Superduplex stainless steels tubes for subsea umbilicals

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Vallourec Umbilicals
Summary

- New technical challenges for umbilicals
- Product characteristics
- Vallourec Umbilicals
- Process manufacturing
  - Welding
  - Annealing and quenching
  - Non destructive testing
- Mill and product qualification
- Corrosion resistance in marine environment
  - Crevice and pitting corrosion
  - Hydrogen Induced Stress Cracking (HISC)
- Savings
- Conclusion

* : courtesy DUCO
New technical challenge for umbilicals

- Subsea umbilical systems for deep offshore become more and more demanding regarding:
  - injection capacity
  - number of functionalities
  - water depth
  - tiebacks length and number

  Operating conditions and requirements are significantly impacting the performance of the main umbilical.

- The most common solution:
  - To design:
    - thicker tubes to improve the strength of the umbilical
    - higher cross section to increase capacity
  - Drawbacks:
    - weight rise and fatigue performance degradation (higher loading)
    - cross section increase unsuitable with packing constrains

  Need to improve properties and geometry of the steel tube reducing wall thickness and improving fatigue resistance
Product characteristics

- **On strip : grade 2507 (UNS S32750 / EN 1.4410)**
  - PREN (Cr + 3.3Mo + 16N) ≥ 42.5
  - Suitable pitting and crevice corrosion resistance
  - High mechanical properties (duplex microstructure + cold rolling)

- **On tube**
  - Optimised strength (whatever the tube sizes)
    - YS_{0.2} > 750MPa
    - UTS > 900MPa
  - Elongation ≥ 25%

- **Tight dimensional tolerances**
  - 5% of the Wall Thickness (WT) compared with 10% required by ASTM A789
  - Internal Diameter (ID) : -0/+0.2mm
Vallourec Umbilicals

- **Vallourec (2012 figures)**
  - 5 326 M€
  - Near 70% of sales in Oil & Gas and Petrochemicals
  - More than 50 manufacturing facilities
  - Presence in more than 20 countries
  - 23200 employees worldwide
  - 93M€ R&D investments

- **Pipe project division**
  - SURF market
  - Strong local presence

- **Vallourec Umbilicals**
  - Steel tube for umbilicals
  - Based on the experience of Vallourec Heat Exchanger tubes (formerly Valtimet)
  - With the technical support of TOTAL SA headquarter Technology Division

Manufacturing process

Laser longitudinal welding line

- Strip Preparation & Forming
- Laser welding
- Weld bead finishing
- Heat treatment
- Sizing & Finishing
- NDT & Marking

Orbital Welding line

- X Ray control
- 360° Polishing
- Orbital welding
- Tube ends preparation
- Defect Cutting
- Sizing & Straightening

Moving units in case of bad weld (tube never rolls back)

Hydrostatic test bench

- Pressure test
- Water cleaning
- Flushing & Drying
- Nitrogen filling

Packing

Finished reels storage

(1) Only for segments with defect indications (and strip splice weld)
Manufacturing process - welding

- Longitudinal laser weld
- Orbital TIG weld
Manufacturing process – Annealing and quenching

**Objectives**

- **Annealing** (AT: annealing temperature)
  - Stress (brought to forming and welding) release
  - Optimal ferrite – austenite ratio
  - Dissolution of detrimental phases precipitated during welding and cooling (if any)
- **Cooling** (CR = cooling rate)
  - Avoid formation of detrimental phases

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Manufacturing process - NDT

- **In-line, real time non destructive test bench**
  - First EC
    - Detection of punctual defects
  - UT
    - Phased array technology: control of 100% of the tube length and circumference without any rotation of the tube or the UT head.
    - To detect longitudinal or transversal defects inside and outside
    - To check wall thickness and diameter outside (OD)
  - Second EC
    - Sigma phase detection

- **Defect marking**
  - Any defect detected by UT or EC controls is monitored and highlighted by a red mark

- **NDT bench calibration**
  - On rails
Qualification

- **Protocol**
  - Raw material and its manufacturing process
    - ASTM A240, ASTM A789 and NORSOK M650
    - Umbilical manufacturers and end-users specifications
  - Tube and its manufacturing process
    - ASTM A789 and NORSOK M650
    - Umbilical manufacturers and end-users specifications

