has been successfully performed and all pipes are ready for pipe laying. The fabrication of L555MB/X80 hot induction bends was qualified without any deviation to the specified requirements.

The only issues that have to be discussed in the future by both the gas transportation company and the pipe manufacturer are the influence of Bauschinger-effect and the avoidance of local brittle zones in the HAZ of X80 and higher grades.

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