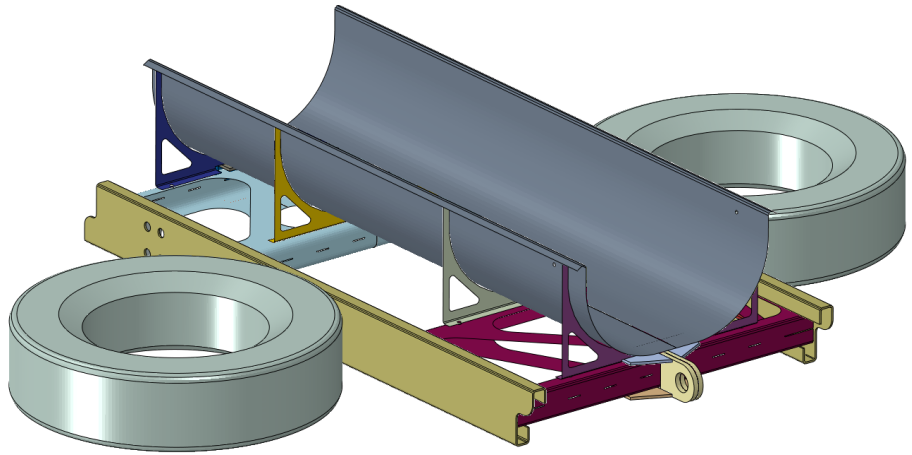

Operational loads measurement and design optimization of a gold mine rail hauling system showing fatigue cracks

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Optimec Consultants inc.

Background

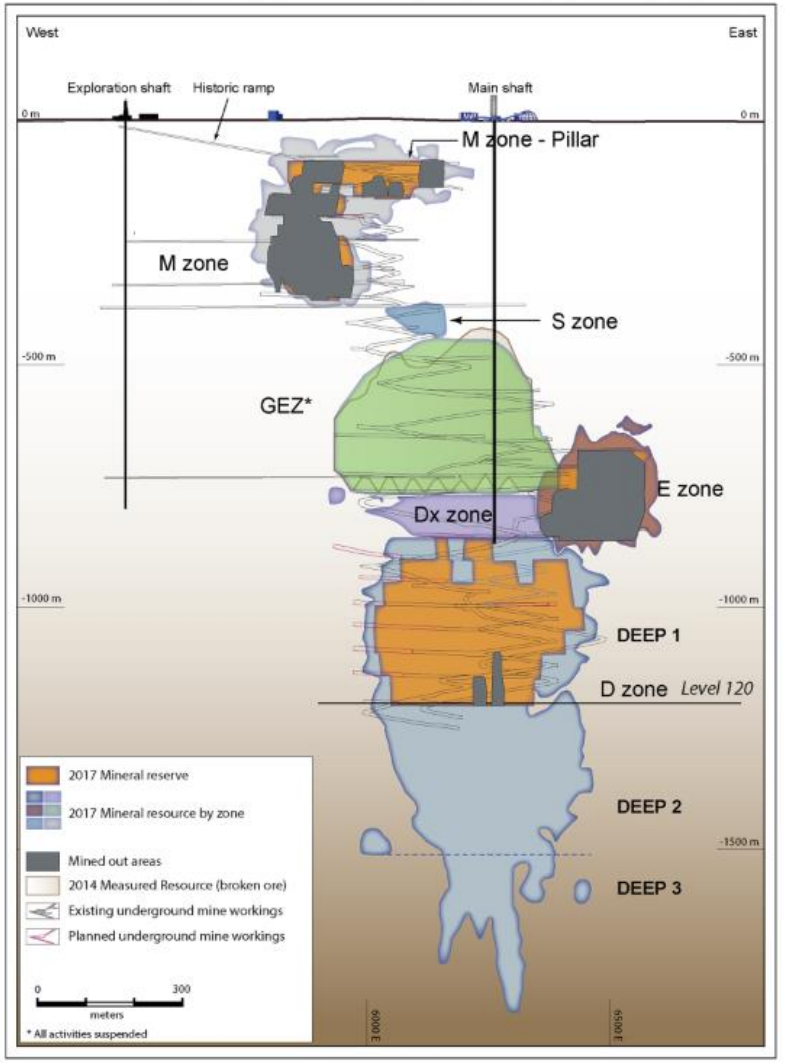
- Engineering consulting firm specialized in Simulation since 2002

- Goldex Project
  - Underground Gold mine in Val D'Or, Quebec operated by Agnico Eagle since 2008.
  - Total Gold reserves evaluated at 962,000 oz (1,4 B$ USD)

Goldex Mine – Deep 1 zone

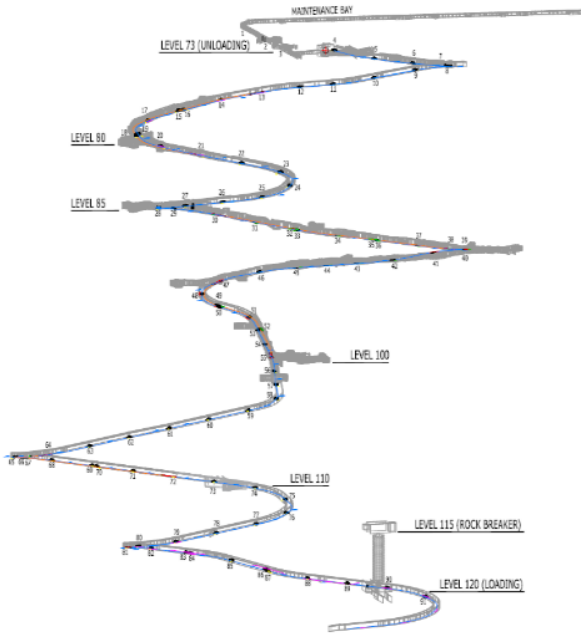
- Deep 1 Zone:
  - 2017
  - from -1200m to -720m
  - Gold concentration 1.7 grams / T (1.7 ppm)
  - Gold : 3,74 T (132,000 oz) / year
  - Ore extraction : objective 2,200,000 T/year

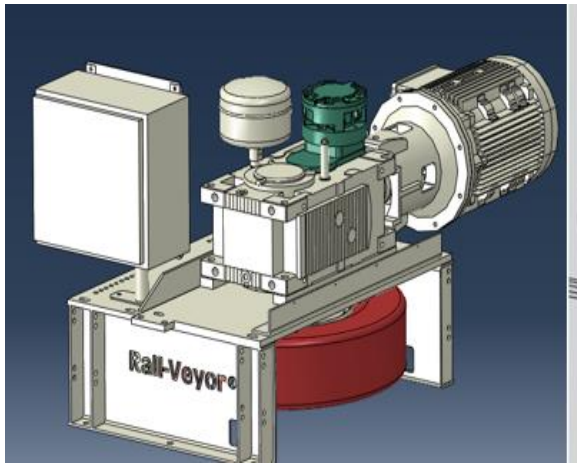
  - Developed a train hauling system with Rail-Veyor company to transport ore up.

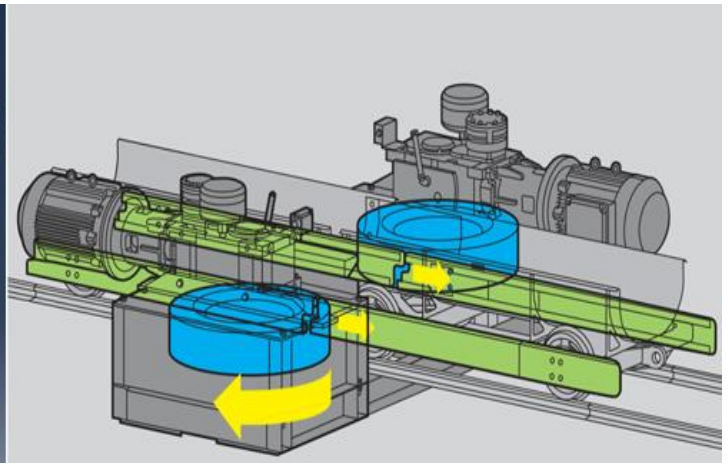


Deep 1 zone – Rail hauling system

- Mono rail – 3km long
- 6 trains, 68 cars / train
- Max slope 17%
- 90 electrical drive stations – One motor each side.
- Cars have side plates (green) to make contact with tires.



