Computer Modeling for Low Impact Frog Design

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Computer Modeling for Low Impact Frog Design

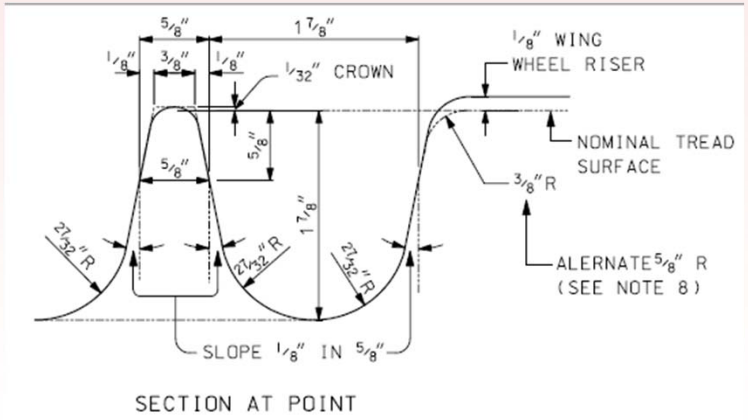
Outline

- Frog Design Comparison
- Frog Wear and Spalling Crack Formation
- Computer Modeling of Wheel/Frog Interaction and Review
- Alternate Profile Frog
- CN Frog Improvements for 2016

AREMA Frog Design

AREMA Frogs

- Industry standard configuration since 1980's
- Widely adopted by all Class 1 Railroads, Transits, and Industries
- Flat Top and Depressed Point
- Used as baseline for evaluation



SECTION AT POINT

Conformal Frog Design

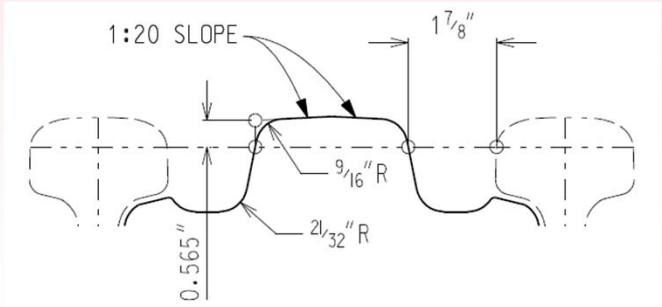
Conformal Frogs

- Developed by TTCI and Western Class 1's in early 2000's
- Widely adopted by all Class 1 Railroads
- 1:20 Top Slope to match Unworn Wheel
- Heavy Point Design to withstand impact from Wheel

