OFFICE OF RESEARCH & DEVELOPMENT

2012 R&D REVIEW

Evaluation of Wheel/Rail Contact Mechanics & Dynamics

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Federal Railroad Administration

U.S. Department of Transportation
Federal Railroad Administration

Program Area & Risk Matrix

Evaluation of Wheel/Rail Contact Mechanics & Dynamics

Program Areas / Risk Factors	Trespass	Grade Crossing	Derailment	Train Collision	All Other Safety Hazards
Railroad Systems Issues					
Human Factors					
Track & Structures					
Track & Train Interaction			X		
Facilities & Equipment					
Rolling Stock & Components					
Hazardous Materials					
Train Occupant Protection					
Train Control & Communications					
Grade Crossings & Trespass					

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Acknowledgements & Stakeholders

Acknowledgements

- Mr. Michael Craft, Virginia Tech
- Mr. Mehdi Taheri, Virginia Tech
- Mr. Alex Keylin, Virginia Tech
- Mr. Brain Marquis, Volpe
- Mr. Matthias Anders, SIMPACK AG
- Dr. Robert Fries, TTCI
- Mr. Nicholas Wilson, TTCI
- Mr. Scott Keegan, NS

Stakeholders & Project Partners

- U.S. Railroads
- Norfolk Southern
- Railway Technologies Laboratory – Virginia Tech

Description

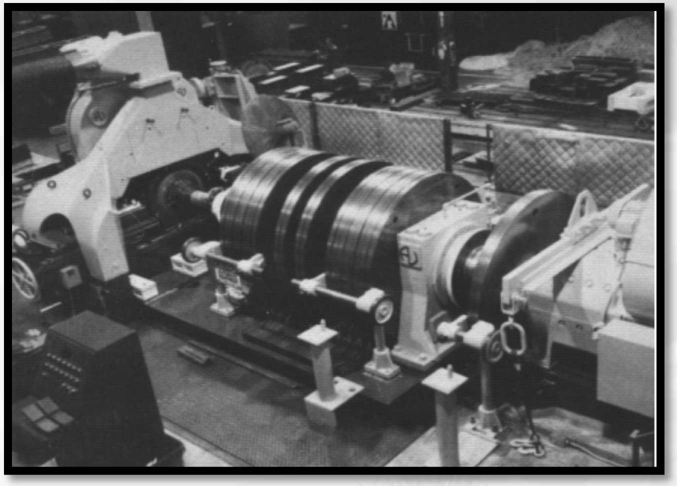
- Design a wheel/rail contact mechanics evaluation test rig
- Provide the means for thorough understanding of the mechanics and dynamics associated with the wheel/rail interaction, under conditions that can be verified against field measurement
- Provide the means for verifying and validating contact mechanics and dynamics theories that are commonly used for vehicle dynamic modeling studies
- Study the performance of wheelset in terms of stability and wheel climb (future plans, beyond the current phase of the project)

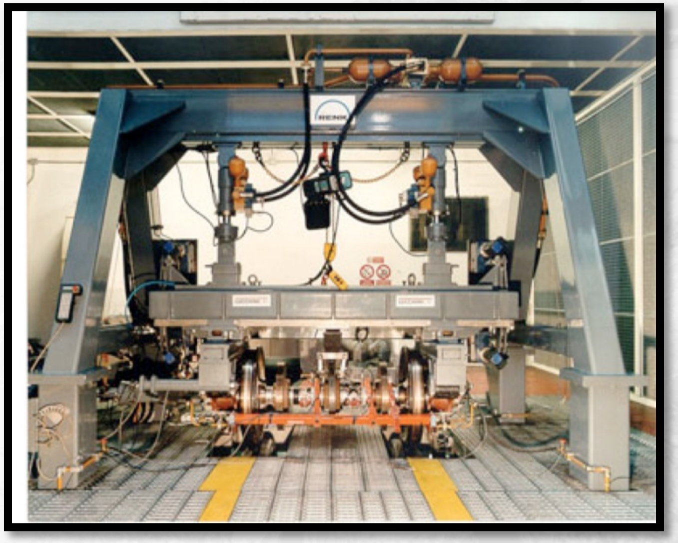
Objectives

- Improve the understanding of wheel/rail contact mechanics
- Understanding the complex mechanics and dynamics that occur at the wheel-rail interface is critical for improving railway equipment operation safety and efficiency
- Provide the capability to more accurately measure the critical forces, moments, and displacements that are necessary for rail vehicle modeling and engineering analysis, far beyond the means currently available to the FRA and rail industry

