

Current Important Wheel and Axle Issues

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Presentation Outline

- High Impact Wheels
- Thermal-Mechanical Shelling
- What Can We Do About High Impact Wheel Removals?
- Locomotive Wheel Stresses
- Axle Fatigue Issues
- Axle Radial UT Testing

High Impact Wheels

- Number of removals has accelerated dramatically in recent years
- For a 36" wheel, 560 impacts per mile, or, an impact every 9.4 feet
- Some cars accrue 100,000 miles per year
- Very damaging to wheels, rails, etc.
- Must work to fix this problem

Cause of High Impact Wheels?

- Spalling – Sliding/martensite formation
- Shelling – Rolling contact fatigue
- Thermal-Mechanical Shelling (TMS)
 - Based on car inspections in 2004, western Nebraska, TMS seems to occur often in unit coal fleets
 - Heat from braking, combined with rolling contact fatigue loads causes TMS

What Can We Do About These High Impact Wheel Removals?

- Always best to fix the root cause of a problem....
- However, perhaps we could treat the “symptom” by improving the wheel steel
- Desired – A steel with:
 - Improved hot hardness/yield strength
 - Improved fatigue resistance

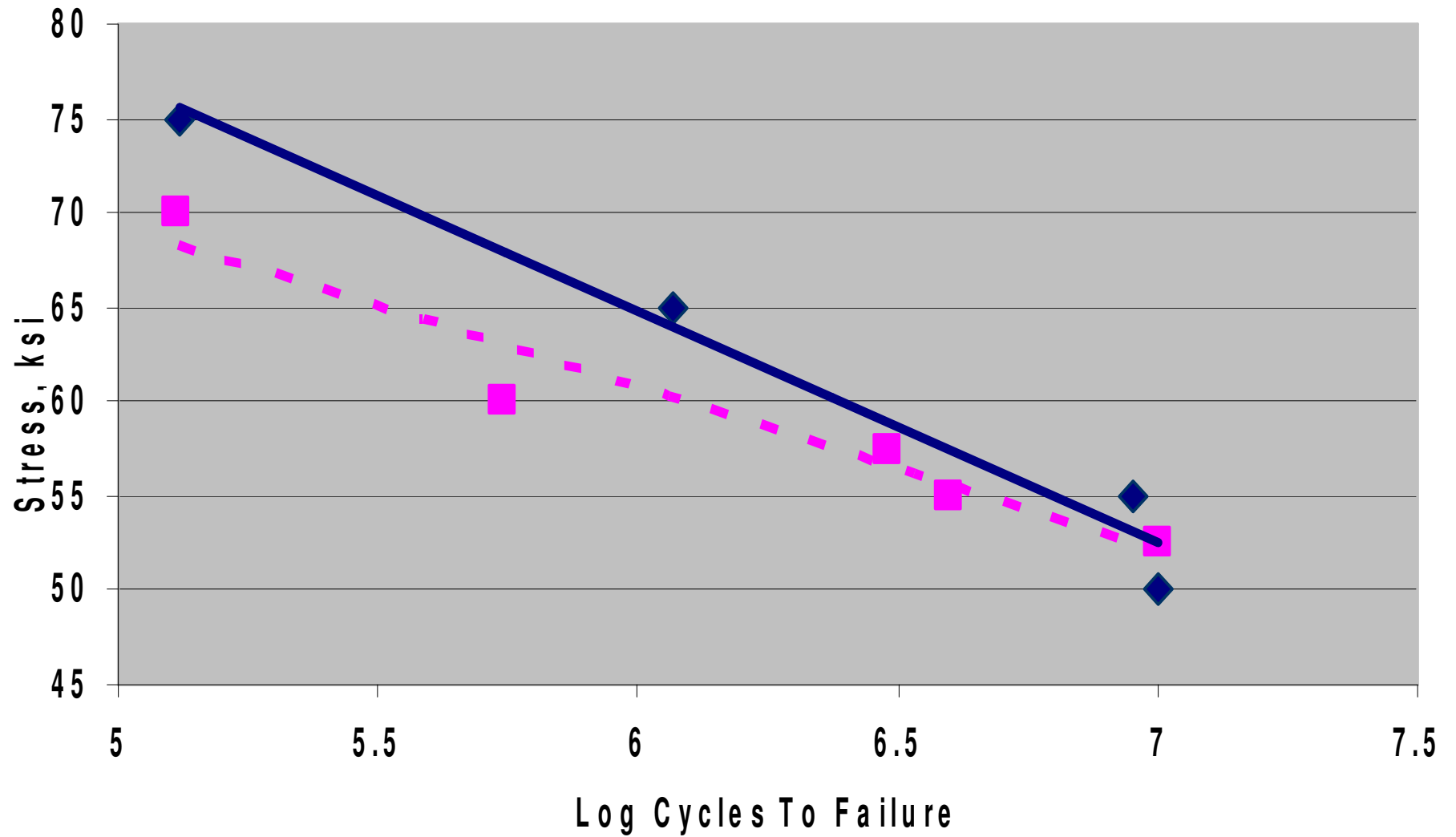
Does Microalloying Wheels Help?

