APRIL 2025

THE ENGINEERING QUARTERLY

TABLE OF CONTENTS

ACUREN

WELCOME TO THE ***FIRST*** ENGINEERING QUARTERLY.

We're excited to introduce Acuren's first **Quarterly Engineering Newsletter**. I'd like to thank our engineering and marketing teams who contributed to creating the content you're reading and putting together this publication. Our intent with this newsletter is to showcase the wide range of services and capabilities that Acuren provides across North America and to highlight how **our teams collaborate to deliver exceptional value to our clients**.

While Acuren is widely recognized for its inspection services, our engineering teams offer an extensive portfolio of specialized expertise and technical capabilities. Acuren's engineering presence spans numerous locations throughout the United States and Canada, with specialized teams that bring diverse skills and experience to solve our clients' most challenging problems.

Our engineering services include failure analysis, welding engineering, mechanical testing, fracture toughness testing, finite element analysis, field engineering, full-scale destructive testing, materials engineering, structural engineering, corrosion engineering, civil engineering, reliability engineering, mechanical engineering and integrated project management. Our laboratories maintain rigorous accreditations, including some locations being fully accredited to ISO 9001 and ISO 17025 standards, ensuring the highest quality of testing and analysis.

What sets Acuren apart is our ability to collaborate across disciplines and borders. **Our teams work together to provide integrated solutions that combine the strengths of our inspection, engineering and lab services**. This collaborative approach allows us to deliver comprehensive, turnkey solutions with the technical depth and practical experience our clients require.

This inaugural edition highlights just a few examples of the innovative work happening throughout our organization. In future newsletters, we'll continue **to spotlight additional capabilities, locations, and the talented professionals** who make up our engineering teams across North America.

We hope you enjoy this newsletter and the content we have created. This is an exciting time for Acuren as we continue to expand the services we offer across various industries and work together to provide the best possible integrated solutions.

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Engineer or Detective? Uncovering the True Cause of Vessel Bracket Failures

When a chemical processing client approached Acuren with a recurring equipment failure, they had a seemingly simple hypothesis: the brackets were too weak. But through careful analysis and field measurements, Acuren's engineering team uncovered a completely different root cause—leading to a cost-effective solution where the originally proposed "solution" would have made the problem worse.

The Challenge: Annual Forced Outages

A chemical processing vessel was experiencing a persistent and costly problem. This 8-foot diameter by 12-foot tall vertical vessel, used for batch processing of amine products, had an agitator shaft running through its center. At the bottom of the vessel, a steady bearing bracket secured the shaft. This critical component was failing repeatedly, with cracks forming at the bracket welds on a nearly annual basis.

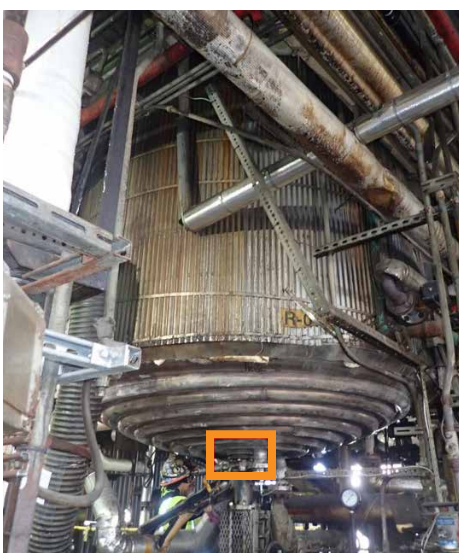

Fig. 1 - Overview of vessel and lower head with boxed area highlighting the region of interest.

In multiple instances, through-wall cracking occurred, leading to forced shutdowns and emergency mobilization of a welding crew to perform repairs. This incurred repair costs and lost production opportunity costs. The client assumed that forces from the agitator, which rotated at 40 RPM, were simply too great for the bracket design. Their intuition suggested a straightforward solution: reinforce the bracket to make it stronger.

Fig. 2 - External surface of vessel head showing multiple weld repairs and visible deformation (arrow).

"The client wanted to follow the old engineering adage of 'when in doubt, make it stout,'" explains Judah Rutledge, PE, Consulting Engineer with Acuren's Austin office. "This approach makes perfect sense for components under external loads, but we needed to confirm if that was actually the problem."

We needed to confirm if [external load] was actually the problem.

The Approach: Field Measurements Reveal the Truth

To properly diagnose the issue, Acuren's engineering team decided to measure the actual stresses occurring during operation. This presented a significant challenge—the brackets were welded to the internal shell of the vessel, and confined space entry was not possible. Therefore, strain measurements had to be taken from the outside.

The team developed an innovative approach that combined engineering analysis with non-destructive testing. First, they created a finite element analysis (FEA) model to correlate internal bracket stresses to external strain. Then, they partnered with Acuren's NDT team to precisely locate the bracket weld toe positions from outside the vessel using ultrasonic testing.

Fig. 3 - Strain gauge placement on vessel bottom head.

"We ended up working with a local Acuren NDT office and used ultrasonics to measure from the outside the exact location of the bracket on the inside so we could apply strain gauges at the correct location," Rutledge said.

With this information, the team installed strain gauges on the vessel's exterior directly beneath the internal bracket welds. They monitored the equipment through a complete production batch cycle, capturing real-time stress data from all operational modes.

The Revelation: Thermal Strain, Not Mechanical Loads

The data revealed a surprising finding: the agitator's mechanical forces were contributing only a tiny fraction of the stress affecting the bracket. Instead, the primary driver was thermal strain from the vessel's steam heating jacket.

