

Vehicle Balance and Braking Report. Charles Sangster, 1902452 *by* Charles Sangster

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Vehicle Balance and Braking

By

Charles Sangster

1902452

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Introduction

The following investigation will be studying the different vehicle set ups, how they are best suited to the type of vehicle and the impacts they have on the vehicles handling and comfort. This study will be looking at road and performance vehicles (race and super cars).  1

2 Research

Steering and wheel set up

Toe on a road vehicle is set inwards to allow for a constant side force to help overcome small disturbing forces acting on the wheels, this reduces shimmy and results in better handling and comfort (Newton, Steeds & Garrett 1989). Race vehicles have their tyres toed out at the front to produce optimum slip angle, and their rear tyres toed-in to help with oversteer during exit. This creates understeer. This set up allows for efficient cornering abilities and good handling on straights, but  3 courses the rear tyres to experience wear and heat (Krönke, 2017; Rowley, 2006; Gili, 2014).

Road vehicle camber is set positive to give the vehicle centre point steering to allow for better tyre wear and cornering. On a race vehicle it is set to give the best camber gain for better handling under mid to high speeds (Rowley, 2006; Newton, Steeds & Garrett, 1989).

4 Load and Wait transfer

The anti-roll bars control the amount of roll experienced by the body and allows the roll rate and weight transfer between the front and rear of the vehicle to change. On road vehicles the anti-roll bar stiffens the suspension when the body of the vehicle experiences roll, or when one-wheel experiences vertical movement. Due to this a softer spring can be used, these will absorb small bumps and irregularities in the road better, and can reduce the weight of unsprung mass. Dampeners are used to dampen the vibration caused by the springs, allowing for a better ride. (Newton, Steeds & Garrett, 1989). In racing application, the stiffer the spring, the larger the contact patch with the road. This impacts the acceleration and braking of the vehicle. The anti-roll bar stiffens the suspension when cornering, but during accelerating and braking allows the spring to be independent, this gives the best handling for a race vehicle (Racing Car Technology, 2017; Heisler, 1999; Rowley, W 2006). Super cars would use a proactive chassis control system, this is an electrical adjustable system that replaces the anti-roll bar and shocks for a fluid system. By altering the flow of fluid through the system the car is able to alter their damping and the rate of body roll whilst at speed resulting in better handling and keeping the body flat when cornering. This is different from the fixed set up found in race cars (Petrany, M. 2017).  5

The roll centre of a vehicle is dependent on the suspensions set up, due to this the front and rear suspension have different roll centres. When a line is drawn between these two centres the roll axis is found. On a road vehicle the axis is designed to slope down towards the front of the vehicle (Heisler, 1999).

All forces within a vehicle must travel through the Centre of gravity (CoG), the height of the CoG will affect the impact these forces have. Any forces that don't travel through the CoG will cause the vehicle to rotate, unless balanced by an equal force. Race vehicles and super cars have their CoG close to the ground, this lessens the forces when accelerating and cornering, giving them better performance (Shreyas, Shashank, Surendran & Krishna, 2018; Rowley, 2006). On road vehicles, having a low ride height/CoG would make the ride uncomfortable due to the lack of ground clearance and space for suspension, due to this road vehicles have a greater ride height to allow for comfort whilst reducing handling and cornering capabilities.

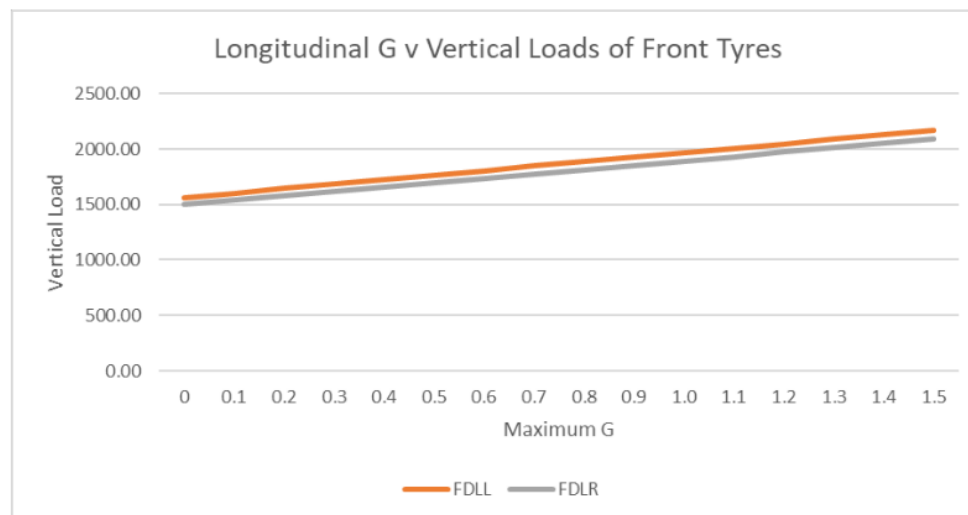
Weight distribution is affected by the height of the centre of mass relative to the track width, it can affect the contact patch of the tyres and how well the suspension is able to adapt to acceleration, cornering and braking. The CoG of a race vehicle only moves a small amount due to the vehicle having a low ride height and roll radius, this results in a 1% or less weight transfer of sprung mass. Race vehicle suspension must be able to adapt to this transfer, this allows for better handling at high speeds. (Rowley, 2006; Cann & Hathaway, 1995). When looking at road vehicles the weight transfer is greater due to the increased CoG, due to this a more robust suspension system must be used. This increases the unsprung mass of the vehicle (Tudor 27th February).