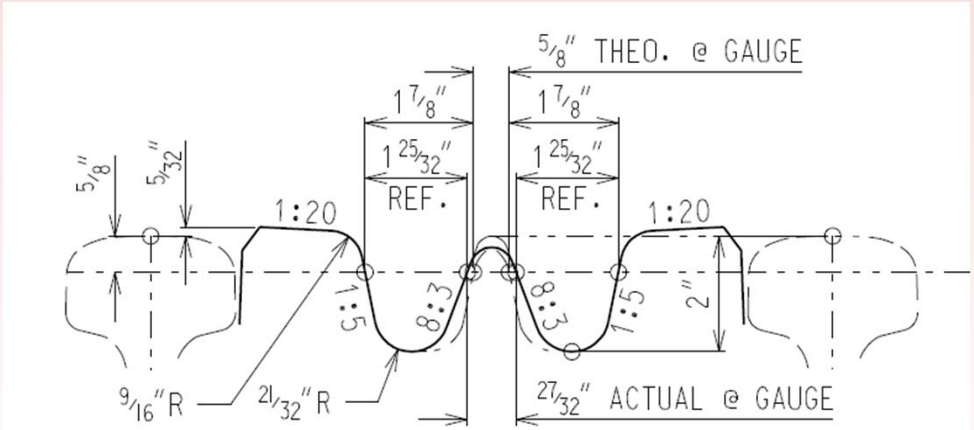
Conformal Frog Design

Conformal Frogs

- **Introduced in 2007 to CN**
- **27/32” Heavy Point**



1:20 SLOPE TOP RUNNING SURFACE DETAIL



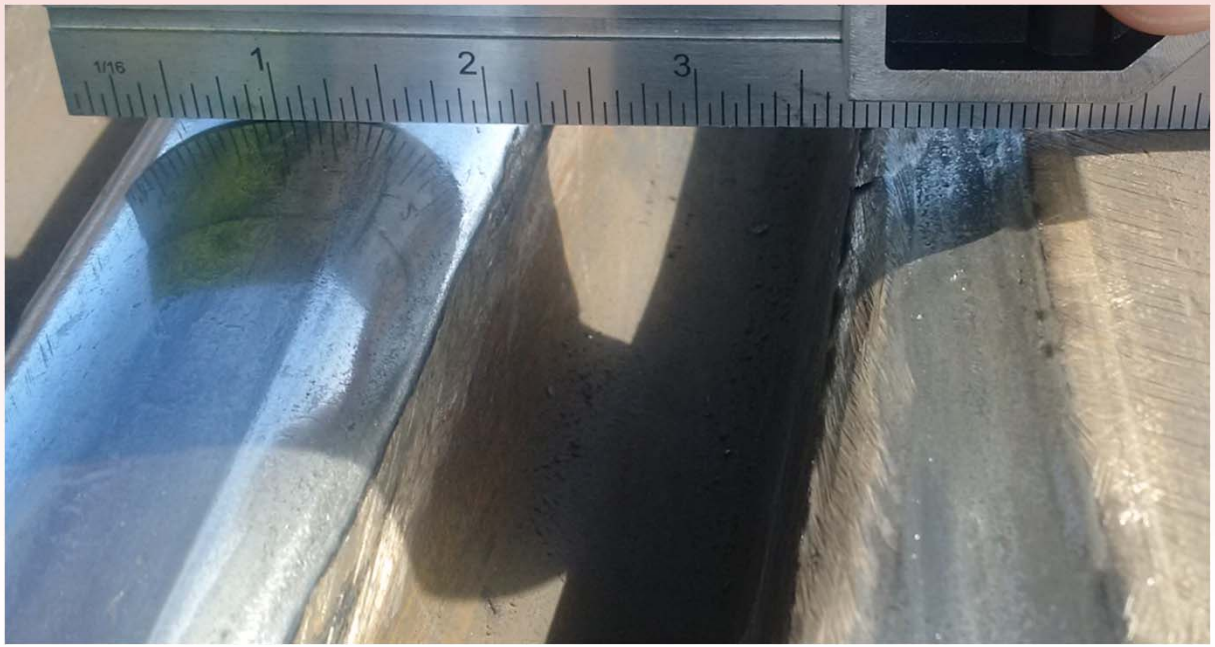
SECTION VIEW AT 5/8" POINT

Frog Wear
#20 Frog, Supplier X

Frog Wear
#12 Frog, Supplier X

Frog Wear

#12 Frog, Supplier X



Frog Wear

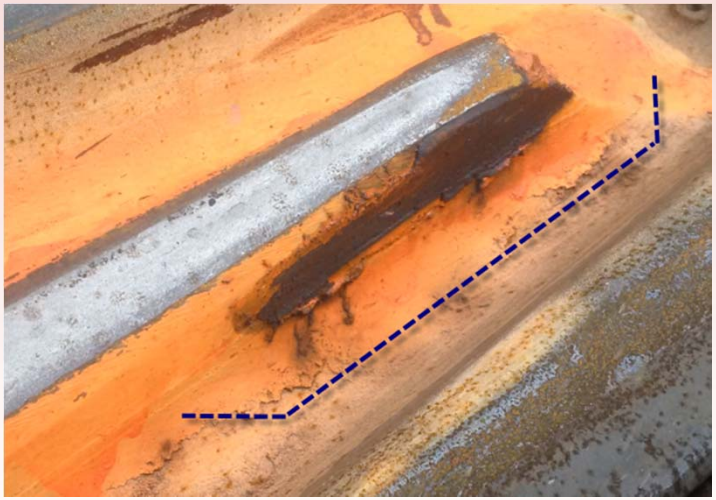
#12 Frog, Supplier Y

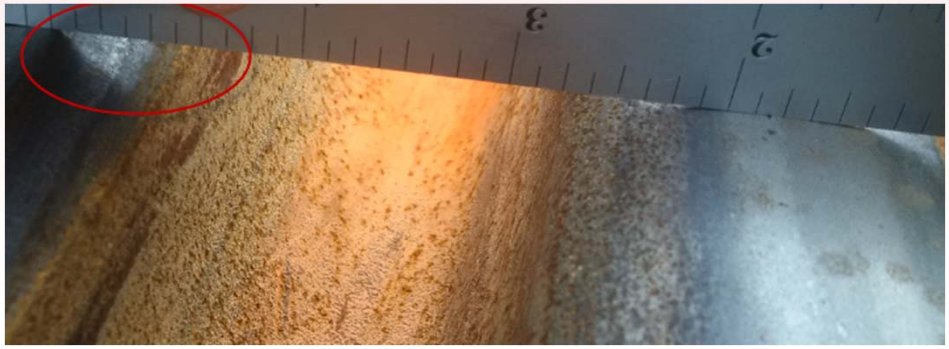
Frog Wear
#20 Frog, Supplier Y

Frog Wear
#15 Frog, Supplier Y

Frog Wear
#15 Frog, Supplier Y

Frog Wear
#10 Frog, Supplier Y





Frog Wear
#15 Frogs, Supplier Z

Frog Wear

Observations

- Spalling Cracks due to High Impact Loading
- Cracks occur in Wheel Transfer Zone
- Instances from multiple manufacturers, across the System
- Occurs on new Frogs. Cracks visible after 6 months on Core Route
- Root Cause appears to be Frog Design rather than Manufacture

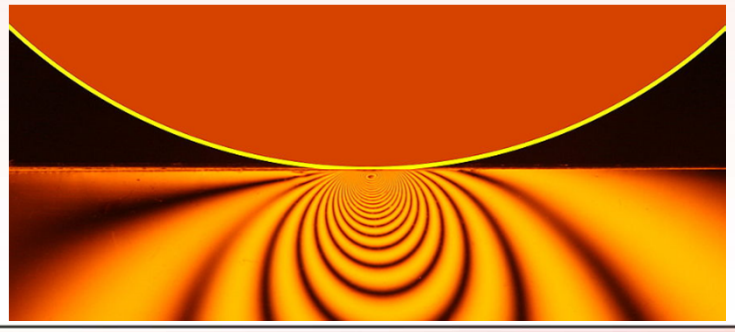
Frog Wear

Why is this happening?

