Updating the horizontal VUC: Progress update

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Scope of review

- 1. Converting damage to cost
  - Can better relationships between damage and maintenance requirements be developed whilst maintaining an acceptable level of simplicity/transparency?
- 2. Friction coefficients
  - Evaluate the effect of changing the flange (lubricated) friction coefficients to values which we believe better describe the conditions for lubricated rail
- 3. Track alignment
  - Evaluate the effect of introducing ‘real’ track misalignment features into the curving simulations
- 4. Wheel profiles
  - Wear/RCF damage depends on wheel wear (mileage). Allow use of alternative wheel profiles

1. Converting damage to cost

- From “Methodology to calculate variable usage charges for Control Period 4” UK NR Report 08-002, J. Tunna, R. Joy, X, Shu and B. Madrill, TTCI

or $Ty \leq 15$ N (B8a)

$(Ty - 15)$ for $Ty > 15$ N (B8b)

$$\frac{WearDamage}{Axle} = 0 \text{ for } Ty \leq 65 \text{ N} \quad \text{(B9a)}$$

$$\frac{WearDamage}{Axle} = WearDamageRate(Ty - 65) \text{ for } Ty > 65 \text{ N} \quad \text{(B9b)}$$

At $Ty = 175$ N the crack and wear damage rates are equal. Thus:

$$WearDamageRate = \frac{160}{110} \times CrackDamageRate \quad \text{(B10)}$$

Now, the amount of material lost from the side of the rail for each axle is the sum of the depth ground and the depth worn for each axle:

$$\frac{SideLoss}{Axle} = \frac{DepthGround}{Axle} + \frac{DepthWorn}{Axle} \quad \text{(B11)}$$

where:

$$\frac{DepthGround}{Axle} = \frac{DepthGround}{GrindingCycle} \times \frac{GrindingCycles}{Axle} = \frac{DepthGround}{GrindingCycle} \times \frac{RCFDamage}{Axle} \quad \text{(B12)}$$

For $15 < Ty \leq 175$ N:

$$\frac{DepthWorn}{DepthGround} = \frac{WearDamage}{RCFDamage} \quad \text{(B13)}$$

Thus:

$$\frac{DepthWorn}{Axle} = \frac{WearDamage}{RCFDamage} \times \frac{DepthGround}{Axle} = \frac{DepthGround}{GrindingCycle} \times \frac{WearDamage}{Axle} \quad \text{(B14)}$$

Substituting Equations B11, B12 and B14 into Equation B6 gives $15 < Ty \leq 175$ N:

$$\frac{Cost}{Axle} = \frac{RCFDamage}{Axle} \times GrindingCost + \frac{DepthGround}{GrindingCycle} \times \left(\frac{RCFDamage}{Axle} + \frac{WearDamage}{Axle}\right) \times \frac{RenewalCost}{SideLossLimit} \quad \text{(B15)}$$

and finally for $15 < Ty \leq 175$ N Equation B16:

$$Cost = RCFDamage \times GrindingCost + \frac{DepthGround}{GrindingCycle} \times (RCFDamage + WearDamage) \times \frac{RenewalCost}{SideLossLimit} \quad \text{(B16)}$$

For $Ty \geq 175$ N:

$$\frac{DepthWorn}{Axle} = k \times \frac{WearDamage}{Axle} \quad \text{(B17)}$$

At $Ty = 175$ N the depth worn per axle from Equations B14 and B17 should be the same. Thus:

$$k = \frac{DepthGround}{GrindingCycle} \quad \text{(B18)}$$

Substituting Equations B11, B17 and B18 into Equation B6 gives for $Ty \geq 175$ N:

$$\frac{Cost}{Axle} = \frac{DepthGround}{GrindingCycle} \times \frac{WearDamage}{Axle} \times \frac{RenewalCost}{SideLossLimit} \quad \text{(B19)}$$

and finally for $Ty \geq 175$ N Equation B20:

$$Cost = \frac{DepthGround}{GrindingCycle} \times WearDamage \times \frac{RenewalCost}{SideLossLimit} \quad \text{(B20)}$$

Thus, an equations have been derived that gives the cost of rail surface damage in terms of known variables and the wear index (Ty) generated by a vehicle. Table B1 lists assumed values for the variables in Equation B15.

