Development of a National Track Database

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16. Abstract

As described in our companion reports, we are developing track safety models for both rail buckling and railhead cracking. And while these two failure modes are not the most commonplace causes of train derailments according to the FRA, when derailments due to one of these causes occur, they tend to be both catastrophic and costly to the nation. It is therefore advisable to append to our models sufficient information for track engineers to be able to make timely and cost-effective decisions regarding track worthiness as it relates to these two failure modes. We, therefore, proposed to develop a national database for assessing track worthiness on the fly, similar to a procedure developed at the Texas A&M Transportation Institute for assessing small airport worthiness. This database was intended to provide track engineers with on-track information so that on-the-fly decisions could be made regarding both track buckling resistance and track resistance to catastrophic rail fracture.

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List of Abbreviations

FE	Finite Element
FEM	Finite Element Method
FRA	Federal Railroad Administration
NTDB	National Track Database
USDOT	U.S. Department of Transportation
UTC	University Transportation Centers

Disclaimer

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Research Overview

As previously mentioned, we are developing two state-of-the art models for predicting failure of railway due to buckling and/or rail fracture, and these research efforts are detailed within our companion annual reports for this year. Related to the development of these two models is the necessity to provide on-track information to railway field engineers who encounter track anomalies that may cause either rail buckling or rail fracture. Our intention in this research was to develop a national database of local track type, material properties and structural configurations required to deploy both of our models. Toward this end, we are developing computational algorithms in our companion research projects that can be accessed remotely in the field for the purpose of aiding field engineers in making informed decisions regarding the potential necessity of removing local track sections from service for the purpose of performing remediation that will return the section in question to service as quickly as possible. Since it is quite costly to remove railway track from service, our models are intended to help field engineers better assess when remediation is necessary, and when it can be avoided or delayed.

We had two main goals within this project for the current year: 1) to complete development of a remote APP for providing remote access to our computational algorithms by field engineers; and 2) to begin developing a national database containing the local track properties necessary to deploy our computational algorithms in the field. This database was intended to include information such as the local rail classification, time in service, aggregate type, base and sub-base type, local meteorological data such as recent rainfall amounts, etc.

Research Results to Date

Regarding our remote APP, in order for field engineers to access our computational algorithms for predicting both rail buckling and rail fracture, we have developed a cellphone-based APP called *BuckleBot* (Fig. 1), and this APP is now completed and ready for utilization by track engineers. Furthermore, we supplied it to researchers at MxV Rail this year, and they have been able to deploy our buckling code remotely using this app. Thus, this part of their research project has now been successfully completed.

Figure 1: Cellphone image of BuckleBot command interface structure

This APP served as the ideation point for the development of a National Track Database NTDB, as soon after developing this APP we realized that populating the required inputs within the APP for the purpose of predicting track buckling resistance locally by a track engineer would require the track engineer to:

- Implement to the APP a large and complex set of input data regarding local track conditions;
- Have access to local track properties that are not normally available to track engineers; and
- Become a specialist at running our track buckling algorithm successfully.

It became apparent that such requirements were simply not realistic from a practical standpoint. We, therefore, recognized that deploying our track buckling algorithm in the field by track engineers is not feasible without the development of additional technology in the form of the NTDB.

As a second component of this research project, we, therefore, proposed to develop a strawman for the state of Texas as a means of determining the feasibility of such a database. We then began contacting Class 1 rail companies toward this end, and over a span of five months we were unable to obtain any information whatsoever. Accordingly, we contacted our partners at MxV Rail, and they informed us that the Class 1 Rail companies in the U.S. consider their track data to be proprietary information, so that in their view such a database cannot be constructed by us. We, therefore, wasted a significant amount of time and effort toward this end.

Fortunately, we expended only a small portion of our resources on this project (less than 5% of the first-year budget for this project), so that we were able to nonetheless complete the development and demonstration of the usefulness of the APP *BuckleBot*.

Furthermore, since the failed effort to develop a national database only spanned a five-month period, we were able to reallocate the majority of the resources set aside for this project to one of our second-year projects (Proposal entitled "Experimental Determination of Crack Growth in Rails Subjected to Long-Term Cyclic Fatigue Loading" that is funded for the second year of the UTCRS). This effort is going quite well, to the point that we have acquired four rails from MxV Rail (Figs. 2 and 3) that were previously in service and were removed from service due to the in-field detection of internal defects with acoustic emission devices.

