Optimal Execution Strategy for EPCI projects with CRA pipelines in deepwater fields

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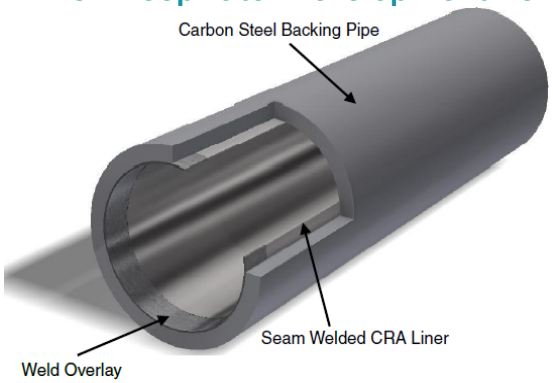
Context & agenda

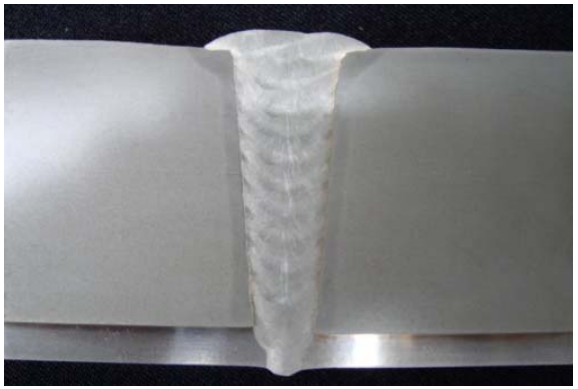
- Increasing demand for CRA solutions for deepwater fields
- Deepwater & CRA add complexity & cost
  - importance of optimization
- Is there an optimal execution strategy?

- Presentation contents
  - EPCI reflection based on recent project and study experience from HMC
  - Highlight ongoing development

Fabricating & installing CRA pipelines

- High procurement costs of linepipe
  - CRA clad (HRB) and lined (MLP) pipe generally more cost effective than solid CRA
  - Main focus on clad / lined solution
  - Limited number of suppliers, finite capacity & long lead times
- Difference in liner / linepipe mechanical properties
- Welding & inspection challenging
  - Challenge of overmatching
  - Low interpass temperature, more complex welding
  - Complex NDE, low acceptance criteria
    - Higher risk of rejections





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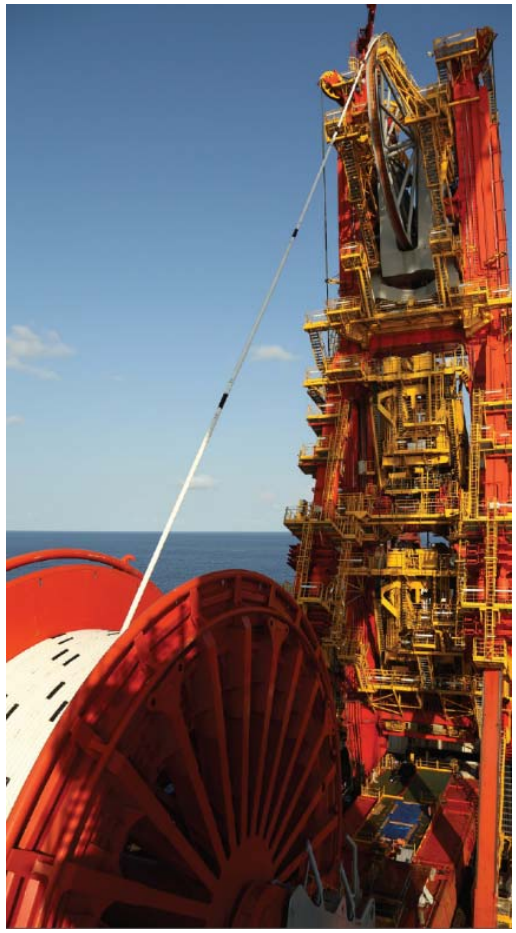
J-lay introduction

