

# Measurement of Residual Stress in Rails using Ultrasonics

ICRI Discussion

Dr Henry Brunskill  
henry@pktopk.co.uk

[www.pktopk.co.uk](http://www.pktopk.co.uk)



The  
University  
Of  
Sheffield.

---

Peak to Peak  
Measurement Solutions



# Contents

---

- Introduction.
- New ultrasonic applications in wheel/rail.
- Residual stress in rails.
- Currently available measurement techniques.
- Ultrasonic measurement of residual stress.
- Discussion questions.

---

Peak to Peak

Measurement Solutions



# Introduction – Dr Henry Brunskill

---

- Dr Henry Brunskill did a PhD at The University of Sheffield in 2008.
- Almost exclusively worked on industrial applications.
- Since worked for a Sheffield based Engineering consultancy.
- Specialist in using active ultrasonics to measure tribological parameters, particularly:
  - **Contact pressure and area distribution;** Wheel rail, metal-to-metal seals.
  - **Wear;** wheel-rail, tribometers, combustion engines.
  - **Stress;** longitudinal rail, L/V, tie bars, fish plates, bolts, fasteners, pin joints.
  - **Lubricant film thickness;** bearings, rail lubrication, combustion engines.

Peak to Peak

Measurement Solutions



# Introduction – Peak to peak

---

- **Peak to peak measurement solutions** is a new organisation bridging the gap between cutting edge research and industry.
- Working with leading research organisations and other industrial partners, Peak to Peak deliver high quality products and services to a wide range of markets at low cost and with short lead times.
- Peak to peak specialise in providing the following measurement solutions in the form of consultancy services and bespoke products:

Lubricant Film Thickness

Wear/Erosion/Corrosion

Viscosity

Contact Pressure

Fluid Properties

Stress/Load

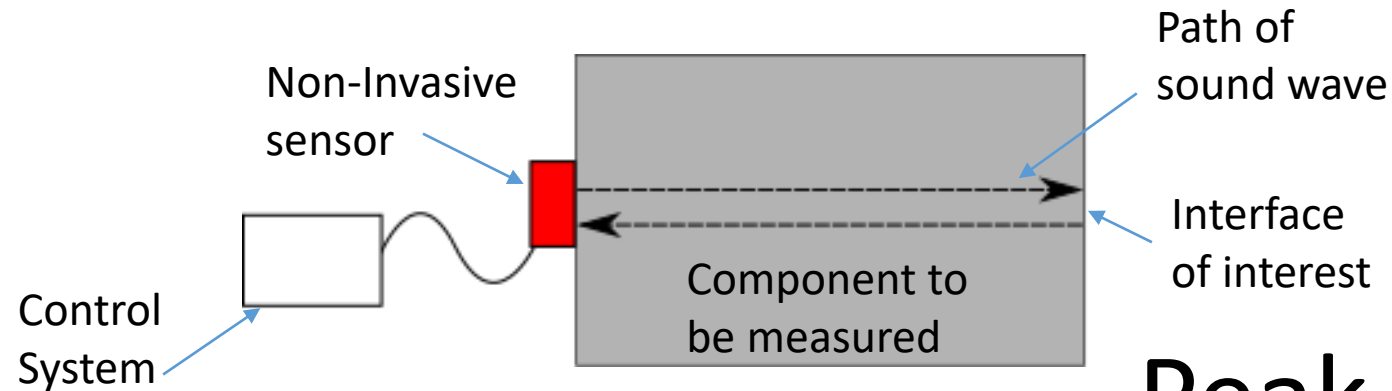
**Peak to Peak**

Measurement Solutions



# Technology overview

- Peak to peak specialise in **ultrasonic reflectometry**.
- This is similar to traditional NDT crack detection but instead using **embedded low cost sensors** to perform various measurements.
- Sensors are mounted on the outer surface of the component and the soundwave travels through the material reflecting off the interface and travels back to the same sensor.