Spalling Crack Formation

Process

- Wheel applies a Hertzian contact stress at the point of impact
- Greatest compression stress under the point of contact
- Maximum shear stress occurs below the surface, which leads to spalling cracks



Computer Modeling of Wheel/Frog Interaction

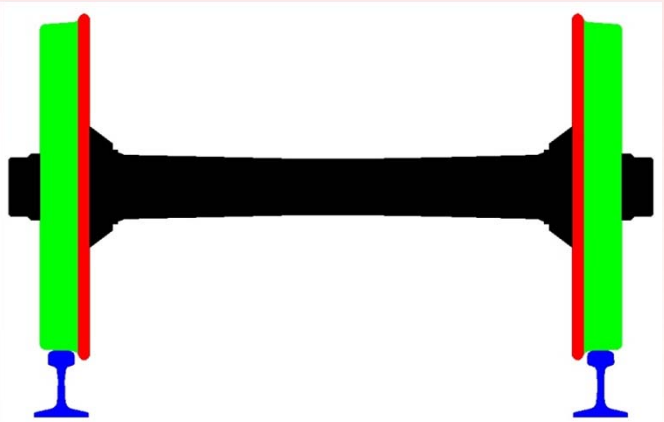
Goal

- Develop model to indicate most severe loading in Frog
- Use simple to use/accessible software
- Confirm model with field measurements
- Understand Wheel Transfer Zone

Computer Modeling of Wheel/Frog Interaction

Conditions

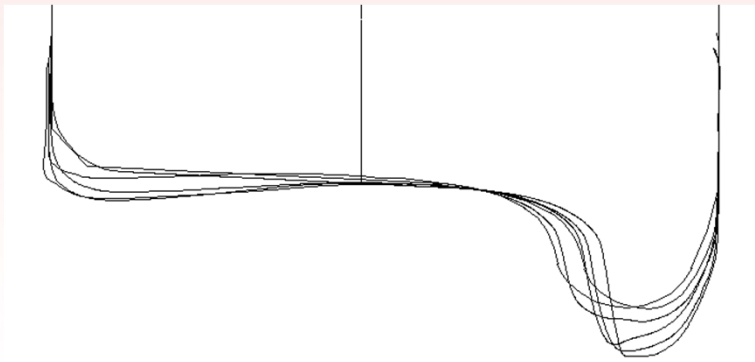
- 56-1/2” Track Gauge
- Wheel centered on track
- No lateral movement through frog
- 53-3/32” Wheel Back to Back Spacing
- 1” between section views
- Constant Speed through Frog



Computer Modeling of Wheel/Frog Interaction

Wheel Profiles

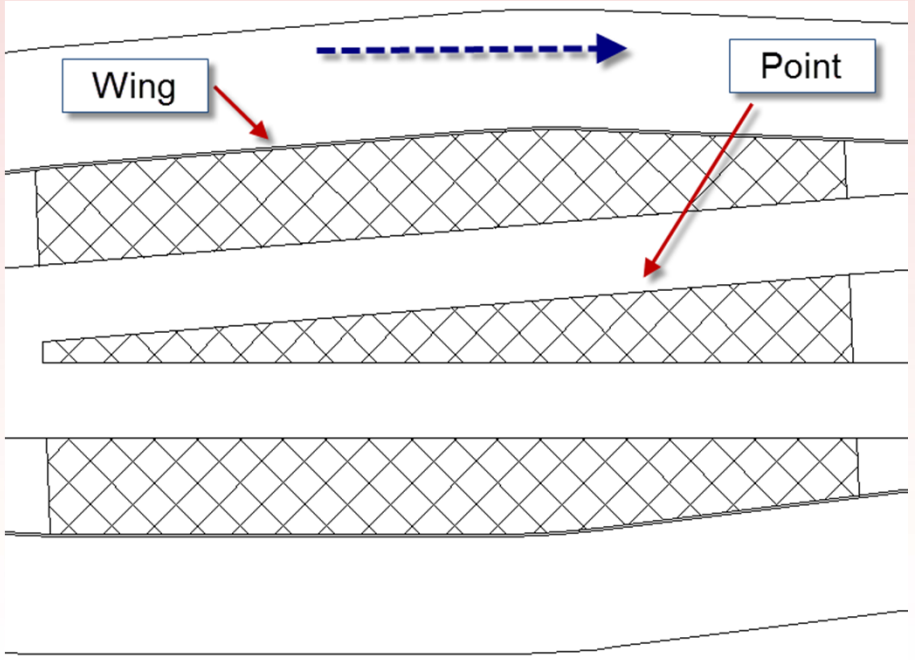
- AAR-1B wheel profile (unworn narrow flange)
- AAR-1B wheel profile (unworn wide flange)
- 1.0mm worn wheel
- 2.1mm worn wheel
- 3.1mm worn wheel
- 3.8mm worn wheel