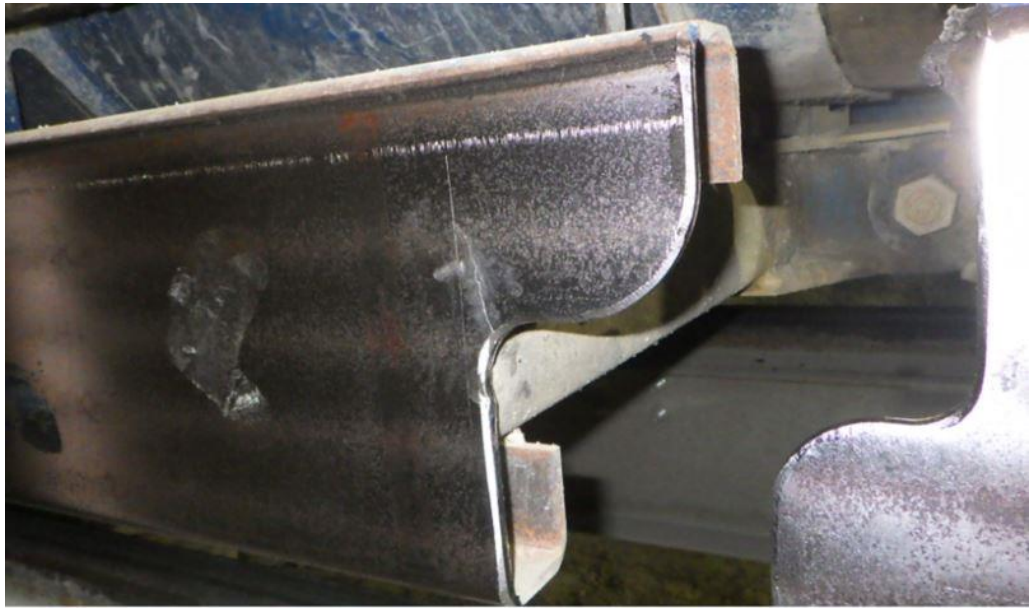




Deep 1 zone – Rail hauling system

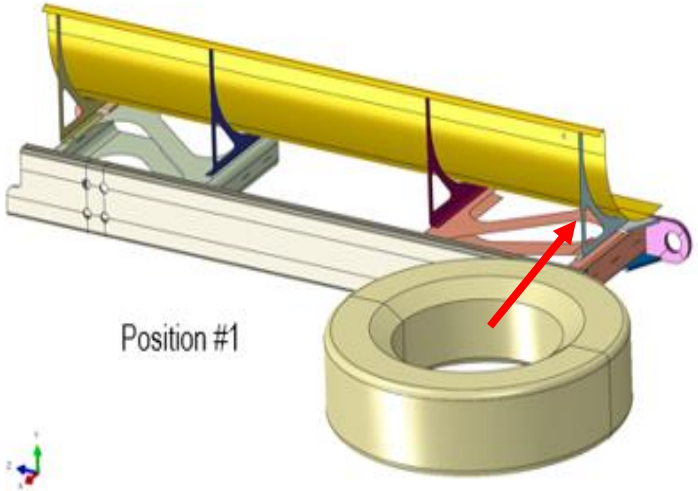
Cracks

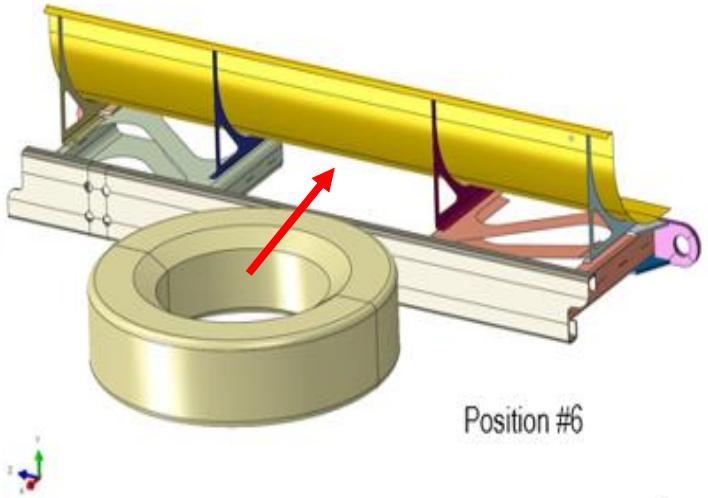
- 1800 cycles
- Side plates at extremities
- Then side plate near cross members

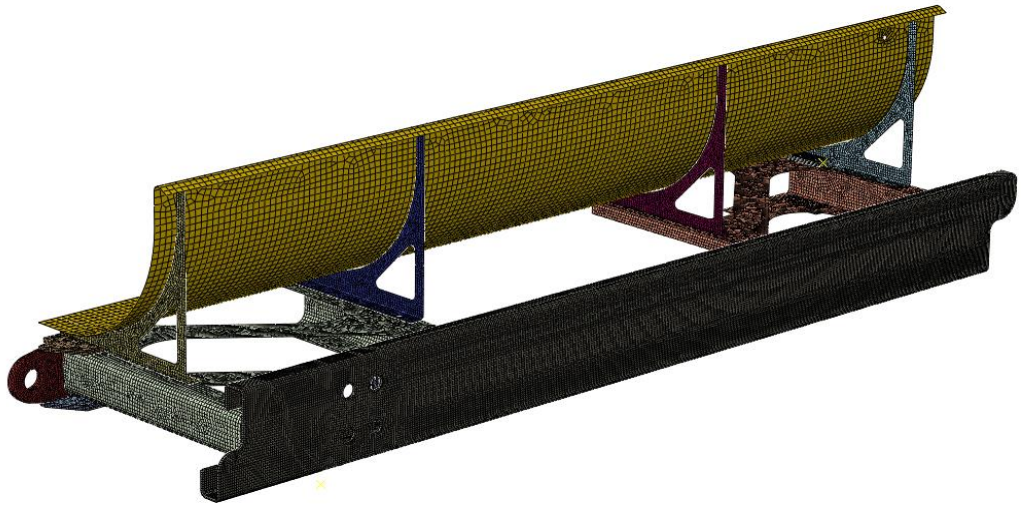


Simplified Fatigue analysis

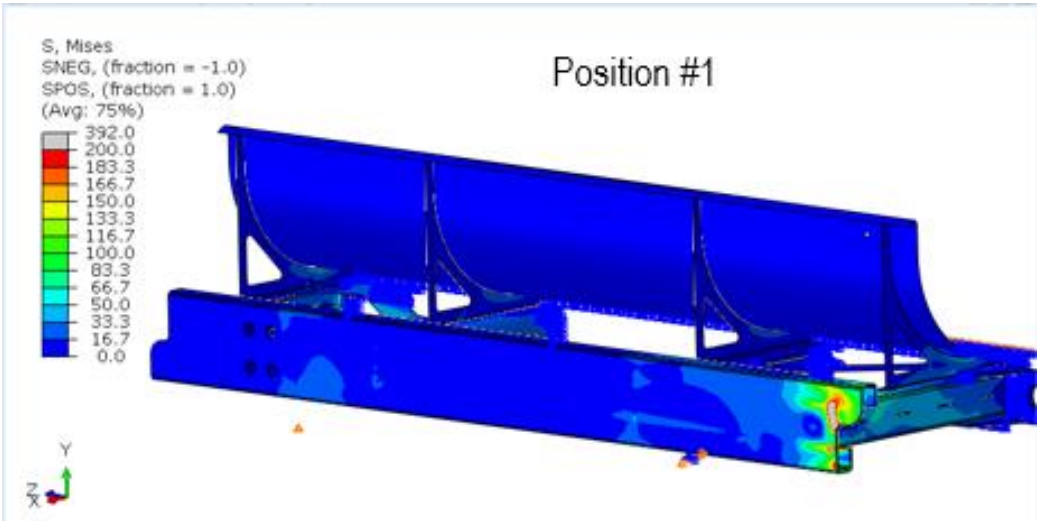
- Built FE Model in ABAQUS to study the study stress distribution created by Tire Normal force when passing through a drive station
- Non-linear static cases with tire at different positions along length
- Used displacement load to create a load of about 12,000 lbf at position 1
- Used a simplified modeling of the tire