"The fluctuating stress due to the agitator was very small compared to the stress due to thermal strain," Rutledge explained. "While the agitator bearing moment generated a fluctuation of up to 11 microstrain, the thermal strain created up to 1,200 microstrain—two orders of magnitude greater."

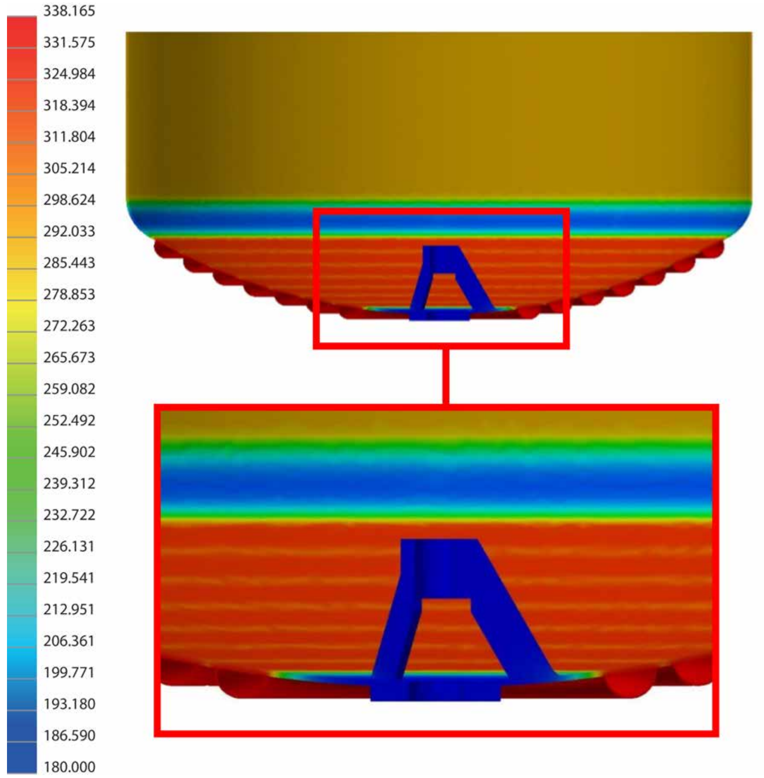

Fig. 4 - Temperature distribution (°F) showing high thermal gradients where heating coils surround the steady bearing.

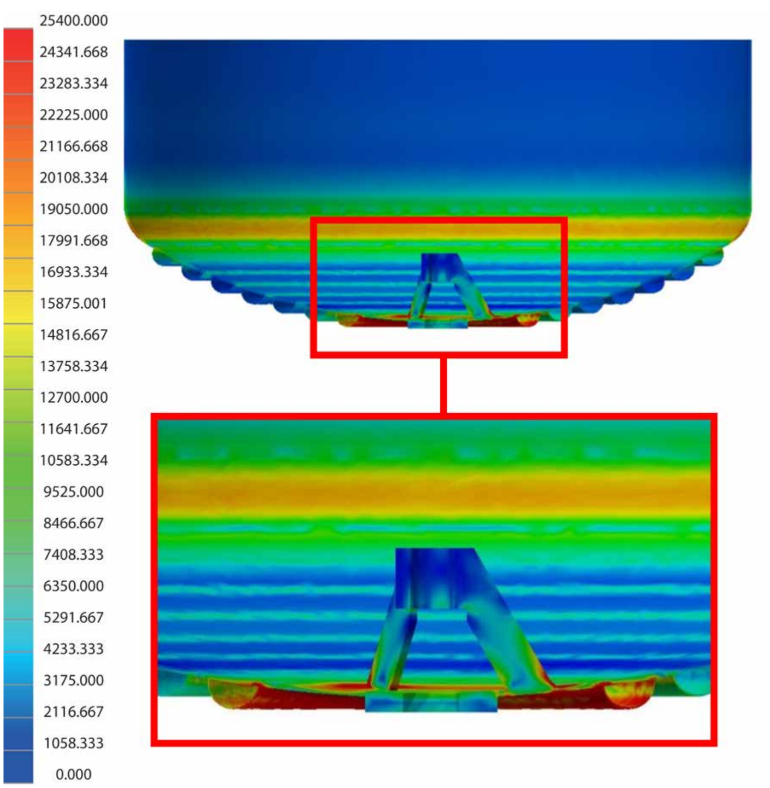

Fig. 5 - Stress distribution (psi) showing yield-level stresses at the steady bearing bracket from heating coil strain.

When the vessel's steam jacket activated, it created temperature gradients of approximately 200°F over just a few inches near the steady bearing bracket. This temperature difference caused expansion in the heated areas while adjacent regions remained cooler, creating severe thermal stresses that exceeded the material's yield strength.

The strain gauge data directly correlated with the heating and cooling cycles of the vessel's jacket, conclusively identifying thermal strain—not mechanical loads—as the root cause of the recurring failures.

The Solution: Reducing Thermal Gradients

Armed with this insight, the team ran Multiphysics simulations incorporating thermal and structural analyses to evaluate potential solutions. The results were counterintuitive:

the client's proposed "make it stronger" approach would have actually worsened the problem. FEA modeling showed that adding reinforcement would increase system stiffness, resisting the thermal displacement and significantly increasing stress.

"Understanding the physics driving the failure is critical to arriving at the proper resolution," Rutledge emphasized. "If we had gone off of intuition and the proposed first cause, we would have made the problem worse."