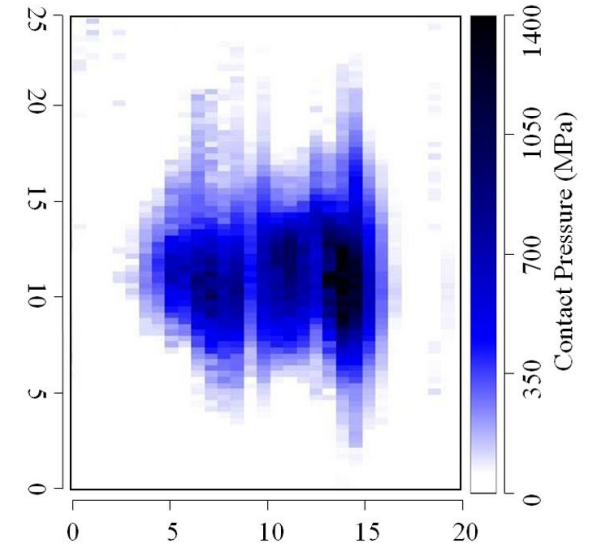
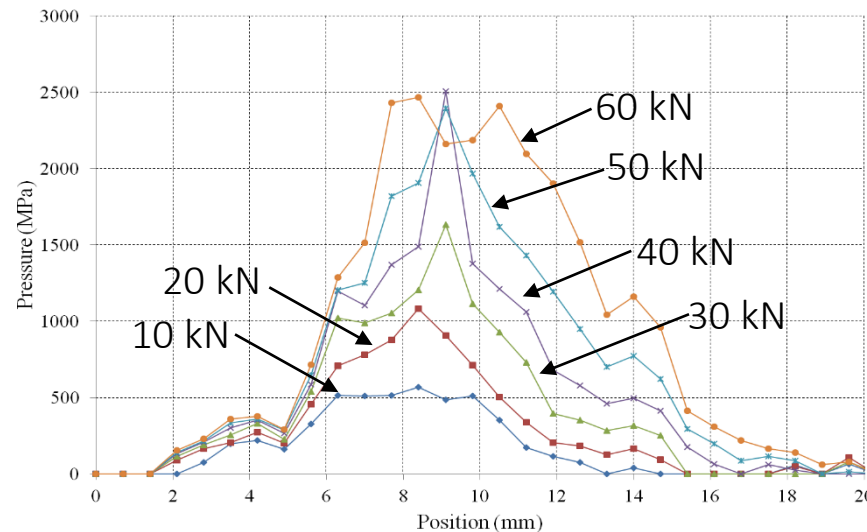
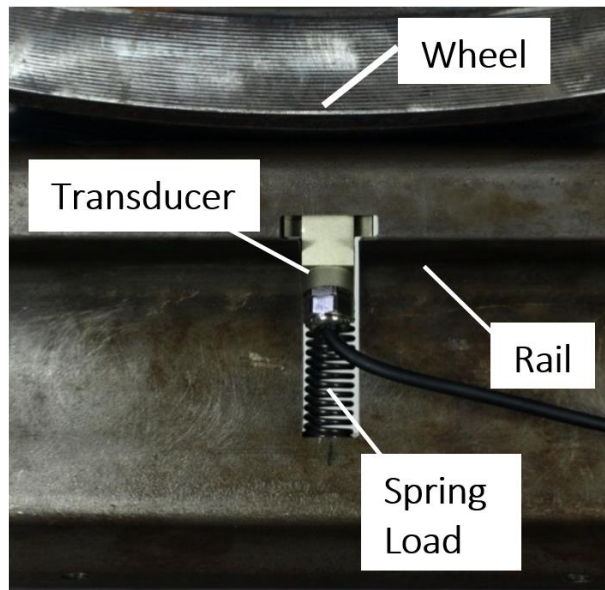
## Peak to Peak

Measurement Solutions



# Contact pressure with modified rail

- An ultrasonic array sensor is mounted in a hole cut in the rail body.
- The wheel-rail contact pressure distribution is measured as the wheel passes the sensor by reflecting soundwaves off the rail head.



