Minimising wheel wear by optimising the primary suspension stiffness and centre plate friction of self-steering bogies

TRANSNET

freight rail

Shelley Fergusson, Robert Fröhling & Hennie Klopper

SAICE SYMPOSIUM

11 SEPTEMBER 2007

PRESENTATION OVERVIEW

- Introduction
- Bogie development
- Problem definition
- Running dynamics simulation models
- Running dynamics simulation results
- On-track tests
- Conclusions

INTRODUCTION

- **Wheel maintenance ⇨ High cost component**
- **Technical interventions to reduce wheel tread and wheel flange wear rates should continuously be investigated**

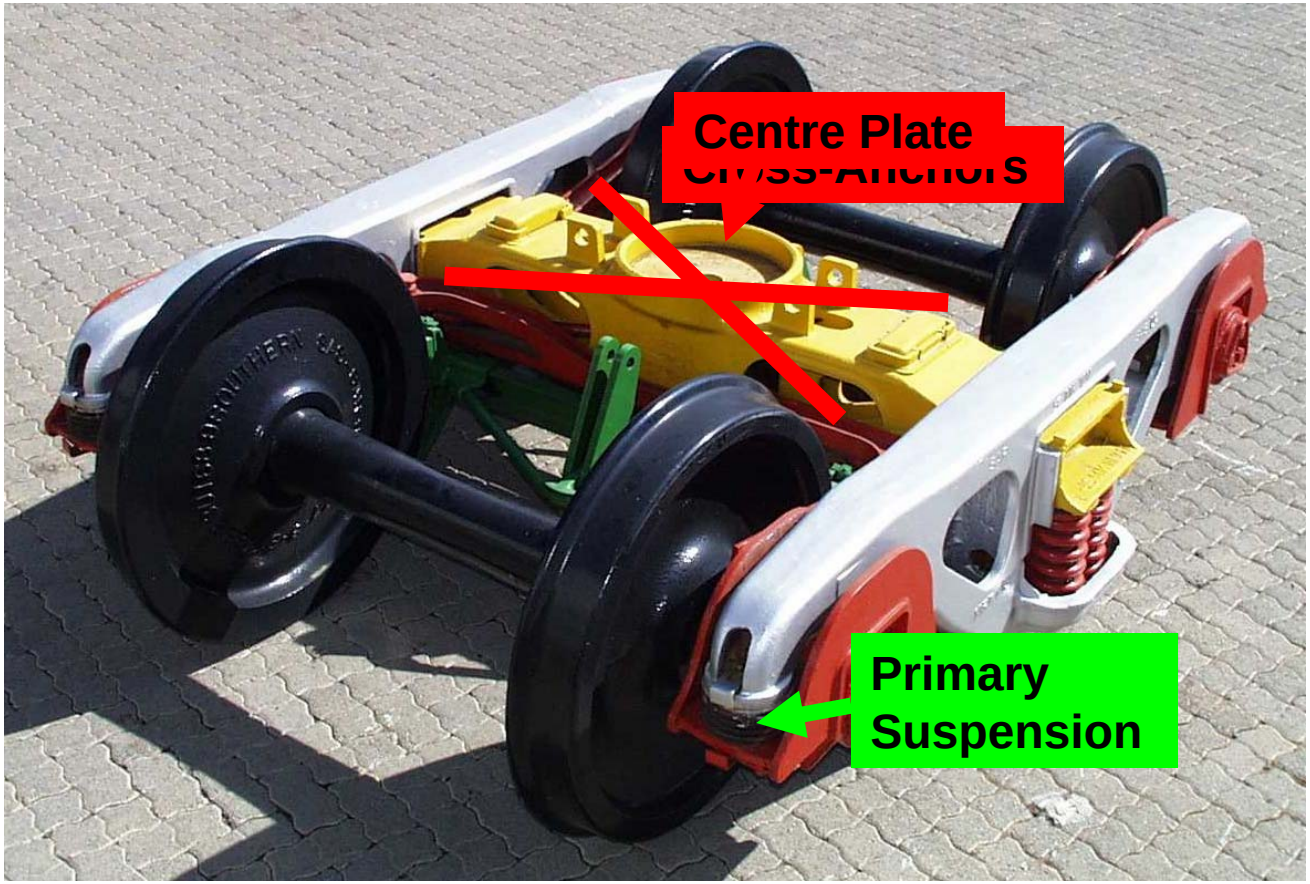
- **Research project:**
  - **Investigate the possibility to further reduce wheel wear by optimising the lateral and longitudinal primary suspension stiffness and centre plate friction of self-steering three-piece bogies**