Previous Processes

- Roller rigs have been around for several decades
- They have been used in the U.S. and Europe, and more recently in China and Korea
  - Mostly used for dynamic studies – wheelset hunting
  - Some efforts to use them for energy efficiency measurements
  - Also used for braking studies – more recently for high-speed rail
- Past work has shown that roller rigs can be effective for assessing the gross dynamics of the wheelset
- Question: Can they also be effective for measuring the mechanics and dynamics of the wheel-rail interface?
  - Involves accurate measurement of forces and moments
  - Requires minimal distortion of the contact patch configuration





Technology Background

During the past 2-3 decades, we have come a long way with our measurement technology:

- More accurate sensors
- Miniaturized sensors
- More sensitivity
- Less costly

Most of these advancements have not yet made it into our roller rig technology due to:

- An old technology
- In some ways forgotten
- The required tasks have not required more advanced sensors

Bringing the new breakthroughs in sensory technology with the traditional roller rig test stands can hold promises for:

- More accurate measurements
- Using roller rigs for tasks that goes beyond their traditional usage

How the System Works

There are several elements that are critical to the success of the roller rig implementation:

- Rigorous design process that includes all of the design gates, from specification to implementation
- Thorough modeling and dynamic evaluation to better identify the critical dynamic elements, measurement requirements, and feasibility

Benefits & Disadvantages

Benefits

- Compared to field measurement:
  - More cost effective
  - Far more repeatable and controlled
  - Suitable for more accurate design of experiment
- Significantly improve our understanding of creepage and the way we model it
- Provides effective means for studying different contact condition

Disadvantages

- Challenging measurements
- How to best measure
  - Wheel forces and moments
  - Contact patch mechanics
- Establishing the accuracy of the tests
  - Requires comparison with field data
- Is the test data believable?

Types of Technologies Being Evaluated

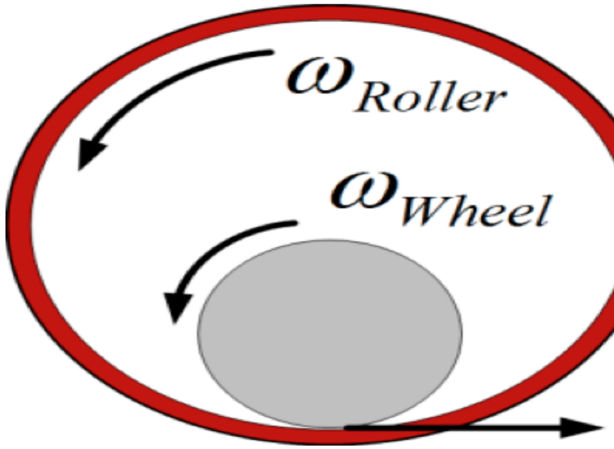
Issued a specification document

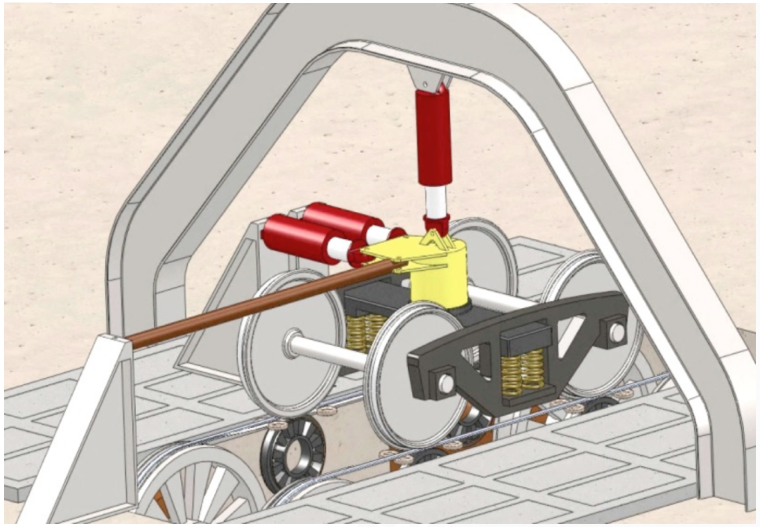
Completed concept design review:

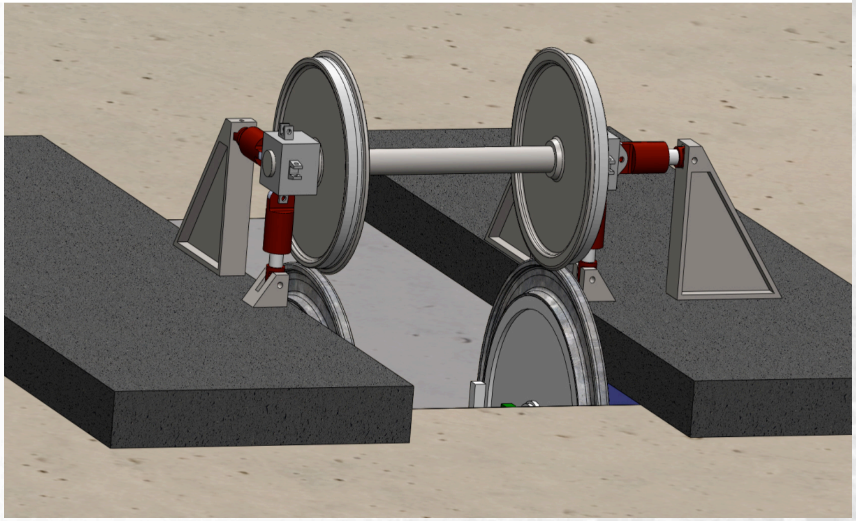
- 18 different concepts were considered
- The merits of each concept were evaluated using an extensive design matrix
- 2 concepts were selected from those considered