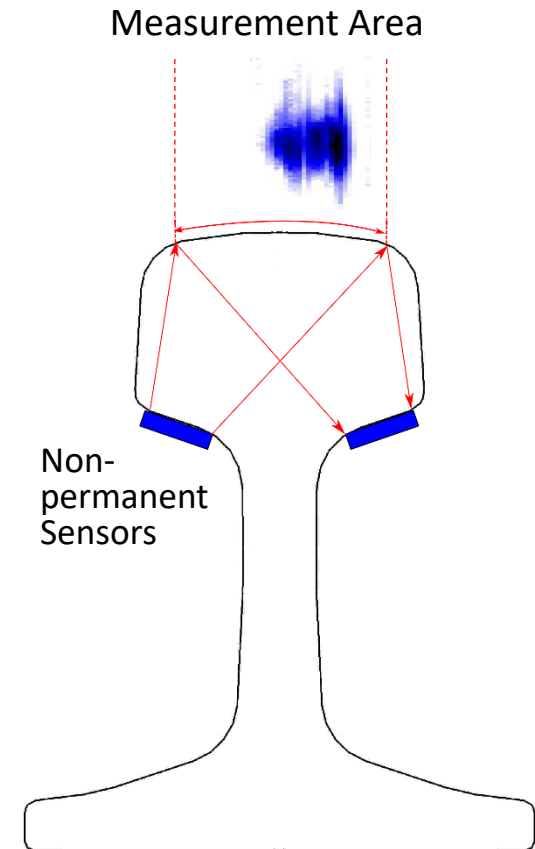
Peak to Peak

Measurement Solutions



# Contact pressure: non-destructive

- Non-permanent magnetic or bolted transducers fit to the underside of the rail head.
- Real-time contact measurement of high speed railroad vehicles – 280km/h.
- Current system measures contact only on the upper surface of the rail.
- Proven to be able to measure flange contact with same system.



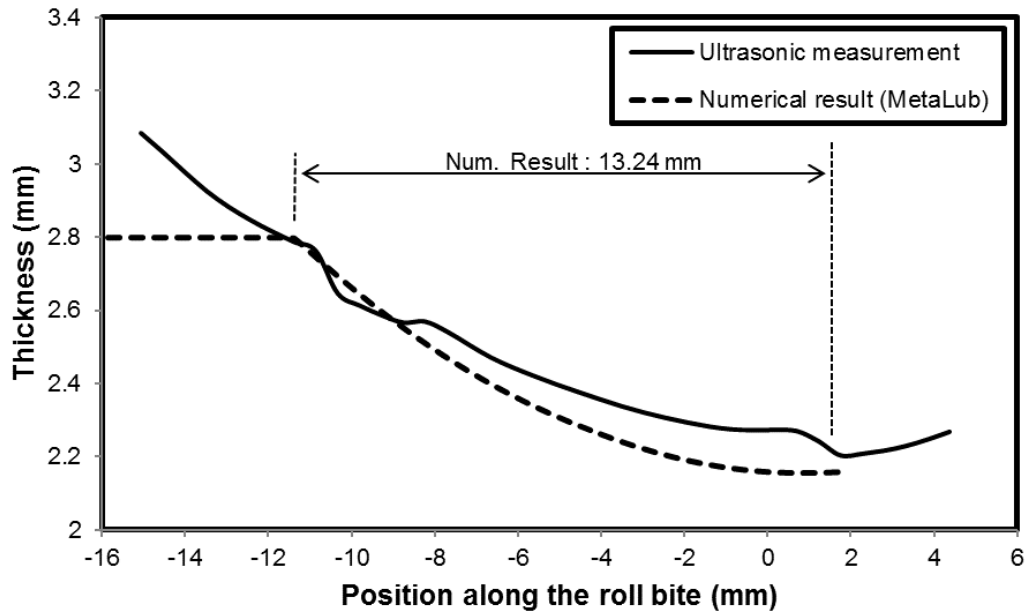
Peak to Peak

Measurement Solutions

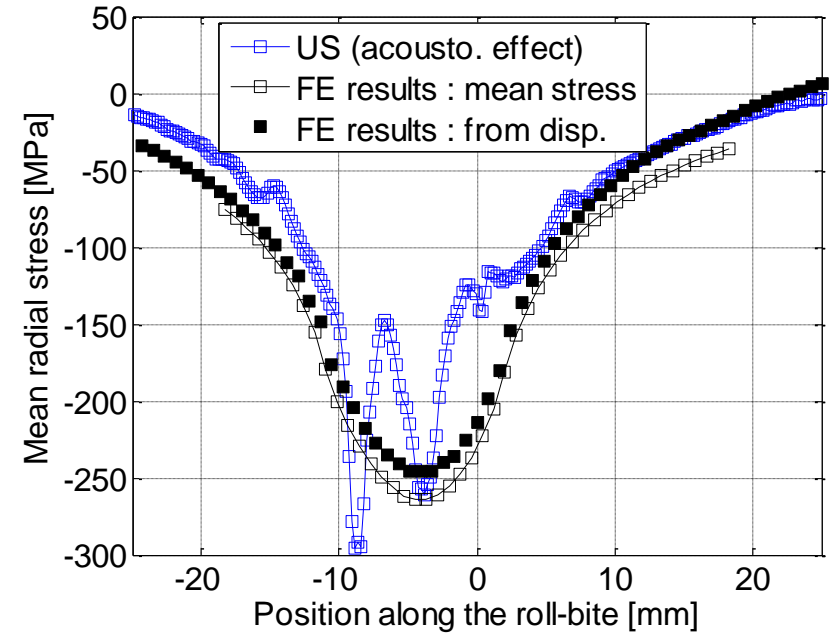


# Rail manufacturing monitoring

- Steel rolling can be monitored in real time and in-situ. Including product geometry, roll contact length, lubrication and roll stress.