BOGIE DEVELOPMENT

- 1779: First known proposal of a bogie
- 1829: Importance of bogie alignment in curves highlighted
- 1832: First locomotive with a swivelling leading bogie
- 1850's:
  - Restrained bogie yaw by centre plate friction:
    - Improved bogie curving performance and acceptable stability
  - Three-piece bogie development:
    - Still used today due to low life cycle cost and continuous improvements to meet new business demands (speed, axle load, …)

BOGIE DEVELOPMENT

- **1970’s: Scheffel developed the self-steering three-piece bogie**

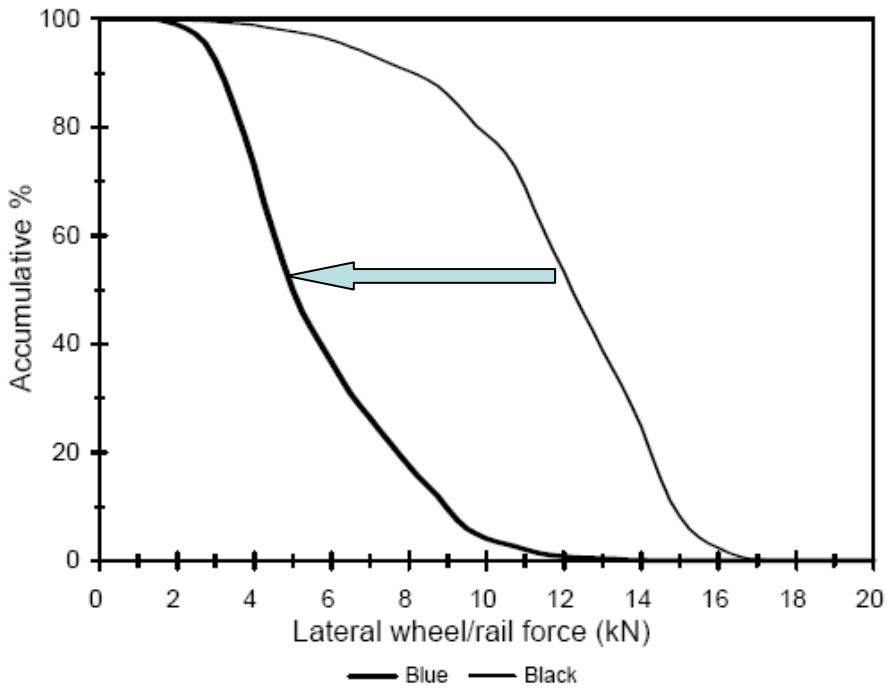


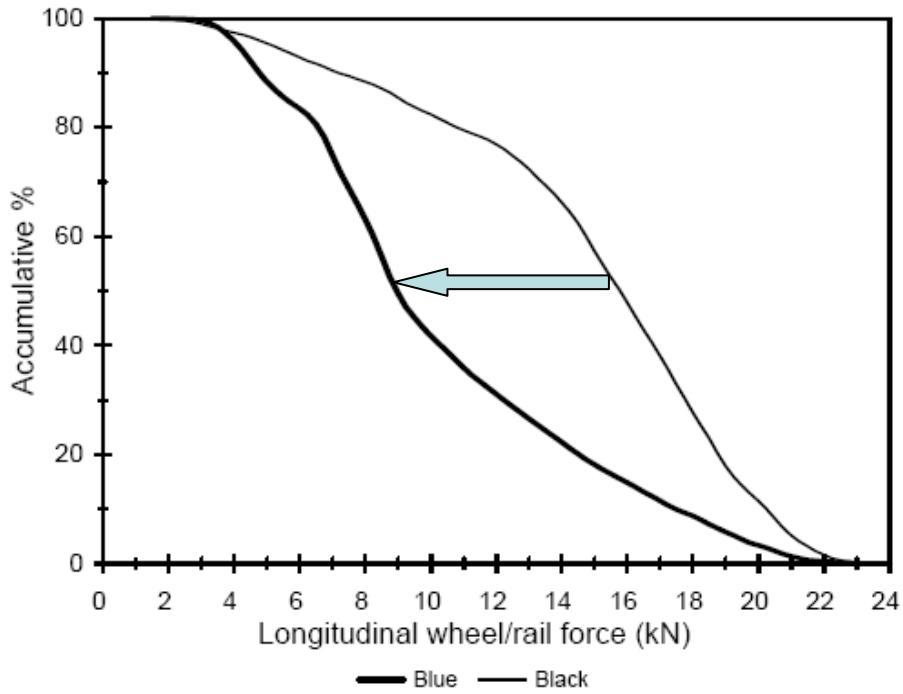
