4th InnoTech Partner Event,
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Development of a Plate and Pipe Qualification Program for Critical Service Pipelines

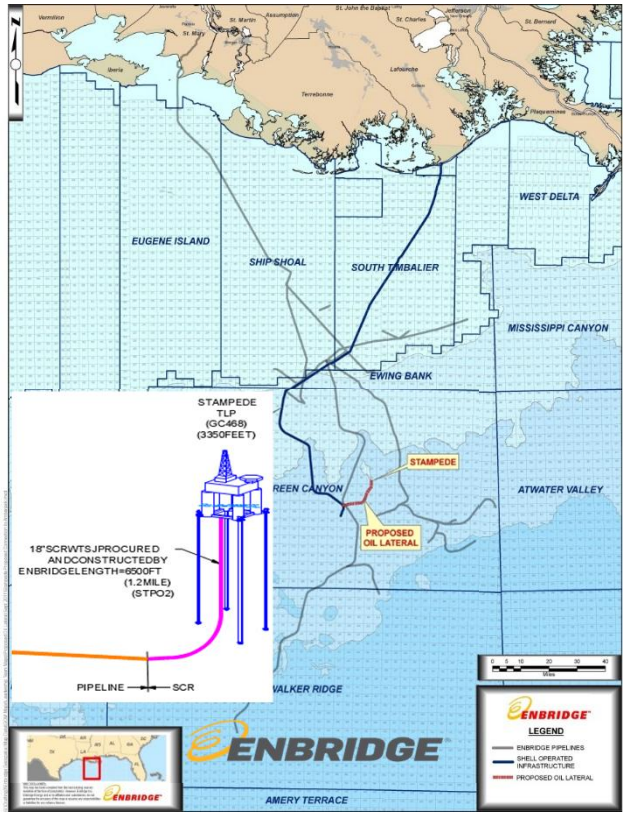
Richard Hill and T.S Kathayat

Sequence of Presentation

- Project Details
- Supplemental Requirements
- Objectives
- Plate Manufacturing Process
- Pipe Manufacturing by JCOE Process
- Behaviour of Mechanical Properties - Plate to Pipe
- Comparison of Pipe End Dimensions - Manual vs. OMS
- New Automatic Pipe Dimension Measurement System Adopted by Welspun
- Summary

Project Details

- Project Name:
  - **18-inch Stampede Oil Export SCR**
- Pipe Size:
  - **18" (457.2 mm) OD x 1.0" (25.40) mm WT**
- Grade:
  - **API 5L X65MO / L450MO PSL2**
- Plate Size:
  - **25.4 x 1349 x 12,375 mm**
- Plate Supplier:
  - **voestalpine, Grobblech GmbH**



Supplemental Requirements

- Supplemental requirements were defined for the steel plate and pipe manufacturing processes . Emphasis was on obtaining information covering process control and statistical assessment used to ensure the total population of plates and pipes met the agreed performance criteria.
- Information specific to steel melting , secondary refining , continuous casting and plate rolling was discussed in detail. An agreed MPS/ITP was developed between the steel/ plate supplier and the line pipe manufacturer.
- Supplemental line pipe requirements focus on mechanical and dimensional properties that would impact either the installation or the operation performance. Achievable values and tolerances were agreed based on historical data.
- **All supplemental requirements were addressed on the basis of adding value to the project and optimal performance of the product. Unnecessary restrictions were avoided and the relationship between the plate supplier and line pipe supplier was maintained to ensure there was a clear understanding of roles and responsibilities.**

Objectives

The characterizing of plate mechanical properties distribution along the length and width of the mother plates	• To know the plate to pipe change in mechanical properties during pipe forming.
The optimization of cold expansion ratio during mechanical expansion	• To reduce variation in the YS as well as to insure tight dimensional control of pipes.
The selection of welding consumables, essential welding parameters and weld groove configuration	• To optimize strength, toughness and hardness of weld and HAZ.
The influence of plate chemical composition	• To determine dilution during welding and response to the thermal cycles related to the welding process.
The mitigation of risks and developments at the both plate and pipe manufacturing stages	• To meet the critical challenges and the successful delivery of finished pipes as per the client specification.

PLATE MANUFACTURING PROCESS

Production Route for SCR Plates

BOF – LD Converter

- Decarburisation
- Dephosphorisation
- Temp adjustment

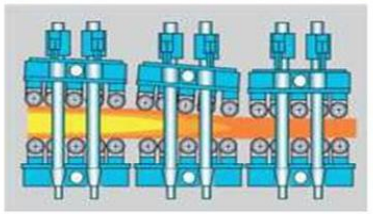
Ladle Refining

- Slag free tapping
- Calcium treatment-low 'S'
- De-oxidation
- Main alloying
- Lime addition

Vacuum Degassing

- Low nonmetallic inclusions,
- Denitrogenisation
- Dehydrogenisation
- Desulphurisation
- Trim alloying