- Small alloy additions made to Cl. C steel
- Longitudinal tensile samples from rim
- Room temp.- UTS and Yield
 - Class C: 164.5 ksi & 113.5 ksi
 - Microalloy: 157 ksi & 110 ksi
- 1000F - UTS and Yield
 - Class C: 63.2 ksi & 46.3 ksi
 - Microalloy: 78.1 ksi & 63.1 ksi

Does Microalloying Wheels Help?

- Fracture toughness for microalloy is 23% better than Class C
- Fatigue testing of Cl. C vs. Microalloy wheels shows that the fatigue life of microalloy steel is slightly better
- Temperature has a strong effect on fatigue life of wheel steels

1000F Fatigue Results



■ Class C ◆ Microalloy - - - Linear (Class C) — Linear (Microalloy)

Microalloy Wheel Discussion

- Maximum current Class C hardness limit of 363 BHN does not maximize fatigue benefits
- Amount of alloy elements should be further increased to combat TMS
 - Drawback, more elements means more susceptible to martensite formation from wheel sliding.....
- AAR "Class D" wheel?
 - We suggest a hardness range of 363-403 BHN
 - Further resistance to thermal mechanical shelling
 - Must be produced with existing heat treatment methods and equipment for best economics

Microalloy Wheel Discussion

- However, wheel tread damage is a symptom of other problems
- Improving the wheel steel fixes a symptom, not the root cause
- To fix thermal mechanical shelling we need to look at:
 - Tread brake heating/brake system issues
 - Truck steering issues
 - Etc.

Locomotive Wheel Stresses

- Loading environment for high-horsepower, high-adhesion locomotive wheels is still not well understood
- Need further over-the-road service testing with strain gauged wheels
- Effects of slow-speed, stick-slip, high torque?
- Effects of vibration on various designs?
- Role of residual stress in the wheel?

Axle Fatigue Failures

- Vast majority of axle fatigue failures are caused by surface initiated fatigue cracks

Comments on Axle Fatigue

- Establishing endurance limit is a key factor
 - Based upon many assumptions
- We currently do not have an epidemic of axle fatigue failures in North America, therefore operating stresses are below the endurance limit most of the time
- Axles that fail due to fatigue have exceeded their endurance limit

Comments on Axle Fatigue

- TTCI has presented data on axle service stresses at FAST
 - Highest stress levels in axles occur during curving, lead axle, high rail
 - Lateral loads are important to axle fatigue
- Notch defects shown to reduce fatigue life in TTCI FEA work
- Full scale fatigue testing of axles was last done by AAR many years ago – this is necessary to determine the endurance limit for today's axles – New TTCI work is underway now

Comments on Axle Fatigue

- Smaller axle bodies have higher bending stress levels and are more susceptible to fatigue damage in service
 - Allowable 2nd hand axle body diameter is 6-3/4" – too small !!
- If nicks and dents occur on smaller axles, fatigue damage will be accelerated
- AAR recently granted Standard Steel conditional approval to manufacture the Modified K axle with 7-7/8" body diameter and no taper
 - Designated as the "K+" axle by AAR
 - 4,000 car sets can be made

Comments on Axle Fatigue

- Increase the minimum allowable body diameter for newly manufactured K and F axles in 286 GRL service
- Remove body taper in axle – no need for minimum dimension in axle center
- Increase the minimum allowable body diameter for 2nd hand axles, perhaps to at least 7 inches. Condemning diameters should be determined through further testing