PROBLEM DEFINITION

- **Curving performance of LKAB self-steering bogies under load:**
  - **Not acceptable due to binding at centre plate**
  - **Binding at centre plate compensated by significant wheelset yaw**
- **Solution:**
  - **Reduced centre liner's coefficient of friction ✓✓✓**
- **Influence on wheel wear due to**
  - **Centre plate friction / binding ???**
  - **Wheelset yaw = *f* (primary suspension) ???**
- **Some answers to these questions are presented in this paper …**

PROBLEM DEFINITION

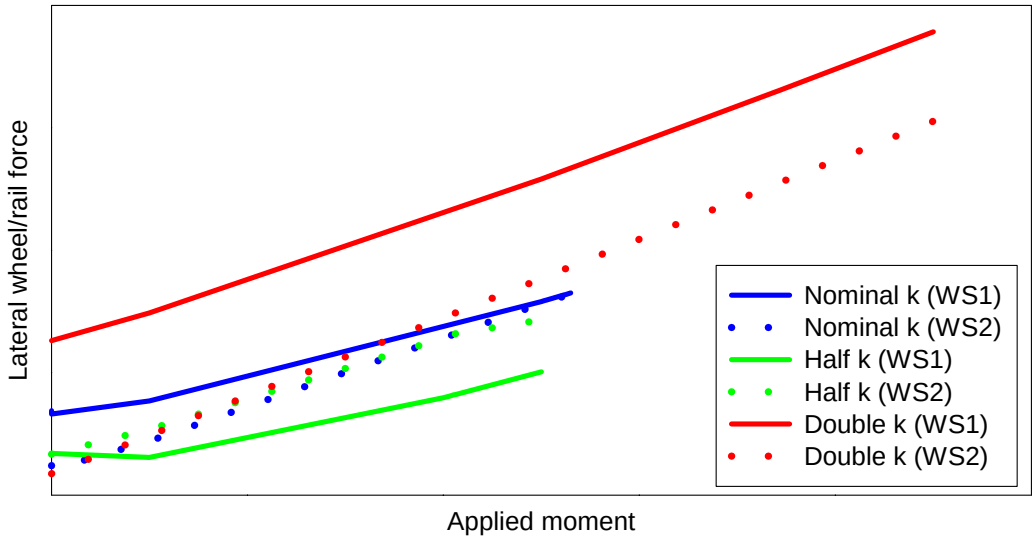
- **Tests on South African coal export line to evaluate bogie curving performance**