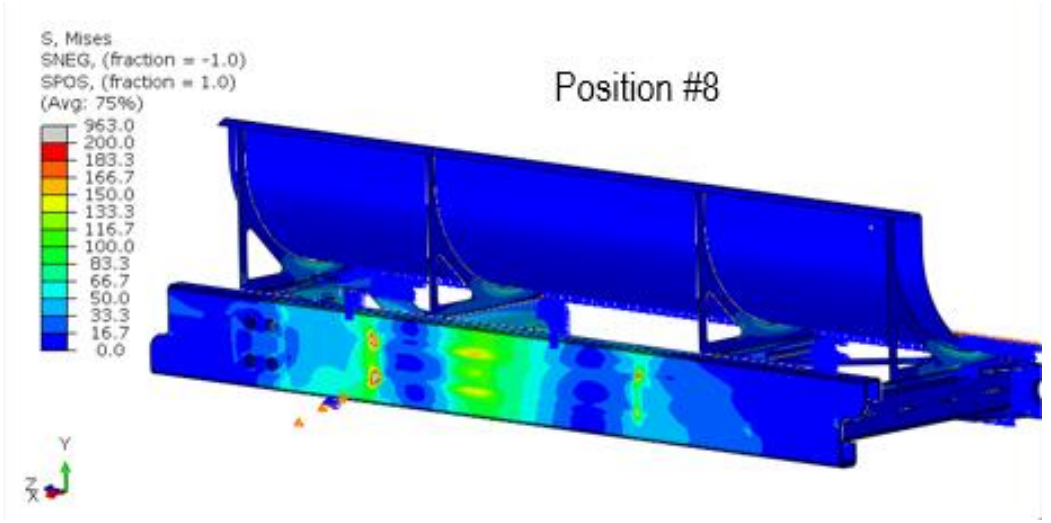


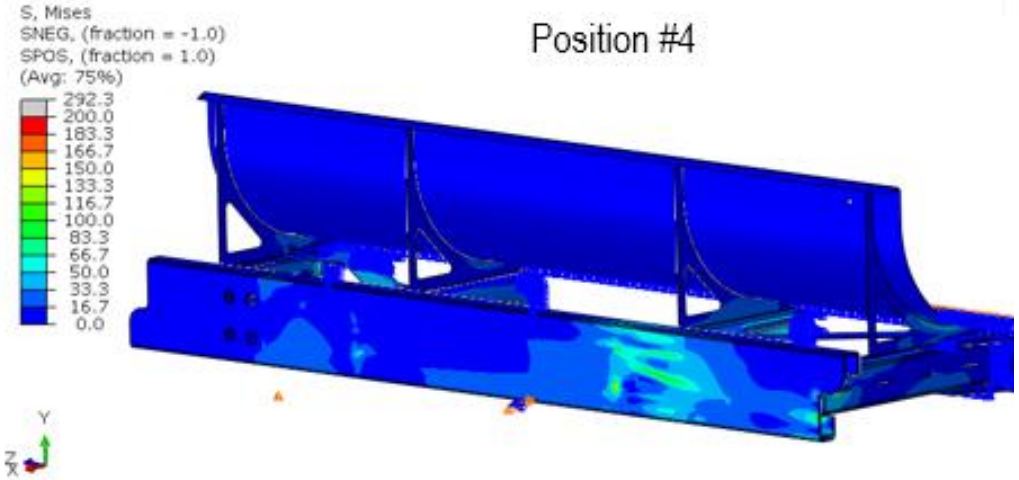




Simplified Fatigue analysis

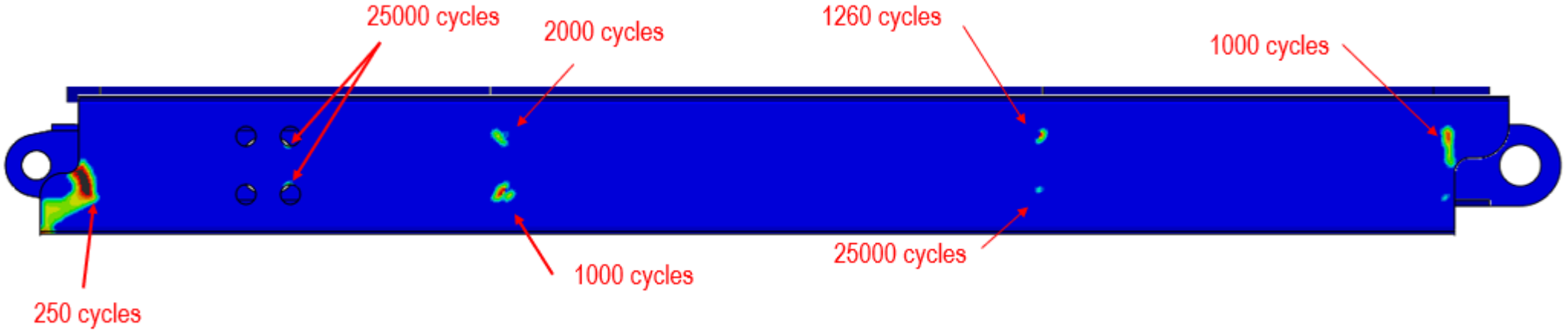






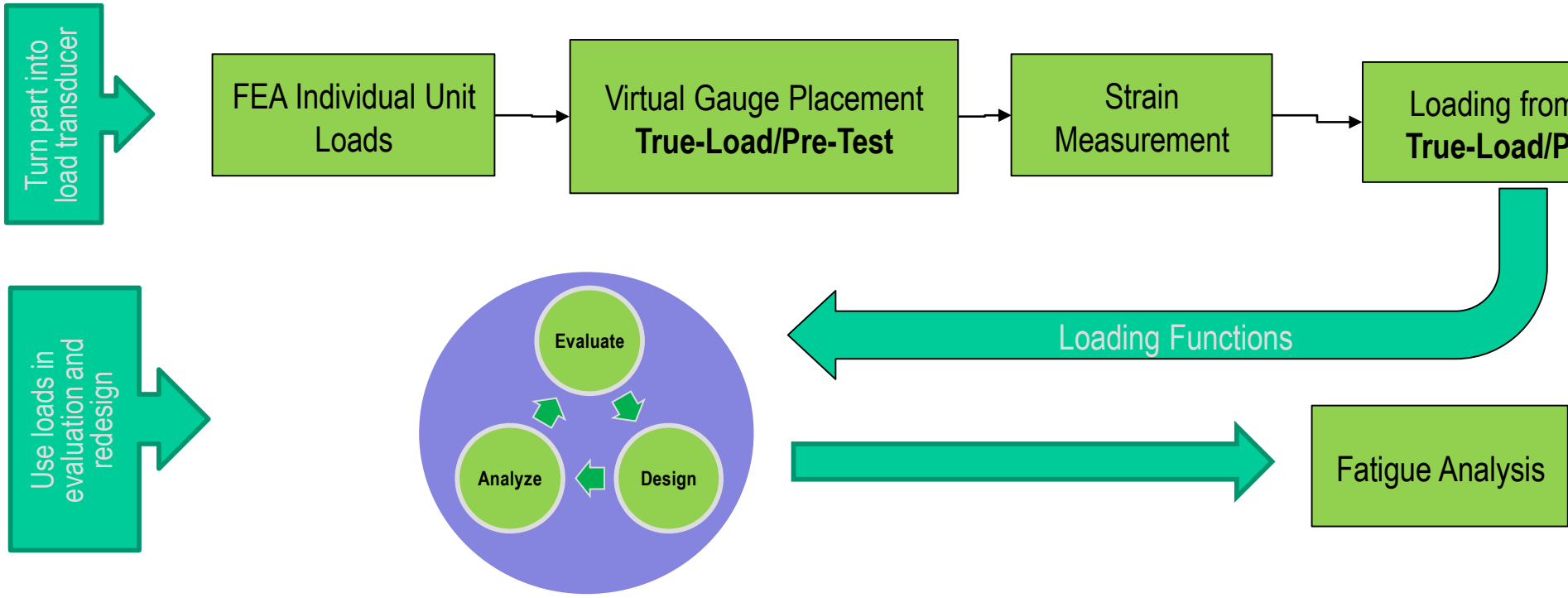
Simplified Fatigue analysis

- Used Fe-Safe to combine tire loads only into a duty cycle as a sequence.
- Repeat for 180 drive stations (assuming same load at each drive station)
- Highlighted zones corresponded well with cracks.
- Number of cycles not expected to be accurate since approximated loads.

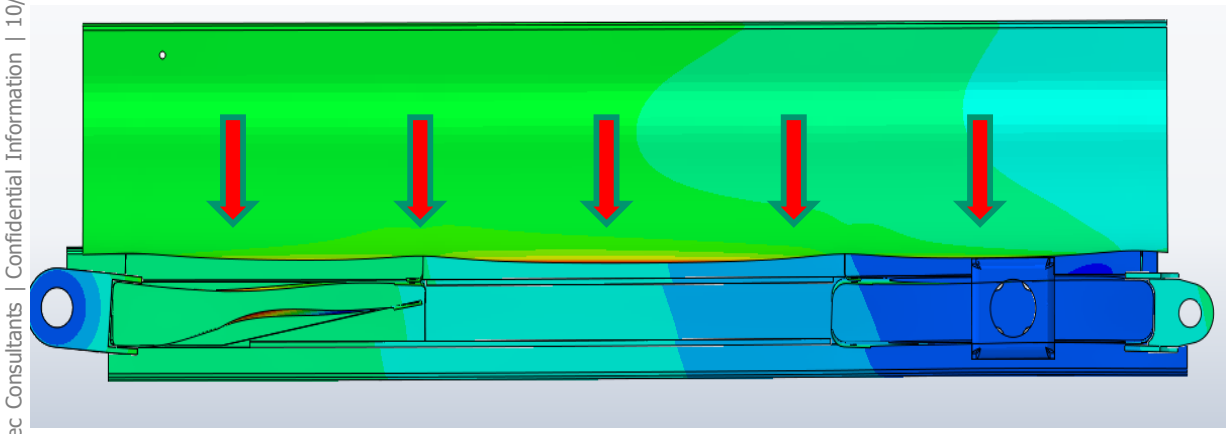


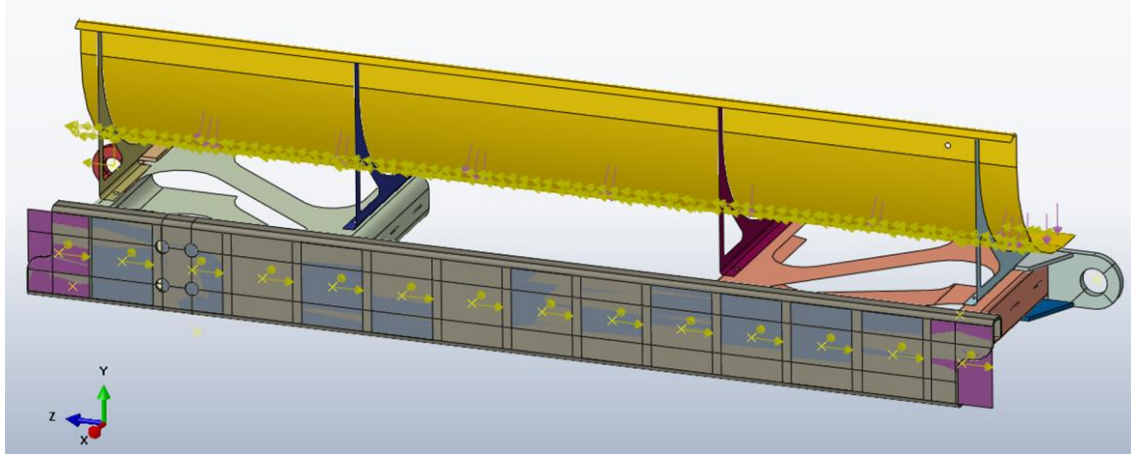
Loads analysis

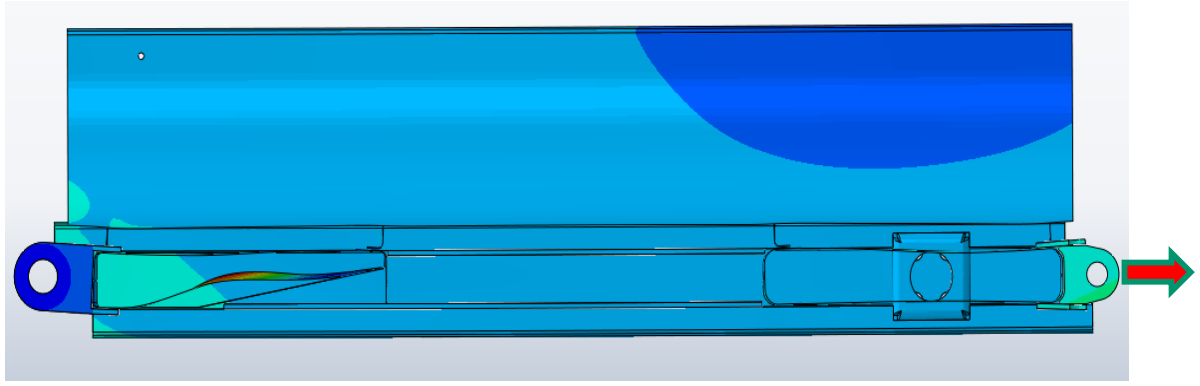
- Desire to better understand the loads acting on the car for redesign work.
- Loads difficult to calculate / measure in such a dynamic application.
- Decided to use True-Load software to calculate loads of the car.

