TECHNOLOGY DIGEST

Timely Technology Transfer

"NEW VEHICLE MOUNTED ANGLE OF ATTACK MEASUREMENTSYSTEM,"

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Summary

The Association of American Railroads (AAR) and TTX Company have jointly developed a new angle of attack (AOA) measurement system which mounts on the bearing adapter of a wheel set and allows continuous AOA measurement. The rail industry uses wheel set AOA in the evaluation of new and exisitng car designs, and in the study of derailments.

Features of the new system include the following:

- Non-contacting sensors mounted 2 inches above top of rail
- No interference with special track work
- Resolution of 1 mradian
- Insensitive to rail surface quality and railhead shape
- Relatively insensitive to inclination angle and vertical position
- Rugged and reliable

The AOA system, which was designed, developed, and tested at the Transportation Test Center (TTC), Pueblo, Colorado, utilizes non-contacting ultrasonic displacement sensors to measure the angle between wheel set and rail.

The new system was tested on a TTX autorack car in several curves at the TTC. During these tests, the system occasionally lost its signal, producing "dropouts" in the data. However, these high frequency events were easily filtered out. Refinement of the system will continue to minimize dropouts and to improve the signal processing software.

Suggested Distribution :

- ❑ R&D/Test Dept.
- ❑ Operating/Engineering Dept.
- ❑ Operating/Mechanical Dept.
- ❑ Operating Dept.

Association of American Railroads
Research and Test Department

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INTRODUCTION AND CONCLUSIONS

The angle-of-attack (AOA) of a wheel set, which is generally defined as the yaw angle between the wheels and the rails, is a critical factor which is used in assessing rail vehicle performance. During curve negotiation, for example, the potential for a wheel set to climb the rail or to generate large gage spreading forces increases with its AOA.

In the past, numerous systems have been devised to measure the wheel/rail AOA. These systems fall into two groups: track-mounted and vehicle-mounted. Track-mounted systems have been developed which reliably and accurately measure AOA with a resolution of 1 mradian (3.44 arc minutes) or better. However, these systems have the distinct disadvantage of a fixed location; that is, each system measures the AOA of each passing wheel set at only one location on the track. On the other hand, vehicle-mounted AOA systems are able to measure a particular wheel set AOA continuously as the vehicle travels. However, such systems have been plagued by unreliability and inaccuracy, as explained below.

In general, vehicle-mounted AOA systems are either those that physically contact the rail and those that do not. The first group suffers from problems with interference from special track work, joint bars, and grade crossings. The second group, which has utilized numerous non-contacting sensors to measure the AOA, suffers from sensitivity to rail surface qualities, railhead shape, and vertical position relative to the rail.

In 1994, a team of engineers at the Transportation Test Center (TTC) embarked on a study to determine if AAR instrumented wheel set designs could be suitably modified to accurately measure AOA. After a thorough study using finite element models, it was concluded that this approach held little promise. As a consequence, the focus of the project was changed to developing a more conventional vehicle-mounted AOA system. At this point, TTX Company, which was pursuing a similar system, joined the AAR in this effort.

Jointly, the AAR and TTX produced a new non-contacting, vehicle-mounted AOA system. A series of track tests demonstrated that the new AOA system has the following capabilities:

- The AOA system can be mounted above the FRA limit of 2 inches above top of rail.
- The AOA system is capable of measuring the angle between an axle and the rail head with a resolution of 1 mradian.
- The AOA system is insensitive to rail surface qualities and railhead shape.
- The AOA system is relatively insensitive to inclination angle and to vertical position.
- The AOA system does suffer from occasional dropouts; however, these are easily filtered out of the data.
- The AOA system is rugged and reliable.

- Currently, the AOA system mounts on vehicles with standard bearing adapters; however, it is adaptable to other suspension designs.

AOA SYSTEM DEVELOPMENT

As discussed above, the AOA is generally defined as the angle, in yaw, between the wheel set and the rails. Exhibit 1 shows how this angle can be measured directly. The distances between the ends of a beam, which is mounted on the wheel set or bearing adapter, and the rail are measured by non-contacting displacement sensors. AOA is then calculated by subtracting the two displacements and dividing by their separation.

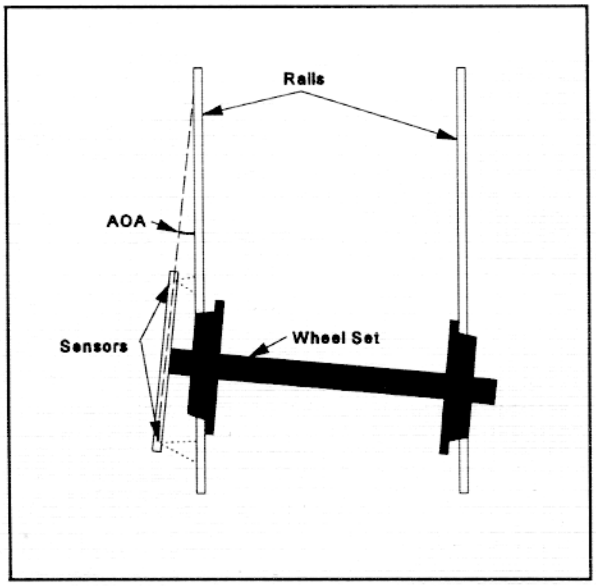

Exhibit 1. Direct Measurement of AOA

The AAR and TTX chose to use ultrasonic displacement sensors (UDS's) to measure the distance from the ends of the beam to the rail. This change resulted from previous experience with this type of sensor in severe measurement environments. The UDS's used in this application measure distance by transmitting an ultrasonic pulse and then receiving the pulse after being reflected from an object (the rail). Distance is calculated by measuring the time between pulse transmission and reception and multiplying by the speed of sound in air.