Understanding the physics driving the failure is critical to arriving at the proper resolution.

Instead, Acuren recommended removing the two steam coils nearest to the steady bearing bracket from service. This relatively minor modification would reduce the thermal gradient around the bracket while only marginally affecting process performance. Modeling showed this change would eliminate yielding in the bracket area and extend fatigue life by more than an order of magnitude.

The Takeaway: Data-Driven Solutions Beat Intuition

This case study demonstrates how engineering intuition, while valuable, must be validated through measurement and analysis. The right solution wasn't to strengthen the component against mechanical forces, but to address the thermal conditions creating excessive strain. "Don't implement a solution until

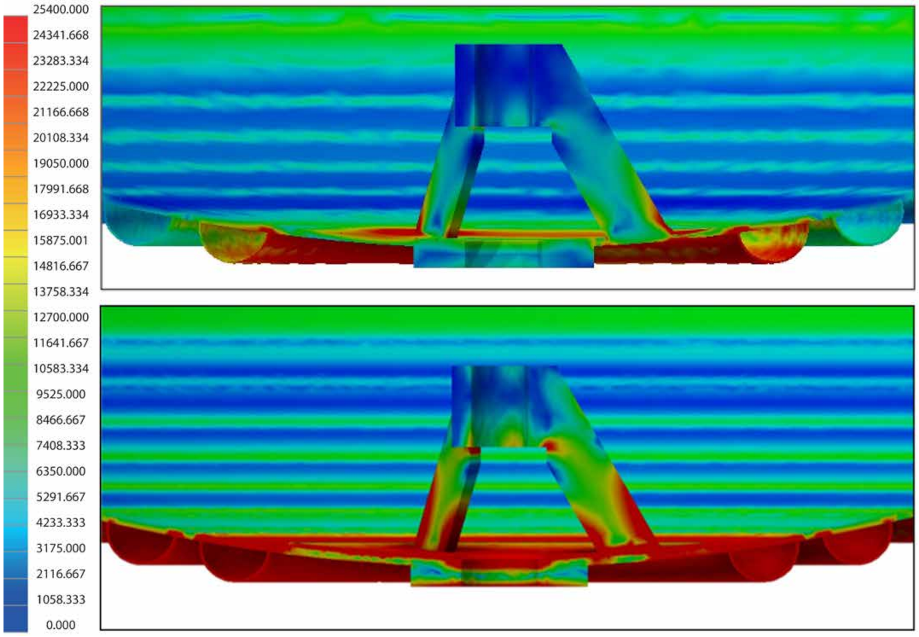

Fig. 6 - Comparison between original design condition and added reinforcement pad, showing increased stress (psi).

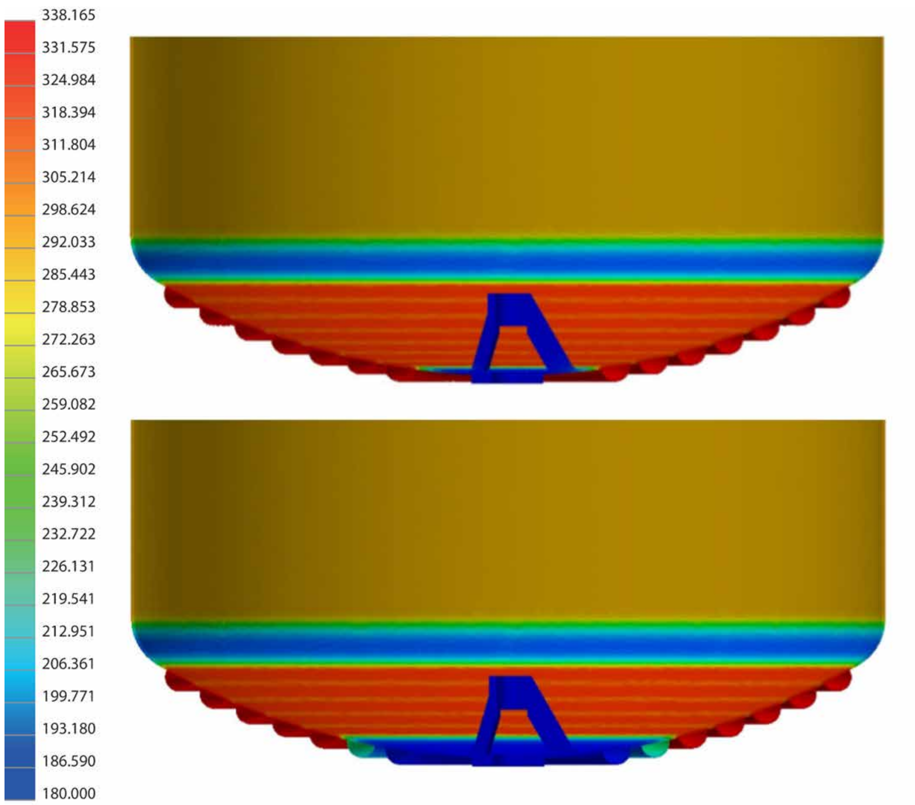

Fig. 7 - Temperature distribution (°F) comparing original design (top) versus design with two coils removed (bottom).