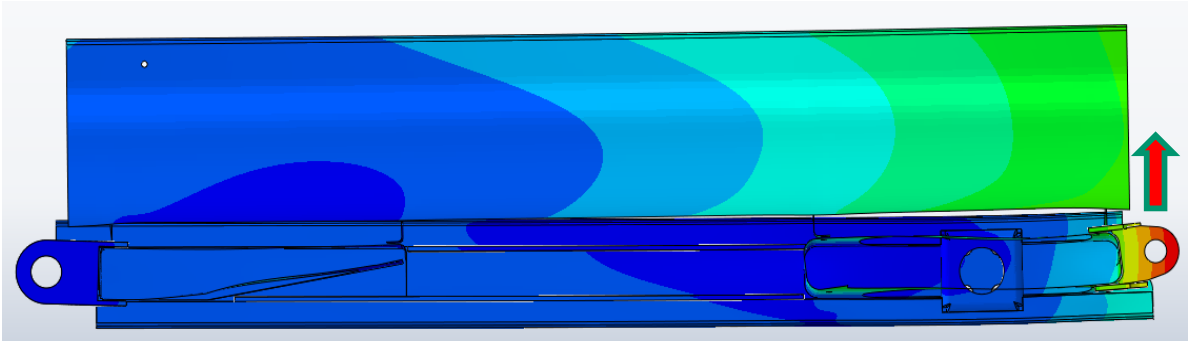


Unit Load cases

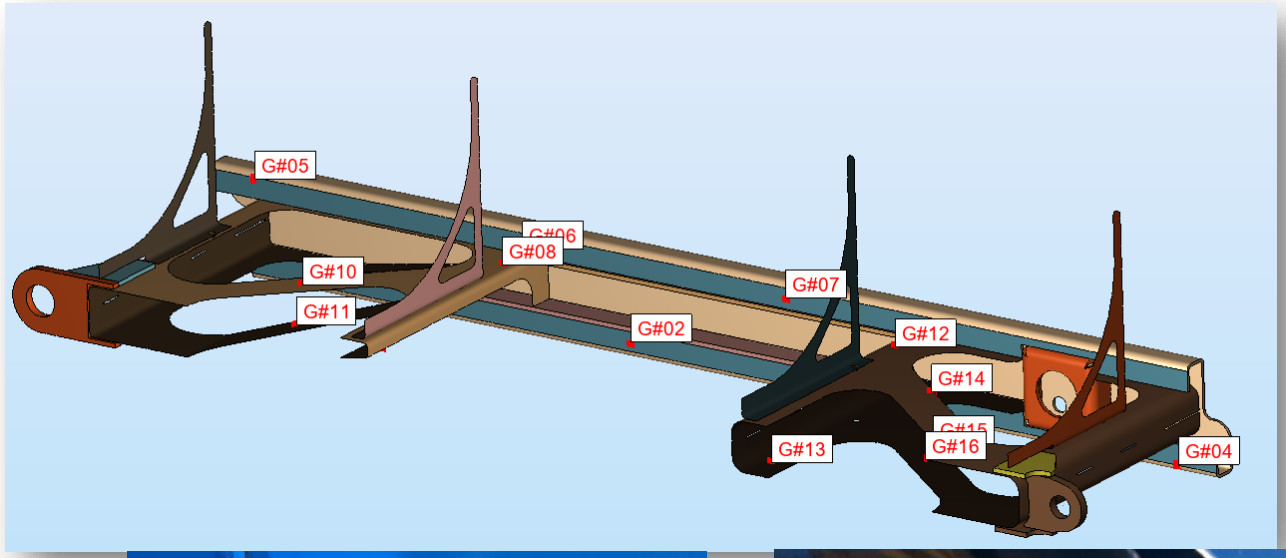


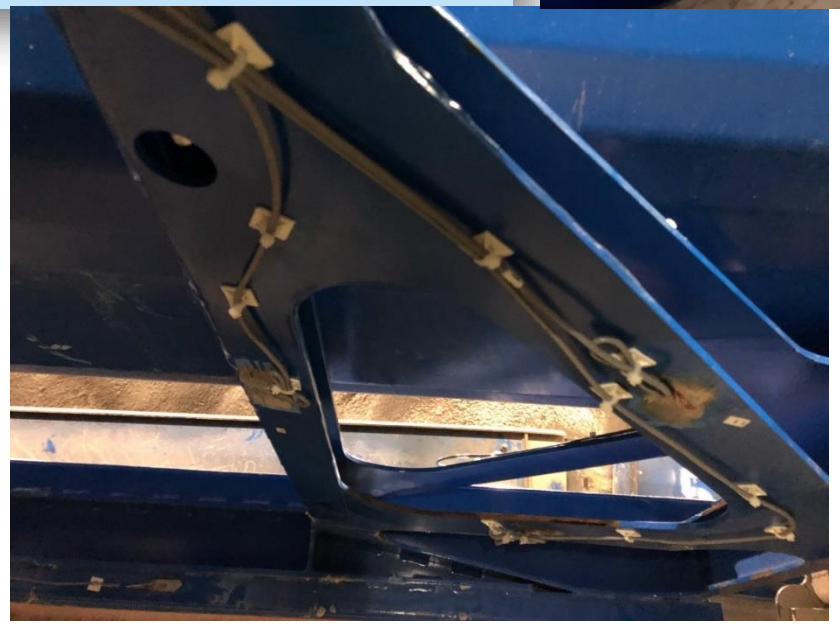


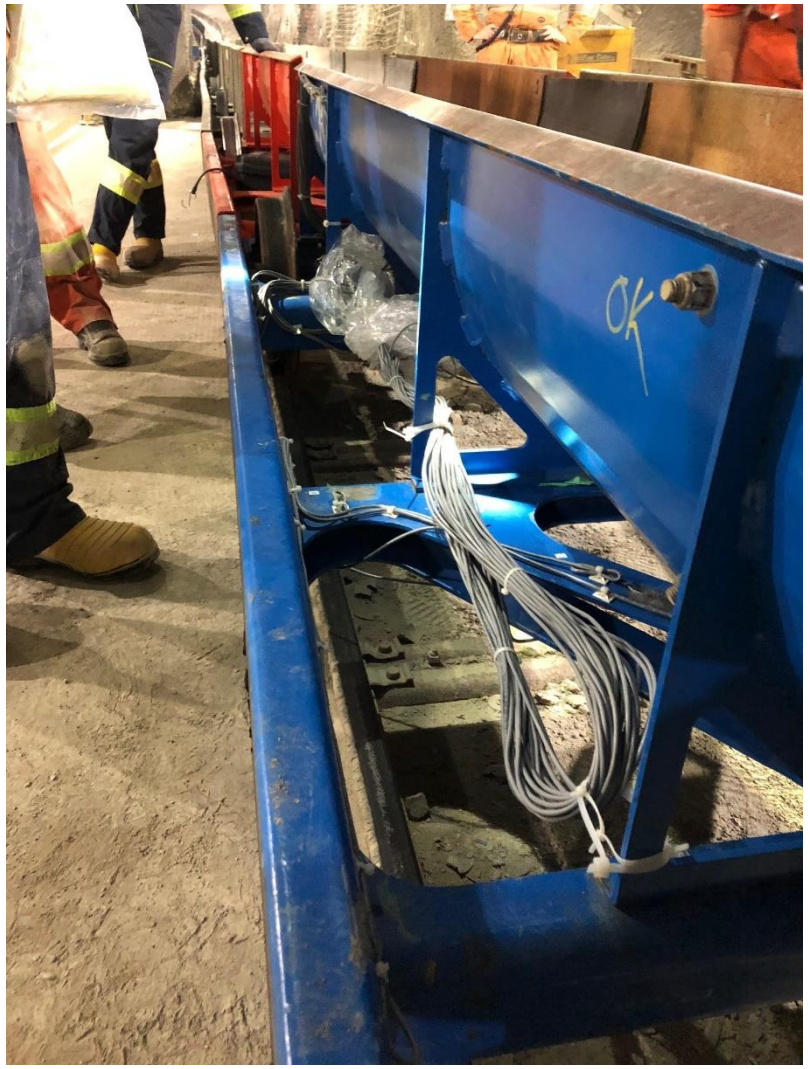




Virtual & Real Strain gauges

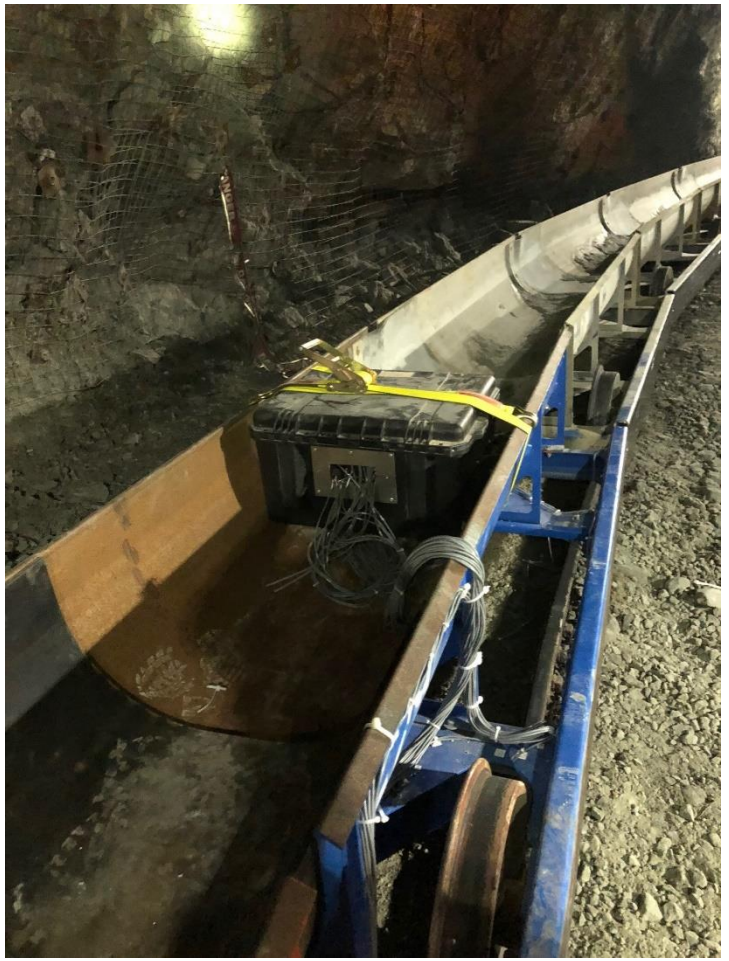






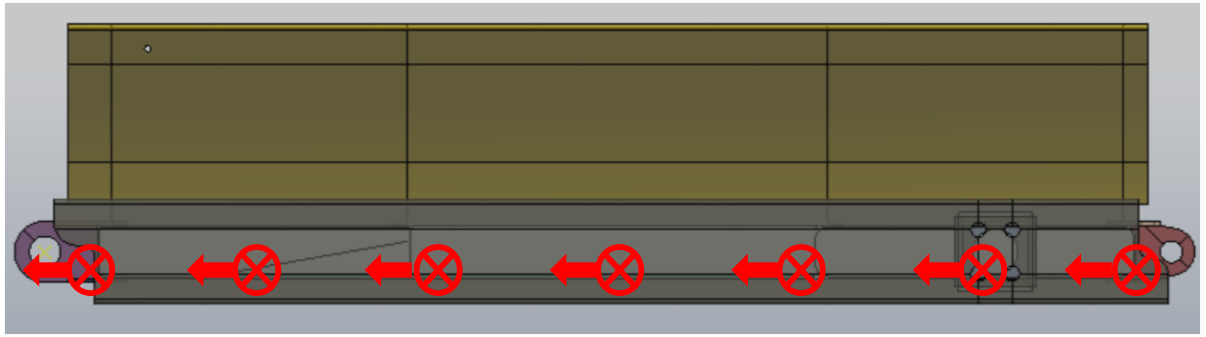
Experimental tests