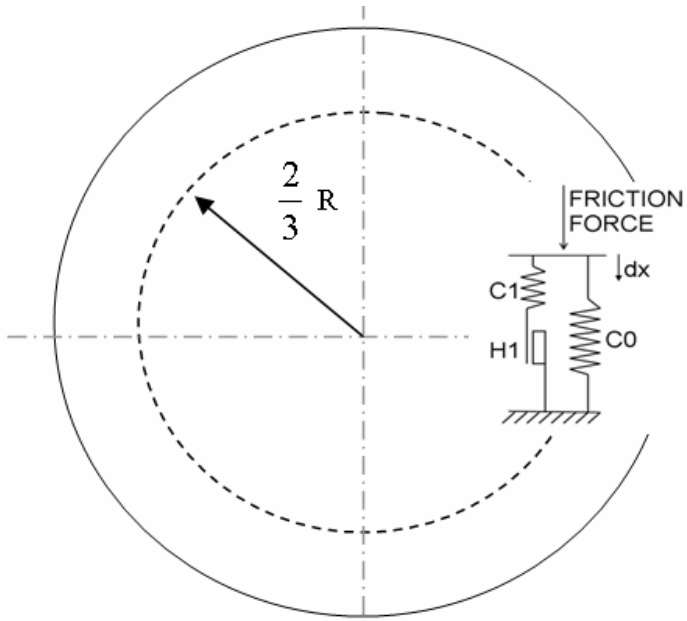
RUNNING DYNAMICS SIMULATION MODEL

- **Linear 6 degrees of freedom model**
- **Lower longitudinal primary suspension stiffness**
  - **Lateral wheel-rail force ⇩ at leading wheelset**
  - **Insignificant changes at trailing wheelset**
- **Lower lateral primary suspension stiffness**
  - **No significant changes**



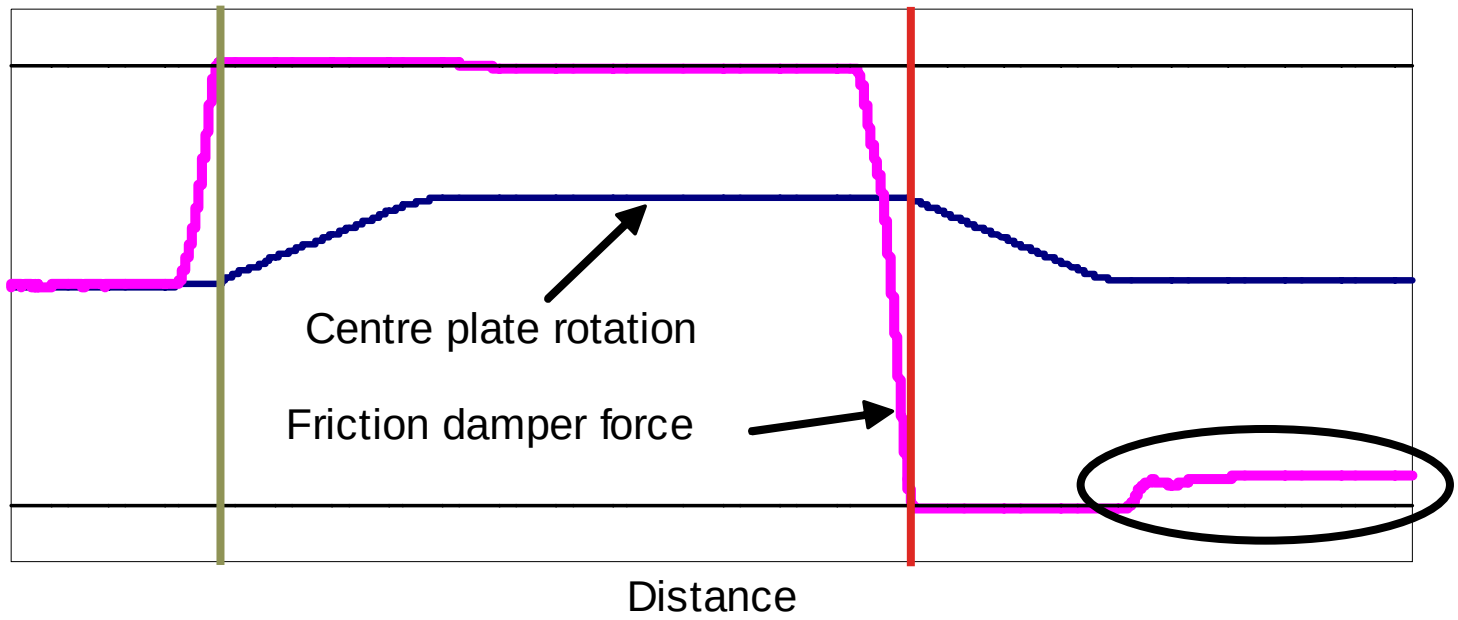
RUNNING DYNAMICS SIMULATION MODEL

- **Non linear MSC.ADAMS/Rail model of container wagon with three-piece self-steering bogies**
- **Centre plate model:**
  - **Correct modelling of stick-slip behaviour ⇨ critical**
  - **Connection model:**
    - **Rotational joint**
    - **Bushing element**
    - **Linear friction damper**



RUNNING DYNAMICS SIMULATION MODEL

- **Bogie rotation through 300m curve at 70km/h**
- **Bogie rotation once friction damper force is exceeded**
- **Misalignment on straight track**