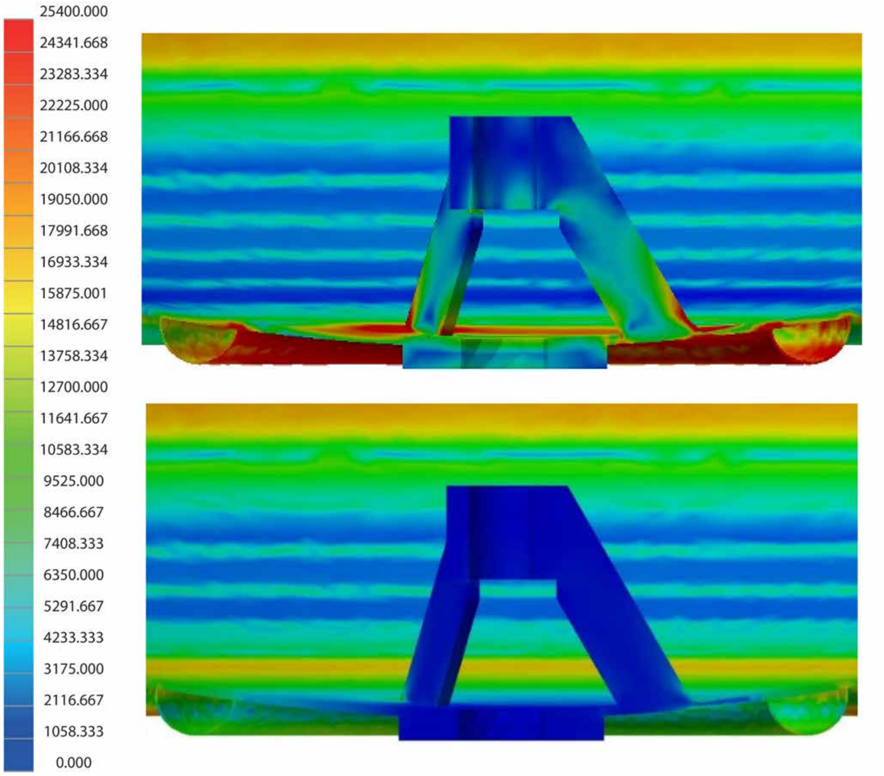

Fig. 8 - Comparison of stress levels: original design (top) versus inactive coils near steady bearing (bottom) showing stress reduction (psi).

you've fully defined and understood the problem," Rutledge advises. "You have to understand what's driving the damage before you can remediate it."

The project also highlights the value of cross-functional collaboration between engineering and inspection teams. By combining NDT expertise with engineering analysis, Acuren delivered a solution that addressed the true root cause while working within the client's operational constraints.

As Rutledge notes, "The holy grail of engineering analysis is when your measurement and your model give you the same answer. You can only have the confidence to predict the future once you've been able to effectively model the past that caused the damage in the first place."

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JUDAH RUTLEDGE

Judah D. Rutledge, PE is a Consulting Engineer specializing in Advanced Engineering/FEA at Acuren's Austin, TX office. With degrees in Mechanical Engineering from LeTourneau University, he specializes in fixed equipment inspection, repairs, alterations, and fitness-for-service assessments. Judah is passionate about solving solid mechanics problems real-time, whether it involves finite element models or hand-calcs on the back of a napkin.

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Average Vector Balancing of a Hydro Generator with Load Dependent Forces

Uneven air gap, thermal rotor sensitivity and Morten effect may cause magnetic and mechanical unbalance forces that vary with load and/or thermal stabilization. The root causes may vary from rotor/stator runout variation, automatic voltage regulator tuning, post field rewind assembly error, bearing/stator cooling system thermal gradient, etc. This article provides a case study of a vertical Francis Hydro turbine and the balancing process used to achieve acceptable vibration at all operating loads.

The generator-turbine set discussed in this article is represented in Figure 1 below and is considered a group 4 machine according to ISO 20816-5:2018[1]. Unit power is not relevant to the process when we consider the hydro turbine operation as a percentage of wicket gate opening from 10% to 100% at 10% steps. Note that the minimum wicket gate opening varies for designed operating conditions (head gate level and tailrace levels) and the required operating range. The rotor mass is approximately 100,000 lbs which gives us a target displacement of less than 5.4 mils, pk-pk to achieve a G6.3 balance quality[2].

Data acquisition system consisted of system capable of 0 to 2kHz, with 3,200 lines of resolution, and appropriate sensors; 8mm radial proximity probes (200 mV/mil) at the thrust/guide bearing and turbine bearing; phase or tachometer reference (capable of speed detection below 500 rpm).

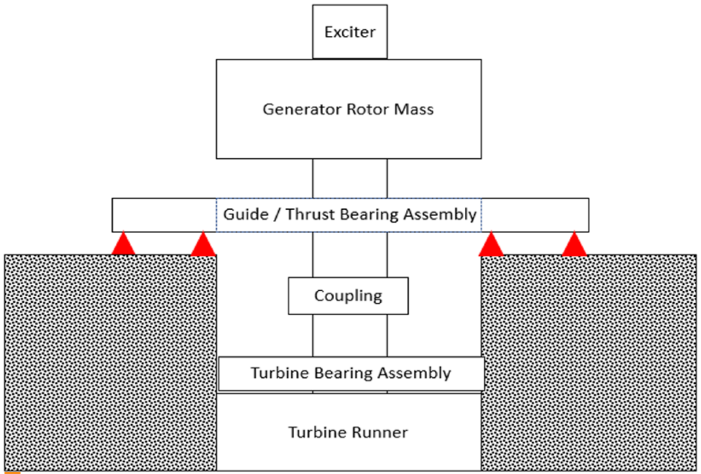

Fig. 1 - Francis Turbine, block diagram

Average Vector Balancing Process

As with any balance process we need to assess the initial or “As-Found” condition. Figure 2 is a representation of the 1x vectors (amplitude and phase) at load increments of 10% wicket gate open. The guide / thrust bearing indicates a number of load conditions that exceed the target but some would also exceed trip parameters (refer to ISO 20816-5), whereas the turbine 1x vectors are within the target displacement amplitude. The guide / thrust bearing exhibits an average light spot vector much larger than the turbine bearing, and the requirement to average both turbine and guide/thrust vectors should be continuously assessed during the process.