- Two experimental tests
  - Going up full of ore
  - Going down empty
- Recorded strain histories for all 16 strain gauges
- 25-35 min per test



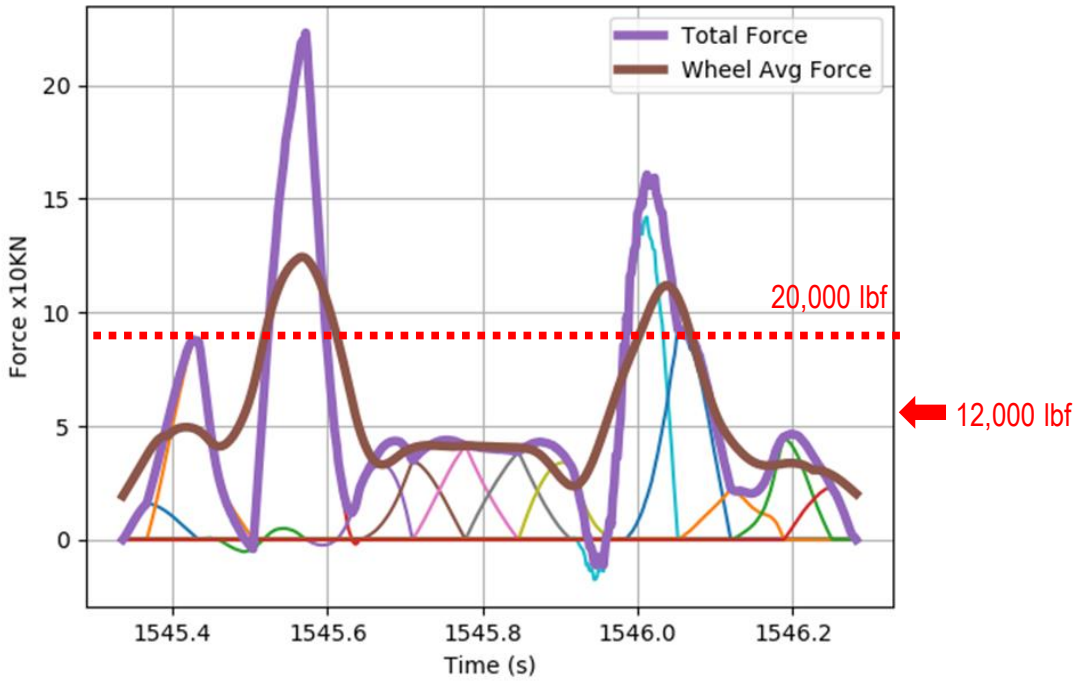
Loads reconstruction – Tire on side plate

- Train going up
- Normal & Shear Tire force results
- Drive station 6 (Top)