Aero

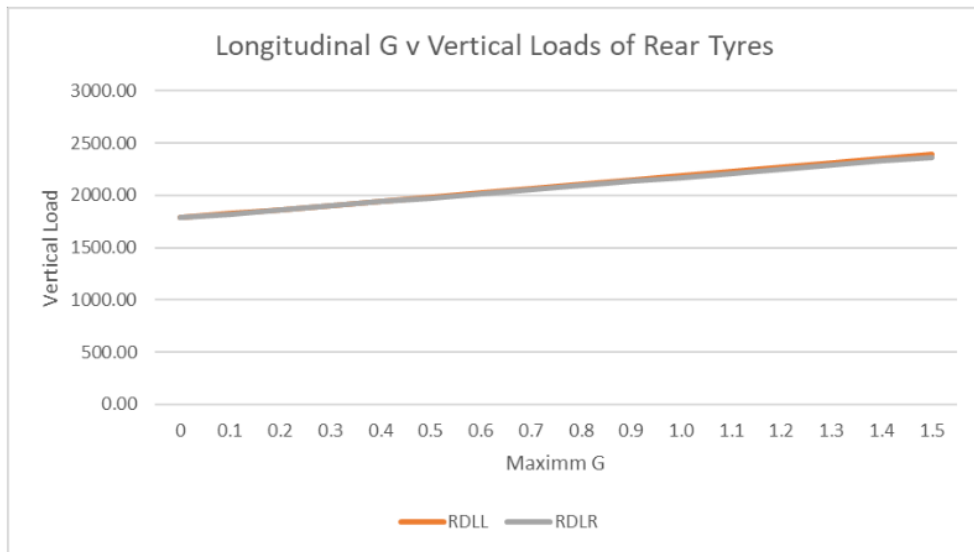
Road vehicle body shape is used to make the car attractive and reduce wind resistance to help improve fuel efficiency. Race car body work is designed to create aero load to help acceleration, braking and cornering; this factor is also applied to super cars whilst also taking in to consideration the aesthetics.

Aero load can shift and change depending on the situation, this is best described in the following extract by Warren J. Rowley. "Any type of change will result in a change in the aero loads. Changes in speed, ride height, yaw, proximity to another chassis and/or a wall, wind shear, etc. will all change the chassis aerodynamics." (Rowley, 2006 Chapter 17 pg13).