Computer Modeling of Wheel/Frog Interaction

Wheel Transfer Zone

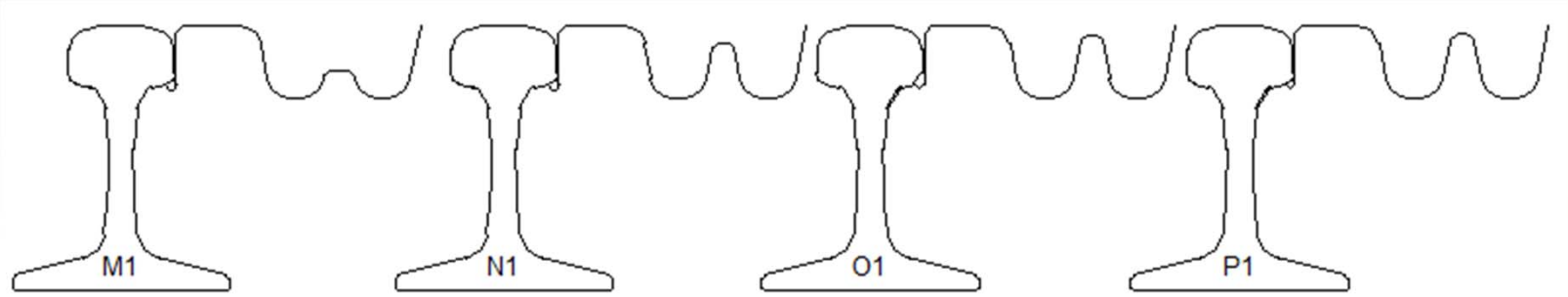
- ½" Point for 20"
- Facing point move (arrow)
- Transfer Wheel from Wing to Point
- Same for Trailing Point, but reverse



Computer Modeling of Wheel/Frog Interaction

Method

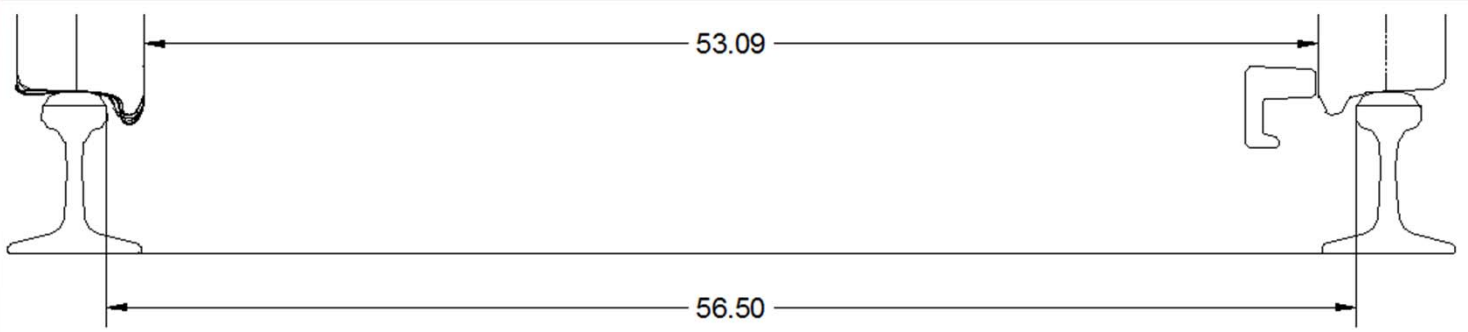
1. **Create AutoCAD Drawing with a section view every 1” through frog**
   - **Numerical Analysis based on 1” pitch spacing of sectional view, values should be regarded as indication of wheel acceleration magnitudes**



Computer Modeling of Wheel/Frog Interaction

Method, cont'd.

2. **Using both unworn and worn wheel profiles, establish reference drawing for wheel placement**

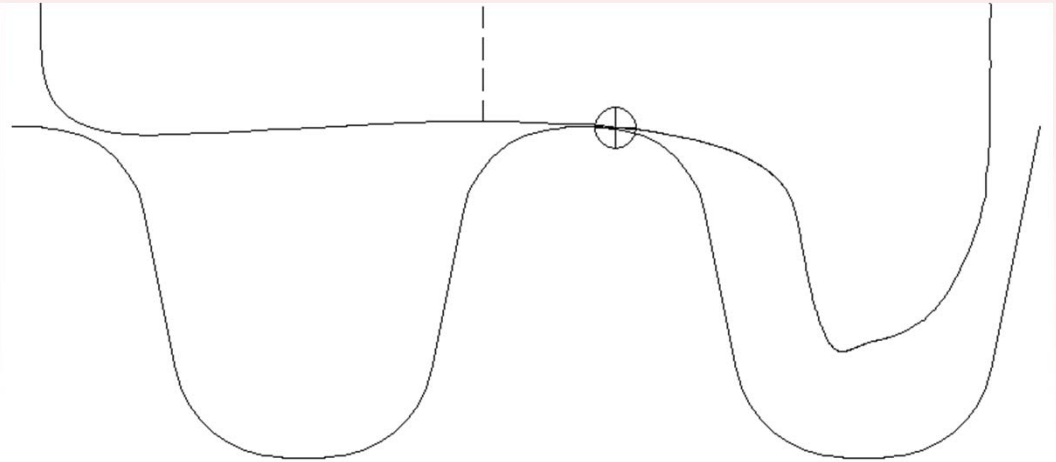


53-3/32" Back to Back
Wheel Centered

Computer Modeling of Wheel/Frog Interaction

Method, cont'd.