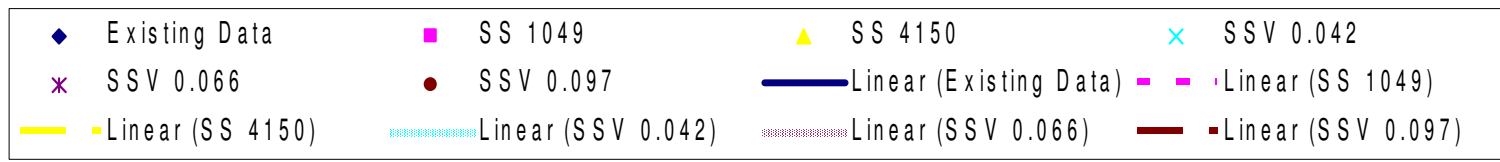
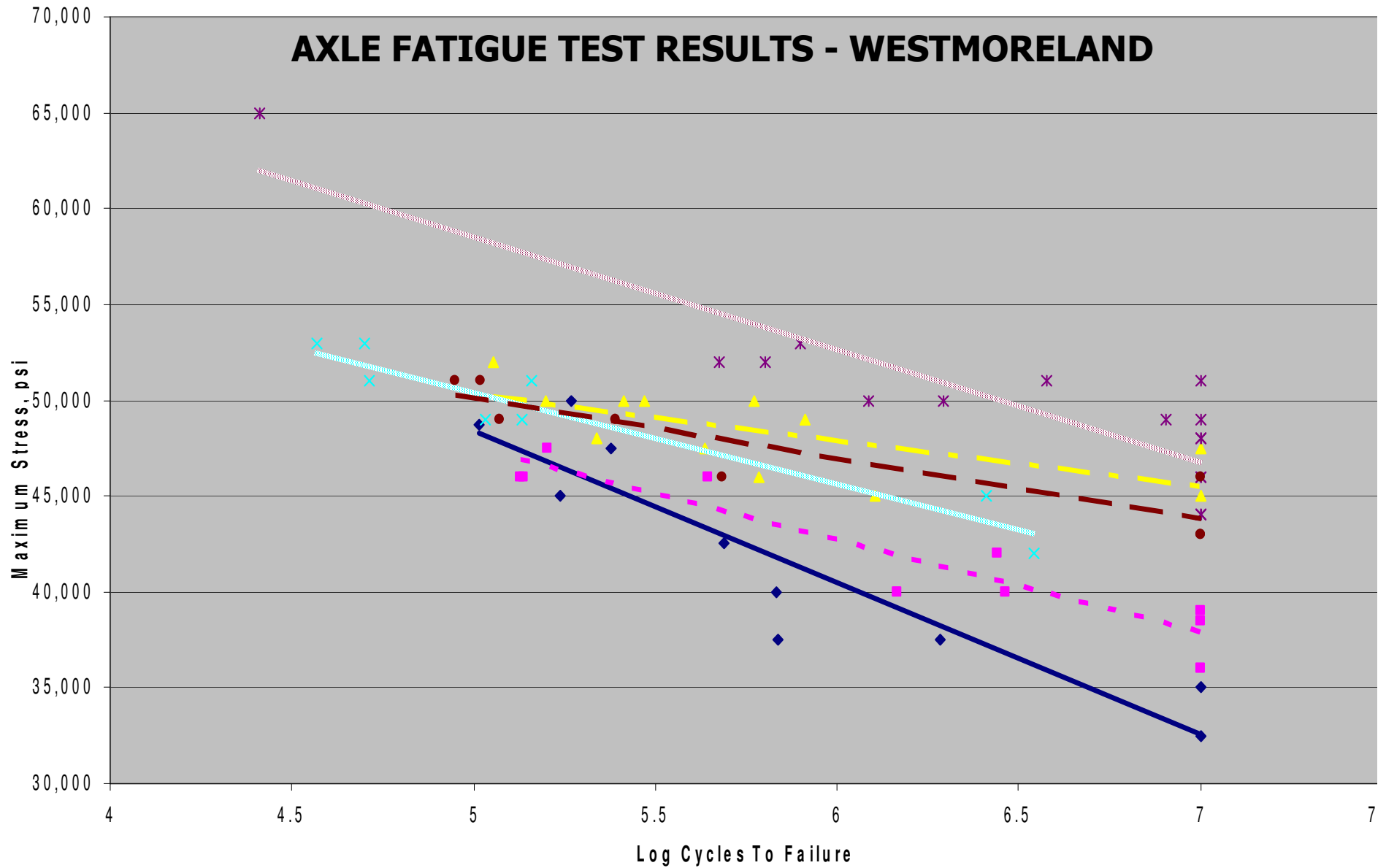
Comments on Axle Fatigue

- Efforts to improve axle handling should continue
 - Reduce nicks, dents, etc. on axle body surface
 - Although damage can be repaired by grinding or machining, the body diameter is reduced
- Magnetic Particle Inspection of all axle bodies in wheel shops should be adopted
 - Find and remove surface initiated cracks
 - Axles in 286 GRL service should be targeted

Axle Fatigue Improvement

- Goal: “Improve fatigue strength of axles while maintaining current manufacturing and heat treating methods”
- Review of past Standard Steel axle fatigue results with various Vanadium additions
- Additional steel grades are now under consideration