We identified the first rail that we intend to test, and we have now cut the first of these rails (Fig. 3) for the purpose of performing uniaxial cyclic loading tests in our 100 Kip MTS (Material Testing Systems, Inc., Fig. 4). We scanned this rail with an advanced acoustic emission device called a phased array (Fig. 5), whereby we located the internal crack, in the process determining its initial size, location, and orientation within the railhead.

Furthermore, we have set up the testing procedure for subjecting these rails to cyclic fatigue loading, with testing to begin in late September 2024. Briefly, we will cut the railhead down to a uniaxial test specimen, as shown in Fig. 6., so that the reallocation of the resources from this project has thus far been successful.

Figure 2: Three of the rails sent to us by MxV Rail

Figure 3: The fourth rail after removing the railhead for testing in the MTS machine

Figure 4: The 100 Kip MTS Machine to be utilized for the cyclic fatigue testing of the railhead shown in Fig. 3

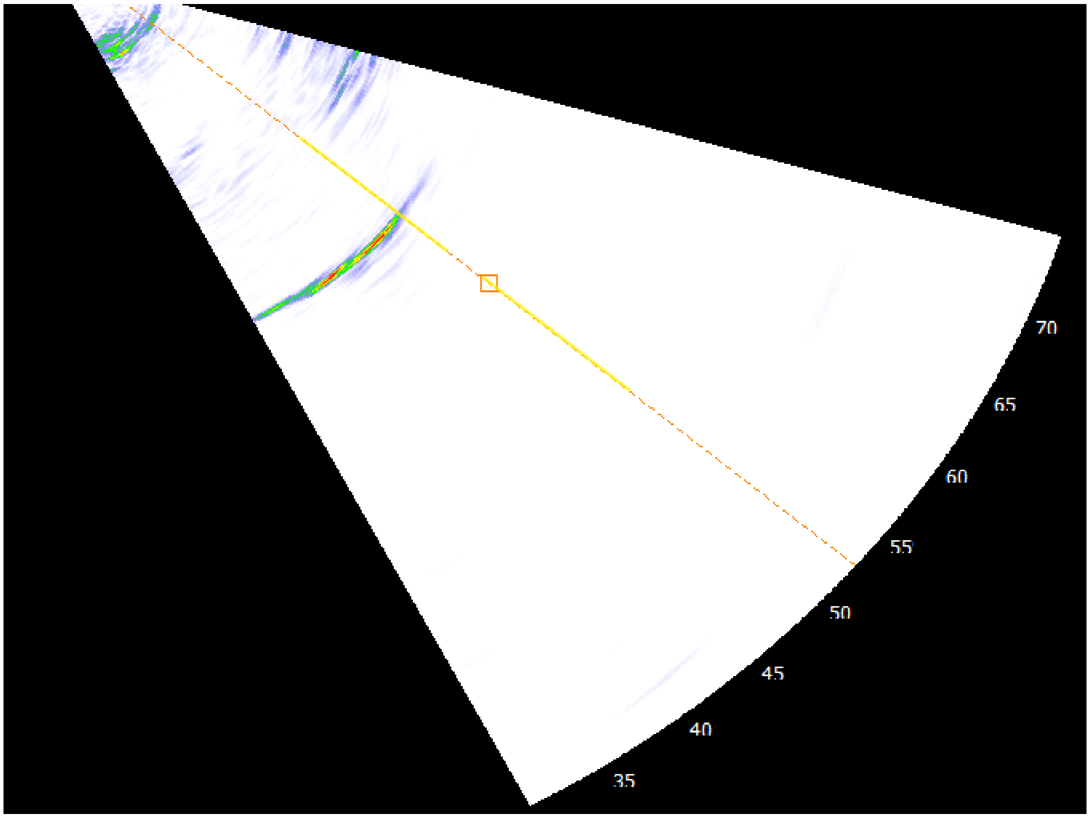

Figure 5: Phased array scan showing internal crack in railhead shown in Fig. 3