Strip Thickness Profile for 2.8mm strip entry thickness



Mean Radial Roll Stress

## Peak to Peak

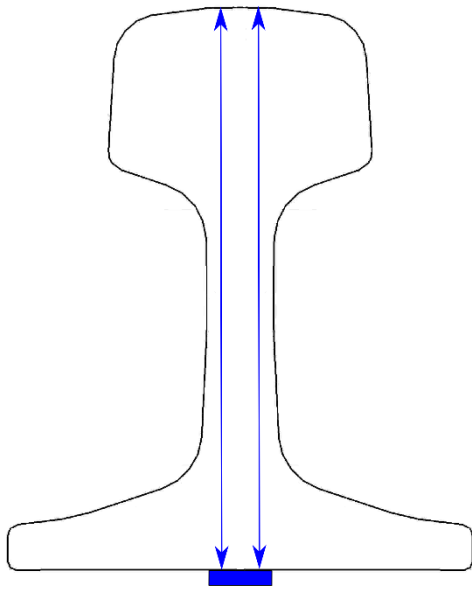
Measurement Solutions



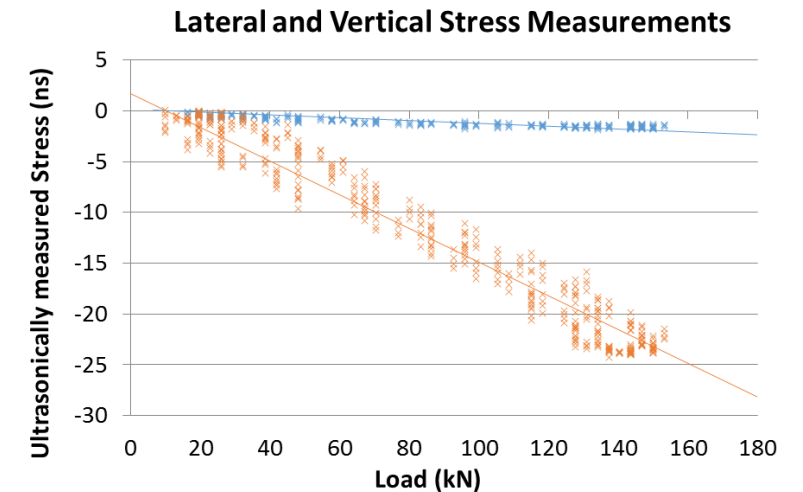
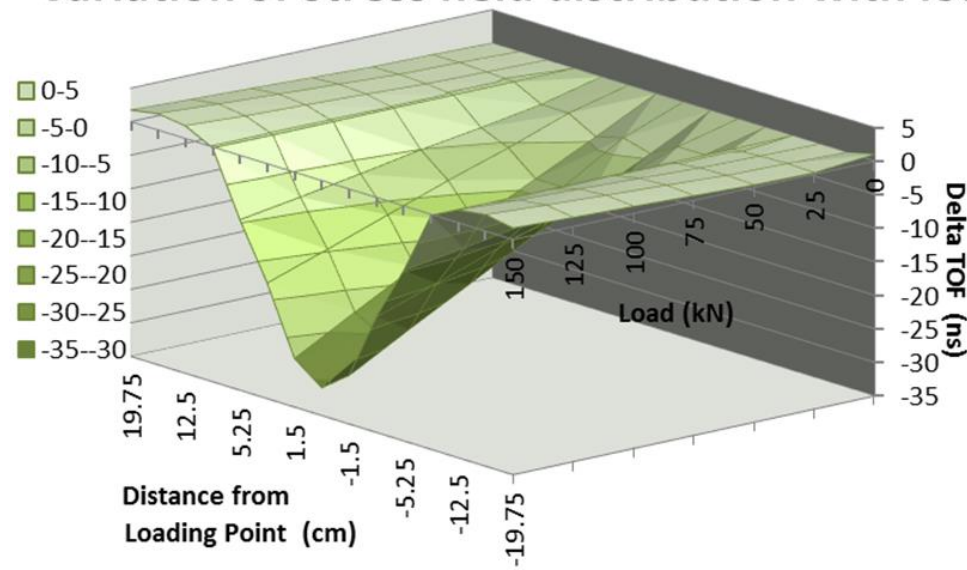


# Lateral & vertical stress measurement

- Ultrasound is a powerful tool to measure lateral & vertical stress.
- Sensors can be permanent or magnetic/bolted in place.
- System can be left trackside to gather data.