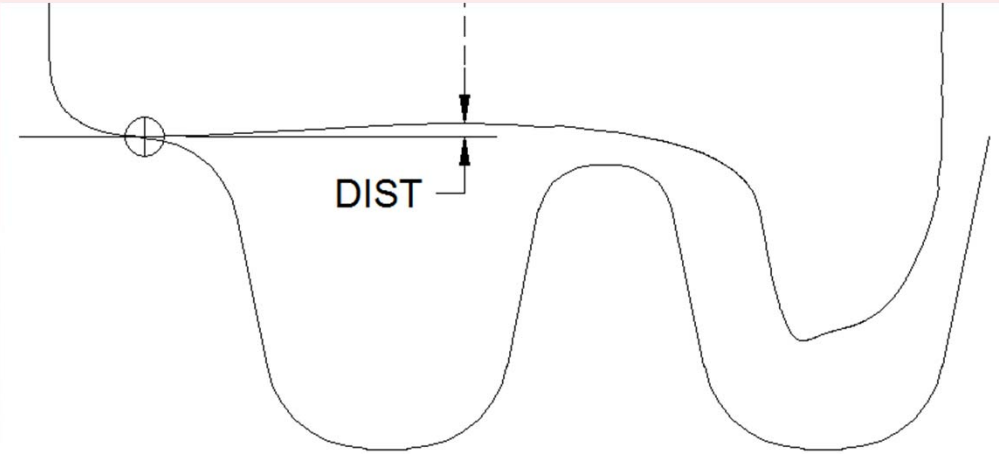
3. **Place wheel profile vertically to contact frog at each section**



Computer Modeling of Wheel/Frog Interaction

Method, cont'd.

4. **Measure vertical wheel distance at each section from same datum**



Computer Modeling of Wheel/Frog Interaction

Method, cont'd.

5. Using vertical wheel distance and time between sections to calculate vertical wheel velocity, acceleration, and jerk.

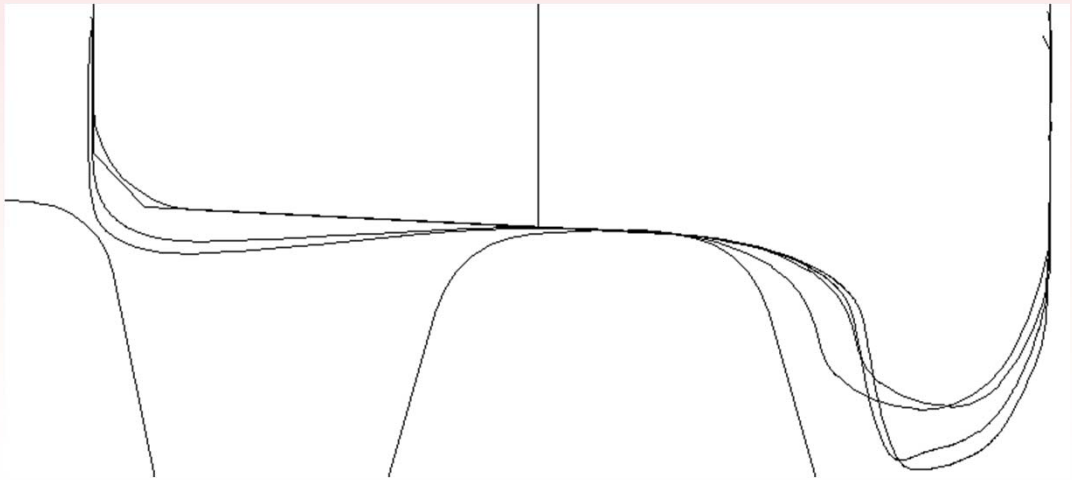
AREMA RBM Frog Design
AREMA Plan: 624-09

			Vertical Distance, in						Velocity, in/s						Acceleration, in/s²						Acceleration, g						Jerk – Impact Load, in/s³					
		Section	U-NF	U-WF	1.0 mm	2.1 mm	3.1 mm	3.8 mm	U-NF	U-WF	1.0 mm	2.1 mm	3.1 mm	3.8 mm	U-NF	U-WF	1.0 mm	2.1 mm	3.1 mm	3.8 mm	U-NF	U-WF	1.0 mm	2.1 mm	3.1 mm	3.8 mm	U-NF	U-WF	1.0 mm	2.1 mm	3.1 mm	3.8 mm
-38	0	A																														
-37	1	B							0.0	0.0	0.0	0.0	0.0	0.0																		
-36	2	C							0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0						
-35	3	D							0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
-34	4	E							0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
-33	5	F							0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
-32	6	G							0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
-31	7	H							0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
-30	8	I							0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
-29	9	J							0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
-28	10	K							0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
-27	11	L							0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0

Computer Modeling of Wheel/Frog Interaction

Method, cont'd.