- Hex/Quad-joints loaded in tower & subsequently welded
  - Pipes can be held on friction or collars
  - Only option for pipelines of OD >18” or top tensions > 800mT
  - Sagbend loads on the pipe generally governing
- Single station tower cycle governs lay-rate
  - Combined welding & coating cycle time
  - Lay rate not significantly slowed down by anodes, structures, etc.
- Fully elastic lay conditions
- Multiple options for pipe logistics
  - Multi-jointing can be done onboard, onshore or combination

Reeling introduction

- Pipeline is stalked onshore & unspooled offshore
  - Pipes directly spooled on vessel or on exchangeable reels (Aegir)
  - High lay-rates offshore possible
  - Pipe is held on friction by tensioners
- Pipe and welds subjected to plastic deformation
  - Local buckling & straightener capacity checks
  - Possible for pipes typically up to 18”
  - General reeling engineering well understood
  - Specific technical considerations for CRA pipe
- Majority of the welding is done onshore
  - Time needed to qualify & stalk
  - Only welding offshore are the tie-in welds



HMC assets & recent CRA installation experience

- Balder
  - 1050mT J-lay tower
  - 3000 & 4000mT cranes
  - Possibility of onboard multi-jointing
  - Vast deep-water pipe-lay track record
  - CRA riser installation on BP Angola Block31 PSVM
- Aegir
  - 800mT reeling / 2000mT J-lay tower
  - 2000mT subsea lowering capacity
  - 4000mT crane
  - Possibility of onboard multi-jointing
  - Extensive CRA pipeline scope on Inpex Ichthys project
    - 7km of 12” Condensate Flowline (CRA Clad + MLPP coated) incl FLETs (4x)
    - 86km of 18" CRA Clad / Lined Production flowlines (MLPP Coated) with 18 FLET / in-line structures weighing up to 210mT

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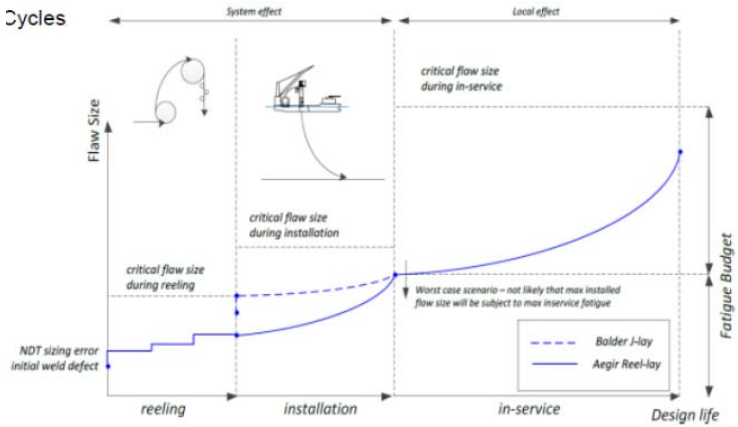
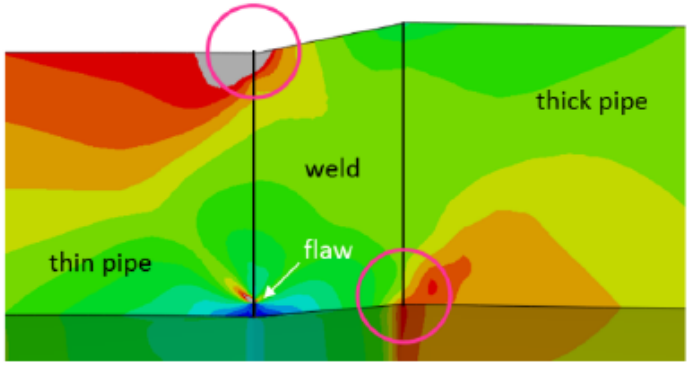
Engineering considerations: installation