Slab Casting



- Re-oxidation prevention
- Prevention of surface & internal cracks
- SMART-technology for soft reduction to minimize center segregation

Plate Rolling

- Close dimensions
- Better surface quality
- Flatness control

Plate ACC

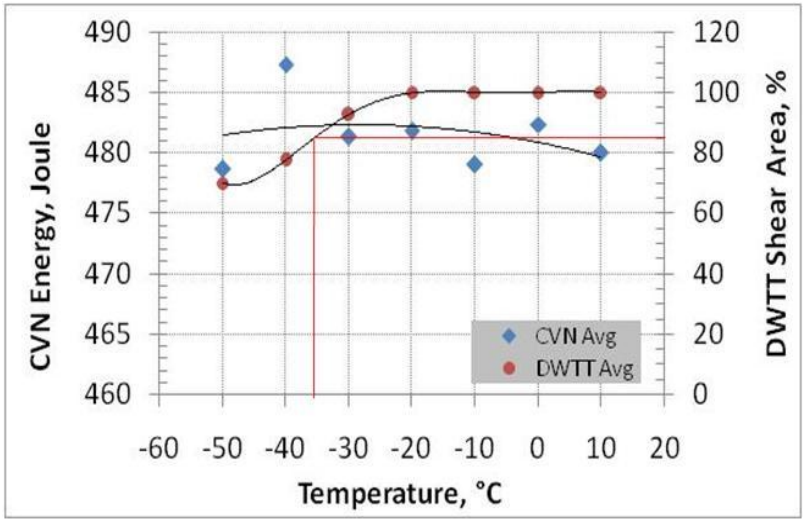
- TMCP and accelerated cooling
- Homogeneous fine-grained structure

- High strength and excellent toughness
- Perfect sour gas-resistance.

Information Source:
voestalpine Austria

Alloy Design

- Use of TMCP for plate rolling; taking advantage of Nb for the development of predominantly acicular ferrite grains across the full plate thickness.
- Carbon maintained at very low level to utilize the full potential of Nb rather than precipitation of Nb (C,N).
- Addition of Cr was beneficial in the reduction of Luder strain and the development of a continuous yielding stress strain response.
- Titanium nitrogen ratio was maintained below 4:1 to ensure heat affected zone toughness was acceptable.



At 85% DWTT SA, DBTT is -35 deg C and CVN energy is 481 Joule.

Chemical Composition, wt%																
C	Si	Mn	P	S	Al-t	Cr	Nb	Ti	N	B	Ca	CE (IIW)	Pcm	Nb+V+Ti	Al/N	Ti/N
0.04	0.30	1.50	0.010	0.010	0.040	0.15	0.045	0.015	0.0075	0.0005	0.0045	0.34	0.14	0.06	7	3.2

PIPE MANUFACTURING BY JCOE PROCESS

Plate UT and Edge Milling

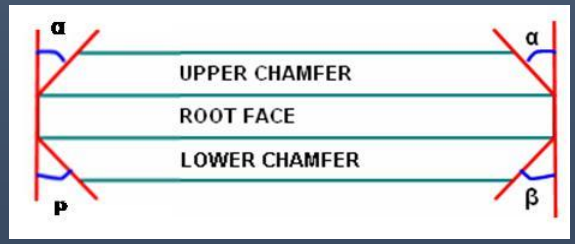
»State-of-art equipment having self evaluation feature with respect to various international standards.

» Plate Edge detecting system with laser sensor to position the probes for edges.

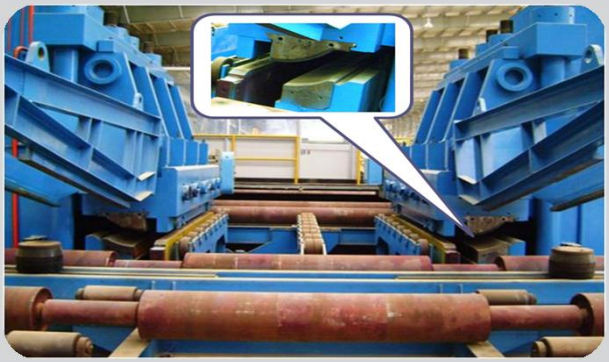
» Sensitivity 3 mm FBH

» Plate surface coverage = 100%

» Preparation of bevel geometry (Single and Double “V”) on top and bottom of the plate edges as per weld joint design.



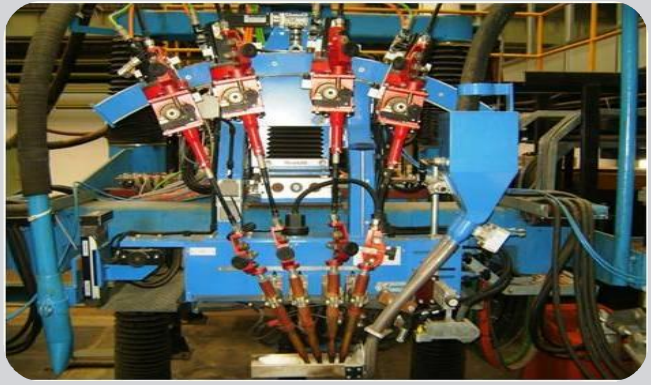
Edge Crimping & JCO Forming Press



» Crimping Press - 3000 MT Force
» Automatic edge bending machine with capability to produce predefined radius profile by specially designed multi radius tool to achieve desired profile minimizing peaking.