STATIC TESTS

The UDS's were tested in a static fixture to evaluate their resolution, their sensitivity to inclination, and their sensitivity to height above rail prior to field testing. A test fixture was built which clamped to a short piece of rail, as shown in Exhibit 2. Two UDS's were mounted in the fixture on a beam which separated them by 36 inches. The beam was designed to pivot relative to the rail to simulate an AOA. A long sector arm was attached to the bracket which allowed an accurate mechanical reading of the AOA for comparison with the UDS measurements.

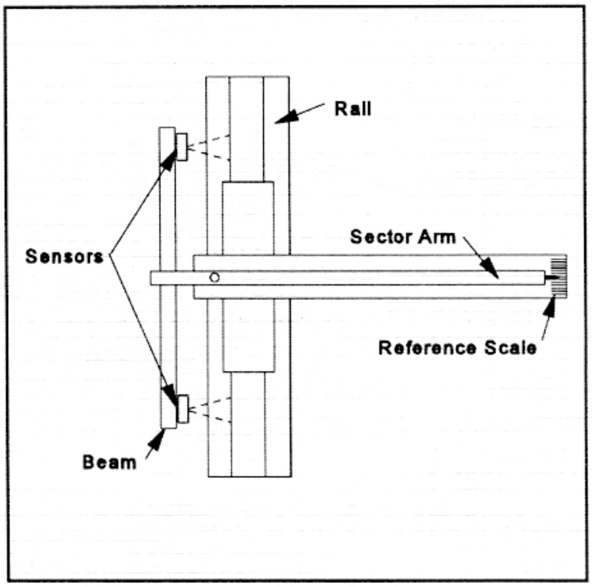

Exhibit 2. UDS Static Test Fixture

The results of the laboratory tests indicated that the UDS's were capable of resolving 1 mradian of angle and that their accuracy was relatively insensitive to inclination angle or to height above rail.

DYNAMIC TESTS

A series of dynamic tests were conducted to evaluate the performance of the UDS-based AOA system in field applications. For the field tests, TTX Company provided a fixture which was mounted on the bearing adapter of a 33-inch wheel set in the leading position of an autorack car. The fixture held two UDS's at a spacing of 36 inches and 2 inches above the top of the rails.

Tests were conducted in the 7.5-, 12- and 10-degree curves of the Wheel Rail Mechanism (WRM) Track and in the 7.5- and 5-degree curves of the Balloon Track.

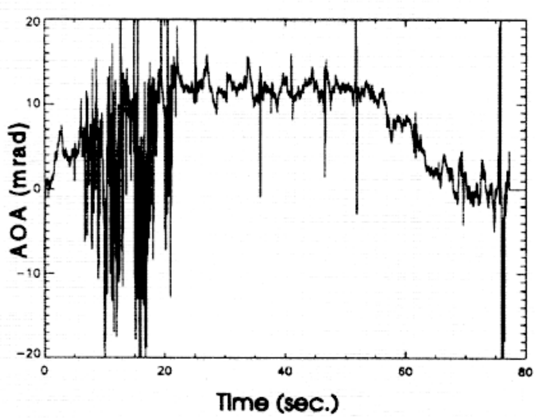

Exhibit 3. AOA Measured in 12-degree Curve of WRM Track - No Filtering

Exhibit 3 shows the plot of the AOA measured by the UDS system through the 12-degree curve of the WRM Track. Many dropouts were evident in the spiral of the curve where the UDS's failed to receive their ultrasonic pulses. However, these events were at relatively high frequencies compared to the very low frequency of the wheel set AOA response. Therefore, the dropouts were easily filtered out of the data (see Exhibit 4).

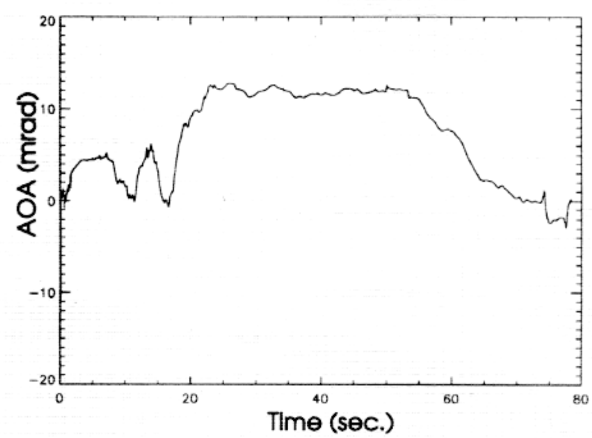

Exhibit 4. AOA Measurement in 12-degree Curve of WRM - after Filtering

The average AOA measured through the body of the 12-degree curve was approximately 12 mradians, which agrees with the well-documented finding that, in general, the leading wheel set AOA is equal to 1 mradian for each degree of curvature. Similar results were obtained in the other test curves.

Contact Stephen Mace at (719) 584-0563 with questions or comments about this document.

A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, WILL BE AVAILABLE AT A LATER DATE THROUGH THE DOCUMENT DISTRIBUTION CENTER, CHICAGO TECHNICAL CENTER, 3140 SOUTH FEDERAL STREET, CHICAGO, ILLINOIS 60616. PHONE: BETTY J. VAUGHAN (312) 808-5421. A REPORT LIST IS AVAILABLE UPON REQUEST.