

### AT A GLANCE

**Problem:**

Early-life fatigue failures on Tier IV production engines from factory misalignment of bellows.

**Objective:**

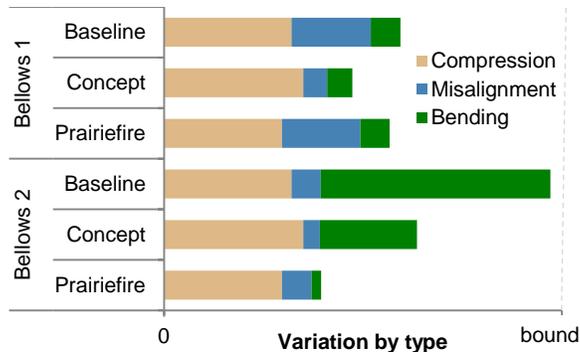
Determine if the new, more expensive concept would last longer and assemble better than the existing design.

**Solution:**

Prairiefire refined the current design, keeping standard components and tolerances. We reduced bellows pre-load by over 28%, allowed 3x more thermal and dynamic deformation before failure, and reduced assembly time.



Products pictured are representative and not necessarily the products on which the work was performed



### SUMMARY

Our customer had early-life field failures in the turbo interstage bellows on their production engines. They asked Prairiefire to compare their more costly concept design with their current support structure in terms of bellows life and assemblability.

Prairiefire analyzed bellows alignment with a sensitivity model - quantitatively linking fit-up and component loads to geometry, GD&T choices, fixture designs, manufacturing variation, and assembly methods. We also include a force balance for over-constrained parts and worked with the suppliers to understand their fixtures and tolerances.

We went on to refine the current design based on exact constraint principles, minimizing cost and complexity while maximizing bellows life. Our refinements reduced bellows pre-load by over 28% and allowed 3x more thermal and dynamic deformation before failure.

Instead of tightening tolerances or making the design overly-adjustable, we made the system less sensitive to variation. We intentionally removed competing constraints and allowed for self-alignment during assembly.

We solved their warranty problems using standard component tolerances and supplier parts. Instead of just fixing the problem here, our best practices documentation is being used to improve new production, too.

### BENEFITS

- Reduced bellows pre-load by over 28%, allowed 3x more in-service deformation before failure, and reduced assembly takt time.
- Lower cost and complexity while keeping standard parts and tolerances.
- Quickly and accurately diagnose assembly errors using existing bellows inspection data.
- Improved company-supplier relations by Prairiefire mediating the shared issue.
- Confidence to select the best solution based on facts and data.
- Guidance on future designs from our best practices documentation.

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Prairiefire has 20 years of industry experience helping improve performance, quality, and fit-up through design and analysis of variation. We are 6σ certified and have taught Sensitivity-Based Design, GD&T, and Dimensional Management to hundreds of engineers in 8 countries.