» State-of-the art JCO forming Press (7800 MT) with PLC based auto correction to achieve controlled formation and desired profile
» Minimizing residual stress uniformly distributed across circumference.
» Uniform behaviour of compression and tension properties of material.
» To achieve excellent pipe geometry
» Reduction in Bauschinger effect by intelligent logic controlled formation
» Forming Parameters:
Tool Width: 200 mm, Tool Radius: R-135 mm
Tool Height: 100 mm, Bottom Die Gap: 180 mm
No. of Strokes: 17, Operating Pressure (Max.): 220 Bar

Submerged Arc Welding – ID and OD



» Specially installed thermal controlled pre-heating system.
» ID: 3 wire tandem: 1 DC (2000 A)+2AC (1500 A)
» OD: 4 wire tandem: 1 DC (2000 A)+3 AC (1500 A)
» Welding speed: 0.5 to 3 m/min
» Double motorized guide wheel for auto seam tracking with CCTV camera for (ID)
» Laser seam tracking with CCTV camera for (OD)
» Online digital control to ensure sound welding quality with defined heat input

» Online welding parameter recording system for each pipe
» Flux storage temp >35 ºC & humidity <70%
» Flux baking at 260-350 ºC for 2 h
» Closed loop automatic flux handling system to ensure diffusible hydrogen <0.03%.
» In-house testing facility for flux moisture Content

Welding Consumables for CVN at -20 °C

Concern:

- CVN energy at -20^{0}C [Individual = 45 J & Average = 60 J] in weld

Root Cause:

- At the low D/t ratio, it becomes difficult to obtain consistent tough weld having higher CVN energy and CTOD at temperature of -20 °C.

Corrective Action:

- Different combinations of wire and flux were tried before execution of the order and finally Ni wire was chosen for consistent results for weld toughness at -20 °C. Role of elements is given below:
  - » Nickel increases strength and toughness as it promotes acicular ferrite in weld metal.
  - » Manganese functions both as deoxidizer and also imparts strength.
  - » Titanium restricts formation of harmful carbide precipitation.

Welding Consumables With Polarity & Position			
Inside		Outside	
DC	EA2TiB (LNS140TB)	DC	EA2TiB (LNS140TB)
AC1	EA2TiB (LNS140TB)	AC1	EF3 (S3NiMo)
AC2	EM12K (IN61)	AC2	EA2TiB (LNS140TB)

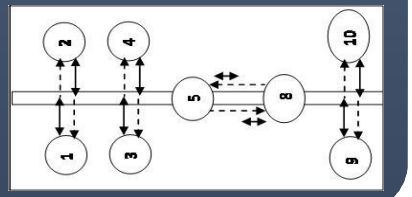
Chemical Composition of Wires in wt%			
Element	EF3 (S3NiMo)	EM12K (IN61)	EA2TiB (LNS140TB)
C	0.11	0.088	0.07
Mn	1.73	0.956	1.11
Si	0.25	0.222	0.25
P	0.008	0.015	0.01
S	0.002	0.005	0.01
Cr	0.02		0.04
Ni	0.93		0.01
Mo	0.53		0.051
Cu	0.01	0.051	0.01
Sn	0.001		0.01
Al	0.002		0.01
V	0		0.01
Ti	0		0.1
B	0		0.015
N	0		0.003

Mechanical Cold Expander & AUT

» Mechanical expanders with precisely logic controlled strokes & specially designed tooling to achieve desired mechanical properties (YS/TS) uniformly distributed and precise dimensional tolerance.

» Flexible multiple tandem to cover full weld and 50 mm HAZ.
» Audio/visual alarm with paint spray for defect location and decoupling.
» A-Scan & strip chart display & reports.
» PLC controlled probe movement to ensure minimum untested zone at the pipe ends.

