Technical Challenges on the Colongra Lateral Pipeline Project

Mar 2009

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GHD

Jemena
Project Context

- Delta Colongra Power Station - 667MWe peaker
- Gas via Sydney Newcastle Pipeline - lacks capacity for continuous supply.
- Lateral required to perform as storage vessel.
This presentation will focus on pipelines, especially 42 inch.
Project Participants

• **Jemena**: Design, construction and operation of gas facilities
• **GHD**: Concept, FEED, then detailed design of pipelines
• **Diona / Codmah**: Pipeline Construction
• **EFPX**: EPCM Contractor for the facilities (stations)
• **Supporting Roles**:
  - EPCM – Project management support to Jemena
  - Brian Martin & Associates – CP & earthing
  - Welding Technology Institute of Australia
  - ANSTO – Fatigue analysis
  - Phil Venton & Assoc and Leigh Fletcher Consulting – Early concept work
  - Advantica, BMT Rail (Bob Andrews) – Fatigue and fracture control verification
  - Many others!
Project Timing

• Detailed Design: 4Q2007 – 3Q2008
• Construction: Apr 2008 - Feb 2009
• Commissioning: Mar 2009
• Commercial Operation: Apr 2009
## Pipeline Specifics – 42 inch section

<table>
<thead>
<tr>
<th>Material</th>
<th>UOE X70 24mm &amp; 30mm wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Cycle Range</td>
<td>3.4 to 13 MPag</td>
</tr>
<tr>
<td>Required Pressure Cycles</td>
<td>4,000</td>
</tr>
<tr>
<td>Gas-In (via compressors)</td>
<td>1.7TJ/hr (recharge ~24hrs)</td>
</tr>
<tr>
<td>Gas-Out (To Power Station)</td>
<td>8.2 TJ/hr (approx 5hr run time)</td>
</tr>
<tr>
<td>Usable Gas Storage</td>
<td>36 TJ (at 15 deg)</td>
</tr>
<tr>
<td>Operating Temps very close to design temps for this pipeline</td>
<td>-10 to 55 deg C</td>
</tr>
<tr>
<td>Toughness</td>
<td>121 Joules (body)</td>
</tr>
<tr>
<td>Coating</td>
<td>2FBE with liquid epoxy joints</td>
</tr>
<tr>
<td>Design Standard</td>
<td>AS 2885-2007 – One of the first……</td>
</tr>
</tbody>
</table>
Challenges - The 9km route with everything

- Fatigue!
- T1 Residential Location Class
- Need for serpentine storage loop
- Need for an underground interconnect station
- AC Interference from numerous HV power lines
- Mine subsidence
- Inundation / swamp zones
- Major bored crossings (Pacific Hwy microdrill & 5m deep railway thrust bore)
- Orchids
- Bends and bend control
- Everything is big!
Fatigue - The Issue

Factory Seam Weld

- Cyclic Pressure
- Cyclic Hoop Stress
- Propagation of SMALL flaws
- Non-governing case

Production Girth Weld

- Cyclic Pressure
- Cyclic Temperature
- Seasonal effects
- Cyclic Axial Stress
- Bend & Soil Effects
- Real world joint tolerances
- Real world welding defects

Pipe ordered:
- before stresses known
- with varying IDs

Significant engineering challenge!
Methods for Fatigue Design

- **AS 2885 Appendix N (IGE / TD1 Method 5)**
  - Impractically thick wall
  - Does not address girth welds well

- **Other S-N Curve Methods, eg Maddox TWI**
  - Encouraging results (8,000 to 11,000 cycles predicted)
  - Not comfortable to rely on this.

- **Fracture Mechanics Models**
  - BS 7910, API 579, or DNV RP-C203
  - Software: R6, Crackwise, FlawCheck, GHD Spreadsheet