It was decided to add a trial mass related to the guide/thrust bearing average vector only, given that the turbine bearing vector is much smaller. Previous balancing influence coefficient experience indicated 2,483 grams of clay at 290 degrees would reduce the 1x vector amplitude of 10% and 20% gate by at least 50%.

The results of the trial mass observed in Figure 3 indicates 1x vectors at all loads are within the displacement target, except guide/thrust bearing 1x vector at 10% gate.

Since the guide/thrust bearing 1x vector is only over the target by approximately 10%, it was decided to remove the trial weight, then attach and weld permanent steel weight to the generator rotor.

The final weight ended up providing 2,457 grams of steel at 289 degrees due to remote facility manufacturing limitation. The "As-Left" 1x vectors after the final weight was added are presented in Figure 4 and they are all within the displacement target.

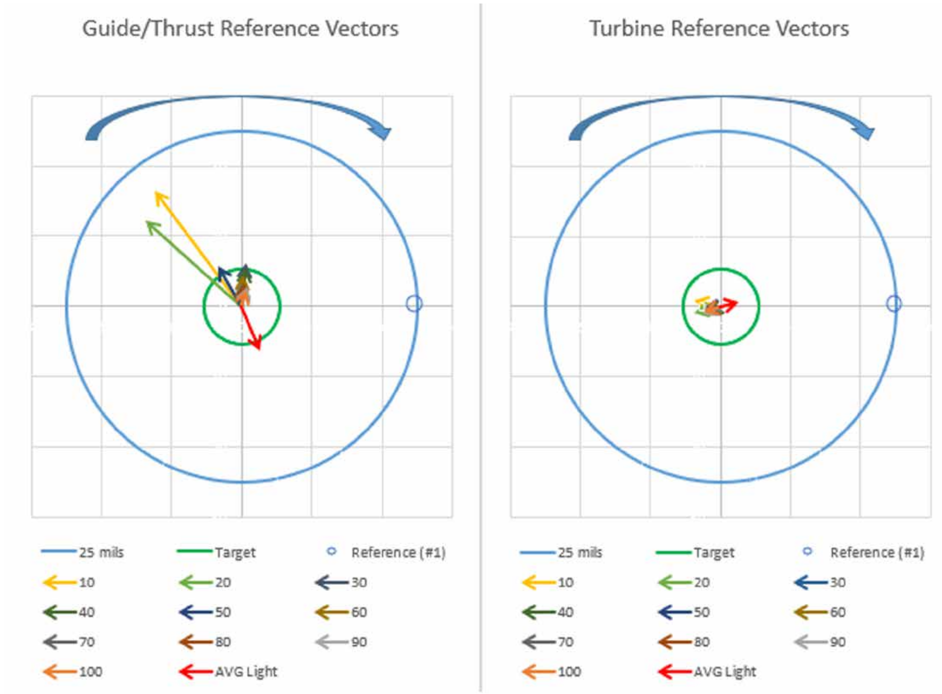

Fig. 2 - Reference 1x vectors, "As-Found"

