AN APPRAISAL OF MASS DIFFERENCES BETWEEN INDIVIDUAL TYRES, AXLES AND AXLE GROUPS OF A SELECTION OF HEAVY VEHICLES IN SOUTH AFRICA

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ICWIM6 - International Conference on Weigh-In-Motion, Dallas, June 4-7, 2012

Introduction

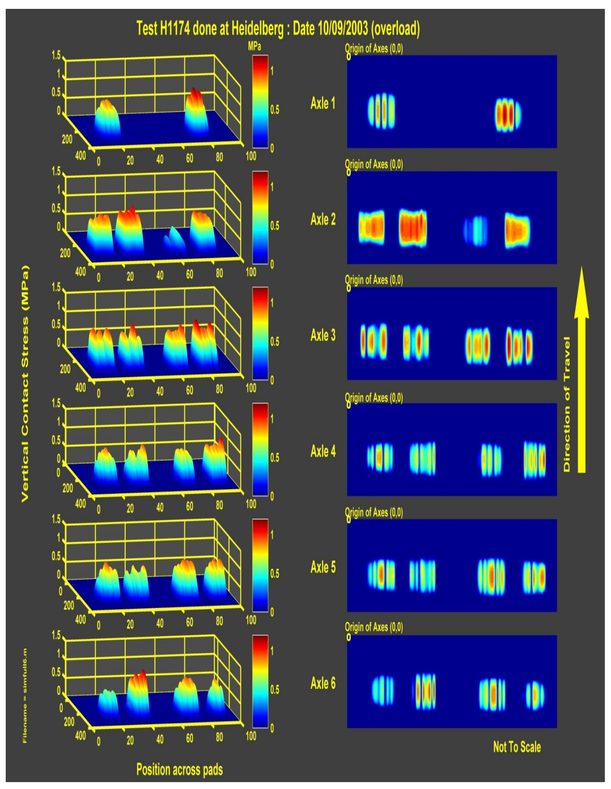
In road design, accurate quantification of traffic loading remains a challenge. Research in South Africa with the Stress-In-Motion (SIM) system has concentrated on interaction forces between slow-moving tyres and the textured SIM device. A field study of 2 666 heavy vehicles (HVs) with Gross Combination Mass, (GCM) > 3 500 kg was conducted, where the mass (or weight) of each tyre (approximately 47 242 tyres (or wheels)) was measured. The measurements were done at slow speed over the SIM device on a rigid concrete platform. Valuable data sets in terms of inter-wheel and axle unit-mass variation were collected. The overall finding is that assumptions in road design of equal load sharing between all tyres, axles and axle groups for HVs are challenged, since unequal load sharing were identified and statistically quantified in this study. It is recommended that this finding be included for ensuring road pavement design optimisation.

Scope

The scope includes the statistical definition and appraisal of mass differences of dual tyre pairs, left vs. right tyres on an axle, or axle groups, as well as between various axles within an axle groups of HVs with 2 to 9 axles. Statistical analyses were made on 11 cases (summarised in Table 1), where the masses were compared to the "average mass" of a dual pair tyres, an axle, or axle group.

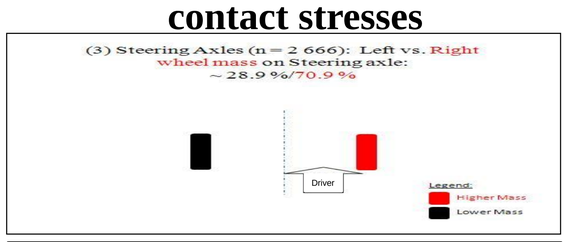
Statistical distributions of the load differences were quantified for simulation in pavement design.

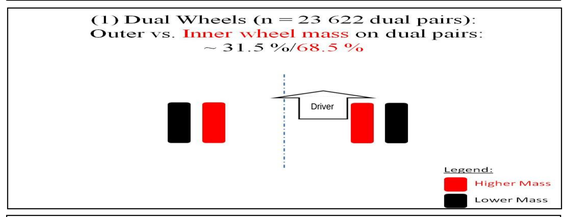
Four-pad Stress-In-Motion (SIM) system used for tyre mass data