Test Conditions	Specific Testing Aspect	Vertical Plane Roller (conventional orientation)	
Standard Components Usage	Fielded Rail	2	Rail must be modified
	Fielded Wheels / Wheelsets	5	Yes, but cannot be instrumented
	Fielded Truck	0	NA
Loads at Speed (Freight)	<40 mph	5	Proven design
	40-80 mph	5	
	> 80 mph	5	
Loads at Speed (Passenger)	<70 mph	5	Proven design
	70-140 mph	5	
	> 140 mph	5	
Test Article Constraints	Angle of Attack	5	Proven design
	Laterally Unconstrained Bolster	0	NA
	Lateral Position Hold	5	Proven design
Special Conditions	Cornering	0	NA (AoA tests indirectly)
	Rail Cant	4	Proven design
	Superelevation	0	NA
	Two-point Contact	3	Geometry of rollers dissimilar to straight rail
	Switch Simulation	1	Can be done with special roller
Data Collection	Steady State Tests	5	Proven design
	Strain (Force) Measurement	4	Proven design, but expensive if using instrumented wheels, instrumented roller also possible
	Displacement / Velocity Measurement	5	Measurement technologies available
Implementation	Current or past studies of the concept	5	Proven design
	Similarity to Typical Rail	3	Geometry of rollers dissimilar to straight rail
	Actuators	5	Proven design
	System Complexity (number of system components)	4	Moderate
Totals (Importance x Implementation Rating)		332	VT score
		378	FRA score