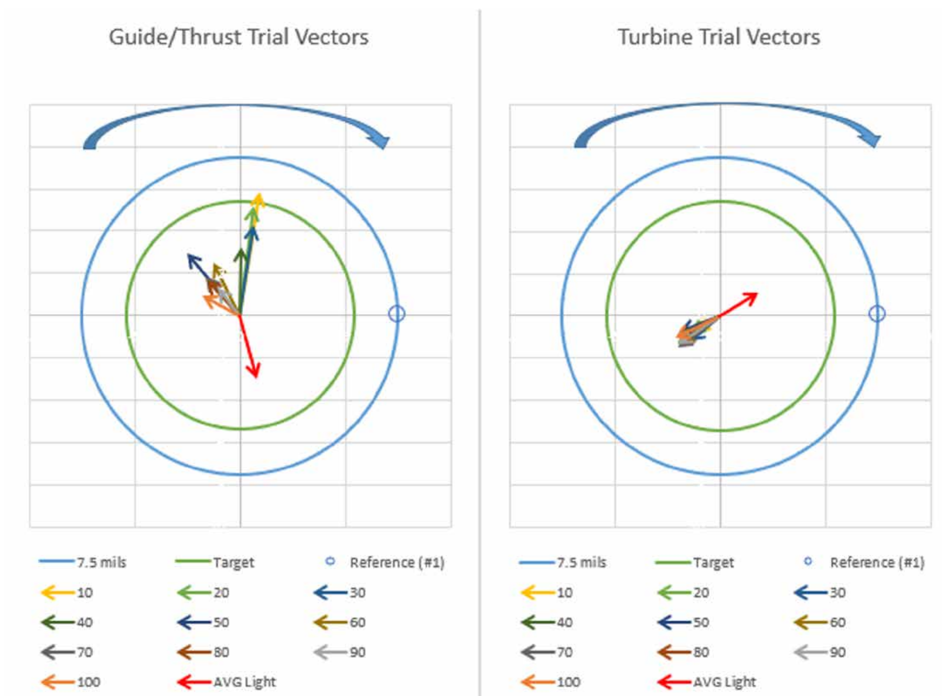

Fig. 3 - Trial 1x vectors

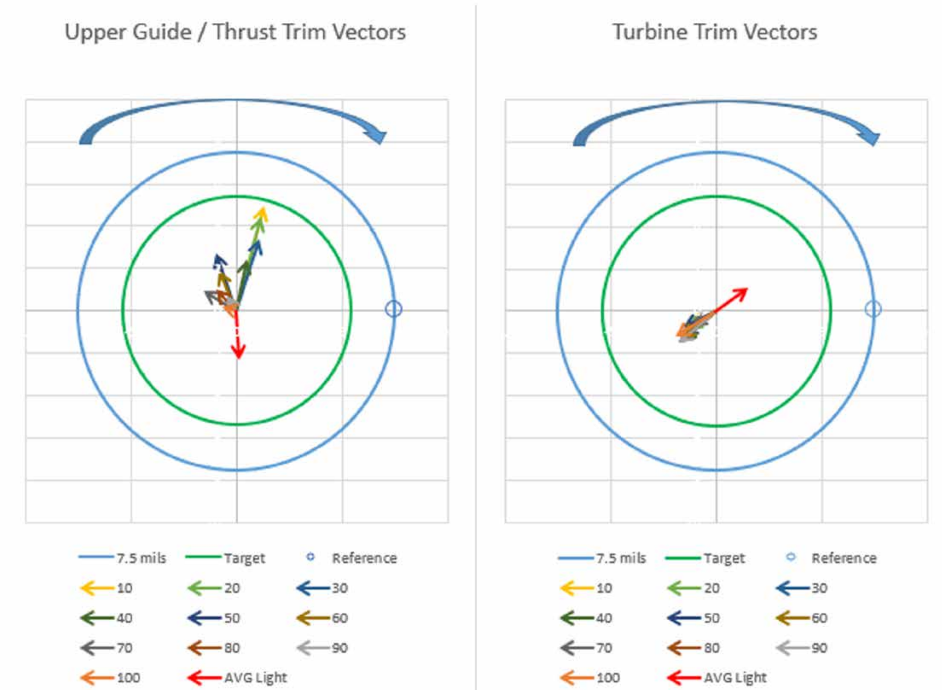

Fig. 4 - Trim or validation 1x vectors, "As-Left"

Conclusions

The "As-Left" balance quality for the average vector meets G2.5 which is better the recommended G6.3[2]. Also, the unit is suitable for unrestricted operations with appropriate monitoring[1].

References

1. Mechanical vibration - Measurement and evaluation of machine vibration - Part 5: Machine sets in hydraulic power generating and pump-storage plants, ISO 20816-5:2018

2. Mechanical vibration - Rotor balancing - Part 11: Procedures and tolerances for rotors with rigid behaviour, ISO 21940-11:2016.

MATTHEW HOLMES

Matthew Holmes, P.Eng. is a Category 3 vibration specialist (CMVA and VI) and professional engineer (Nova Scotia) with 25 years of experience in asset management and diagnostics for multiple industry segments (including power generation, manufacturing, marine vessels, aerospace, military weapons systems). Matthew is currently the Division Manager for Acuren's Reliability Engineering Team supporting Acuren's customers onsite and remotely throughout North America.

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Smart Simplification: *How Three Teams Delivered Greater Value*

When a Midwest refrigerant recycling facility needed to establish a comprehensive inspection program, three Acuren teams united their expertise to create a tailored solution. This collaboration between the Grand Rapids and Austin engineering teams and the Detroit inspection team demonstrates how Acuren's diverse capabilities deliver optimized programs for clients.

The Challenge

The Ohio processing facility requires regular inspection of numerous tanks, vessels, and piping systems for regulatory compliance. The client initially asked for a risk-based inspection (RBI) program—a complex approach that is most effective for much larger facilities.

"For very large facilities with hundreds or even thousands of pieces of equipment, risk-based inspection can save money overall, but requires more engineering investment and detailed analysis," explains Brian Cooper, PE, PMP, who leads the Integrity & Design team in Grand Rapids.

Cross-Team Expertise

The collaborative effort began when Chris Hoelzle from Detroit, who had previously performed inspections for this client, recognized an opportunity for engineering involvement to establish an inspection program.

Judah Rutledge from the Austin Engineering office brought specialized knowledge in facility assessments and was able to guide the client toward a more appropriate solution. "Judah was able to walk the client through the pros and cons of the risk-based inspection program approach and help them make the decision to go with a simpler reassessment interval-based approach," notes Cooper.

The three teams developed a comprehensive service offering combining each group's unique capabilities:

Engineering from Austin: Engineering support and assessments to determine minimum allowable thickness

Engineering from Grand Rapids: Equipment and records database and inspection management system

Inspection from Detroit: Physical inspections and data collection, reinspection interval determination

Value Through Collaboration

The interval-based approach provides the client with a straightforward solution where each piece of equipment will be visually inspected every five years, with more intensive inspections every ten years.

"For this facility with dozens of pieces of equipment, it's much more manageable cost-wise to simply go with prescriptive intervals for inspecting each piece of equipment," Cooper explains.