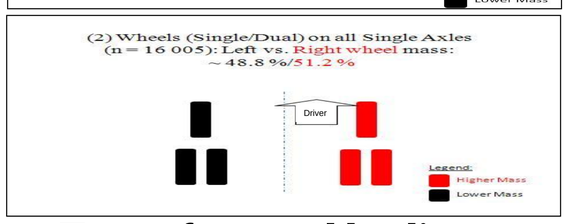


6-Axle truck: Vertical tyre contact stresses

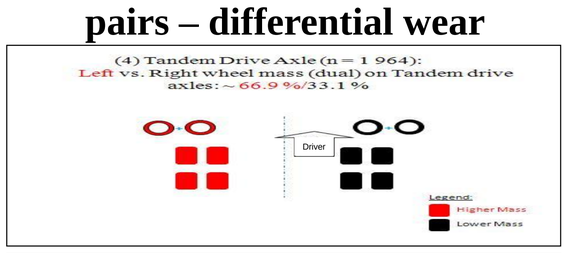
Outer tyre vs. inner tyre of dual pairs – differential wear

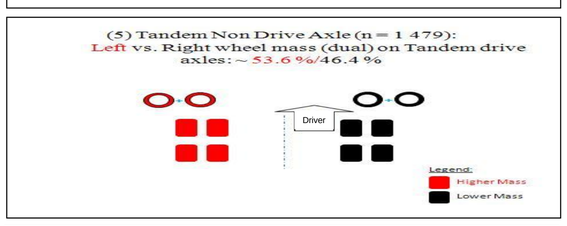


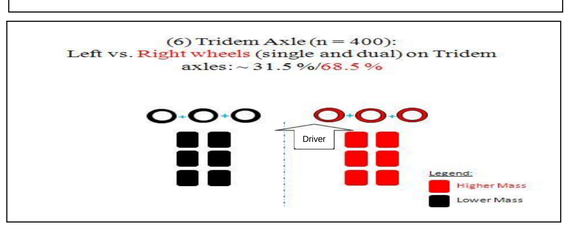




Tyres of unequal loading on dual pairs and axles



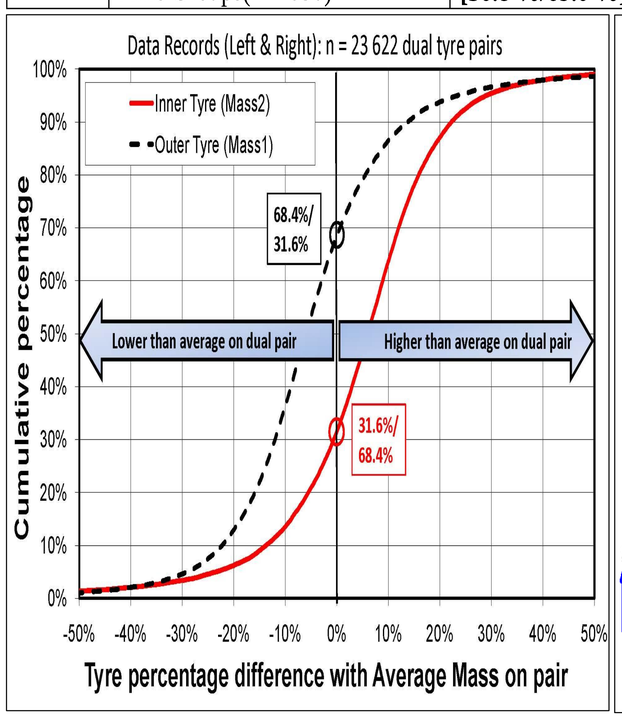




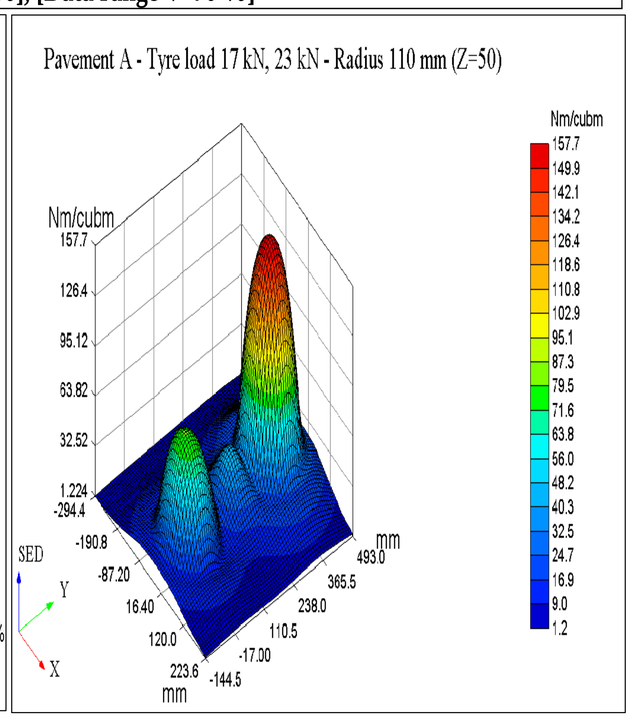
Left/Right unequal loading on dual pairs and axle groups

