Measuring Concrete Sleeper Rail Seat Pressure Distribution with Matrix Based Tactile Surface Sensors

Background and Current Objectives of Experimentation with Matrix Based Tactile Surface Sensors (MBTSS)

- Surveys conducted by UIUC report that North American Class I Railroads and other railway infrastructure experts ranked rail seat deterioration (RSD) as one of the most critical problems associated with concrete sleeper and fastening system performance (2008, 2012)
- RSD is the degradation of concrete directly underneath the rail pad, resulting in track geometry problems
- Research objective: measure magnitude and distribution of pressure at concrete sleeper rail seat and investigate crushing as a feasible failure mechanism leading to RSD
- Experimentation is being performed to compare pressure distributions on rail seats under various loading scenarios and fastening systems, and identify regions of high pressure while quantifying peak values
- MBTSS experimentation is providing a better understanding of the load transfer from the wheel/rail interface to the rail seat

MBTSS Technology

- Sensors are comprised of two thin sheets of polyester with a total thickness of 0.102 millimeters
- On one sheet, a pressure sensitive semi-conductive material is printed in rows; on the other, in columns, which forms a grid when overlaid
- Conductive silver leads extend from each column and row to the “tab” from which data is collected by a data acquisition handle
- Known input loads are currently applied to MBTSS data to measure the pressure distributions
- Sensors can be trimmed to fit various concrete rail seat dimensions

MBTSS Layout and Installation

- The sensor is placed at the interface between the concrete rail seat surface and the rail pad component of the fastening system assembly
- To protect from shear forces and puncture, the sensor is covered on both sides with thin layers of polytetrafluoroethylene (PTFE) and bi-axially oriented Polyethylene Terephthalate (BoPET)
- Sensors are bound the Pad Assembly: Poly pad – Shore Hardness of 94 (A), Nylon 6-6 abrasion frame – Shore Hardness of 76 (D)
- Loading regime of 144.56 kN constant vertical load, lateral load varied with respective L/V force ratio

Laboratory Experimentation – Rail Pad Test

- Laboratory experiments were performed to investigate the effect of pad modulus on load distributions
- Low/high modulus pads were used to bound the problem, as well as a commonly used pad assembly
  - Thermoplastic Vulcanizate (TPV): Shore Hardness of 90 (A), Flexural Modulus of 103.42 mPa
  - Medium-Density Polyethylene (MDPE): Shore Hardness of 65 (D), Flexural Modulus of 827.37 mPa
- Two-Part Pad Assembly: Poly pad – Shore Hardness of 94 (A), Nylon 6-6 abrasion frame – Shore Hardness of 76 (D)
- Contact Area (cm²): 185.5, 180.2, 175.8, 166.1, 154.6, 137.4
- Peak Pressure (mPa): 14.75, 17.74, 19.31, 20.17, 21.80, 23.44
- Contact Area (cm²): 129.6, 124.6, 123.4, 122.7, 120.2, 144.6
- Peak Pressure (mPa): 22.15, 23.92, 24.45, 25.66, 26.46, 28.24
- Conclusions from Laboratory Experimentation
  - Effect of L/V force ratio
    - Lower L/V force ratios distribute the pressure over a larger contact area
    - Higher L/V force ratios concentrate pressure on the field side of the rail seat, with higher pressures
  - Rail Pad Test
    - Lower modulus pads distribute loads over a larger contact area, reducing peak pressure values and mitigating highly concentrated loads at this interface, though allowing greater rail base rotation
    - Higher modulus rail pads distribute rail seat loads over a smaller contact area, possibly leading to localized crushing of the concrete surface, while reducing rail base rotation
    - The two-part pad assembly maintains a relatively consistent contact area under increasing L/V force ratios while yielding peak pressures similar to the lower modulus TPV pad, and reducing rail base rotation similar to the higher modulus MDPE pad
  - Concluding: does not appear to be a feasible mechanism of RSD under these loading conditions
    - Peak values do not approach the ~48 mPa minimum design compressive strength of concrete as recommended by the American Railway Engineering and Maintenance-of-Way Association (AREMA)
    - It is still believed that a “perfect storm” of poor track support conditions and high impact loads in the field could result in peak values that cause crushing of the concrete surface

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Future Work

- Continue investigating common North American fastening systems
- Perform field experimentation to understand varying track and loads
- Incorporate rail seat pressures into other RSD mechanism studies