I+I+On Bead+I



BEHAVIOUR OF MECHANICAL PROPERTIES - PLATE TO PIPE

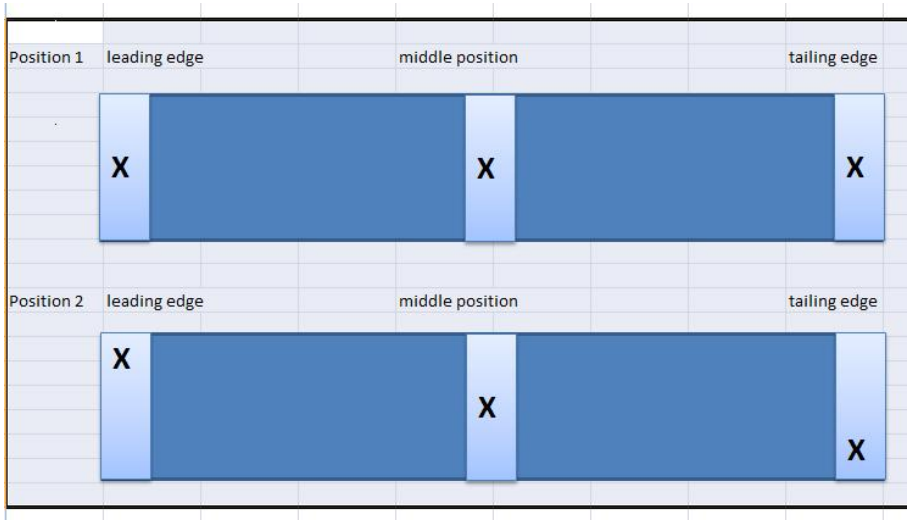
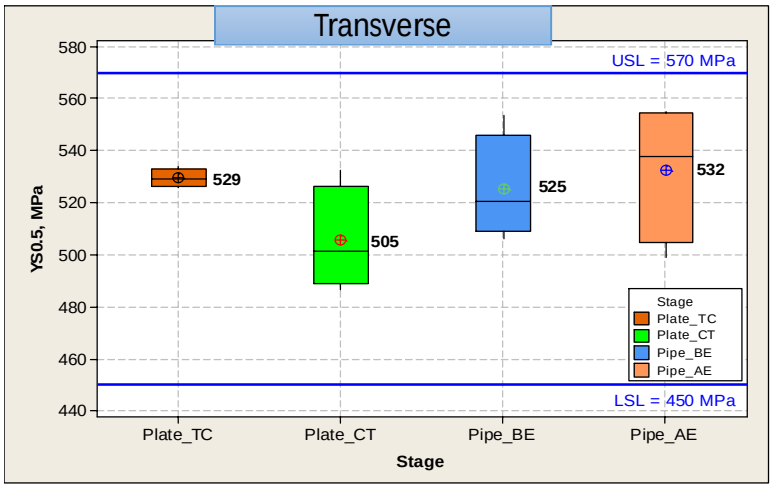


Plate to Pipe: Yield Strength



TC = Plate RMTC
CT = Control Tensile at Welspun
BE = Before Expansion
AE = After Expansion

- Transverse:
  - YS0.5 increased by 20 MPa from plate_CT to pipe_BE and further increased by 7 MPa after expansion
- Longitudinal:
  - YS0.5 increased by 42 MPa from plate to pipe

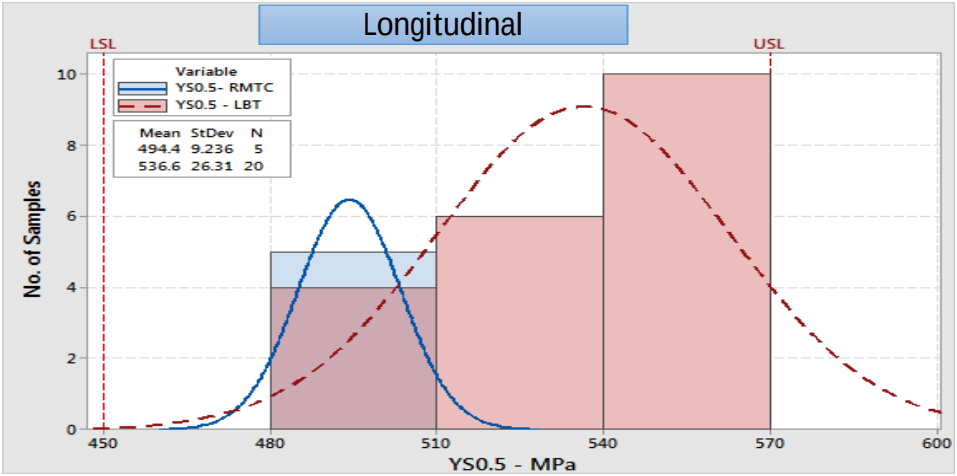
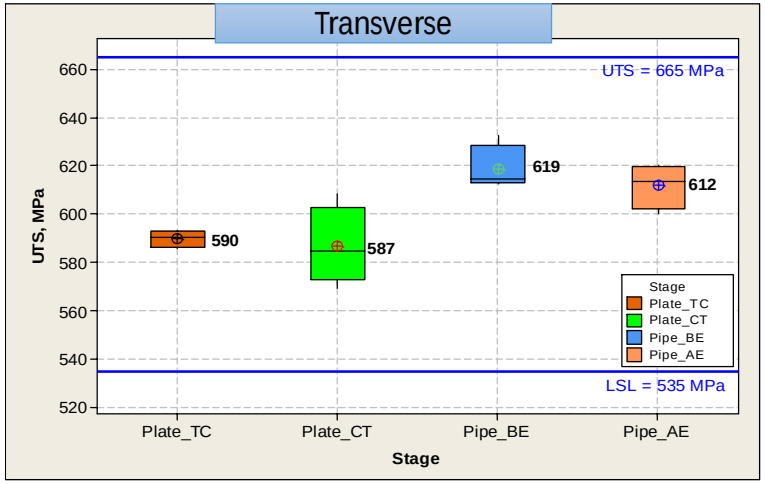