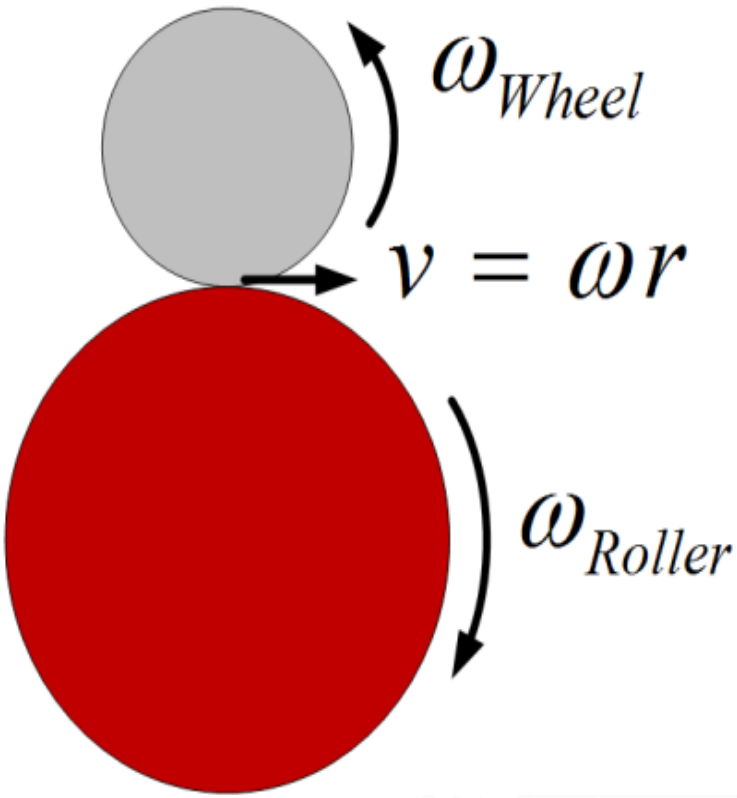
Types of Technologies



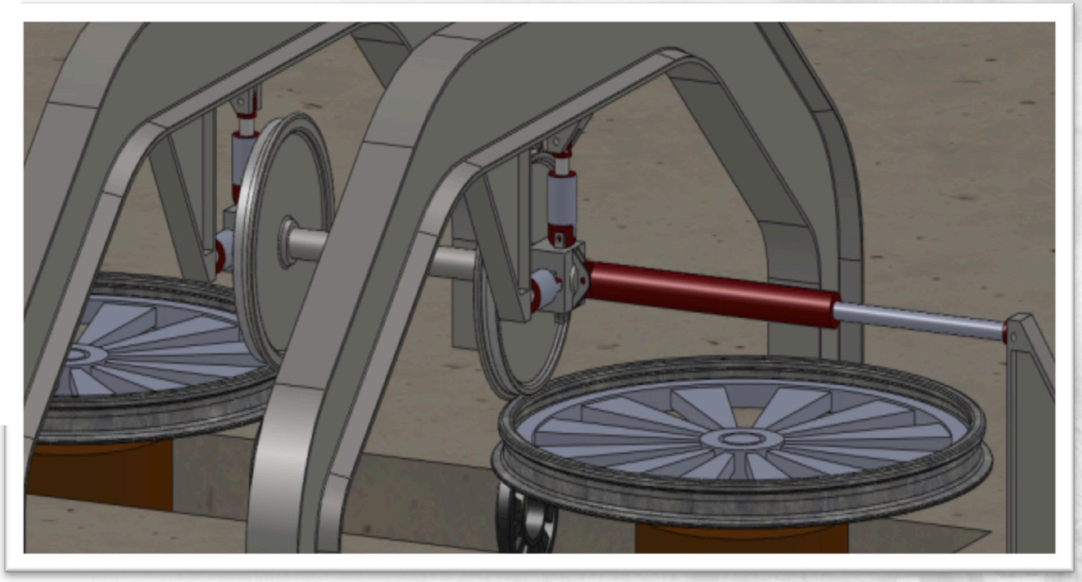




Types of Technologies



Two concepts were selected for further studies and preliminary cost estimation



Project Support

- FRA provided the Virginia Tech team the opportunity to interact with scientists and engineers at Volpe
- Additionally, FRA facilitated interaction with other researchers that had worked with roller rigs in Europe
- We were also provided with a great deal of anecdotal data by FRA from their past work with Track/Train Interaction, in Track and Structures Division

Project Complications

- The greatest complication stems from balancing the project
    - Requirements
    - Costs
    - Timeline
- The logistics of running a roller rig at high speeds are complicated
    - Safety
    - Costs
    - Actuation mechanisms
    - Measurement accuracy
    - Others…
- Calibration with field data
- Results accuracy and validity
- There is some skepticism with believing/accepting the results from a roller rig

Lessons Learned

- A full-size roller rig that can be used for multiple purposes is extremely complicated and costly
  - Acquisition cost
  - Design complexity
  - Operational costs
  - Operational logistics
- The roller rig must be dedicated to one task only, at least in its initial configuration
- The dedicated system can be far simpler (and less costly) than a multi-purpose rig
- The initial modeling and engineering evaluation is key to the success of the project
- For wheel/rail contact mechanics and dynamics evaluation, it is possible to use a scaled rig
  - Our modeling work indicates that the scaling between the full-size and scaled model is deterministic
- The scaled model can be used effectively as a stepping stone for a full-scale model, if one chooses to embark on that initiative

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Key Success Factors

- The key to the success of the project has been due to the frequent interaction between the FRA and Virginia Tech team
  - Periodic program reviews with FRA and Volpe
  - Included the entire research team
  - Opted for face-to-face meetings
  - Went beyond presentations
    - The meetings were working sessions
    - Often lasted ½ day

- The meetings included the project stakeholders beyond our sponsor

- The free and frequent communication between the project team and the stakeholders have proven to be positive and rewarding

Recommendations

- **Build a *scaled*, single wheel roller rig:**
  - 1/4 to 1/5 of full/scale
- **The proposed roller rig is arranged such that the roller rail rotates in a horizontal plane perpendicular to the wheel plane**
  - Reducing the rail curvature effect
  - Reducing contact patch distortion
- **Primary Purpose: Precise creep force data collection and creepage model validation**
- **Secondary Purpose: Steppingstone for a full-scale rig**
  - Allowing for standard and fielded component testing
- **The risks, complexities, and costs associated with the scaled rig are manageable**

Lunch | Nearby Food Options
(all within 5-7 minutes walking distance)

- Au Bon Pain: 601 Indiana Ave NW # 1Washington, DC 20004
- Burger King: 501 G Street NW, Washington, DC 20001
- Chipotle: 601 F Street NW, Washington, DC 20005
- Cosi: 601 Pennsylvania Ave NW # 2 Washington, DC 20004
- Dunkin Donuts: 601 F Street NW, Washington, DC 20004
- Firehook Bakery & Coffee House: 441 4th Street NW, Washington, DC 20001
- Jack's Famous Deli: 501 3rd St NW # 2, Washington, DC 20001
- Quiznos Sandwiches: 772 5th St NW, Washington, DC 20001
- Starbucks: 443 7th St. NW, Washington, DC 20004
- Subway: 501 D Street NW, Washington, DC 20001