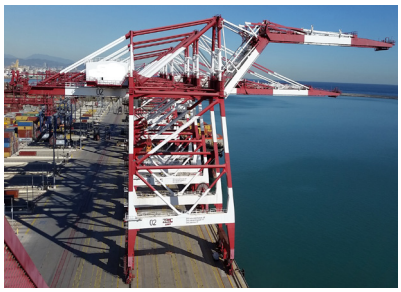
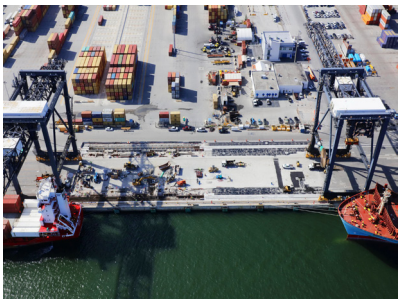
PIPE END CONNECTION





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Quality Assurance Review
for Liftech Consultants Inc.

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EXECUTIVE SUMMARY

Pipe-to-gusset plate connections in pipes that experience significant fatigue, such as upper diagonals, have frequently experienced fatigue cracking on ship-to-shore cranes. The cracking at fracture critical pipes has led to several catastrophic failures. There are several common design approaches to this connection, and all are susceptible to fatigue failure.

This white paper introduces a new approach that significantly increases reliability by eliminating the center gusset plate altogether by using two side gusset plates. The key element to this new approach is two gusset plates, one welded to each side of the pipe, to transfer the load from the pipe to the crane structure. This also improves access to the connection for inspection and repair.

BACKGROUND

The pipe-to-gusset plate connection, "end connection," is one of the most common ways to connect a pipe member to the crane structure. Figure 1 shows two end connections—with and without a seal plate at the end of the gusset plate.

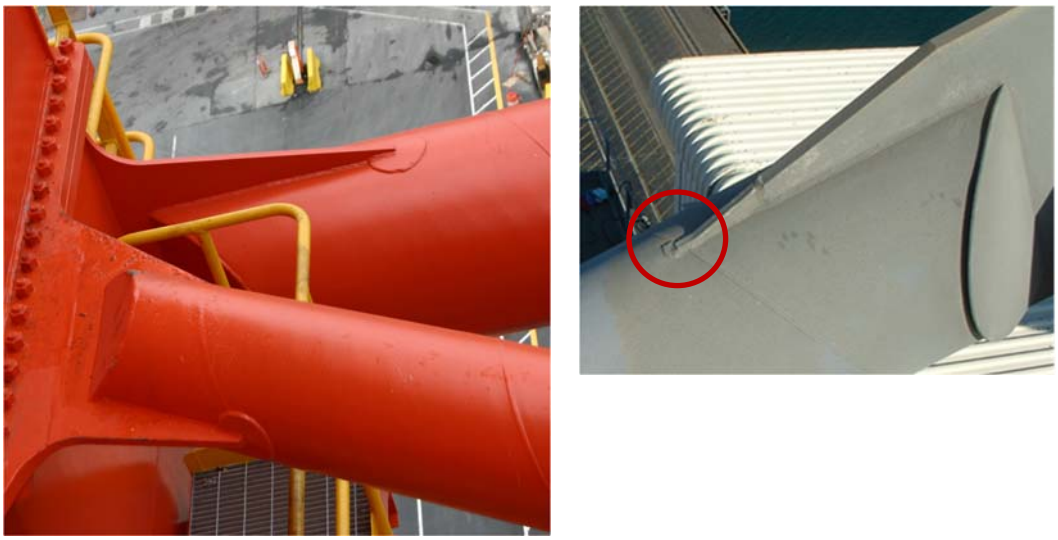

Figure 1: Pipe-to-gusset plate connection, with seal plate (left) and without seal plate (right)

Both types are susceptible to cracking at the end connection, especially for the upper diagonal, as fluctuating fatigue stresses are large. See Figures 2 and 3.