1. Converting damage to cost

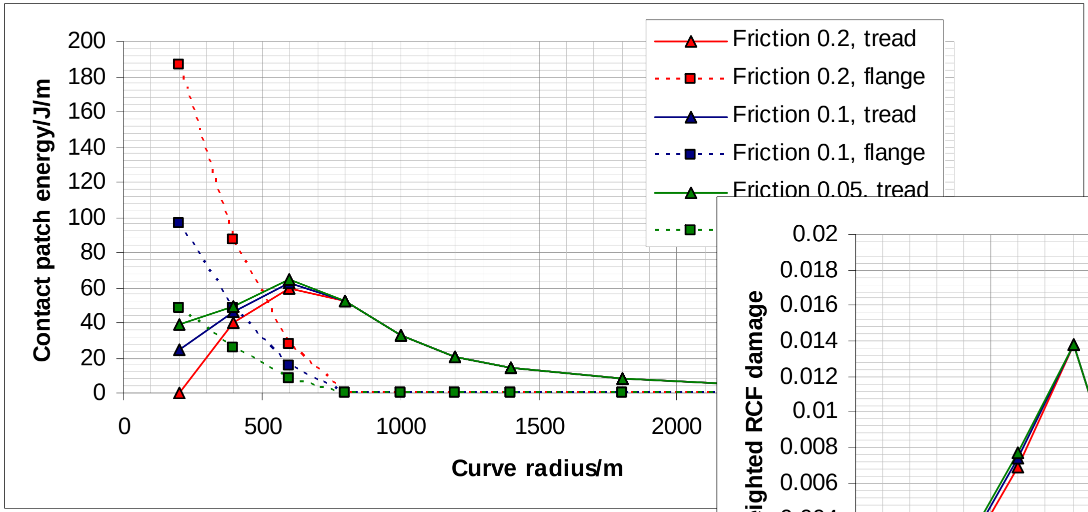
- Existing methodology
  - Includes costs for rail grinding and rail renewal
  - Calculates RCF and wear damage for each vehicle
    - RCF is assumed to trigger grinding
    - Wear is assumed to trigger rail renewal (grinding is also assumed to add to wear)
- But
  - Grinding does not completely control RCF: we undertake renewals because of RCF
  - And, grinding is planned to be undertaken on a tonnage basis (15MGT on curves), not necessarily as a direct result of RCF

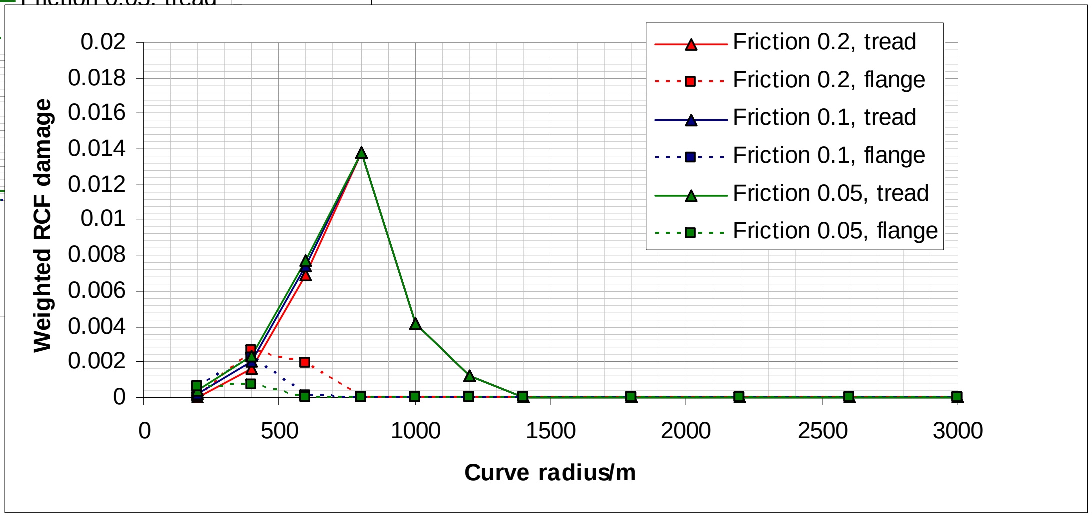
1. Converting damage to cost

- So….we have started reformulating the equations to
  - Still have grinding related to RCF
    - But also include a relationship with axleload since tonnage also drives grinding
  - Include rail renewal triggered by RCF
    - The total RCF before renewal is much higher than for grinding, so the contribution of each vehicle to rail renewal is lower than for grinding
  - Wear contribution stays largely the same
    - Wear limit is the same, and grinding adds a small amount to the total wear