The Grand Rapids team's expertise in program and database development and management was crucial for creating a sustainable, long-term inspection solution. Their system will track inspection schedules, generate scopes of work, and maintain comprehensive records—turning separate inspections into a cohesive, ongoing program.

"It never would have come to my office without Chris," Cooper emphasizes. "This was his client for NDT work, and they had this need for program development that was beyond his scope."

Cooper adds, "We never would have tackled this kind of facility without Judah being able to help us develop the mechanical integrity piece of it. Having a solid SME to help set us up for success moving forward is awesome."

This team effort showcases how Acuren's technical diversity and cross-regional collaboration can deliver comprehensive, tailored solutions to meet each client's specific needs.

BRIAN COOPER

Brian J. Cooper, PE, PMP serves as Division Manager for Integrity and Design Engineering and Tank Inspection in Grand Rapids, MI. With 18 years of experience in energy infrastructure safety, he leads three specialized teams focused on pipeline integrity, engineering design, and tank inspection.

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Acuren's Full-scale Destructive Test Lab Simulates Real-world Conditions

Managing the integrity of North America's aging pipeline systems is one of the most challenging undertakings facing today's engineers employed by pipeline operators. The challenge is further intensified when considering the critical role that pipelines play in the everyday lives of those in North America. Along with advanced inspection and engineering assessment methods, full- scale testing can play an important role in helping pipeline executives and integrity engineers make the best decisions concerning injurious defects. Essentially, full-scale testing helps "sharpen the pencil" to ensure that integrity dollars are spent where they achieve the highest return on investment.

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Acuren's Magnolia Office includes a 14,000 ft^2 test facility where failure analysis, mechanical testing, and full-scale destructive tests are conducted. Provided in this article are examples where full-scale testing has been used to evaluate the effects of dents, girth welds, wrinkle bends, and cracks on pipeline serviceability. A discussion is also included on the creation of simulated defects and techniques employed for their creation.

Simulated Defect Creation

Because there are a limited number of real-world features available for experimental assessment, testing often requires the creation of simulated features and defects. An important advantage in creating features is the ability to construct a well-defined test matrix that includes variations of key variables, including corrosion depth and length, dent depth, and crack depth and length.

Corrosion features can be fabricated using conventional machining techniques, electric discharge machining (EDM), and chemical etching to generate a pitted profile. Dents are fabricated by pressing an indenter into the pipe to a prescribed depth, often with internal pressure in the pipe. There are several techniques for fabricating axial cracks, although one of the most repeatable involves the installation of an EDM notch into the pipe wall followed by limited pressure cycling to generate cracking at the base of the notch. Girth weld defects have been created by grinding out a portion of the root pass during weld fabrication or in the case of an existing girth weld, using an EDM notch to generate lack of penetration or incomplete penetration features.

The sections that follow provide examples of how real world and simulated defects were tested destructively to quantify their severity.

Dents

Most pipelines have dents. Since the inception of the pipeline industry, dents have been a threat. Over the past 40 years a significant body of research has been conducted to quantify the threats posed by dents and mechanical damage, including full-scale burst and pressure cycling. Provided in Figure 1 is a photograph showing a dent installation rig and a process by which dents are created in the test lab using an indenter and a hydraulic cylinder. Once the dent us installed in the pipe sample, cyclic pressure is applied to the pipe sample to simulate future operation until a fatigue failure occurs.

Fig. 1 - Dent installation test rig

Figure 2 shows a photo of a dented test sample along with a fatigue crack that developed in the shoulder of the dent after approximately 10,000 pressure cycles were applied.

Fig. 2 - Failure of pressure cycled dent

Girth Welds

Pipeline loss of containment from geohazard loading can occur when high axial strains are generated in a displaced pipeline. When the loading is in tension, failure generally occurs as a rupture at a girth weld. When the loading is in compression, a buckle first forms, followed in some instances by a crack at the buckle. Full-scale testing is an ideal means for evaluating the strain capacity of vintage welds and can include lack of penetration features. In full-scale testing, loading includes either axial tension loading as shown in Figure 3, or with the application of bending using a 4-point bending frame as shown in Figure 4. Loading can either be quasi-static or cyclic and conducted with internal pressure in the pipe.

Fig. 3 - Photo and schematic of Acuren's 1-million lbs. tension load frame

Fig. 4 - 4-point bending frame

Wrinkle Bends

Wrinkle bends were a common method for constructing bends in transmission pipelines until the mid-1950s. There are literally tens of thousands of wrinkle bends in North America. Wrinkle bends typically fail as circumferentially oriented cracks due to high strain / low cycle bending fatigue. There are several challenges associated with testing wrinkle bends: the first is obtaining actual wrinkles removed from service and the second is simulating the extreme bending loads to which they are subjected.

Provided in Figure 5 is a photograph of Acuren's high strain-low cycle fatigue frame with a bending capacity of 800,000 ft-lbs. Testing wrinkle bends is an effective method for quantifying the number of cycles a wrinkle feature can survive before leaking. Once this value is determined pipeline operators can determine if geohazard loading in a particular region might generate similar conditions.

Fig. 5 - High strain bending frame (800,000 ft-lb capacity)

Planar Defects and Crack-like Defects

Some of the most significant work involving full-scale testing has been completed in relation to evaluating the impact of planar defects and crack-like features on the pressure capacity of vintage pipe materials. Current crack assessment methods tend to underestimate the failure pressure of vintage pipeline materials having cracks, resulting in excessive excavation and repair. There are several reasons for this, but the primary being the underestimation of fracture toughness using conventional sub-scale testing methods.

