

Longitudinal Rail Stress Measurements Using the Debro-30 Device

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Summary

The Debro-30 ultrasonic stress measurement device has been successfully used at several sites on member railroads to monitor changes in rail stress in track as a function of temperature. Such stress measurements are useful in reducing the occurrence of track buckling or pull-aparts, which can cause derailments. Application of the device currently has some drawbacks, such as the need to calibrate on a force-free sample of the very same rail in track. This makes it impractical to use at the moment, however, there is reason to suggest that these problems can be overcome in the future through appropriate screening tests that would differentiate between various rail metallurgies.

Measurement test sites on member roads were established in several states. Various rails were "calibrated" when they were free of external longitudinal force, in conjunction with rail welding operations or installations. The longitudinal stresses at these sites were then monitored by the AAR over a seven month period using the Debro-30 under leasing arrangements with the Polish Academy of Sciences. In all instances, a very reasonable linear correlation was determined between rail stress and temperature. The value of this relationship however, was somewhat higher for most sites than that predicted for fully constrained rail. This may be accounted for by a systematic offset induced by a faulty calibration of the particular device used in this study. Further tests are anticipated to address this concern. Tests performed under laboratory conditions, however, yielded quite valid results.

A survey of stress-free calibration values, or times of flight at zero stress, for 13 different rail metallurgies was correlated to alloying content in the steel. A pronounced decrease in calibration values was noted as the weight percentage of alloying additions increased. This discovery indicates that if a suitable screening test can be developed to determine alloy content in a rail, stresses could be measured without calibrating or disturbing track.



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INTRODUCTION AND CONCLUSIONS

The Debro-30 is an ultrasonic-based device used to measure stresses in components. Its implementation is based on the acoustoelastic effect, or the stress-dependent velocity of sound waves in materials. This velocity is measured as a time-of-flight reading for a fixed distance of ultrasonic wave travel. The AAR had observed field tests of an early version of this device, and also performed a number of laboratory tests during a previous lease of the equipment from the Polish Academy of Sciences. This work is described in AAR Research Report R-779. The current study incorporates data obtained during a recent 8-month lease of the equipment, wherein the major emphasis was on measuring variations in longitudinal rail stress in track as introduced by changes in temperature.

Measurement sites were established on member roads in several states, and data was obtained from the fall of 1992 through to the early spring of 1993. This data consisted of a measurement of rail temperature and the corresponding stress value, as determined with respect to a required calibration condition of zero net longitudinal stress.

During the course of this study, additional measurements were also performed to determine the degree to which the need for a calibration measurement could be eliminated or at least minimized. The (thermal) stress-free calibration times were determined for a variety of rail specimens with the Debro, and these results contrasted with chemical analysis and eddy current examinations.

The results of this study indicate:

- The Debro-30 provides a plausible record of rail stress in track as a function of rail temperature. Data obtained over a period of seven months at various test sites yielded very linear trends.
- The measured relationship of stress and temperature was somewhat higher, in most cases, than a predicted theoretical maximum value. However, it is felt that some refinement of the measurement technique and possible equipment adjustments could account for this discrepancy.
- The device may be utilized by a trained individual to monitor stresses in track, assuming that suitable calibration values for signal transit time can be obtained for that particular rail.
- A good correlation between the calibration data and the weight percent of alloying elements in the steel suggests that a "screening" test is theoretically possible, which would eliminate the need for calibration under stress-free conditions.

RAIL STRESS MEASUREMENTS WITH THE DEBRO

The stress measurement process involves light grinding on the upper base flange of the rail, just below the web/base fillet. A smooth surface, preferably free of scale, has been shown to provide better reproducibility in laboratory tests, and the upper base region of the rail has been shown to possess minimal roller straightener-induced residual stress. The probe that generates and detects the ultrasonic signal is affixed to the specimen surface after a layer of material which couples ultrasonic signals to the base material is applied to the rail. The raw data obtained consists of a time-of-flight measurement of a subsurface ultrasonic signal that travels along the rail length, over the distance of the measurement probe. A more detailed explanation of the Debro-30 operations was provided in AAR Report R-779, which also details earlier experiences with this device under laboratory conditions.



Use of the device for stress measurement requires knowledge of the rail's zero force transit time, or the time necessary for the ultrasonic signal to travel the required distance under longitudinal force-free conditions. This was provided during the in-track measurements by working in conjunction with welding operations or rail installations. Calibration times were obtained by performing measurements near free rail ends as they awaited installation or welding. Such calibration did not actually measure the residual stresses introduced by roller straightening, but in effect negated this contribution from later stress measurements through the observance of a change in apparent stress from this initial value. It is such temperature-induced stress changes that could lead to buckling or pull-aparts.

A representative example of data obtained from one test site is shown in Exhibit 1. Although some scatter exists, a very definite linear trend is evident. The rate of change in stress as a function of temperature, however, is somewhat higher than the maximum value predicted by a consideration of the thermal expansion of a fully constrained rail. This was the case in most of the test sites examined. The actual equipment that was used during this study is currently being recalibrated; some discrepancies have already been noted, and appropriate steps are being taken to provide an enhanced evaluation of the data.