6. **Repeat process for each wheel profile**

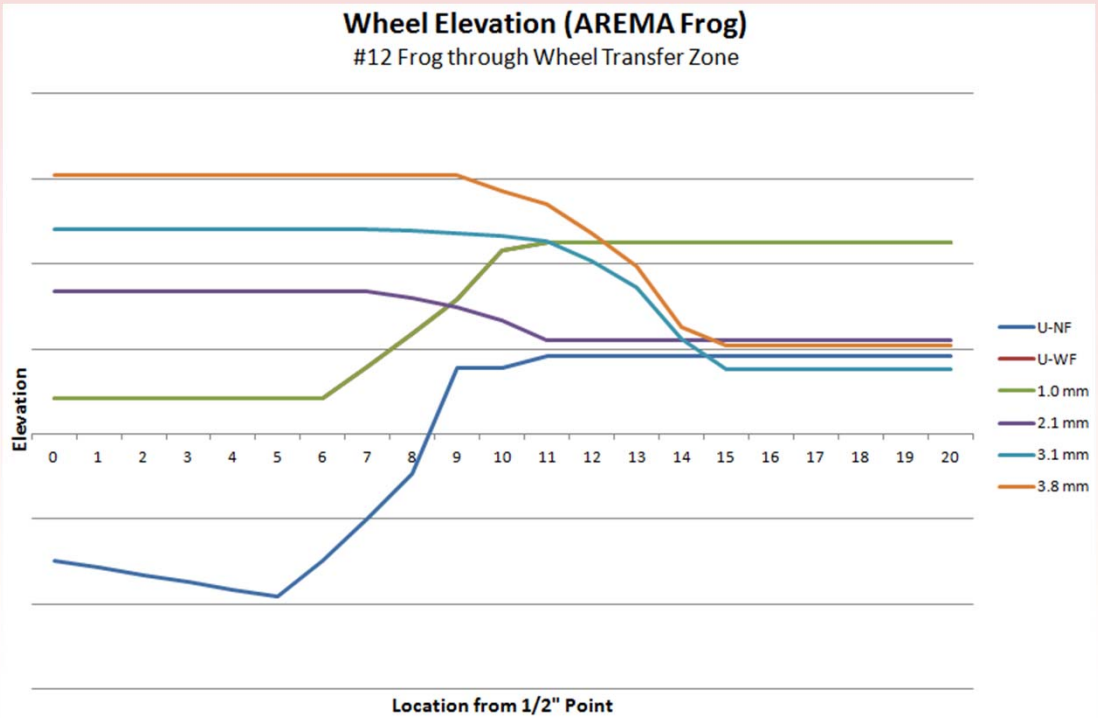


Computer Modeling of Wheel/Frog Interaction

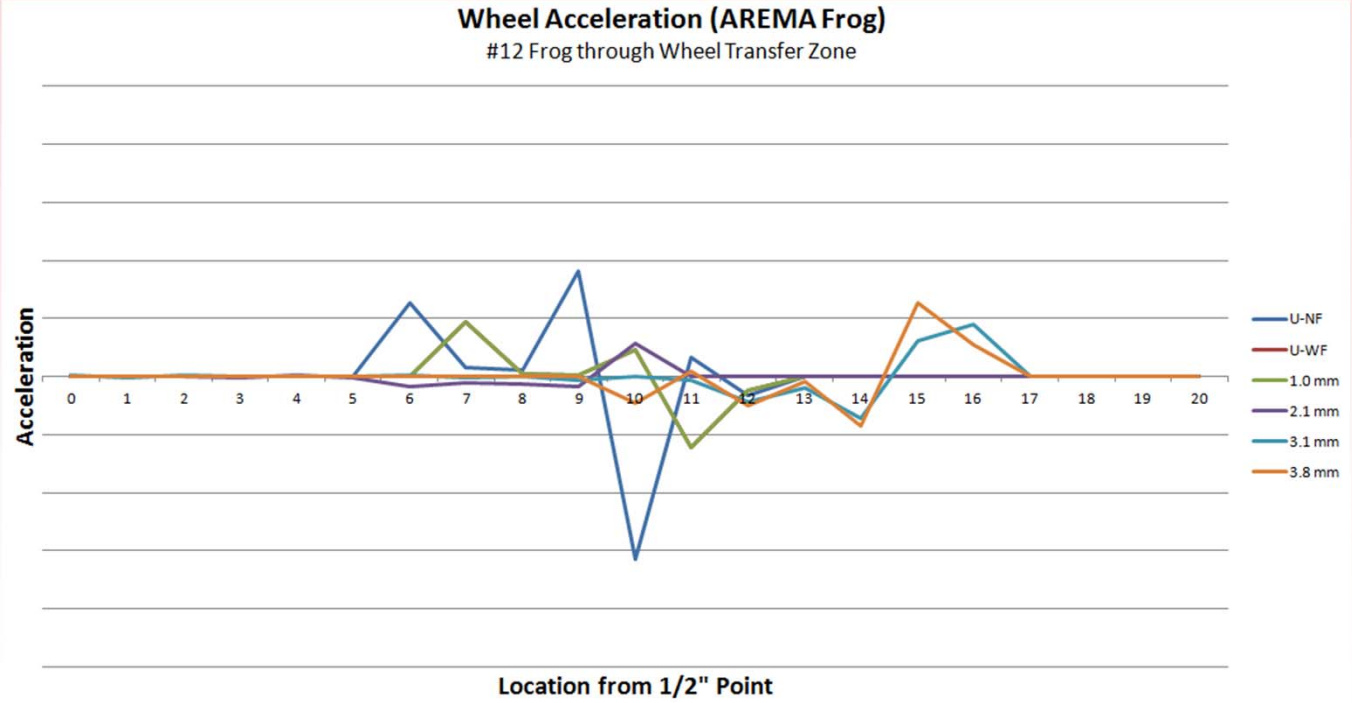
Method, cont'd.