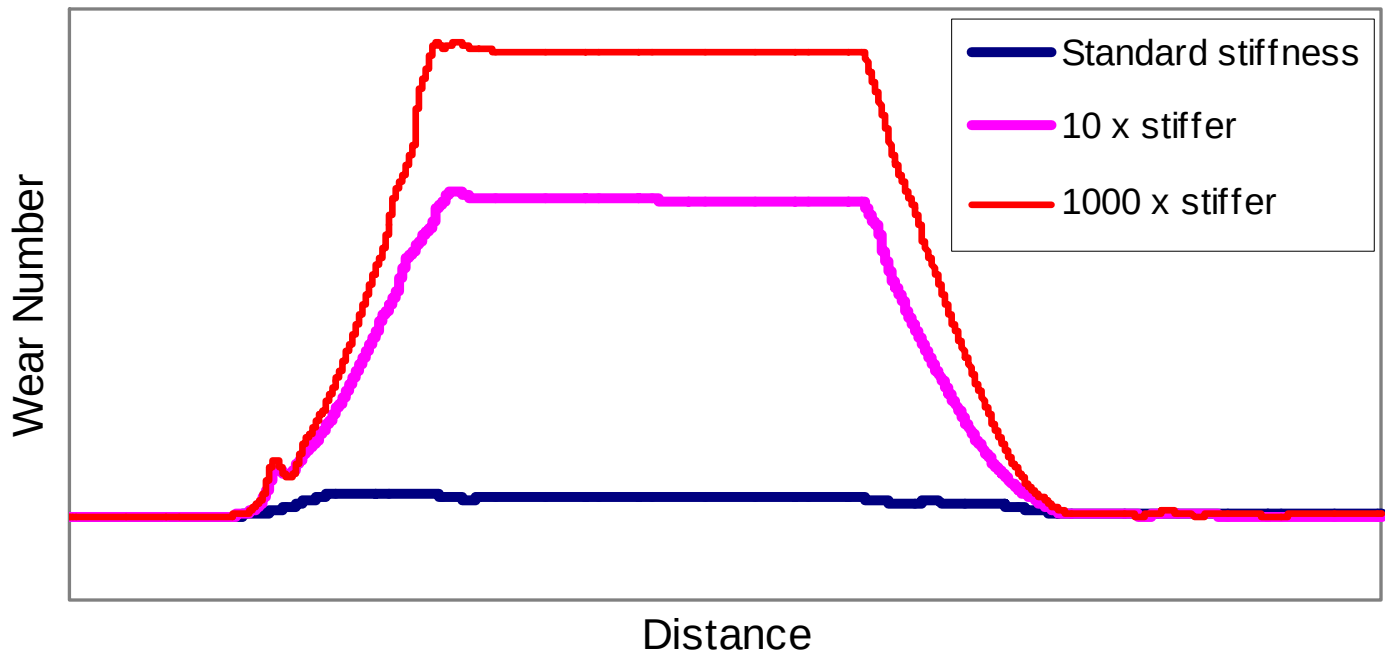


RUNNING DYNAMICS SIMULATION MODEL

- **Performance parameters:**
  - **Bogie rotation**
  - **Friction torque at centre plate**
  - **Longitudinal, lateral and spin creep forces**
  - **Equivalent longitudinal and lateral wheel/rail forces**
  - **Angle of attack**
  - **Derailment ratio**
  - **Wheel unloading**
  - **Wear number**
    - **Leading bogie high rail wheel**
    - **Sum of leading bogie wheels**

RUNNING DYNAMICS SIMULATION RESULTS

- **Wheel wear prediction:**
  - **Self-steering three-piece bogie <<< Standard three-piece bogie**



RUNNING DYNAMICS SIMULATION RESULTS

- **Loaded wagon at balancing speed through a 300m curve**

Primary suspension stiffness	Average bogie wheel wear number Centre plate friction			
	Free	0.11	0.49	Fixed
0.5K-lat; 0.5K-long	420	457	1061	1903
K-lat; 0.5K-long	470	502	1305	3902
0.5K-lat; K-long	1435	1653	3088	5127
K-lat; K-long	**1562**	**1743**	**3070**	**8132**
2.0K-lat; K-long	1817	1957	3212	18073
K-lat; 2.0K-long	4341	4580	6572	19915
2.0K-lat; 2.0K-long	4552	4767	6838	30909
10K-lat; 10K-long	14156	14838	17434	119852
1000K-lat; 1000K-long	19398	20048	23639	300388