Figure 2: End connections with no stress relief hole, square cut without reinforcing plate (left) and with seal plate and fatigue cracks (right)

Figure 3: Cracking at the weld of the seal plate

NEW DESIGN: SIDE GUSSET PLATES RATHER THAN A CENTER GUSSET PLATE

If the center gusset plate can be eliminated, the end connection and associated cracking would also be eliminated.

To achieve this, Liftech Consultants Inc. (Liftech) developed a concept using two side gusset plates rather than a center gusset plate. See Figure 4.

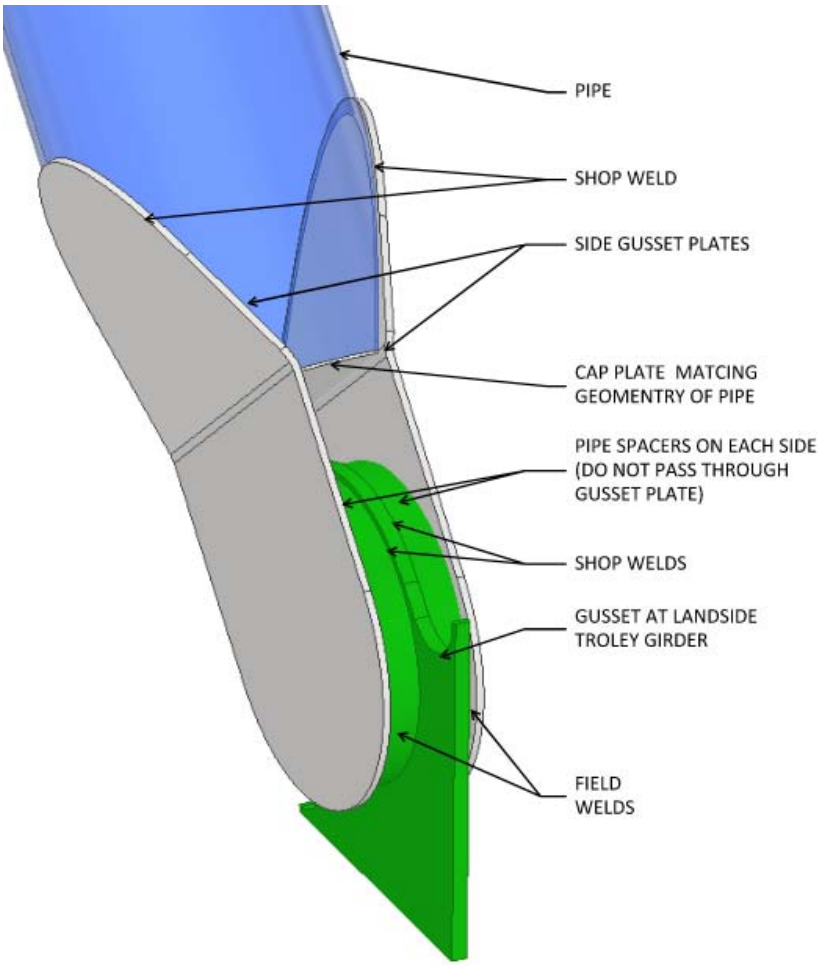

Figure 4: Side gusset plate design

The two side gussets serve as closure plates of typical conventional pipe end connections. However, in this new design, instead of terminating at the center gusset plate, each side gusset plate is bent parallel to the gusset plate of the adjoining structure with a gap between them to provide sufficient space for welding and periodic MT and UT examination and repair, if necessary. The side gusset plates at the connection to the diagonals are sloped 1:4 to reduce stress concentration and provide a gradual transition. The side gusset plates are connected to the single gusset plate on the crane structure with two pipe spacers. The portion shown below will be shop fabricated.