7. Use Vertical dimensions to evaluate accelerations, and use horizontal dimensions to evaluate running band

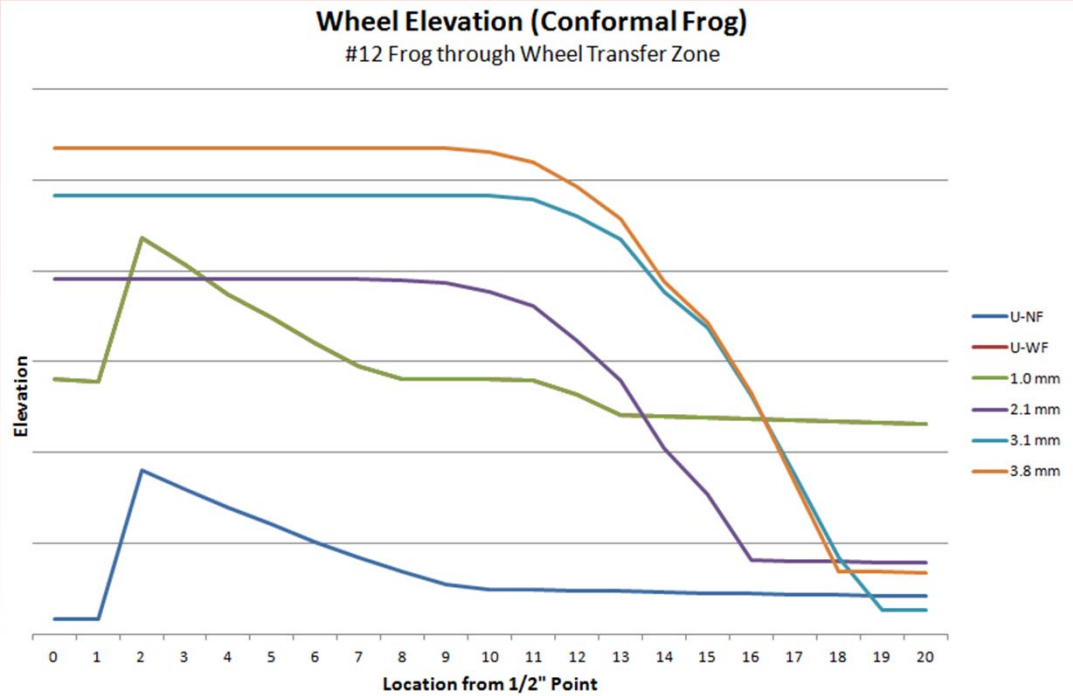
Computer Modeling Review



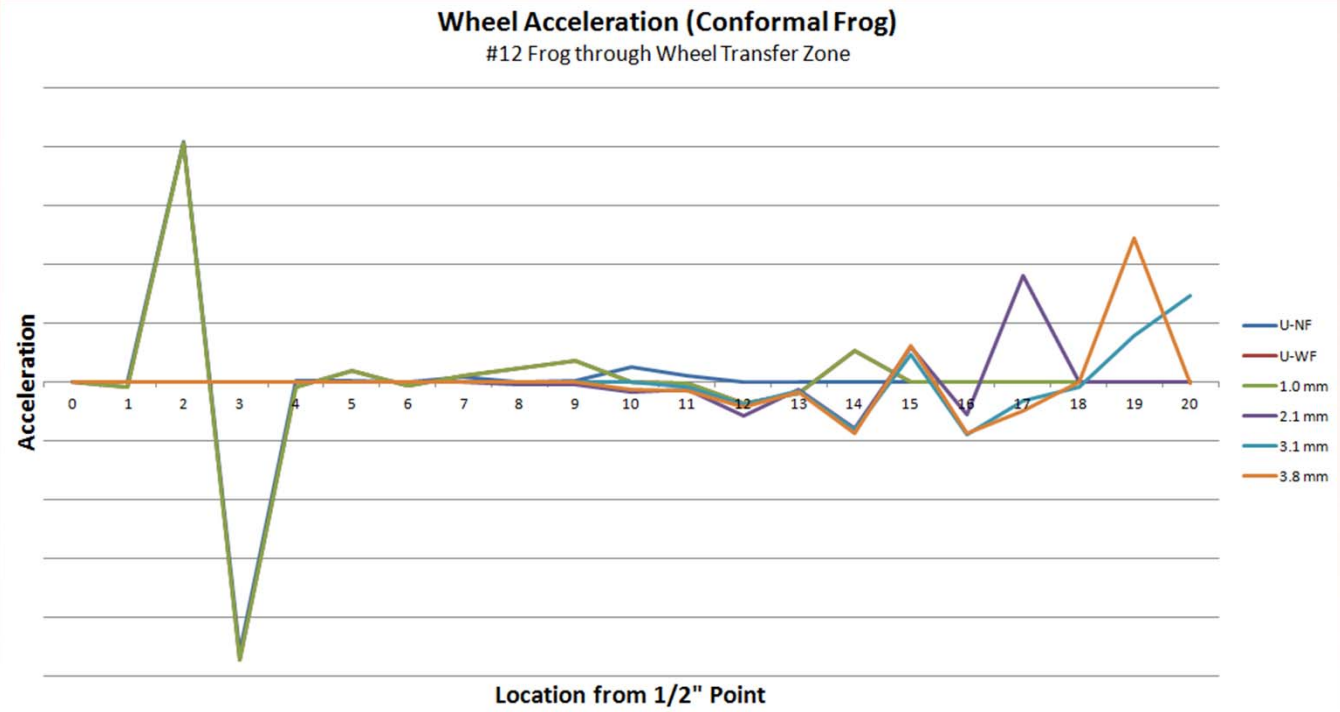
Computer Modeling Review



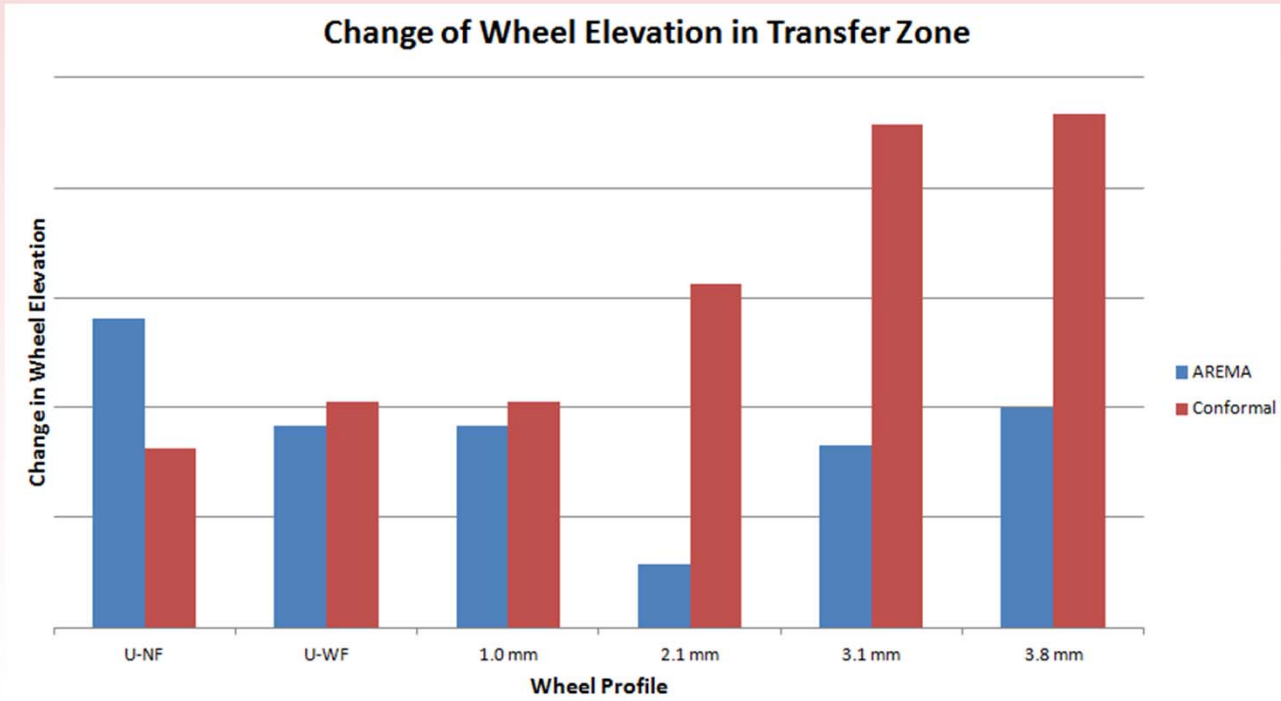
Computer Modeling Review



Computer Modeling Review



Computer Modeling Review



Computer Modeling of Wheel/Frog Interaction

Key Findings

- Conformal Frogs have greater vertical wheel accelerations than AREMA Standard Frogs
- Large acceleration values create greater forces in the Frog
- Peak accelerations in computer model occur at same location as observed Frog cracks in the Field

Computer Modeling of Wheel/Frog Interaction

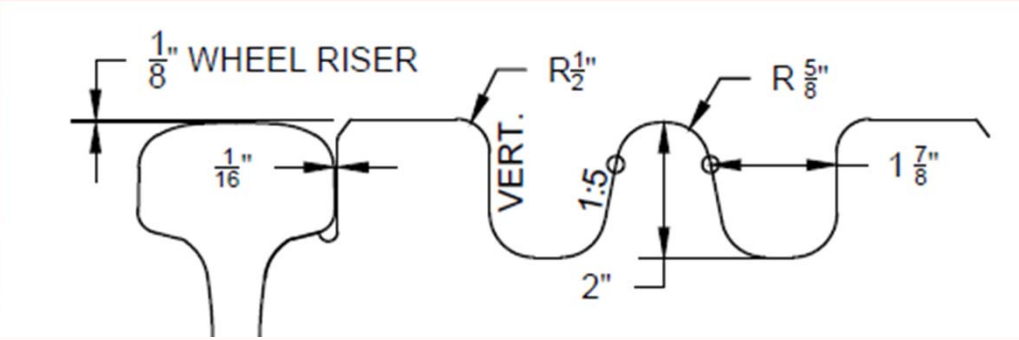
What next?

- Design a Lower Impact Frog using Computer Model
  - Reduce vertical wheel movement
  - Reduce vertical wheel acceleration
  - Improve wheel transfer area

Alternative Profile Frog

Design Features

- Conventional Point Design with AREMA Recommended Point Slope
- 1/8” Wheel Risers
- Flat Top Profile
- 5/8” Gage Corner Radius
- Vertical Guard Flangeway



Alternative Profile Frog

Field Testing

- (10) new Frogs, from Various Suppliers and Various Sizes (#12 to #20)
  - Various Locations on CN
- Use dye penetrant to check for spalling cracks
- Use contour gauge to evaluate running surface condition

CN Frog Improvements for 2016

- Continue to refine Computer Modeling method and process
- Refine process to determine Frog Life based on service life
- Evaluate Alternative Profile Frog Design