Variation of stress field distribution with load



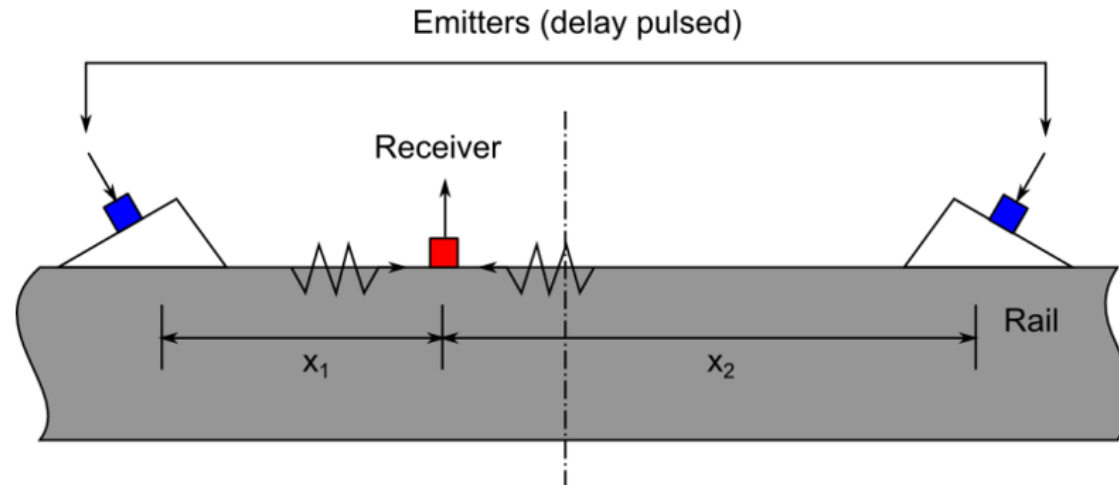
Peak to Peak

Measurement Solutions



# Longitudinal stress measurement

- Non permanent measurement system magnetically clamped to rail.
- Highly accurate rapid measurements achievable using dual emitters.
- Concept proven, further development work required.



Peak to Peak

Measurement Solutions



# Introduction - residual stress in rails

---

- Importance of understanding residual stress increasing due to higher axle load and increased traffic density and faster speed.
- Residual stresses in rolled products are generated due to uneven cooling after hot rolling and also during finishing operations, such as roller straightening / levelling.
- Subsurface stress can toughen the rail head, but results in tension lower down that increase fatigue damage and can cause cracks.

## References

D. Utrata, A. Strom and M. Negley, STRESS MEASUREMENT IN RAILROAD RAIL USING ULTRASONIC AND MAGNETIC TECHNIQUES

Peak to Peak

Measurement Solutions



# Current measurement techniques

---

- Main measurement methods include x-ray method, Barkhausen noise method, acoustic emission method, ultrasonic method and strain gage method.
- Most methods are destructive, slow, lacking accuracy/resolution and are expensive.
- ICRI have identified that there is an industry requirement for a more suitable measurement system.

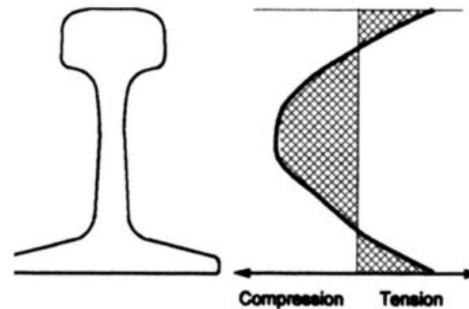
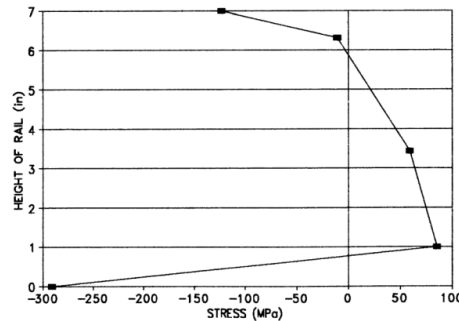
Peak to Peak

Measurement Solutions



# Ultrasonic measurement of stress

- Ultrasound is a highly accurate method for measuring stress.
- Work has been done to measure cross sectional stress distribution.