RUNNING DYNAMICS SIMULATION RESULTS

- **Loaded wagon at balancing speed through a 300m curve**

Primary suspension stiffness	Average bogie wheel wear number Centre plate friction			
	Free	0.11	0.49	Fixed
0.5K-lat; 0.5K-long	420	457	1061	1903
K-lat; 0.5K-long	470	502	1305	3902
0.5K-lat; K-long	1435	1653	3088	5127
K-lat; K-long	**1562**	**1743**	**3070**	**8132**
2.0K-lat; K-long	1817	1957	3212	18073
K-lat; 2.0K-long	4341	4580	6572	19915
2.0K-lat; 2.0K-long	4552	4767	6838	30909
10K-lat; 10K-long	14156	14838	17434	119852
1000K-lat; 1000K-long	19398	20048	23639	300388

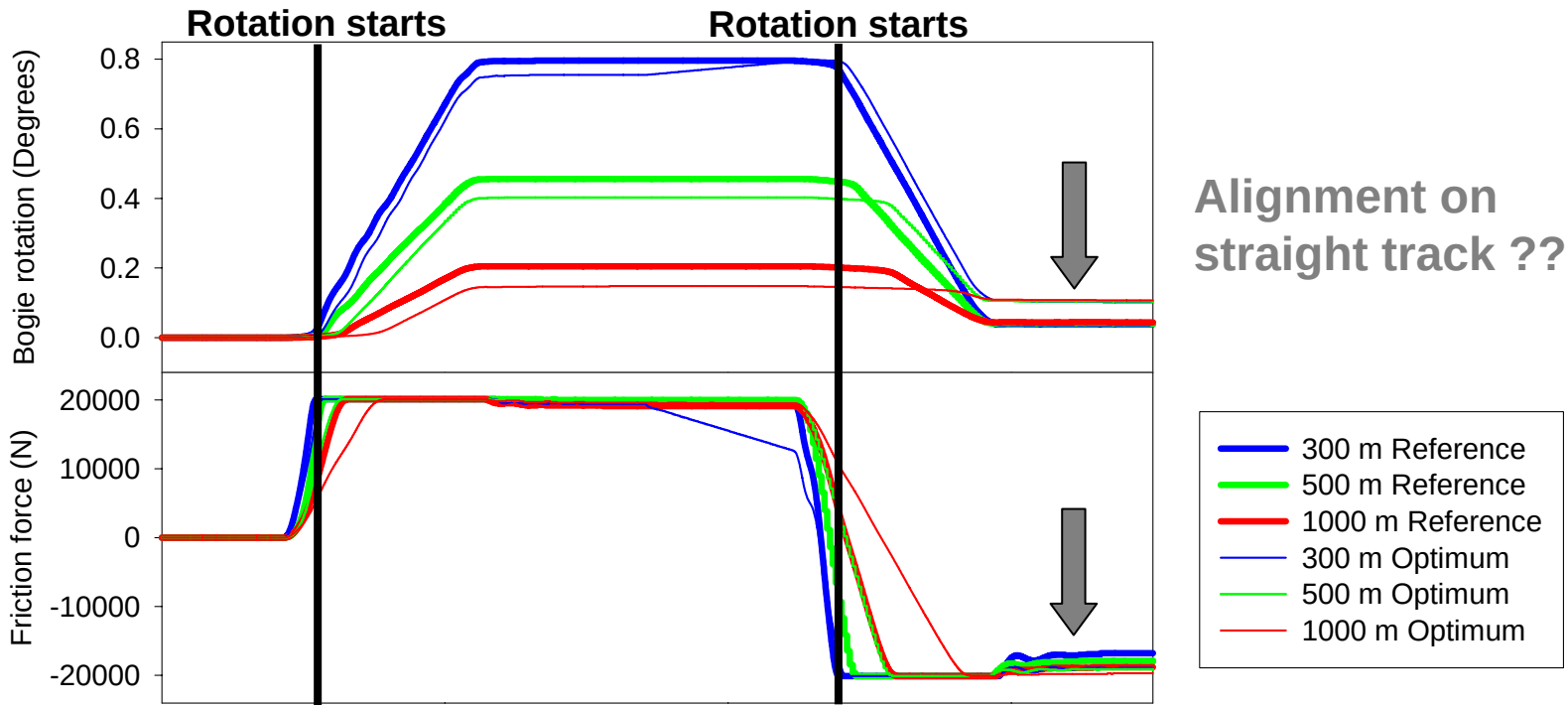
RUNNING DYNAMICS SIMULATION RESULTS