- **3 tube dimensions / 250km / 10 heats**

- **More than 11000 tests results:**
  - Tensile, hardness, burst and collapse tests
  - Chemical composition
  - Roughness measurements
  - Dimensional checks
  - Ferrite content
  - Cleanliness
  - Corrosion tests (according to ASTM G48 methods, SSC and HISC)
  - «Technical» tests (i.e. reverse flattening, flaring, flange and bending)
Main results – Tensile tests

- **Dim**
  - 1 = 15.25mm OD x 1.15mm WT
  - 2 = 28.5mm OD x 1.45mm WT
  - 3 = 18.1mm OD x 1.00mm WT

- **PP** = pre production
- **FP** = full production

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**YS_{0.2}**

- YS_{0.2} average
- Min acceptance

**UTS**

- UTS average
- Min acceptance

**E% average**

- E% average
- Min acceptance
Main results – Burst and collapse

Burst resistance

Collapse resistance
Corrosion resistance in marine environment
Operating conditions

- **Immersion in natural seawater**
  - 3 months
  - Heated at 30°C and 50°C
  - One complete renewal of seawater every two days
  - Open circuit potential (OCP)

- **Crevcorr type assembly (30°C test)**
  - Torque = 1Nm (≈ 550N)
  - PVDF crevice washer
  - Ti fasteners

- **Tubes**
  - 25.4mm OD x 2mm WT x 300mm L
  - Seam welded (VU)
  - Seamless tubes

- **Evaluation**
  - Max crevice depth
Corrosion resistance in marine environment
Open circuit potential

- Seam welded tubes

\[ T = 30^\circ C \]
(crevice test)

- Seamless tubes
Corrosion resistance in marine environment

Observations

- Seam welded tubes
  - Laser weld
  - Average maximum crevice depth
    - 355µm
  - Max corrosion attack

- Seamless tubes
  - Laser weld seam is not especially sensitive to crevice corrosion

Corrosion resistance in marine environment

Observations

OCP 50°C (pitting test i.e. no crevice washers)
Subsea HISC failures – Examples
Statoil REX[3]

1. Leakage from a 25Cr duplex 2” methanol line on umbilical termination head
   — Very high local stresses due to accidental loads (heavy rock dumping)

2. Leakage in MEG line in umbilical due to cracked 25Cr duplex compact flange
   — FEA analysis: Large hoop stresses in transition between flange ring and neck

Hydrogen Induced Stress Cracking (HISC) resistance
Operating conditions

- **Aim:** study the influence of accumulated plastic strain (APS) resulting from
  - tube steel production
  - umbilical manufacturing
  - laying-out processes

  on HISC resistance of seam welded tubes

- **HISC procedure**
  - **H₂ prep charging:**
    - 20mA/cm²
    - 0.5M H₂SO₄ and 3g/L of KSCN
    - 24h at room temperature
  - **Constant load test**
    - -1050 +0/-50 mV vs SCE
    - 0.9AYS₀.²
    - 500h at room temperature

Reference electrode
Counter electrode
Working electrode (tube sample)
Hydrogen Induced Stress Cracking (HISC) resistance
Pre straining

- **Straining conditions**
  - Strain variation ± 1%
  - Frequency 0.07Hz
  - Accumulated plastic strain (APS) = 20%

- **Load and strain history**
Hydrogen Induced Stress Cracking (HISC) resistance

- I and E vs time during precharging
- Tube surface at the end of the test
  No cracks

- I and E vs time during CLT
- Seam weld
- Base metal

Examples of savings\cite{4}

- **Wall Thickness according to DNV OS F101**
  - Taking into account:
    - Increased YS$_{0.2}$
    - Tight tolerances
    - Reduced ovality
  - **Results**
    - Wall Thickness vs Internal Diameter

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This innovative technology is proposing a new product offering:
- a significant **reduction of weight**
- combined with an **increased strength**

**Added valued:**
- easier installation and manufacturing for the umbilicals manufacturer (i.e. radius reduction)
- improved fatigue resistance for the end-user (reduced number of girth welds taking benefit of strip length)

**The manufacturing process and product have been certified by Bureau Veritas in October 2012 and qualified by TOTAL in April 2013**

meet the new challenges linked to ultra deep water developments