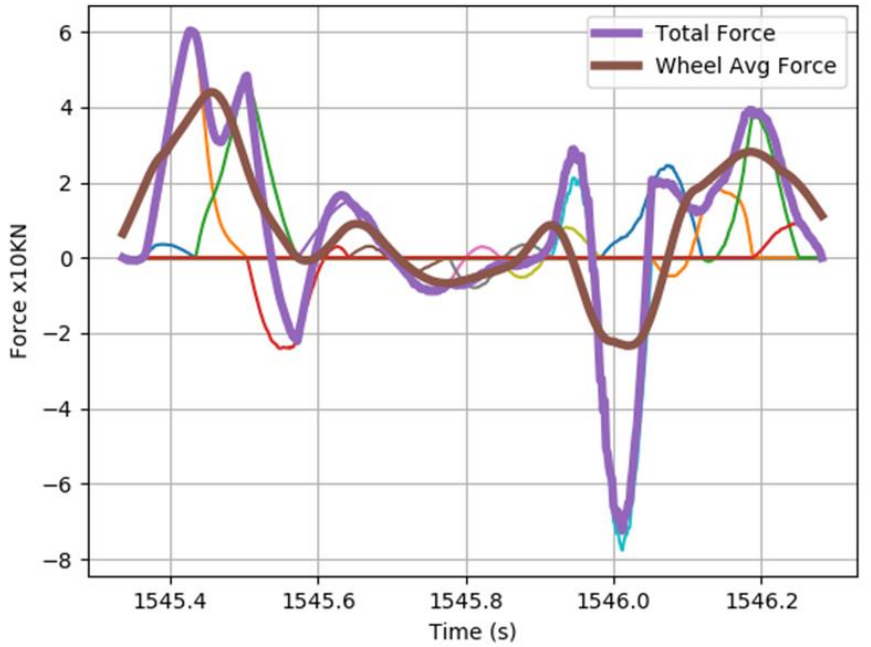


Direction

Normal Tire Force

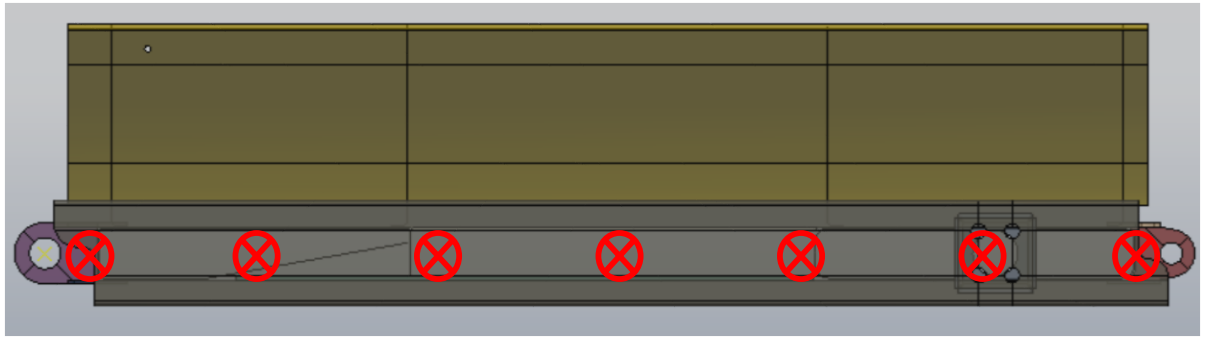


Shear Tire Force

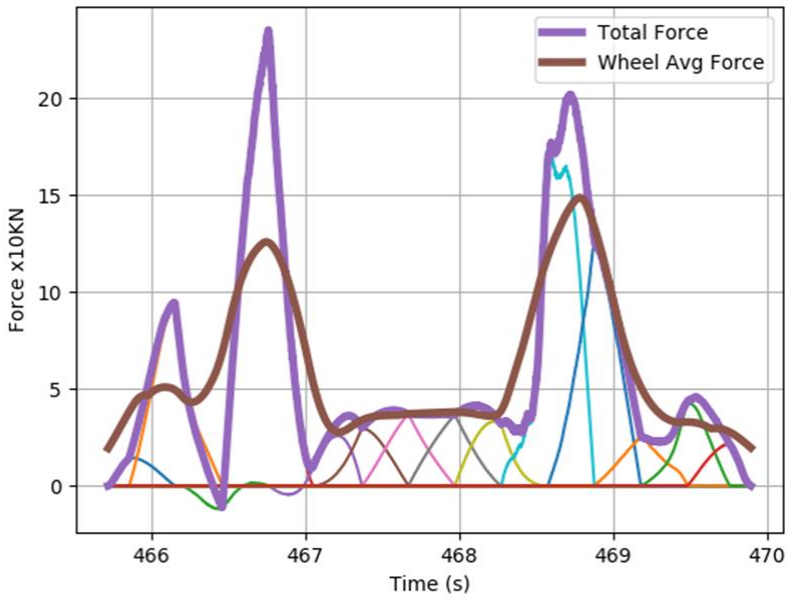


Loads reconstruction – Tire on side plate

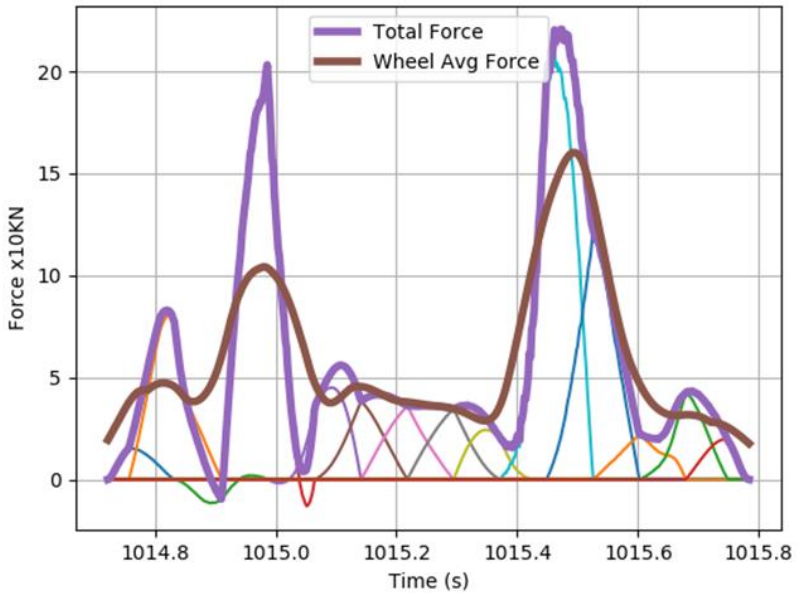
- Train going up
- Normal Tire force results



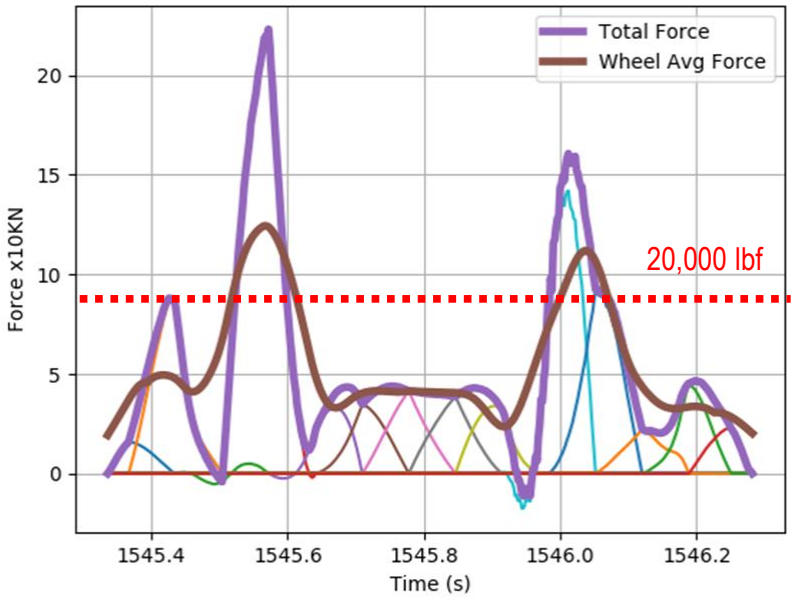
Drive station 86 (Bottom)



Drive station 51 (Middle)

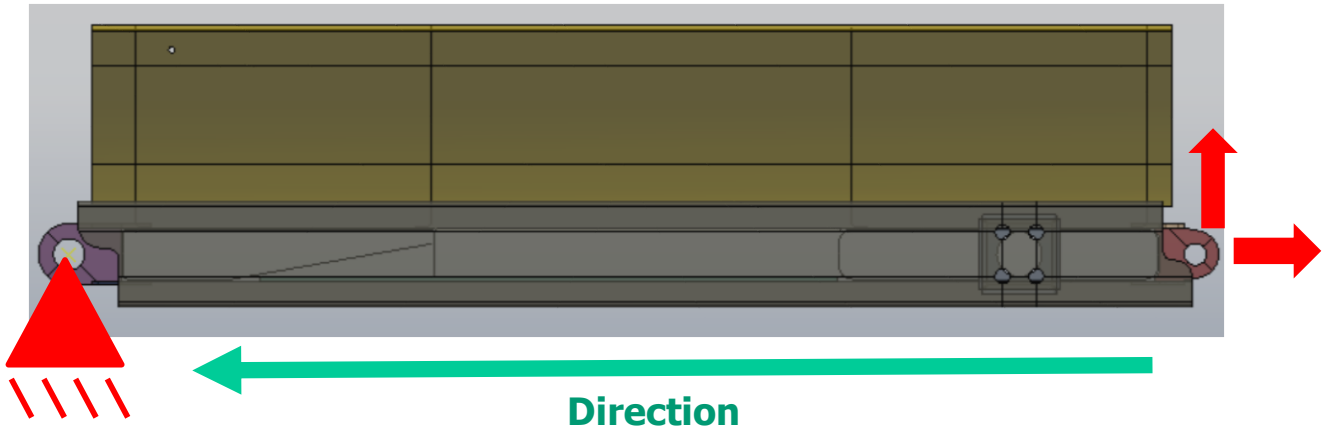


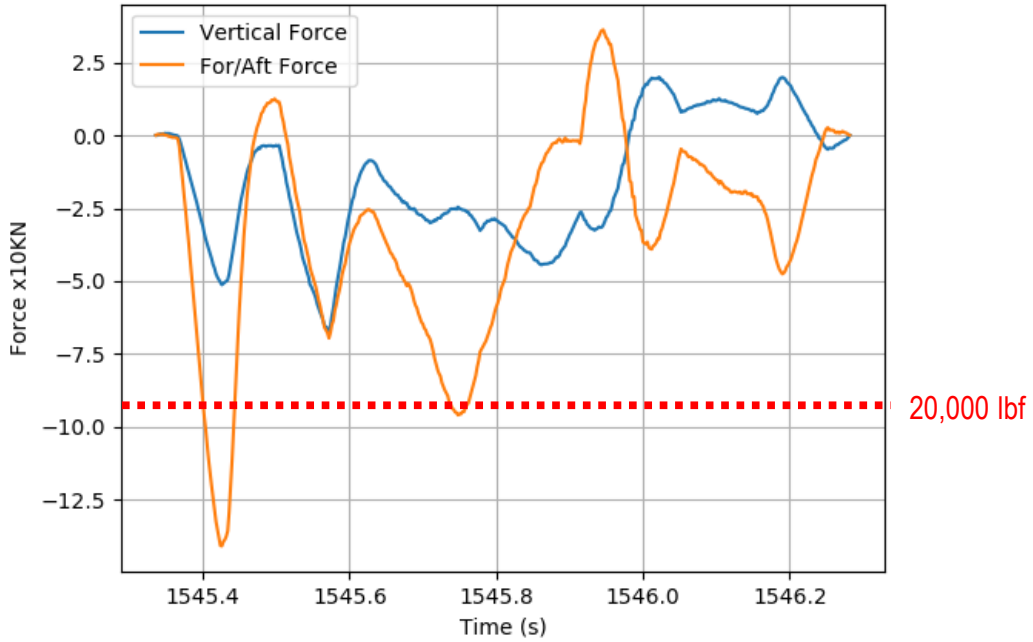
Drive station 6 (Top)

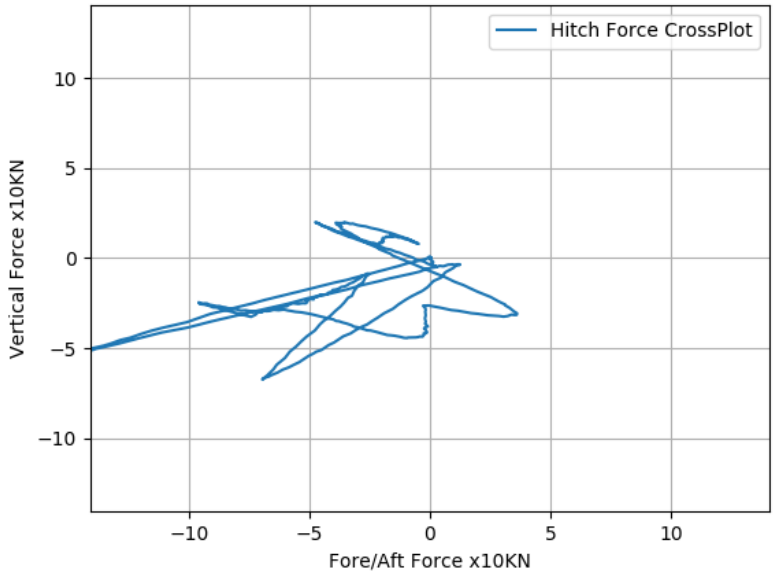


Loads reconstruction - Handle

- Train going up
- Handle force results
- Drive station 6 (Top)