- **Less wear but what about the stability speed ???**

Centre plate friction	Wear number	Stability Speed [km/h] Empty	Loaded
0.5K-lat; 0.5K-long	**457**	**80**	**140** ✓
K-lat; 0.5K-long	502	80	150
0.5K-lat; K-long	1653	90	160
K-lat; K-long	**1743**	**90**	**160**
2.0K-lat; K-long	1957	100	170
K-lat; 2.0K-long	4580	110	190
2.0K-lat; 2.0K-long	4767	110	210
10K-lat; 10K-long	14838	120	> 210
1000K-lat; 1000K-long	20048	100	100

RUNNING DYNAMICS SIMULATION RESULTS

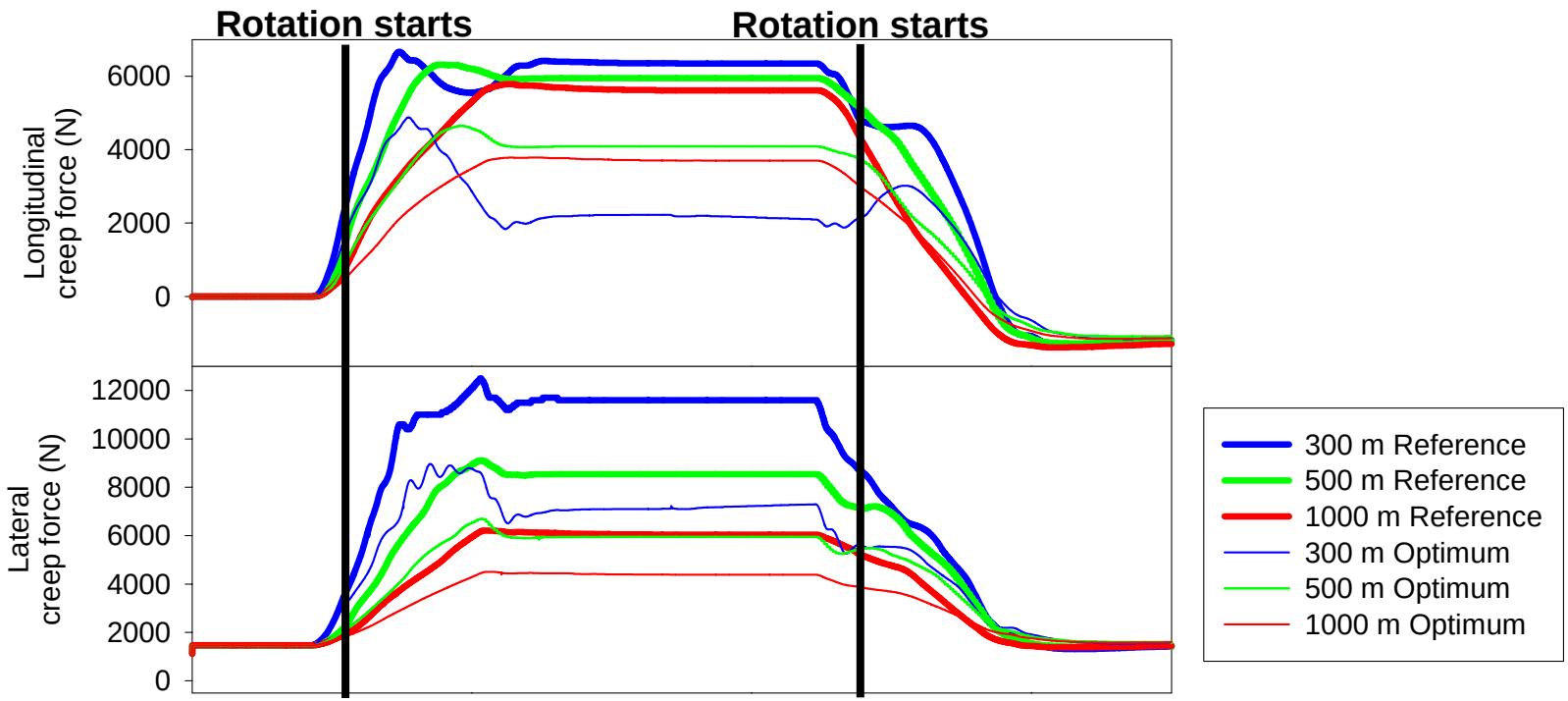
- **Bogie rotation:**
  - **Lower primary stiffness ⇨ More wheelsets yaw ⇨ Bogie rotation ⇩**
  - **Lower moment transferred from w/r interface to centre plate**