Plate to Pipe: Ultimate Tensile Strength



TC = Plate RMTC
CT = Control Tensile at Welspun
BE = Before Expansion
AE = After Expansion

- Transverse:
  - UTS increased by 32 MPa from plate_CT to pipe_BE and further decreased by 7 MPa after expansion
- Longitudinal:
  - UTS increased by 39 MPa from plate to pipe

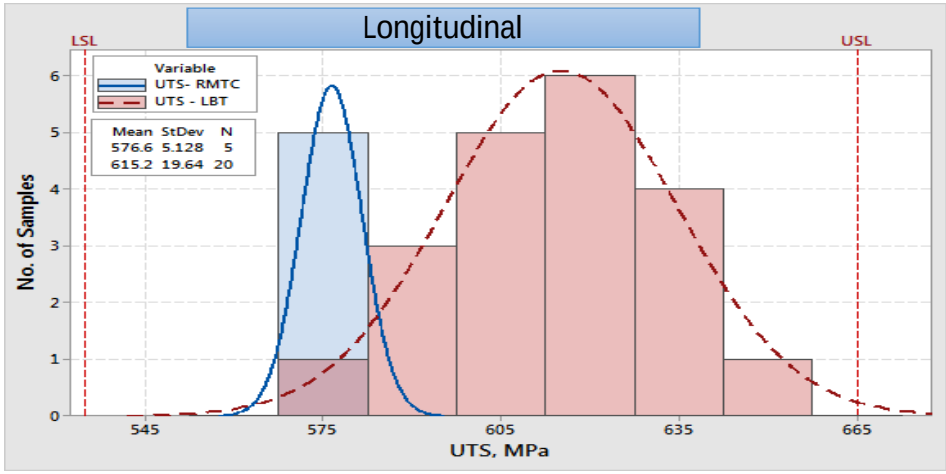
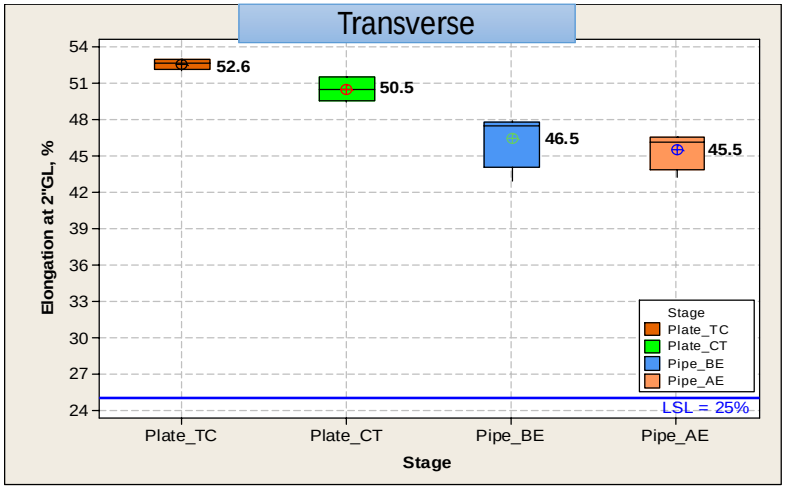


Plate to Pipe: Elongation



TC = Plate RMTC
CT = Control Tensile at Welspun
BE = Before Expansion
AE = After Expansion

- Transverse:
  - Elongation decreased by 4% from plate_CT to pipe_BE and further decreased by 1% after expansion
- Longitudinal:
  - Elongation decreased by 8% from plate to pipe

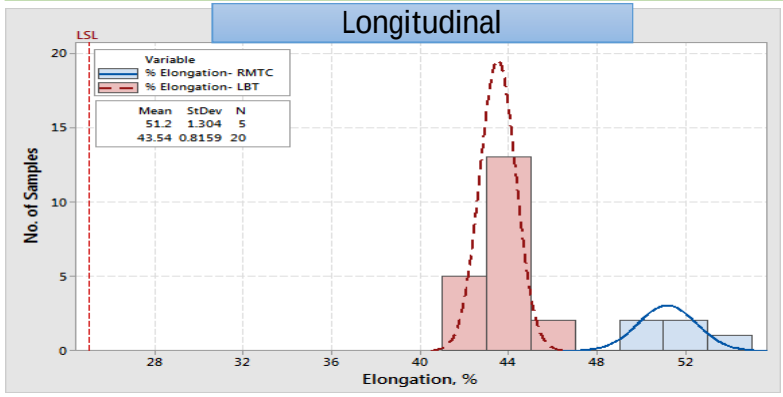
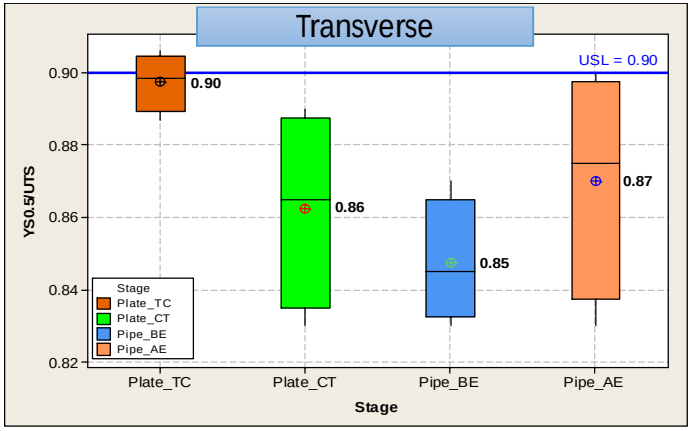