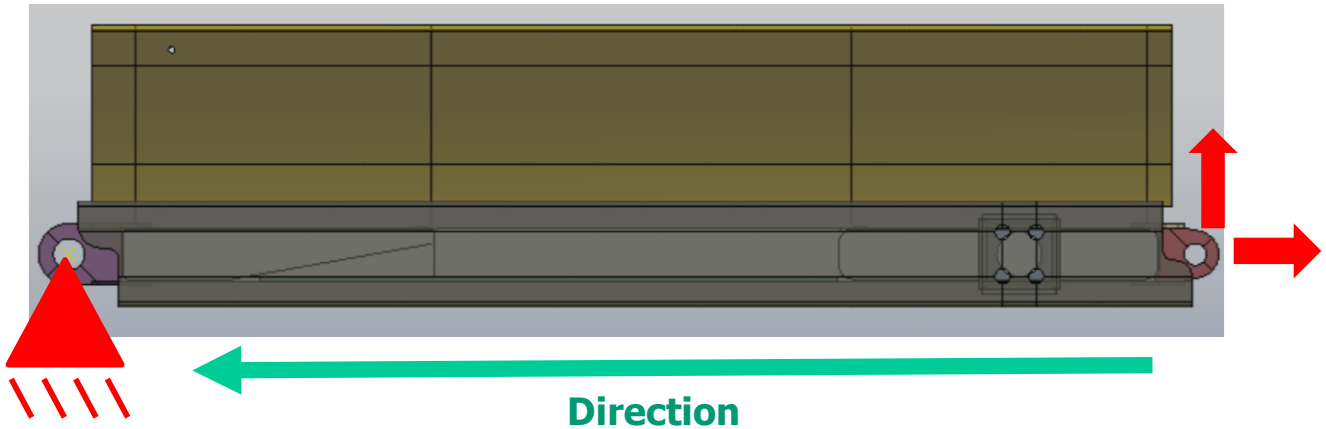




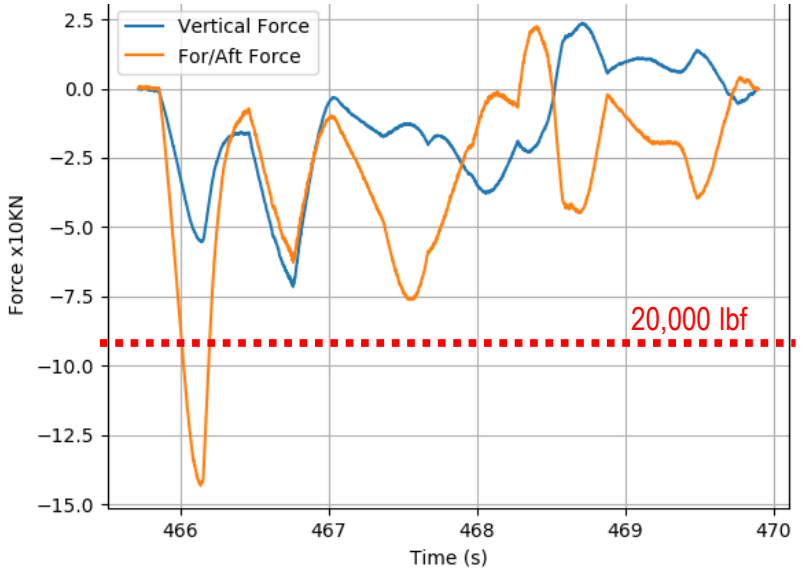


Loads reconstruction - Handle

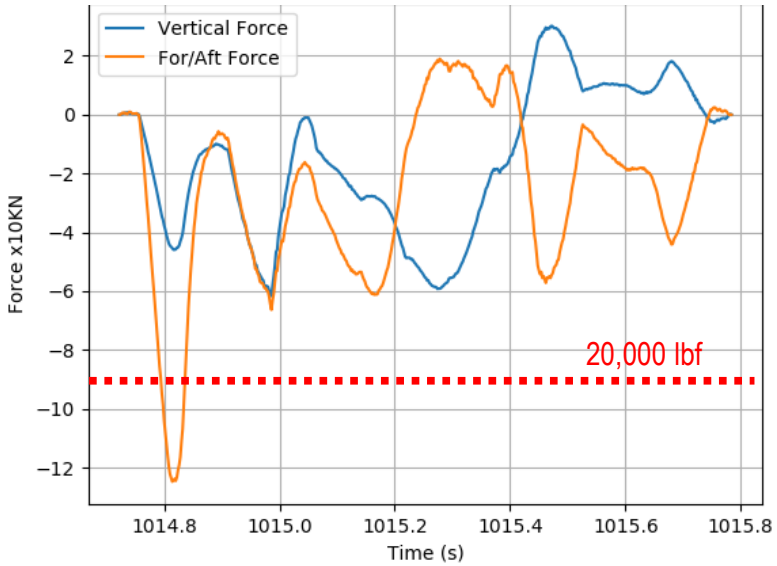
- Train going up
- Handle force results



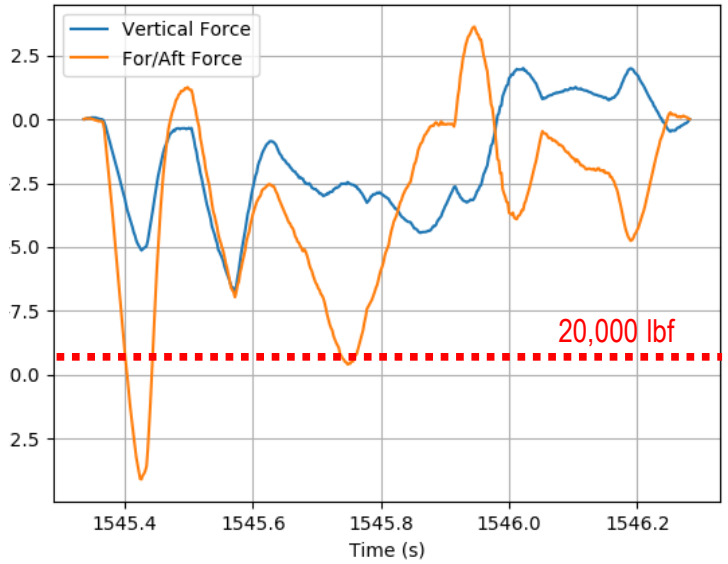
Drive station 86 (Bottom)



Drive station 51 (Middle)

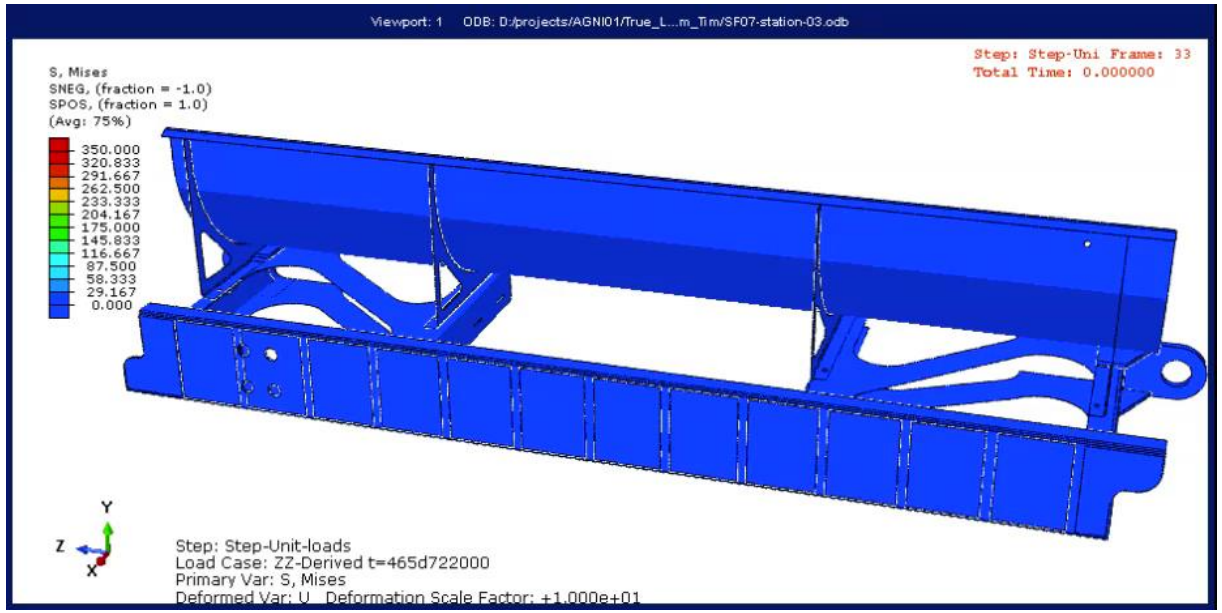


Drive station 6 (Top)