Results: Mass Differences & Ranges (%)

Generic Case	11 x Analyses Cases: Wheel/Axles (n = Records)	Description & Load Sharing and Data Range Results in Percentages (%)
Wheel (or tyre)	(1) Dual Wheel Pairs (n = 23 622)	Outer (Mass1)/Inner wheel (Mass2) of dual pairs vs. average mass on pair. **[68.4 %/31.5 %*], [Data range -/+50 %] - *Legend: Lower/Higher**
Axle	(2) Wheels - all Axles (n = 16 005)	Left/Right wheels (single and dual) vs. average mass of the specific axle. **[51.1 %/48.8 %], [Data range -/+50 %]**
Specific Axles	(3) Wheels - Steering Axle (n = 2 666)	Left/Right wheels: Steering axle vs. average mass of the steering axle. **[70.9 %/28.9 %], [Data range -/+10 %]**
	(4) Wheels - Tandem Drive Axle (single & dual) (n = 1 964)	Left/Right wheels: Tandem drive axles vs. average mass-tandem axle group. **[33.0 %/66.9 %], [Data range -/+22 %]**
	(5) Wheels - Tandem Non drive axle (single & dual) (n = 1 479)	Left/Right wheels: Tandem non drive vs. average mass tandem axle group. **[46.3 %/53.6 %], [Data range -/+20 %]**
	(6) Wheels - Tridem Axle (single & dual) (n = 400)	Left/Right wheels: Tridem axles vs. average mass on tridem axle group. **[68.5 %/31.5 %], [Data range -/+30 %]**
Axle Groups	(7) Axles - Tandem Drive Axle Groups (n = 2 212)	Front axle/Rear axle: Tandem drive vs. average mass on tandem axle group. **[38.1 %/61.8 %], [Data range -/+40 %]**
	(8) Axles - Tandem Non drive Axle Groups (n = 3 327)	Front/Rear axle: Tandem non drive vs. average mass on tandem axle group. **[28.5 %/71.5 %], [Data range -/+35 %]**
	(9) Axles - Tridem Front/Middle Axle Groups (n = 630)	Front/Middle axle: Tridem axles vs. with average mass on tridem axle group. **[31.1 %/68.7 %], [Data range -/+50 %]**
	(10) Axles - Tridem Front/Rear Axle Groups (n = 630)	Front/Rear axle: Tridem axles vs. average mass on tridem axle group. **[26.7 %/73.0 %], [Data range -/+70 %]**
	(11) Axles - Tridem Middle/Rear Axle Groups(n = 630)	Middle/Rear axle: Tridem axles vs. average mass on tridem axle group. **[30.8 %/69.0 %], [Data range -/+70 %]**



Cumulative percentage of inner/outer tyre mass compared with % average mass on dual pair



Pavement response due to unequal tyre loading from dual tyre pair

Conclusions

The statistical appraisal of individual tyre mass in dual pairs, left/right tyres on axles, left/right on axle groups, as well as for inter-axles indicated some significant unequal load sharing. Common general assumptions in road pavement design of equal load sharing between all tyres, axles and axles groups for heavy vehicles are challenged. It is recommended that unequal mass/weight/load sharing (or differences) be incorporated for structural road pavement design. The impact, however, of these wheel/axle mass differences on pavement behaviour needs to be quantified, using statistical cumulative distribution functions such as the 3-parameter general logistic cumulative distribution function.

References

1. De Beer, M, Sallie, I M and Fisher, C (2011), "Special Study: Heavy Vehicle Wheel and Axle Unit Mass Variation": Revision of the South African Pavement Design Method, South African National Roads Agency Limited (SANRAL), Pretoria, South Africa, June 2011. www.sapdm.co.za.

2. De Beer, M, (2008), "Stress-In-Motion (SIM) - A New Tool for Road Infrastructure Protection ?", in Proceedings of the International Conference on Heavy Vehicles HVParis 2008, Data for Pavement Engineering, Paris, France, 433-442.