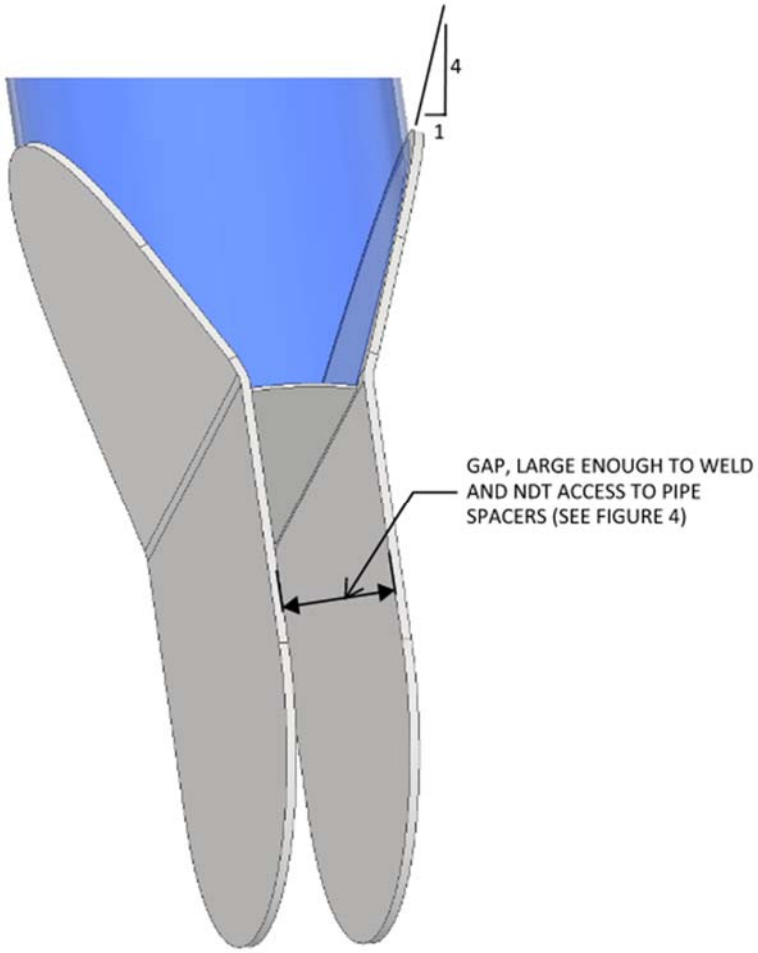

Figure 5: Shop fabricated portion

The end to the landside trolley girder support beam or the apex beam will have two pipe sections welded to it and will offer adjustability when the diagonal is installed onto the crane. If air tightness testing is required, a hole can be made in the gusset plate to allow one test for both sides of the spacer.

FEA Analysis

Liftech performed finite element analysis (FEA) for both the conventional pipe connection design and the new pipe connection design using the same load, pipe size, and modeling approach. We found that the weight of the new design is comparable to the conventional design. For the new design, we found the maximum 1st principal stresses are at locations that are either without welds or are inspectable. In contrast, the maximum 1st principal stresses of a conventional pipe connection are at the end connection, which is often concealed by a seal plate. Also, we found the maximum 1st principal stress of the new design is a little more than half of that of the maximum 1st principal stress of the conventional design. Fatigue life, or the time that fatigue cracking may appear, is related to stress cubed. We expect the fatigue life of the new design to be nearly seven times that of the conventional design.

One concern with the design is that the transverse plate at the bend line may be inadvertently mislocated and create an offset. Liftech performed another FEA to determine the stresses with a 10 mm offset of the transverse plate. The results were similar to the connection results without the 10 mm offset.