Exhibit 2 shows the results of Debro-30 stress readings for a short length of rail undergoing compression testing. At an applied load of 600,000 pounds, the measured stress was only about 10% lower than the actual stress level. More accurate data could have been obtained had precise measurements of the acoustoelastic constant been determined, not assumed, for this steel.

The requirement for longitudinal force-free calibrations is an impediment to the use of this device under in-track conditions. While it was not difficult in this study to determine and record

suitable calibration data, the task of doing so at numerous test sites would prove burdensome.

To alleviate this need, some correlation is desired between measurable properties of test rails and the Debro calibration data. Chemical compositions of 13 different rail metallurgies were contrasted with the force-free calibration data. Exhibit 3 shows that as the weight percentage of alloying additions (the total weight of nonferrous elements) in the rail steel increased, the corresponding calibration times decreased. Current work is aimed at determining a screening test that could be applied in the field, and would provide a ranking similar to the chemical analysis, but would be unaffected by stress. If such a test were developed, the appropriate calibration data for a given rail, via that screening process, could be determined and the Debro-30 used to make a valid stress measurement that did not require disturbance of the track.

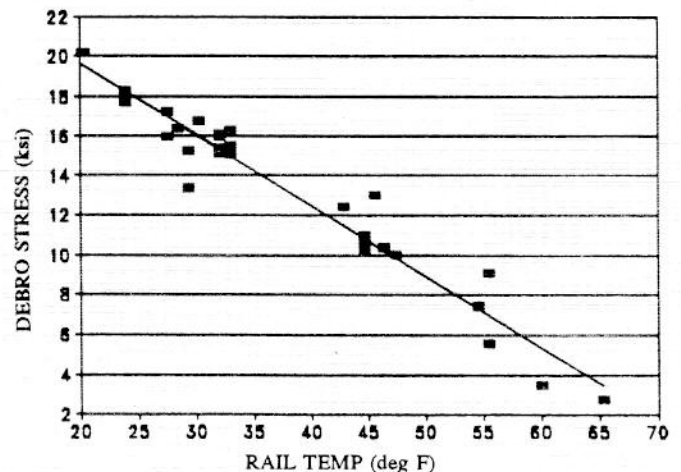


Exhibit 1. Debro stress data for an in-track test site, monitored over 7 months.

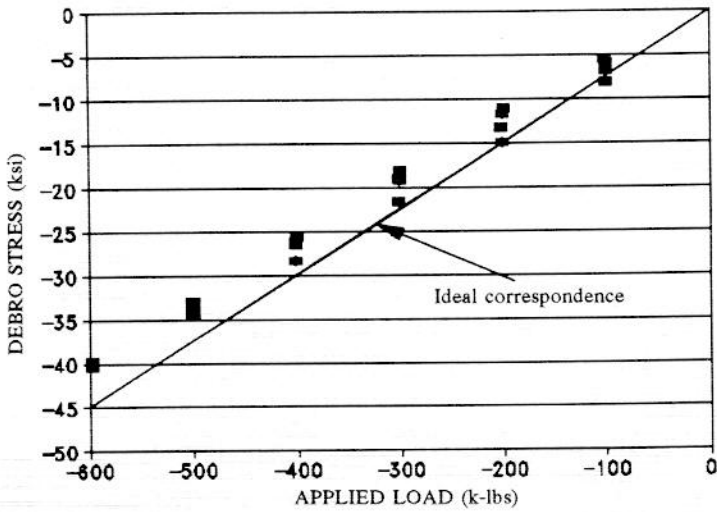


Exhibit 2. Debros stress measurements on rail during compression testing, showing small offset from calculated stress.

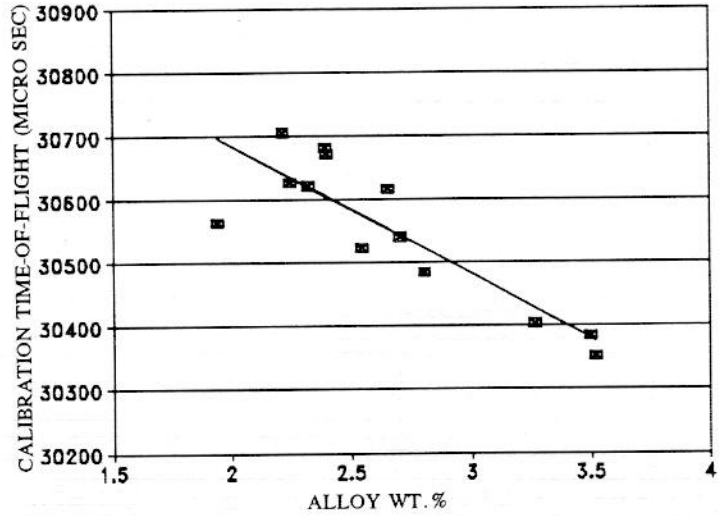


Exhibit 3. Correlation between Debros calibration data and weight percent of alloying elements in various rail steels.

Note: Contact D. Utrata at (312) 808-5878 with questions or comments about this document.

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