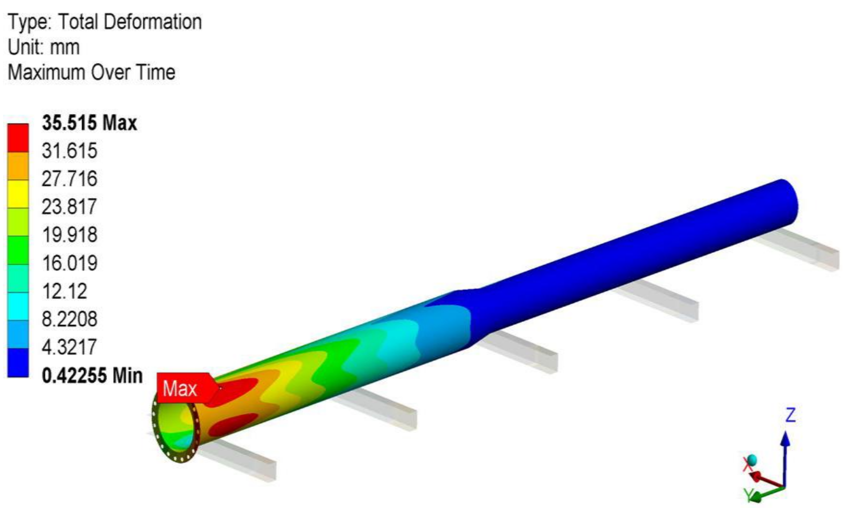
Case Study

<table>
<tr><td>Study Area:</td><td colspan="2">FEA for Cooling Tower Nozzle Load</td></tr>
<tr><td>Job:</td><td colspan="2">To perform structural assessment of the nozzle using Finite Element Analysis (FEA), in order to check structural Integrity of the Nozzle.</td></tr>
<tr><td>Date:</td><td>Q4- 2025</td><td rowspan="2">
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<tr><td>Location:</td><td>Noida, UP, India</td></tr>
<tr><td>Project Background:</td><td colspan="2">A cooling water system was developed with a mild steel (MS) return header directly connected to the FRP-coated UPVC/HDPE flange nozzle flange of a cooling tower. The header routing and civil foundations were executed based on preliminary design assumptions, with the expectation that subsequent piping stress analysis would validate the configuration. Civil works and header supports were substantially completed before the final stress analysis results were issued.</td></tr>
<tr><td>Engineering Challenge:</td><td colspan="2">1. The nozzle connection involved dissimilar materials:
• Mild Steel (MS) flange on the header side
• FRP-coated UPVC/HDPE flange on the cooling tower side.

2. FRP-coated UPVC/HDPE nozzles differ significantly from metallic equipment nozzles causing:
• Lower allowable external loads
• Higher sensitivity to bending moments
• Susceptibility to localized stress concentrations

3. Direct rigid connection between steel piping and FRP-coated UPVC/HDPE equipment commonly results in high flange stresses.

The challenge was also to:
• Quantify actual stress distribution in the FRP-coated UPVC/HDPE flange.
• Identify true failure risk.
• Develop a cost-effective mitigation strategy.
• Avoid changes to existing header alignment and civil works.
• The client provided ten (10) distinct load combinations, derived from header stress analysis.</td></tr>
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Analysis & Key Findings:	• FEA was performed for all ten load combinations which were provided by the client in the input.
	• FEA study was carried-out using ANSYS version 2025 R1 software.
	• Results indicated that nozzle stresses exceeded allowable limits in all cases, resulting in failure under code-based acceptance criteria as shown in fig below.
	• Bending moments as the dominant contributor to overstressing.
	• Uneven load transfer due to stiffness mismatch between MS header and UPVC/HDPE nozzle.
	• The failures were primarily driven by:
	    ○ High external piping loads
	    ○ Stiffness mismatch due to dissimilar materials
	    ○ Limited flexibility at the nozzle interface.