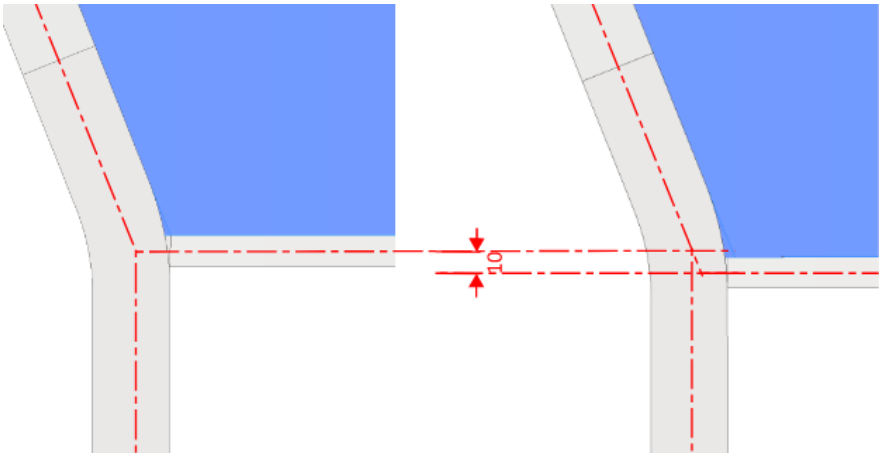

Figure 6: New pipe connection with 10 mm offset

The FEA showed that the maximum 1st Principal stresses do not increase significantly, so the fatigue life is only reduced slightly as well.

See the table of results below. The load applied is a 300-tonne axial load. See Figures 4 and 7 for geometry information.

Table 1: FEA Analysis Results with 300 Tonne Applied Axial Load

	Conventional Design	**New Design**	
		No offset of transverse plate at bend line	10 mm offset of transverse plate at bend line
Maximum Stress Location	End connection of gusset plate	Bend line of transverse plate	Same as "no offset"
1st Principal Stress, MPa	235	124	126
Fatigue Life Comparison	1.0	6.8	6.5
Longitudinal Deflection, mm	1.15	1.65	1.62