AXLE FATIGUE TEST RESULTS - WESTMORELAND



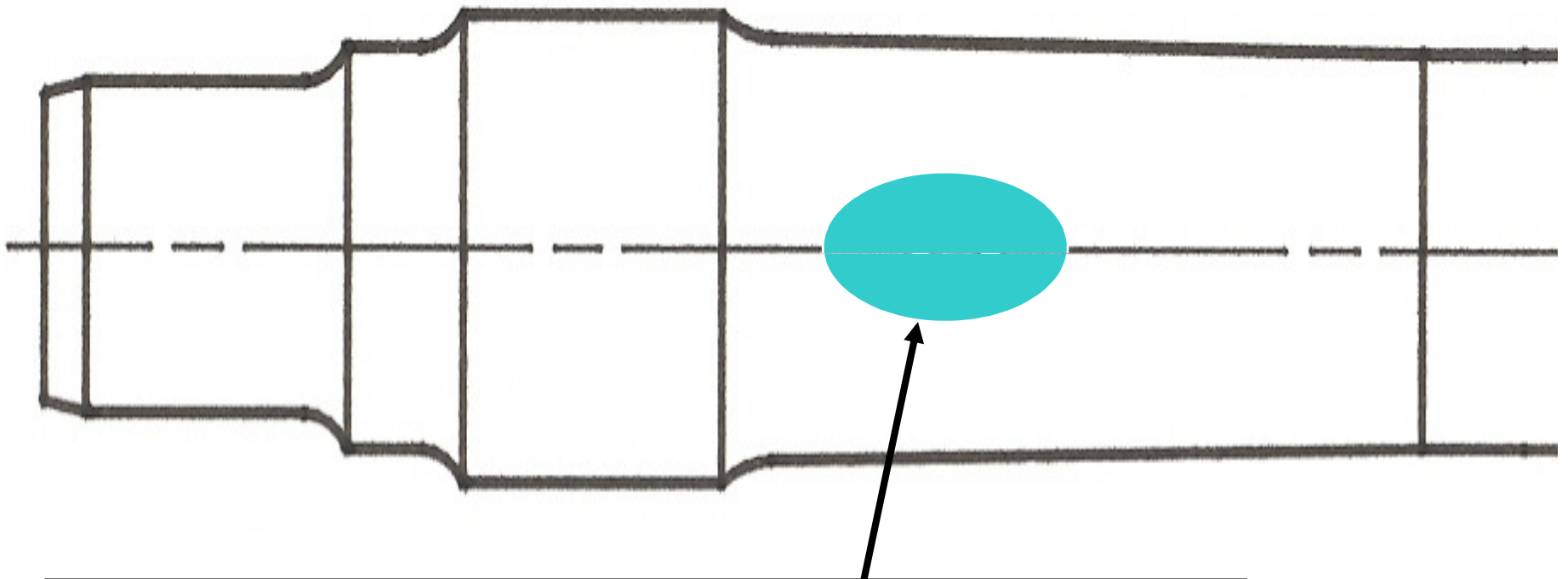
Additional Steel Grades For 2006 Fatigue Testing

- 1049, 0.025 V, no Al, no Ti
 - 1049, 0.25 Mo, 0.012 V
 - 1049, 0.25 Mo, 0.025 V
 - 1049, 0.25 Mo, 0.027 V, 0.49 Cr
 - 1049, 0.025 V, 1.16 Mn, 0.49 Si
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- Yield strength improvements have been noted
 - Fracture toughness testing also will be performed as part of this study

Need for Radial UT Testing of Axles

- Current AAR UT “end testing” does not “see” the sort of discontinuity found by radial UT testing
- The current AAR UT test for axles needs to be updated and improved
- Increased GRL (286K GRL), improved car utilization, and more severe wheel impact loads means that axles are under greater service stresses than ever before
- Radial UT testing finds large central axis discontinuities using a “Loss of Back Reflection” (LBR) criteria