There are several approaches for testing cracks in pipe samples. One involves testing cracks in pipe materials removed from service. The other option, and the one more often used in full-scale testing, involves the creation of cracks generated by pressure cycling notches installed via EDM. Figure 6 includes a photograph of an EDM machine used to install notches. Figure 7 includes a macrograph showing a crack that initiated from an EDM notch. Testing involves either pressure cycling the samples until a through-wall crack develops or pressurizing the pipe sample until a burst failure occurs, as shown in Figure 8.

Fig. 6 - Machine used to install EDM notch

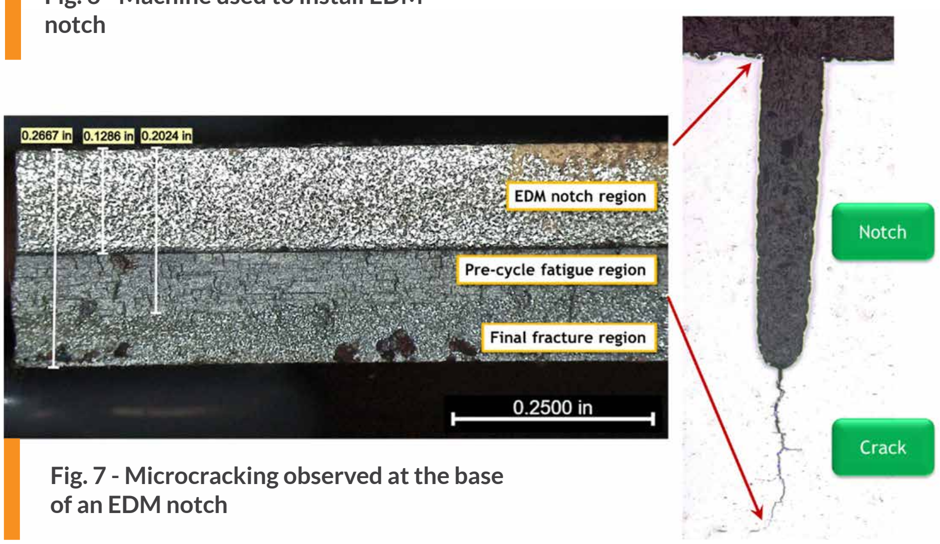

Fig. 7 - Microcracking observed at the base of an EDM notch

Fig. 8 - Burst test of sample having a crack-like defect

Closing Remarks

The pipeline industry has used full-scale testing since its inception. Even before numerical models and analytic solutions were developed, design and metallurgical engineers learned that pipe materials have limits and the best way to determine those limits involved pressurization to failure. Full-scale testing has and will continue to contribute significantly to our understanding on the capabilities and limitations of pipe materials, repair systems, and other pipeline-focused technologies. A well-designed, instrumented, and executed full-scale test can provide valuable insights for design and integrity engineers charged with the responsibility of constructing and maintaining safe pipelines.

Full-scale testing has and will continue to contribute significantly to our understanding on the capabilities and limitations of pipe materials, repair systems, and other pipeline-focused technologies.

CHRIS ALEXANDER

Dr. Chris Alexander, PE, serves as General Manager, US Engineering at Acuren. Previously, he founded ADV Integrity, acquired by Acuren in 2024. With over 30 years' experience, Chris specializes in pipeline technologies, composite repairs, and full-scale destructive testing. He holds three Mechanical Engineering degrees from Texas A&M University, is a licensed Professional Engineer in Texas, and has authored more than 150 technical papers. Chris has organized over 35 Joint Industry Programs throughout his career.

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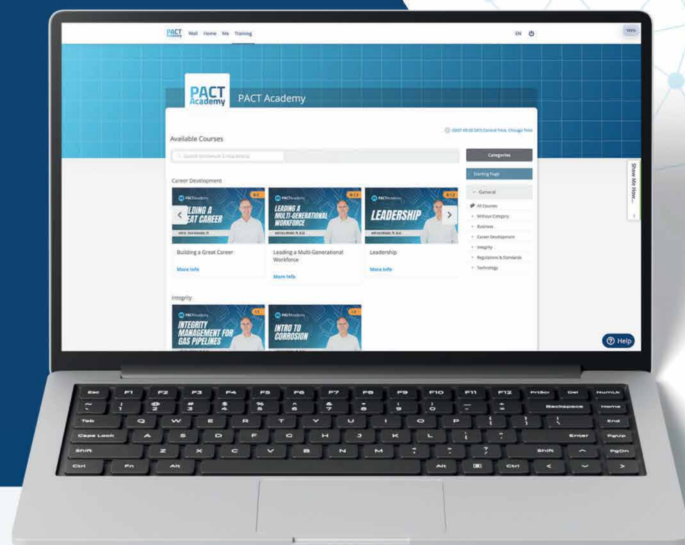

Currently in Academy as of March 2025

PAST EVENT RECORDINGS AND PRESENTATIONS

- Integrity Impact | Midwest 2024 presentations
- Annual PACT Summit 2024 workshops

TECHNOLOGY

- Intro to Composite Repair Technologies

CAREER DEVELOPMENT

- Leadership & Mentoring
- Building a Great Career

PIPELINE INTEGRITY

- Integrity Management for Gas Pipelines
- Integrity Management for Hazardous Liquid Pipelines
- Intro to Corrosion
- Intro to Root Cause Analysis for Integrity Management

REGULATIONS & STANDARDS

- Regulatory Changes – Recent Rule Changes to Parts 192 and 195

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