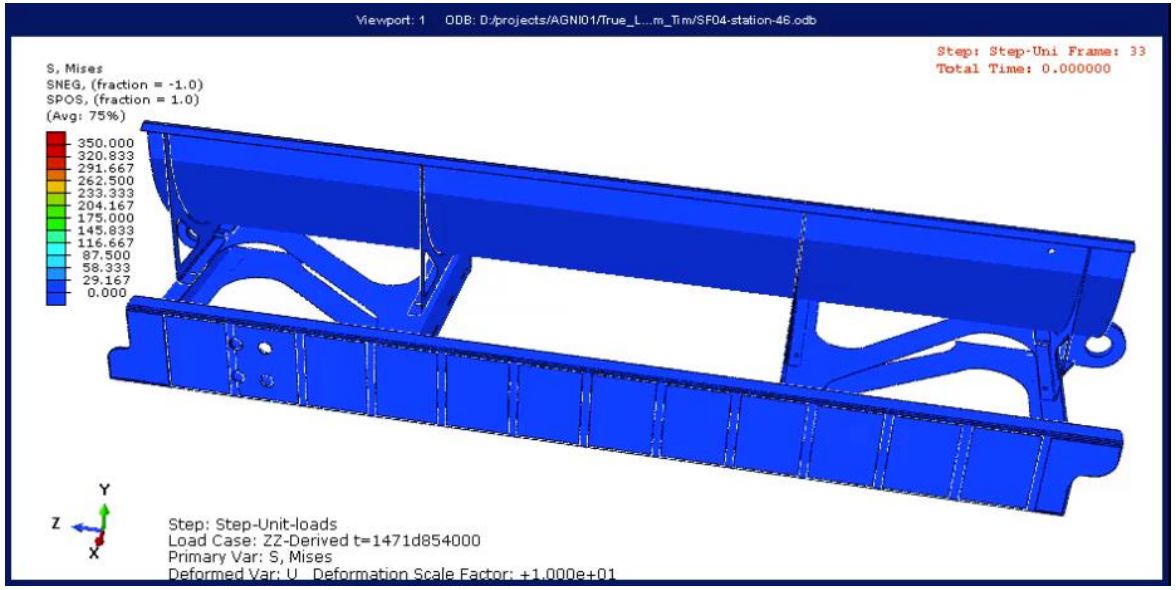


Load Reconstruction Animation

Train going up



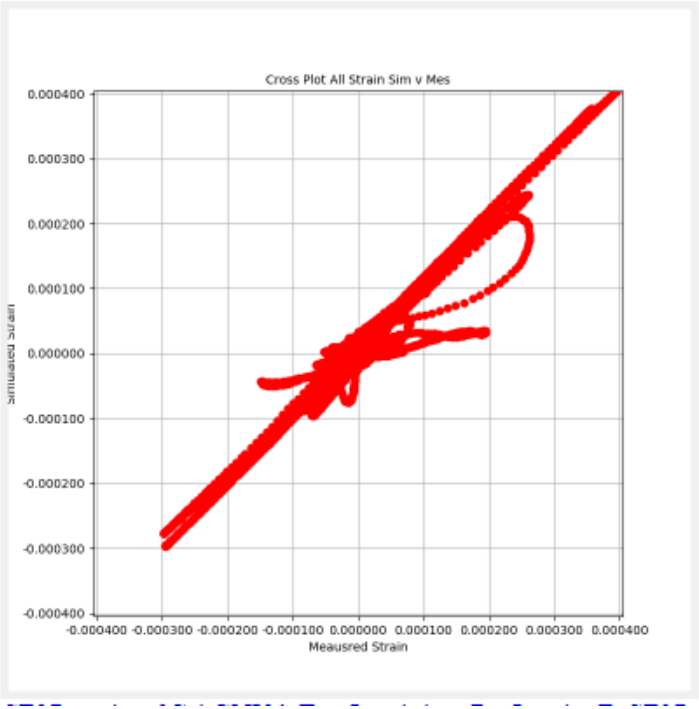
Train going down



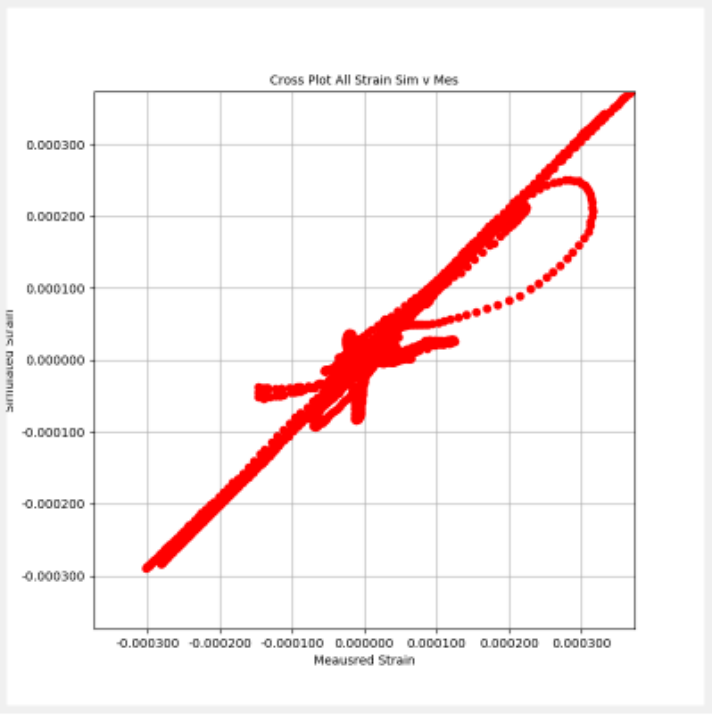
Strain correlation – Measured vs Simulated

- True Load Post Test calculates Loading functions for all unit loads cases.
- Use calculated loads to run an ABAQUS simulation.
- Compare Measured strains vs Simulated strains for all strain gauges.

Train going up

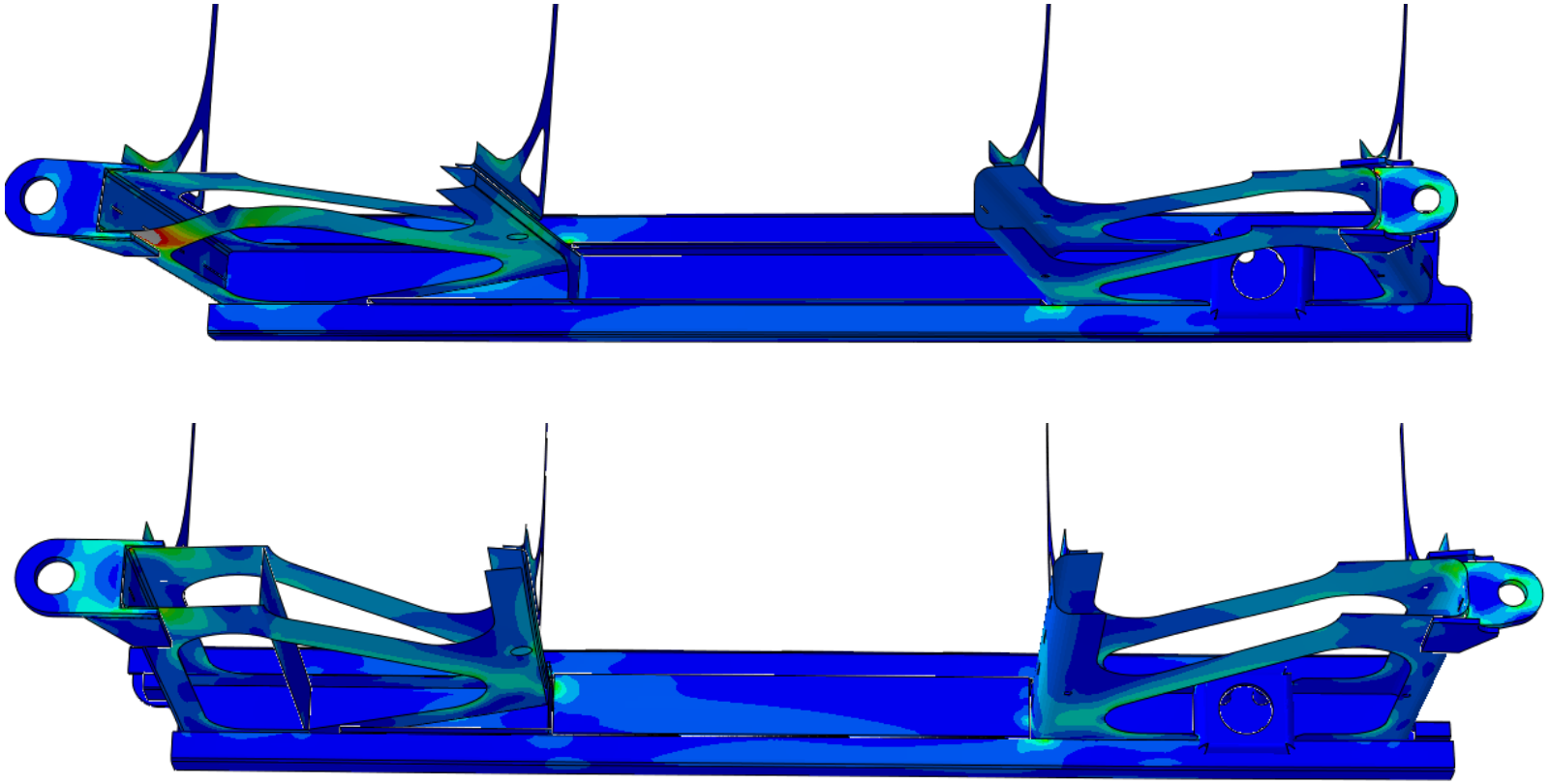


Train going down



Redesign in progress

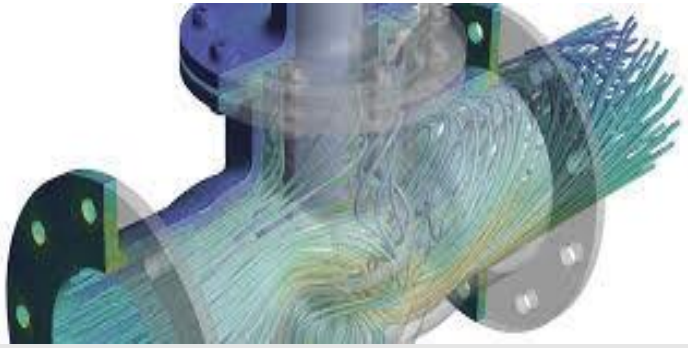
- Buckling issue at front cross member
- Boxing of C channel in the central section
- Stiffening both ends

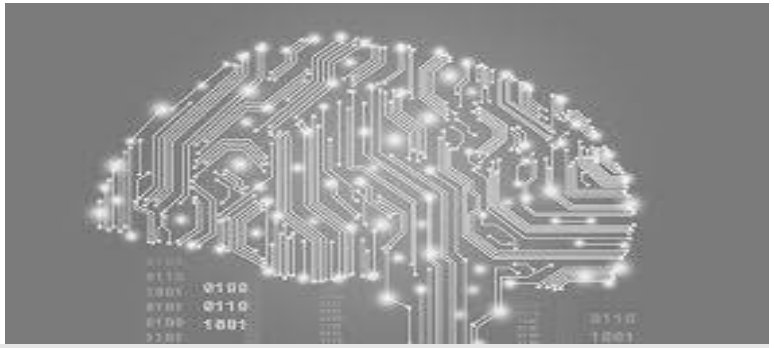


Conclusion

- Started with a simplified Fatigue analysis using traditional approach which gave good results.
- Using True-Load to calculate loads showed useful information about forces magnitude and variation. More or less constant loads were expected.
- Correlation of strains results between FEA and test was good apart from a few gauges. Care must be taken on where the strain gauges are placed.
- Loads acting on a structure are not easy to calculate and it's one of the biggest unknown when realizing FEA work, even more the case for fatigue analysis. Investing time to study loading help reduce GIGO.

Questions ?





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