Diagram Showing Approximate Large Discontinuity Location

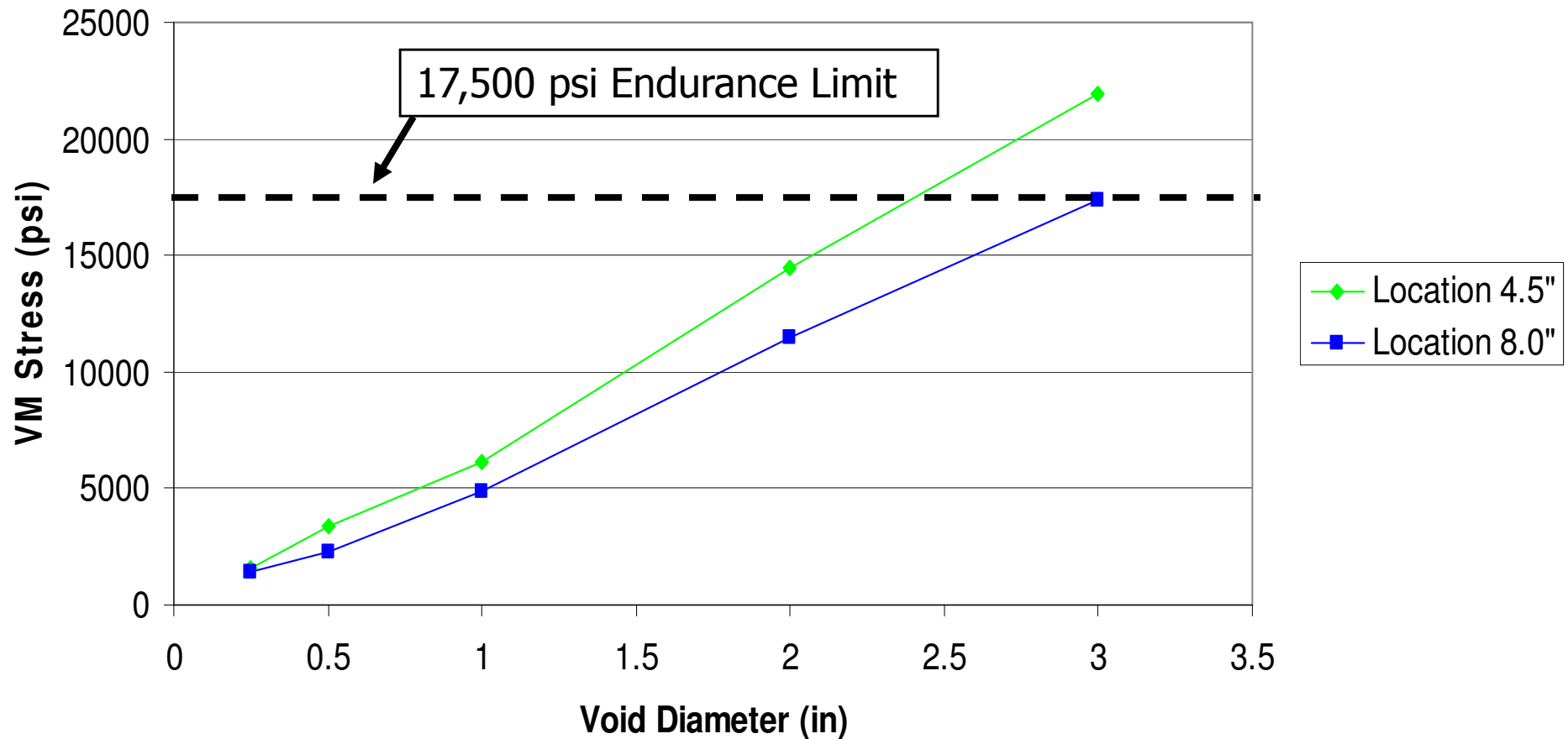


Radial UT Test Can Find Large Discontinuities

Finite Element Analysis

- Simulated discontinuities at centerline in axle body near wheelseat
- Analysis done by Rusin Consulting Corp.
 - Press fit, 286K GRL bending and 8K lateral loads
 - Discontinuity diameters: 1/4", 1/2", 1", 2", 3"
- 1" discontinuity – 6,000 psi stress result
- Fatigue endurance limit (AAR 1938-1950 full scale axle fatigue tests were conducted), body 17,500 psi

Maximum VM Stress (psi) vs Void Diameter (in) at 4.5" and 8.0" from Inside Corner of Wheel Seat on a K Axle



Axle Evaluations

- Axles UT tested radially along length
- 63 Axles with various LBR % cut open to examine physical size of discontinuity
- Wheelseat test blocks, side drilled holes at central axis, tested with 1" diameter transducer, 2.25 MHz
 - 1" diameter hole 100% LBR
 - 2" diameter hole, 100% LBR
- Able to detect large discontinuities

Axle Radial UT Recommendations

- Adopt proposed new radial UT specification for new axles and publish in AAR M101
- Also maintain current AAR UT test for new axles in M101
- Begin testing second-hand axles with same radial UT testing procedure proposed for new axles
 - Pre-1970 axles (approx. date) had no UT test at all
 - Some number of second-hand axles will benefit from this improved inspection procedure
- 80% LBR rejection can find large discontinuities

QUESTIONS

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