- The traditional view is that that the ultrasonic method is too complex.
- Equipment and knowledge has improved vastly but this has not yet been applied to residual stress measurements.

Ref- D. Utrata, A. Strom and M. Negley, STRESS MEASUREMENT IN RAILROAD RAIL USING ULTRASONIC AND MAGNETIC TECHNIQUES

## Peak to Peak

Measurement Solutions



# Requirements discussion questions

---

We need to understand/disseminate the industry requirements.

1. At what point in the rails life to people want to understand stress?
  - a) During manufacturing
  - b) After manufacturing
  - c) During installation
  - d) After installation
  - e) Periodically over time
  - f) After an event
2. Who are the interested parties.
3. Why do they care.
4. What is the value of this information.

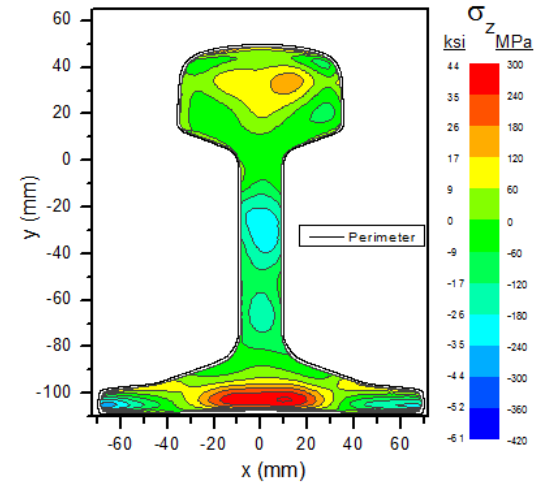
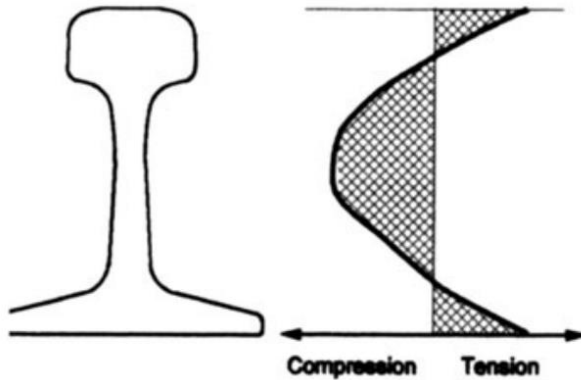
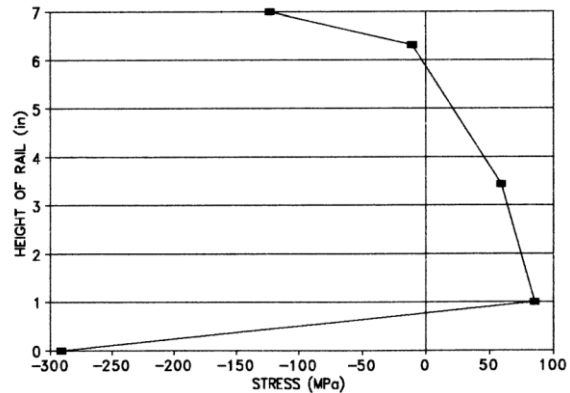
Peak to Peak

Measurement Solutions



# Requirements discussion questions

5. Is it residual stress in the head of the rail that is of interest, or the foot too?
6. Is a 1D line scan of stress useful? If not what is the kind of 2D resolution would provide value?



## References

D. Utrata, A. Strom and M. Negley, STRESS MEASUREMENT IN RAILROAD RAIL USING ULTRASONIC AND MAGNETIC TECHNIQUES  
<http://www.lanl.gov/contour/images/railstress.gif>

# Peak to Peak

Measurement Solutions



# Requirements discussion questions

---

5. Is a relative measurement acceptable (% deviation from normal?) or are exact values required (MPa  $\pm$ x%)?
6. How uniform will the stress be along the rail length – what would be the allowable space along the rail between measurements?
7. Would a clamp on rail system be acceptable? Would it need to roll?
8. Would there be a requirement for permanent monitoring?
9. Would there be an interest measuring the stress as a wheel passes?
10. What would be the value (££'s) of a easy to use handheld system?
11. What would be the operator skill level?

Peak to Peak

Measurement Solutions