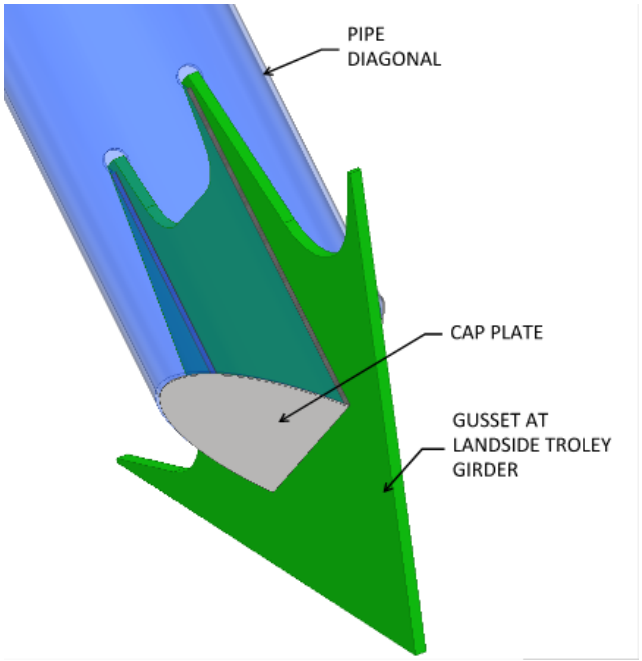

Figure 7: Conventional pipe connection

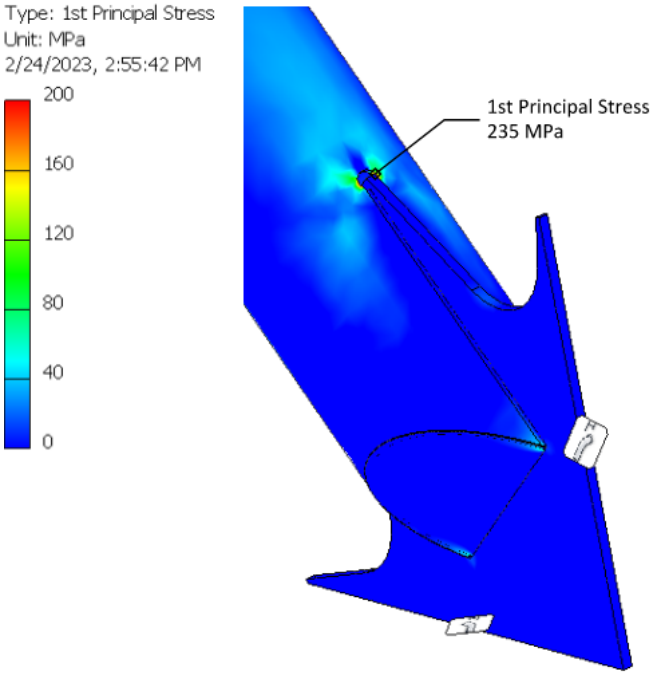

Figure 8: FEA 1st principal stress of conventional pipe connection

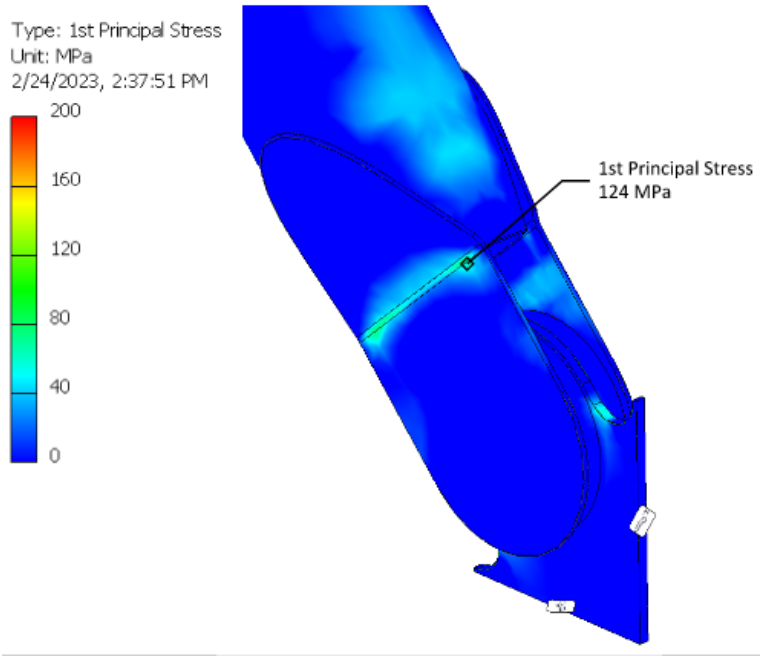

Figure 9: FEA 1st principal stress of new pipe connection, new design, no offset of transverse plate at bend line

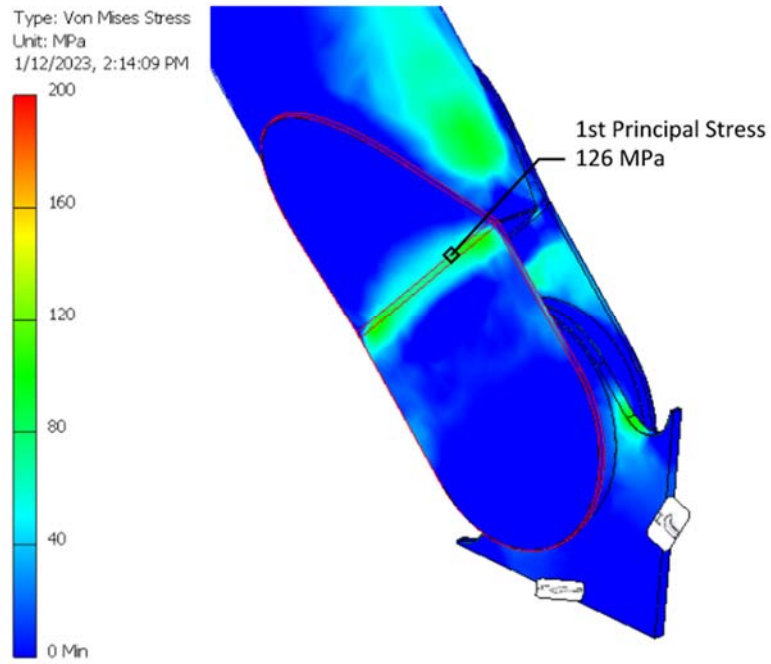

Figure 10: FEA 1st Principal stress of new pipe connection, new design, 10 mm offset of transverse plate at bend line

CONCLUSION

The conventional pipe-to-gusset plate connections of the upper diagonal have frequently experienced fatigue cracking on ship-to-shore cranes. The new approach of eliminating the center gusset plate altogether and using two side gusset plates has the following advantages over the conventional pipe-to-gusset plate connection:

1. The high fatigue stress locations are inspectable and repairable.
2. The fatigue life is expected to be six to seven times that of the conventional connection.
3. The weight is comparable.
4. The longitudinal deflection is comparably small.