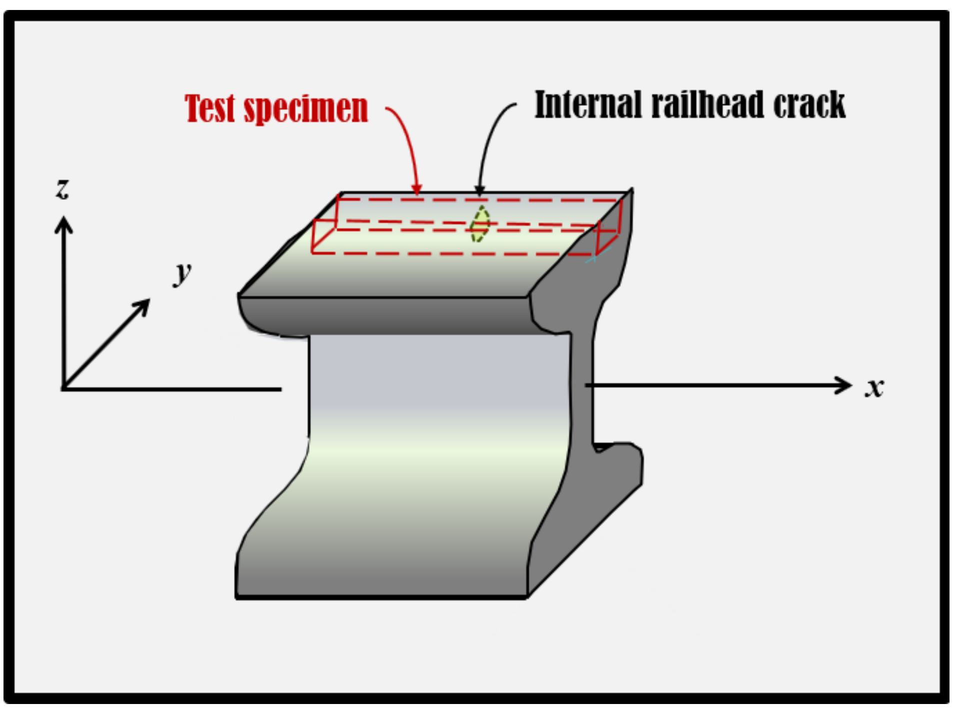

Figure 6: Depiction of rail with internal crack showing test specimen

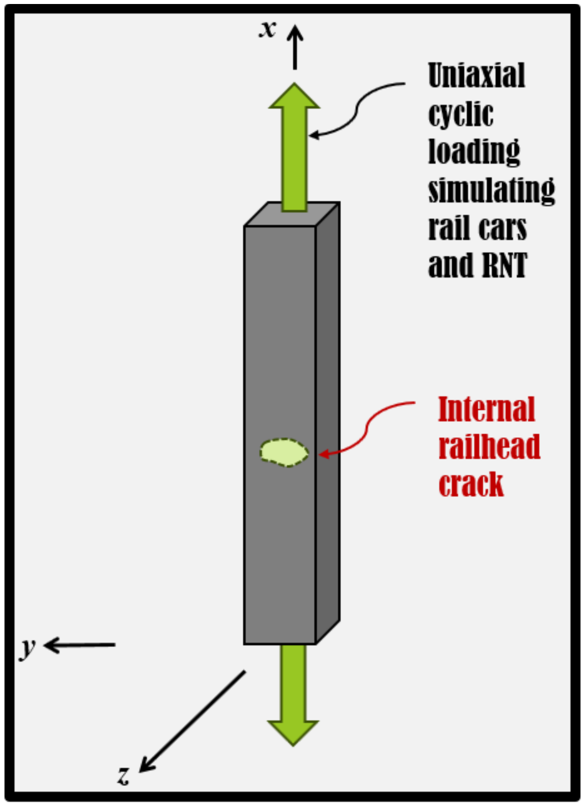

Figure 7: Test specimen to be subjected to cyclic loading in MTS testing machine

The results of the above experiment will be utilized to calibrate our nonlinear cohesive zone model [1,2], given by

$$t_i(t) = \frac{u_i}{\delta_i}[1-\alpha(t)]\int_0^t D(t-\tau)\frac{\partial\lambda}{\partial\tau}d\tau \tag{1}$$

where

- t_i are the components of the crack-opening traction vector
- u_i are the components of the crack opening displacement vector
- D(t) is the cohesive zone relaxation modulus
- α(t) is the current value of the interfacial damage parameter, which is modeled by a damage evolution law.
- λ(t) is the Euclidean norm of the cohesive zone interfacial displacement vector

The above fracture model will be deployed within our multiscale nonlinear finite element computational algorithm [3-10] to predict crack growth in rail subjected to complex long-term fatigue loading, as described in our companion annual report [CRR-2024-02].

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