Alignment on straight track ???

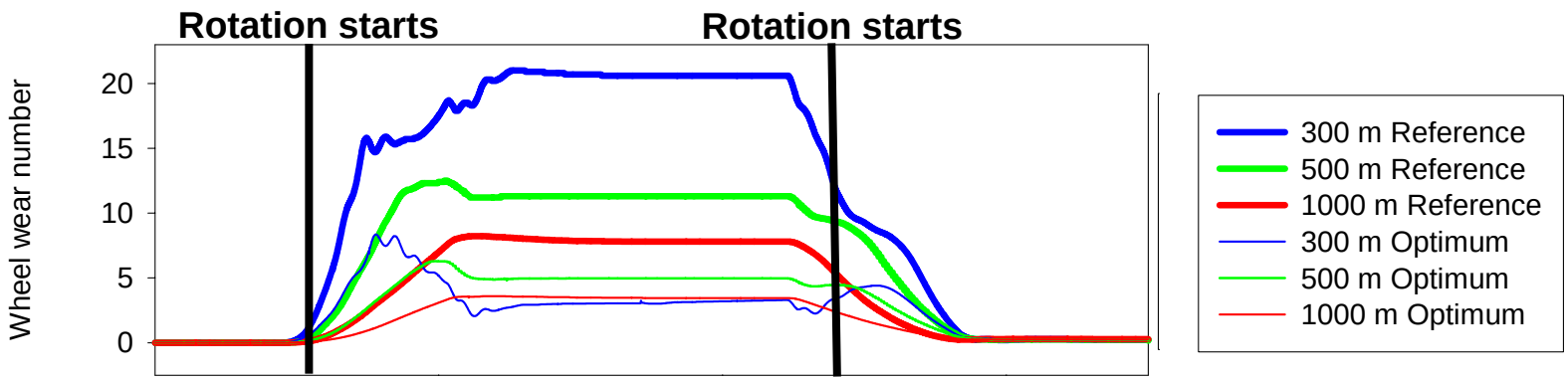
RUNNING DYNAMICS SIMULATION RESULTS

- **Creep forces at leading high rail wheel:**
- **Wheel wear rate dominated by lateral creep ⇨ angle of attack**



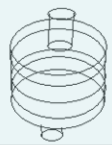
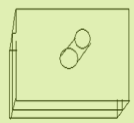
RUNNING DYNAMICS SIMULATION RESULTS

- **Wheel wear at leading high rail wheel:**



ON-TRACK TESTS

- **Validate ADAMS/Rail model**

				Coefficient of friction		
				0.11	0.49	Fixed
Primary suspension arrangements	*K-lat; K-long*	Standard HS Mk VII rubber sandwich		Ref.	X	X
	0.5K-lat; 0.5K-long	Modified HS Mk V rubber sandwich		Opt.	X	X
	K-lat; 2.0K-long	Rubber sandwich chevron		X	X	X
	2.0K-lat; K-long	Rubber sandwich chevron		X	X	X

CONCLUSION

- **Wheel wear:**
  - **Significantly less with lower longitudinal primary suspension stiffness**
  - **Marginally less with lower lateral primary suspension stiffness**
  - **Significantly less with lower centre plate friction**
- **Safe running speed maintained**
- **Final optimisation of lateral and longitudinal primary suspension stiffness depends on the physical load bearing capacity of the rubber suspension elements**
- **Following a model verification through on-track tests a final technical recommendation will be made**
- **Depending on a cost-benefit analysis the technical recommendation will be considered for implementation**

Thank-you

- **Questions**