Plate to Pipe: Yield/Tensile Ratio



TC = Plate RMTC
CT = Control Tensile at Welspun
BE = Before Expansion
AE = After Expansion

- Transverse:
  - YS0.5/UTS decreased by 0.01 from plate_CT to pipe_BE and further increased by 0.02 after expansion
- Longitudinal:
  - YS0.5/UTS increased by 0.015 from plate to pipe

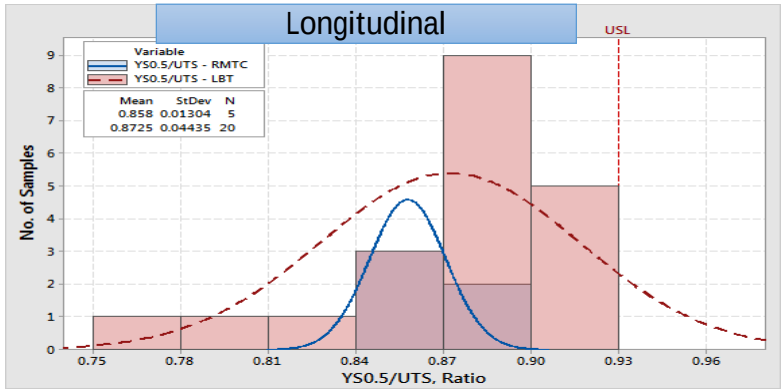
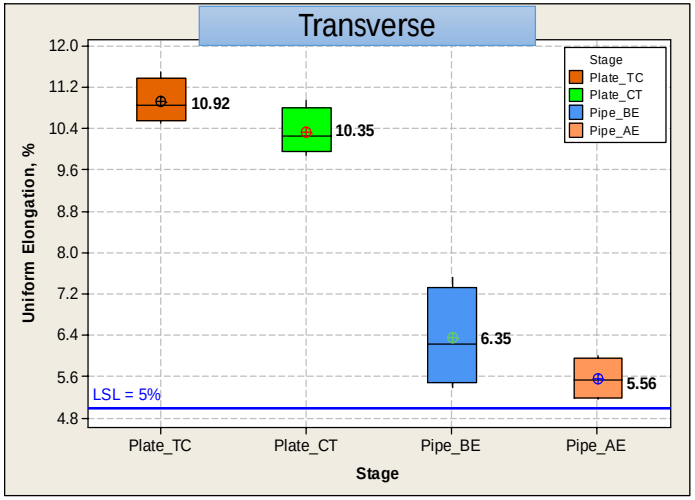
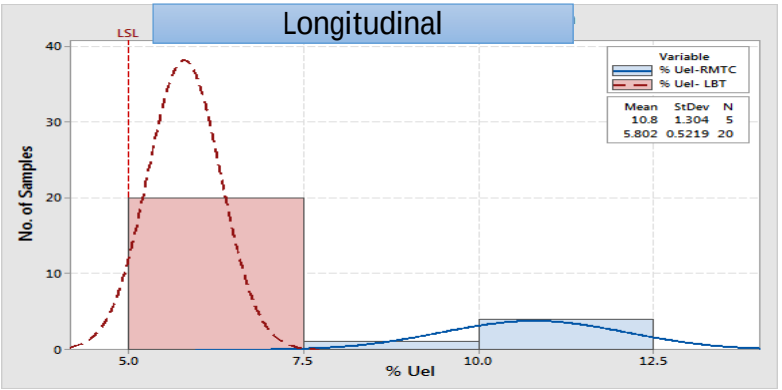


Plate to Pipe: Uniform Elongation



TC = Plate RMTC
CT = Control Tensile at Welspun
BE = Before Expansion
AE = After Expansion