- **Augment with FEA**
### Fatigue Drives Construction Methods 1 of 2

<table>
<thead>
<tr>
<th>Table Title</th>
<th>Selected value for this Project</th>
<th>Typical Value</th>
</tr>
</thead>
</table>
| **Angular Misalignment**  
(End Squareness + Root Gap Variation) | 0.26 deg | API 5L limits end squareness to 1.6mm/dia  
AS 2885.2 limits gap variation to ±0.6  
Result → 0.25°  
However, permits weld angles up to 3° |
| **Axial Misalignment**  
(Hi-Lo)  
(Ovality+ Seam Peaking+ Centreline Mismatch) | Despite API tolerances, this size UOE pipe can have 6-7mm Hi-Lo (worst case).  
Pipes rotated / selected as necessary to achieve 4mm. | -For thinner pipe, clamps help to re-round ovality.  
-For ERW pipe, minimal peaking. |
| **Bevels & Transitions** | -1:4 commonly used  
-AS 2885 permits 1:1.17 taper | |
| **Steel Toughness**  
Driven by SMS / Fracture Control Plan | 24mm WT body: 121J  
30mm WT body: 93J  
24mm WT weld: 70J  
30mm WT weld: 64J | Same |
Modifying Pipe Bevels

Machine Required To:
- Compound bevel
- Cut internal tapers back to counterbores
- Operate with tight tolerances so as to avoid worsening Hi-Lo
## Fatigue Drives Construction Methods 2 of 2

<table>
<thead>
<tr>
<th></th>
<th>Selected value for this Project</th>
<th>Typical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weld Toughness</strong></td>
<td>Only available after trials commenced.</td>
<td>86J</td>
</tr>
<tr>
<td><strong>Weld Toe Angle</strong></td>
<td><img src="image" alt="Diagram" /> 135 deg</td>
<td>Not explicitly limited.</td>
</tr>
<tr>
<td><strong>Weld Heat Input</strong></td>
<td>Fatigue calculations assumed 2.9kJ/mm limit. No PWHT. Further analysis sanctioned slightly higher values.</td>
<td></td>
</tr>
<tr>
<td><strong>Load Cycle Profile</strong></td>
<td>Considered summer and winter. Assumed full depth cycles</td>
<td></td>
</tr>
<tr>
<td><strong>Stresses</strong></td>
<td>Caesar model outputs + roping allowance</td>
<td>-Both max stress and stress range are critical. -Roping 600D (0.1°/dia) ((\rightarrow 169\text{MPa}))</td>
</tr>
<tr>
<td><strong>Size limit for defects</strong></td>
<td>•Crack like •Extended undercut</td>
<td>Tier 1: 3 x 25mm surface breaking or within 5mm of surface (Need high confidence of detection)</td>
</tr>
</tbody>
</table>
Challenge of Controlling Tolerances and Roping Stresses with a 30 Tonne Pipe String
Fatigue Analysis Conclusions

- Can achieve 4,000 cycles.
- Failure predicted by ductile rather than brittle mode.
- Many conservatisms, especially not counting cycles to initiate cracks.
- Avoided “special construction”, however required increased NDT and no roping at some locations.
- BMT independent review and endorsement.
Determining Special Requirements at High Stress Locations

DN1050 MGP Stresses

Interconnect
2nd Highest Stress Range:
103904.2 kPa
Location: Station-end side of gradual bend on East Loop

Max Stress Range:
139651.3 kPa
Location: Vertical S-Bend before DN1050 Pig Receiver

Max Tensile Stress:
164977.2 kPa
(at same location as Max Stress Range)

Tensile Stress at MDS Inlet:
149564.9 kPa

Worst Stress Locations

More Representative Locations

Chainage for MGP Interconnect Section (Approx)
Fatigue - Recommendations

- Assess real temperatures and possibly strains during commissioning.
- Monitor real cycles so that a future Rainflow analysis can determine actual fatigue life.
- Intelligent pigging (cannot rely entirely on calculations)
Serpentine Storage Loop 2 of 2
AC Interference

Map showing
- 66kV
- 330kV
- 33kV
- 330kV

Legend:
- 132kV Transmission Line
- 330kV Transmission Line
- 33kV Transmission Lines
- Power
- Tower
- HV Line
- Green Zone
- Part 3A Concept Approval
- Boundary

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Mine Subsidence

- MSB requires pipelines to be “designed for subsidence”
- No mining plans yet exist to define subsidence parameters.

MSB Parameters
- Subsidence
- Strain (+/-)
- Tilt

MSEC
- Reverse engineer mining plans to produce these MSB parameters

Axial & Trans Soil Displacements to Apply to Pipe

CAESAR Model
- Pass / Fail?

Superimpose mining plans at various angles to pipeline

Results
- SCFs at transitions
- Passes code
- Assumes to upsidence
Inundation and Swamp Zones
Everything is big!

42” Pipe arriving at Munmorah Delivery Station

6MW+ Water bath heater
Thankyou....

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