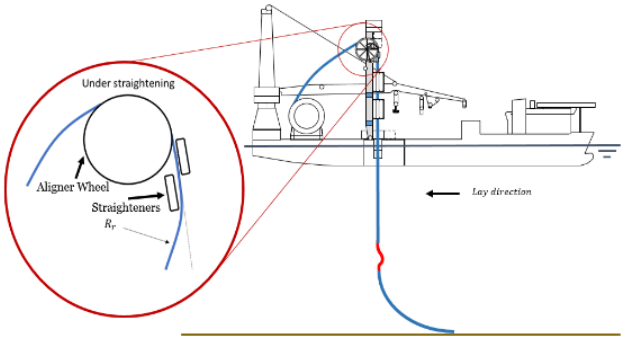
- Reeling imposes additional requirements
  - Reeling mechanical considerations
    - Minimum WT to avoid buckling
    - Increased plastic deformation due to stiffness mismatches
    - Pipe sizing not usually impacted for deep-water / HP-HT pipes
    - MLP wrinkling!
  - ECA is critical part of reeling engineering
    - Confirmation of feasibility / acceptance criteria
    - Potential schedule challenges: input from supplier, client and interaction with qualification effort
- Girth weld requirements
  - Overmatching on strength & corrosion resistance
  - Reeling of partially under matching welds

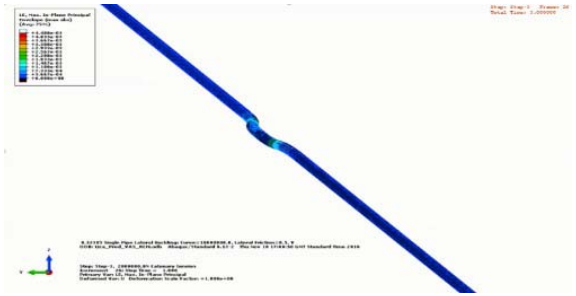


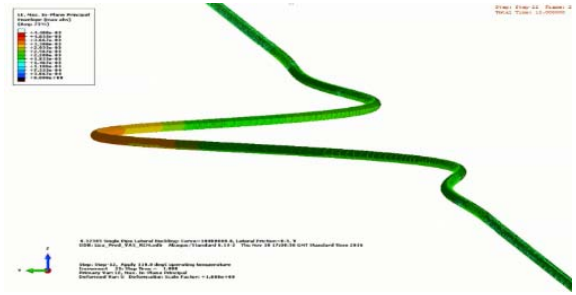


Engineering considerations: design

- Reeling gives option for RCM to manage expansion
  - Deepwater no issue: elastic recovery sufficient to have sufficient curvature
  - Simplified design process
  - Avoiding sleepers/buoyancy reduces cost
- MLP applicability in fatigue critical zones
  - Girth weld vs triple point
  - Fatigue performance potentially impacted by reeling
  - HRB / Clad option in case of insufficient performance
- Reelabilty of insulation coating
  - Criticality of tie-in field joint coating







Procurement & onshore fabrication considerations

- Pipe lead time critical for project schedule
  - Reeling requires pipes longer before start of offshore campaign
  - Effect on overall project duration?

- Early involvement of supplier in design process necessary
  - Reeling imposes additional requirements on suppliers; minor cost impact as long as identified early
  - Input from supplier critical for engineering planning

- Increased WPQ requirements for R-Lay
  - Stress-strain curves, J-R curves
  - Specific Y/T ratio or weld overmatch determined by engineering