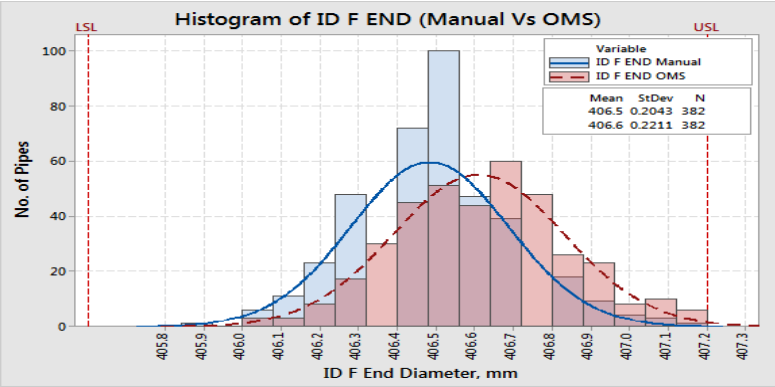
- Transverse:
  - Uniform elongation decreased by 4% from plate_CT to pipe_BE and further decreased by 0.79 after expansion
- Longitudinal:
  - Uniform elongation decreased by 5% from plate to pipe



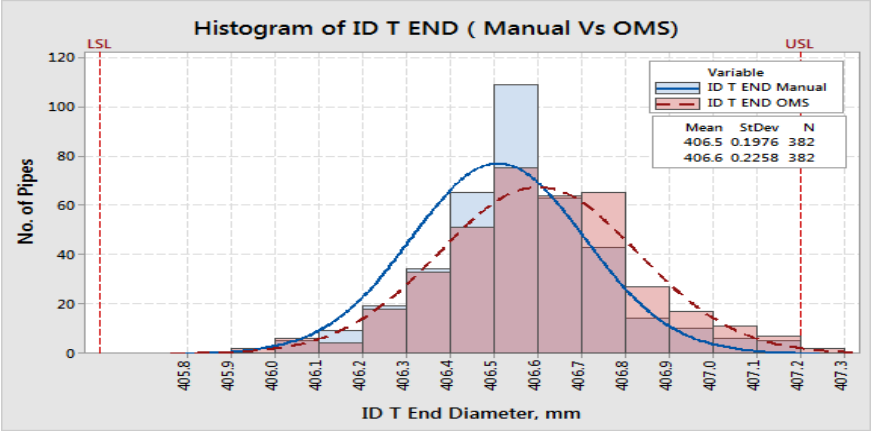
COMPARISON OF PIPE END DIMENSIONS - MANUAL VS. OMS

Pipe Internal Diameter [F End and T End]

SPECIFICATION LIMITS: LSL = 405.60 mm, USL = 407.20 mm

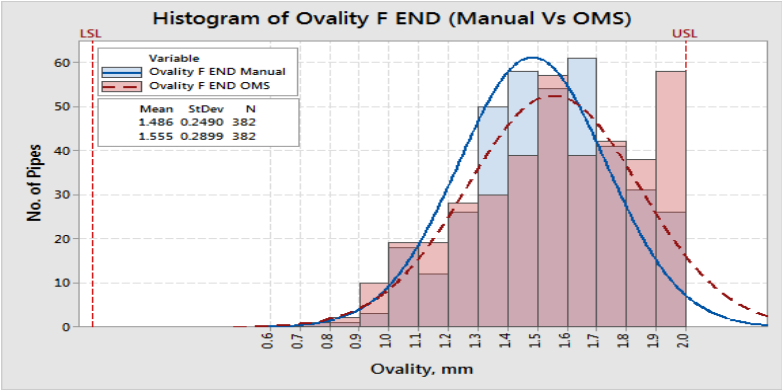


Due to higher precision of OMS compared to manual, standard deviation is more and hence, lower Cpk

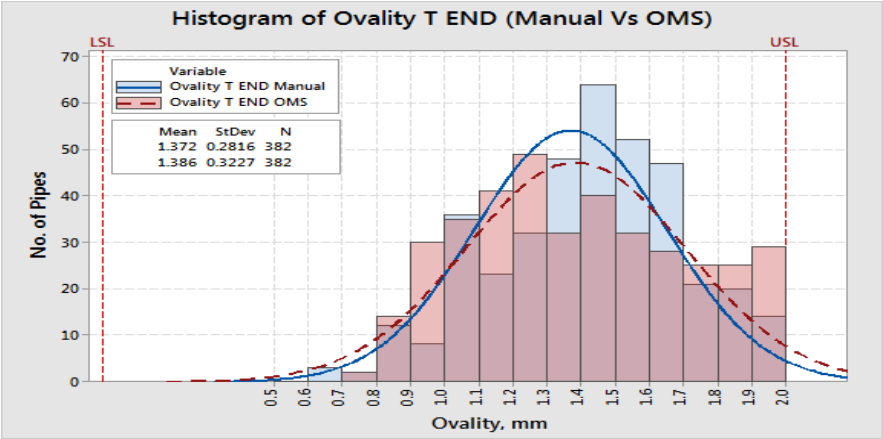


Pipe Out of Roundness [F End and T End]