Based on the promising investigation, the next steps would be the following:

1. Discuss with a manufacturer about how to best fabricate and weld the connection.
2. Build a prototype or mockup.

APPENDIX

FEA Model Particulars

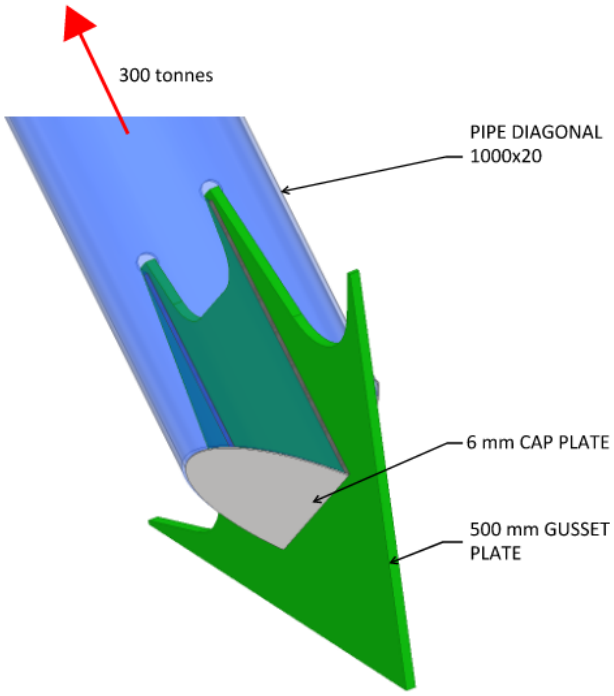

Figure 11: Conventional pipe connection

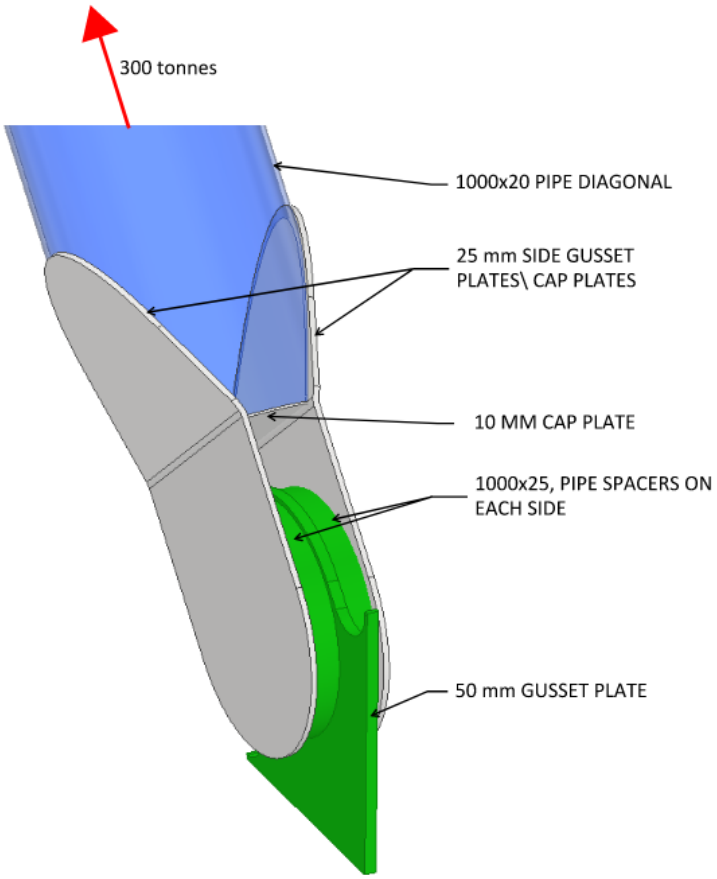

Figure 12: New pipe connection design