Engineering Recommendations:	We proposed conducting a detailed Finite Element Analysis (FEA) of the nozzle–flange–header interface to evaluate realistic stress behaviour and develop an optimized solution.
	1. **Scope of FEA Included:** 3D modelling of nozzle and flange geometry
	2. **Header Load Mitigation:** Revisit header stress results and reduce external loads on the nozzle wherever possible.
	3. **Nozzle Thickness Enhancement:** Increase nozzle wall thickness to improve stress capacity and structural margin.
	4. **Alternative Load Redistribution Solution:** Targeted structural modifications instead of full piping redesign. Introduce a saddle support to absorb and redistribute excess loads away from the nozzle. Controlled load redistribution measures without altering header alignment.
	This approach ensured:
	    • Compliance with allowable stress limits.
	    • Elimination of failure risk.
	    • Minimal site modification.
	    • Preservation of existing civil foundations.

Final Outcomes:	• Increasing the nozzle thickness was technically viable but resulted in significant cost escalation and was not adopted.
	• Even after partial load reduction, nozzle stresses remained above allowable limits.
	• Elixir proposed the addition of a saddle support as a cost-effective alternative which was accepted and was passed during FEA Analysis.
	• Post-implementation FEA confirmed that:
	    ○ Excess loads were successfully redistributed
	    ○ Stresses were reduced within allowable limits
	    ○ The nozzle passed all structural integrity checks

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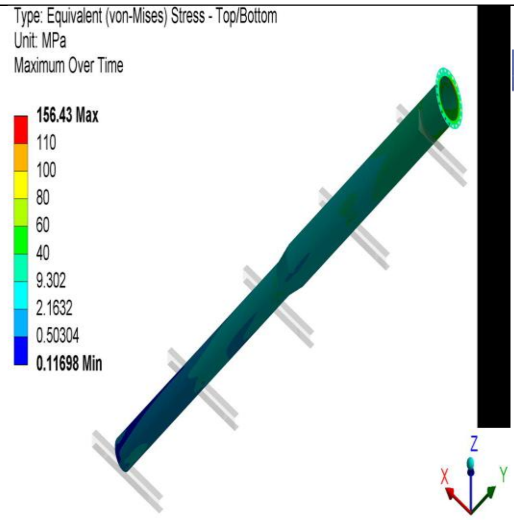
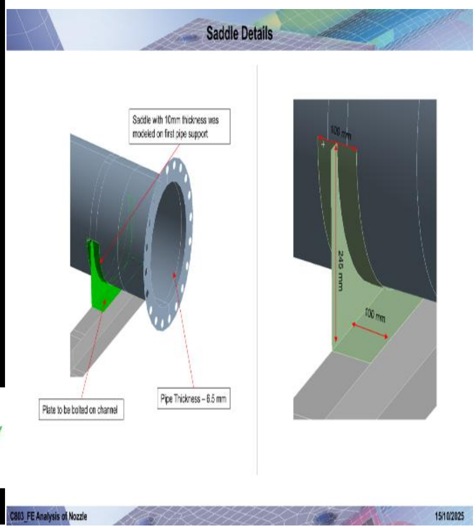
Saddle Details:	

Final Outcomes & Benefits:	**Final Outcomes:**
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	• Post-implementation FEA confirmed that:
	    o Excess loads were successfully redistributed
	    o Stresses were reduced within allowable limits
	    o The nozzle passed all structural integrity checks
	Benefits:
	• Avoided major header rerouting+
	• Eliminated need for civil reconstruction
	• Reduced project delay risk
	• Delivered most economical solution
	• Ensured long-term structural reliability

Key Lessons & Best Practices:	• The importance of advanced simulation for composite structures. • The limitations of conventional piping stress checks when interfacing with UPVC/HDPE and FRP coated equipment. • The effectiveness of Finite Element Analysis in resolving late-stage design conflicts. • The ability to deliver practical, cost-efficient solutions under tight site constraints. • Early integration of piping and structural analysis significantly reduces downstream risk and cost.