SPECIFICATION LIMITS: LSL = 0.00 mm, USL = 2.0 mm



Due to higher precision of OMS compared to manual, standard deviation is greater

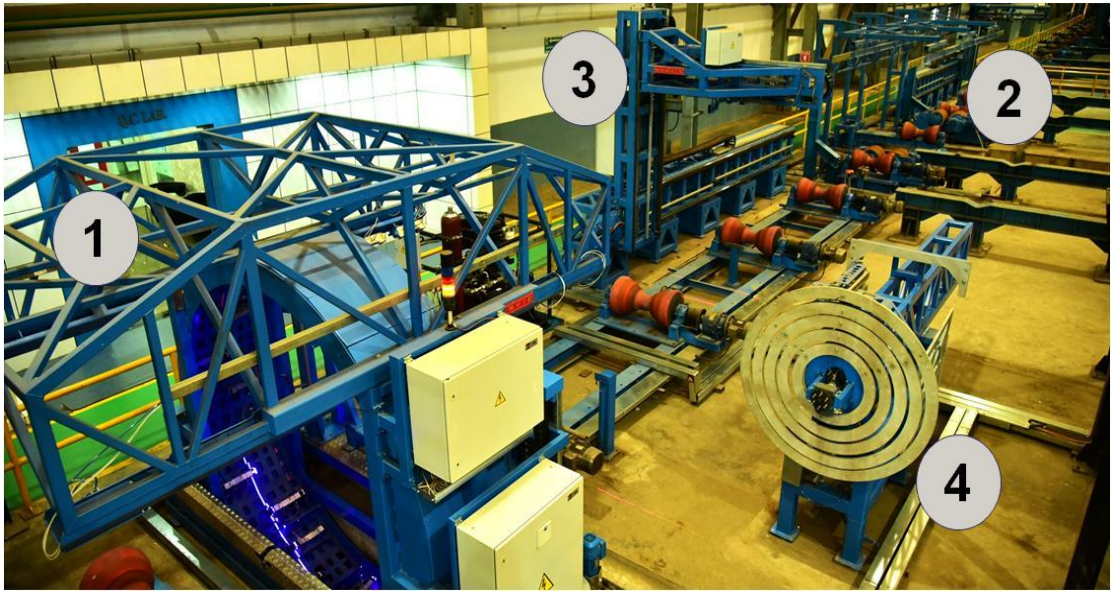


NEW AUTOMATIC PIPE DIMENSION MEASUREMENT SYSTEM ADOPTED BY WELSPUN

Schematic Layout of APDMS

v Automatic Pipe Dimension measurement system is divided in four Sections:

1. **Diameter, roundness and straightness measuring system;**
2. **Bevel & End Squareness measuring system;**
3. **Weld Bead Measurement System**
4. **Calibration Device**



SCR/Pipeline Installation
ALLSEAS - *Audacia and Calamity Jane boats on Stampede Field*

Overall Scope of Work Stampede Project :

- 6500ft of SCR (18” x 25.4mm)
- 13.6 miles of main line (18” x 20.3mm)
- PLET in J-mode (20”, weight ~82t)

v Installation by: Allseas DP PLV *Audacia*

- Pipe (dimensional) survey: PRISM
- Welding system: Allseas Phoenix welding system
- NDT: SHAW AUT
- FJC: Allseas FJC system

v SCR scope for the Stampede Project:

- 18” OD pipe 1” wt, ~6500ft (1981m) divided into 4 sections, respectively sections A, B, C, and D.
- Installing 63ft of Titanium Stress Joint (TSJ), free-issued by Client.
- Wet parking at the future Stampede TLP (Tension Leg Platform) location for recovery and hang-off by others,
- Line-up (Hi-Lo) requirement (internal) of 0.5mm for line-up,
- Welding procedure(s) developed/qualified, inclusive ‘full scale’ fatigue testing SoW.
- SCR critical sections, pipe is pre-sequenced and marked (onshore) by means of using Allseas ‘PRISM’.
- SCR non-critical sections, pipe is hold sequenced by means of using Allseas ‘PRISM’.
- ~3000ft of VIV strakes to be installed o/b at the top sections of the SCR

Summary

- Pipe properties:
  - **The transverse and longitudinal properties of the base metal, weld and heat affected zone were maintained well within the specified limits.**
- Plate to pipe transition in transverse:
  - **Both the yield and tensile strength increased by 27 MPa and 39 MPa respectively.**
  - **Both the elongation and uniform elongation decreased by 5%**
  - **YS/TS increased by 0.01.**
- Plate to pipe transition in longitudinal:
  - **Both yield and tensile strength increased by 42 MPa and 39 MPa respectively.**
  - **Elongation decreased by 8%**
  - **Uniform elongation decreased by 5%**
  - **YS/TS increased by 0.015**
- Pipe dimensions:
  - **Pipe internal diameter maintained within 1.6 mm**
  - **Pipe ovality at ends maintained within 2 mm**

A Plate/Pipe qualification program was used to confirm the mechanical, toughness and dimensional properties required for SCR application could be met. The change in plate to pipe properties will be used when considering future orders .

THANK YOU