Installation considerations

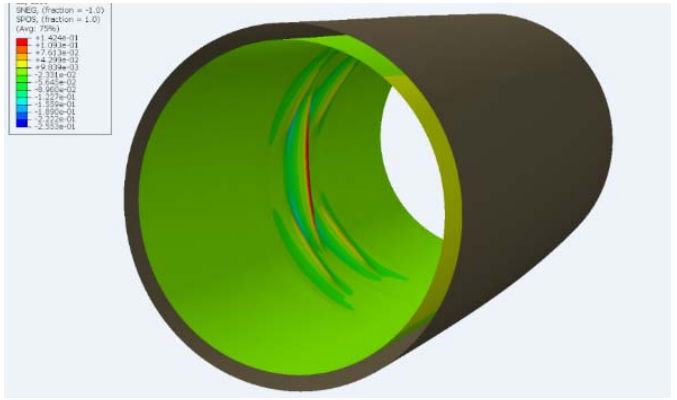
- Increased complexity of CRA welding
  - No root defects acceptable
  - Complexity NDE procedure
  - Need for purging (closure welds)
  - Managing geometrical tolerances
- Managing offshore schedule risk
  - Onshore fabrication mitigates (offshore) risk
  - Pipe buffer to partially mitigate risk with J-lay
  - Short weather window favors reeling
- Complexity of cut to length
- Short lines, structures, appurtenances decrease relative lay-rate advantage of reeling

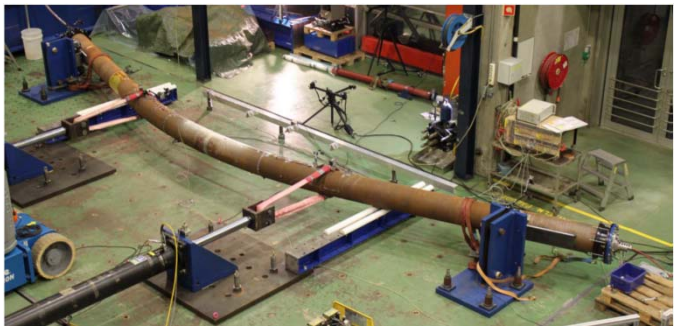
EPCI comparison summary

- Project planning considerations
  - Reeling option puts more pressure on the up-front EPC activities, but de-risks the offshore operations
  - Exchangeable reels allow for de-coupling spool base & Aegir
- Optimal flowline design differs for J-lay and R-lay
  - Pipe specification, CP design, buckling mitigation
  - For short lines with lots of structures reeling advantage is much less than technically feasible lay-rate
- Ability to mix different pipes in case of specific sections, considerations
- Reeling / multi-jointing onshore adds potential local content

HMC & PTL technical development (1)

- MLP DNV GL qualification program
  - Confirmation of reelability (limits)
    - Testing & engineering development program
    - (Pressurized) Reeling procedure development
  - Fatigue performance quantification: enabling MLP on risers / buckle zones
- Deepwater RCM
  - Extend application of RCM to deepwater application
  - In process of obtaining DNV endorsement
- FJC for reeling development program
  - Reduction of risk of cracking of thick (FJ)Coating
  - FJC material & geometries optimization with different vendors





HMC & PTL technical development (2)

- ECA development
  - Comprehensive in-house capability to perform fast level III ECAs
  - Modern ECA methods confirm full / partial under-matching is Ok if toughness, weld geometry & defect sizes are controlled
- Welding process development
  - Advanced in-house welding capabilities through Pipeline Technique affiliate
  - Thick wall & overmatching welding technology development
- Direct deposition J-lay collar (*PTL*)
  - Supply chain optimization for J-lay by collars: lower costs, no additional WPQ
  - Full development program completed
- Full control of geometric tolerances
  - In-house pipe end-scanner & sorting-matching software

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Conclusions (1)

- Advantages J-lay
  - Only option for larger diameter, heaviest pipes
  - Spoolbase not necessary
  - Not necessarily slower, but more welding offshore
  - For complex flowlines J-lay with onshore multi-jointing can have advantages

- Reeling strongpoints
  - De-risks (offshore) execution planning
  - Exchangeable reels adds flexibility avoids need for local spoolbase
    - Decoupling spool-base and vessel (planning & location)
    - Option to limit spool base size / requirements (e.g. water depth)

Conclusions (2) & questions

- Design engineering to be optimized to maximize reeling advantages
  - RCM implementation, CP design optimization
  - Engineered weld selection & linepipe specification
  - Early supplier and contractor engagement
- Versatile installation assets and techniques improve cost effectiveness of (CRA) SURF
- *Optimum?; no single answer & early involvement to reach full benefits*