2. Friction coefficients

- Review of simulations with lower flange friction
  - For many vehicles this has a relatively small impact
    - the curves where varying friction changes the balance of forces have a small weighting in the damage calculation because there are not many of them on the network



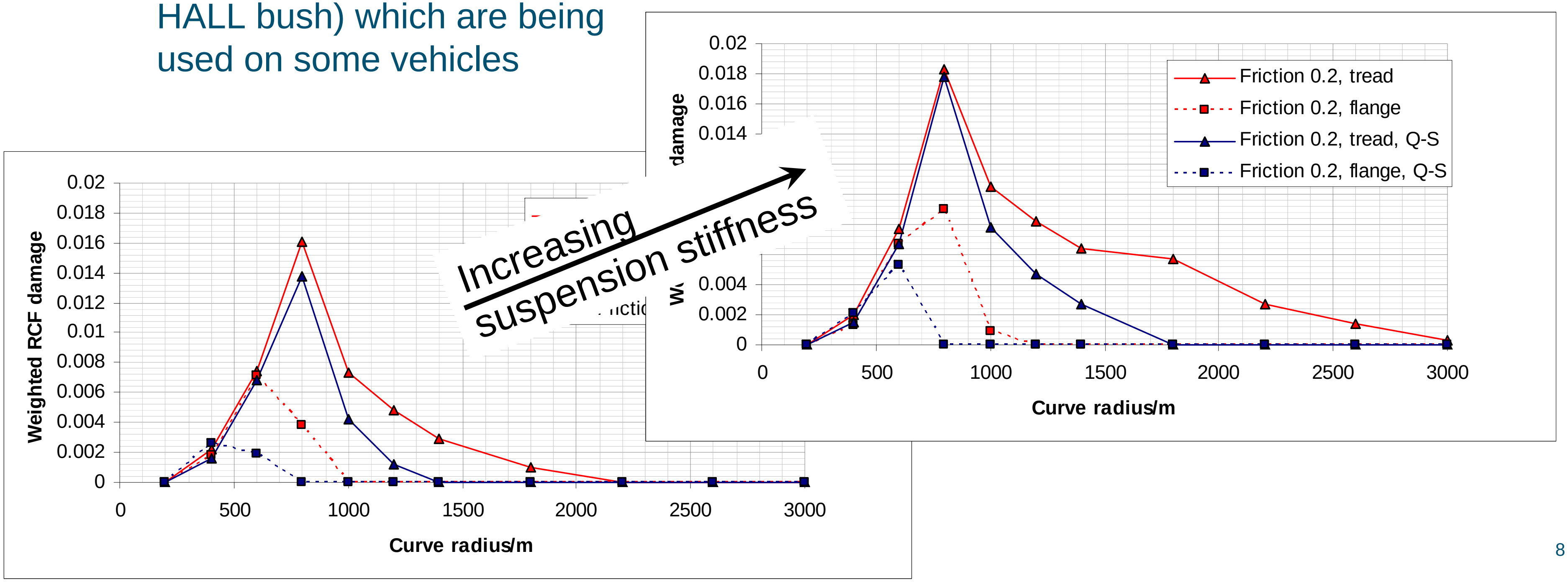


3. Track alignment

- Simulations using a sample ('good') track quality alignment
  - The same track file used for all analysis
    - Ensures that both the static and dynamic performance of the vehicle suspension is tested
  - RCF damage evaluated from forces determined as the mean + 1SD value to include some dynamic effect in the evaluation

3. Track alignment

- Observations
  - Track damage is distributed onto shallower radius curves: which we know do experience RCF
  - Vehicles with stiffer yaw suspensions predicted to cause proportionally more damage on shallower curves: as observed
  - Methodology would allow better classification of novel suspension types (e.g. the HALL bush) which are being used on some vehicles



Summary

- Hundreds of vehicle dynamics simulations have been run
  - And many are still to run!
- Progress is running to plan
- Track cost equations being reformulated to include RCF as a cause for renewal and not just grinding
- Friction coefficient updates will have a small effect on charges
- Proposed changes to account for vehicle dynamics due to track geometry variations: better representation of the range/types of RCF