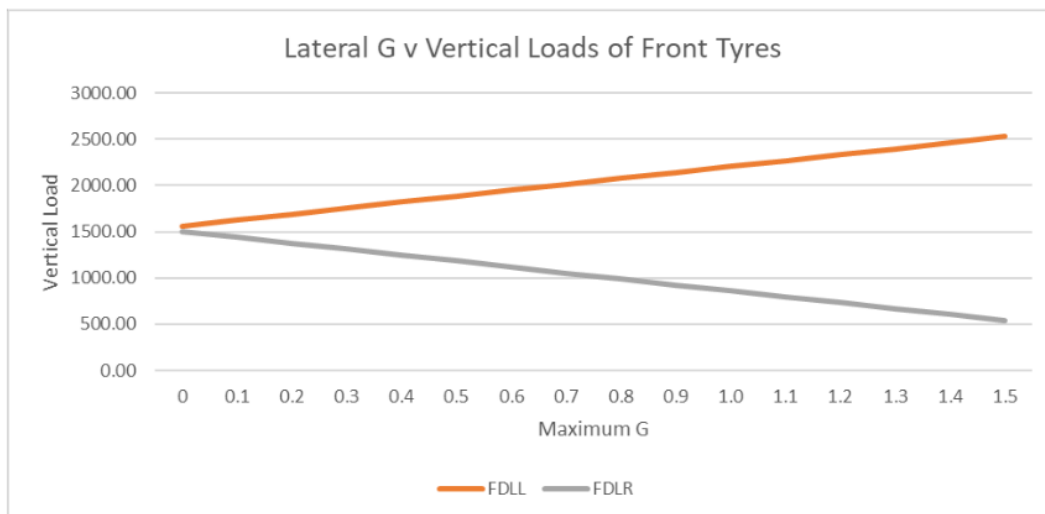
Results 6



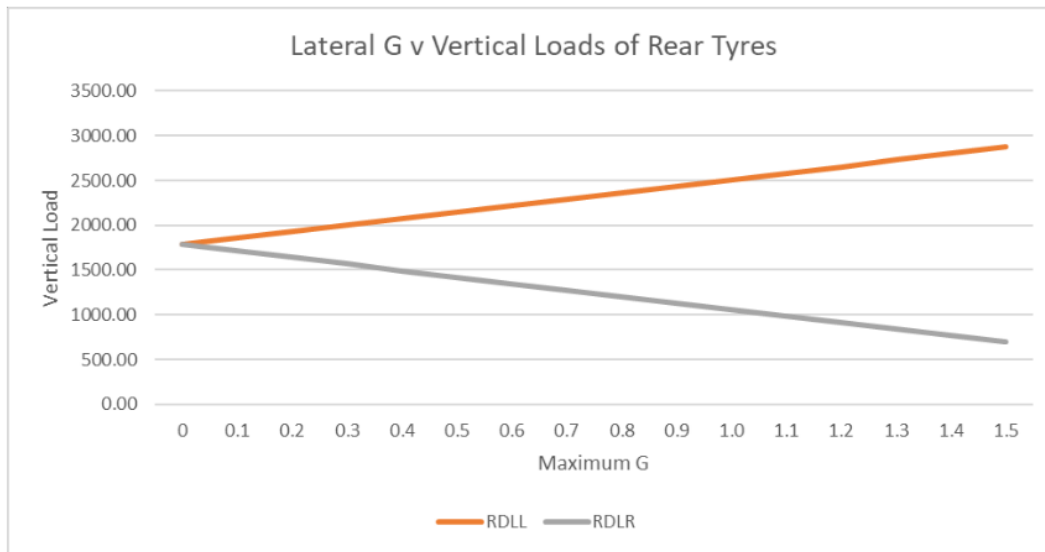
Graph 1: Longitudinal G v Vertical Loads on Front Tyres



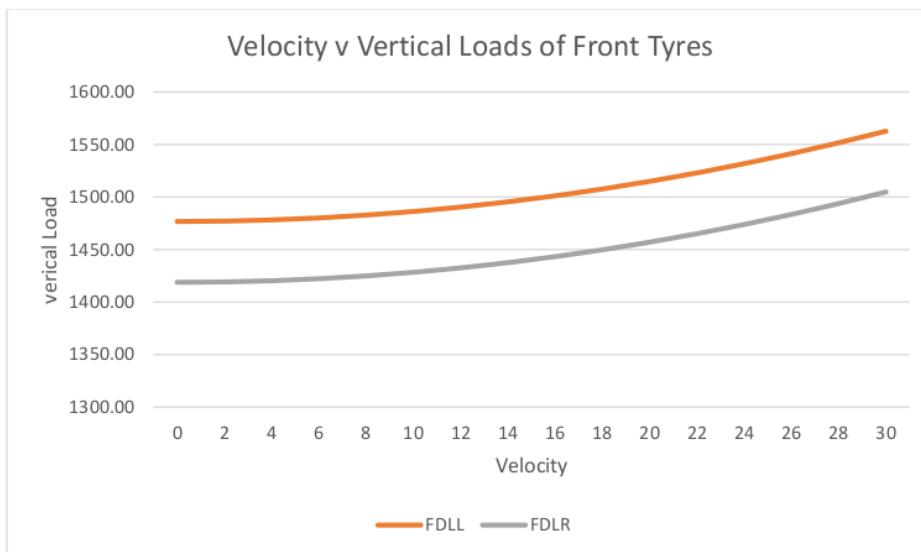
Graph 2: Longitudinal G v Vertical Loads of Rear Tyres



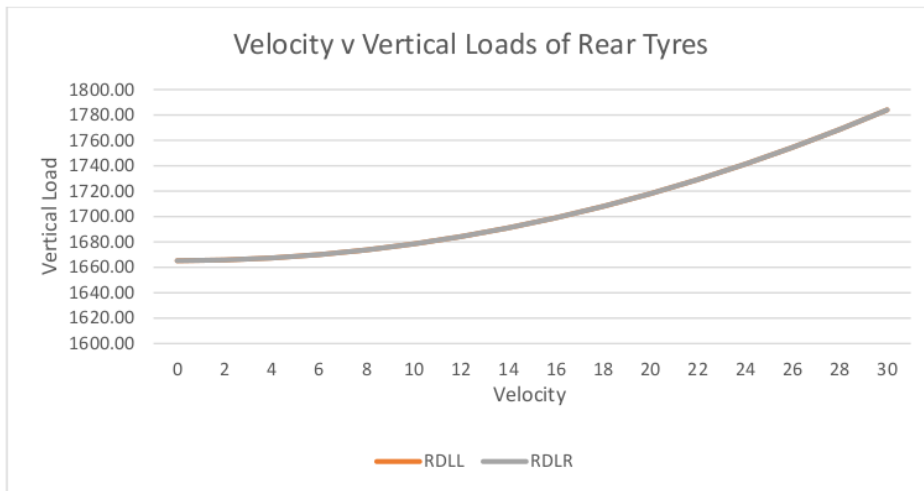
Graph 3: Lateral G v Vertical Loads of Front Tyres



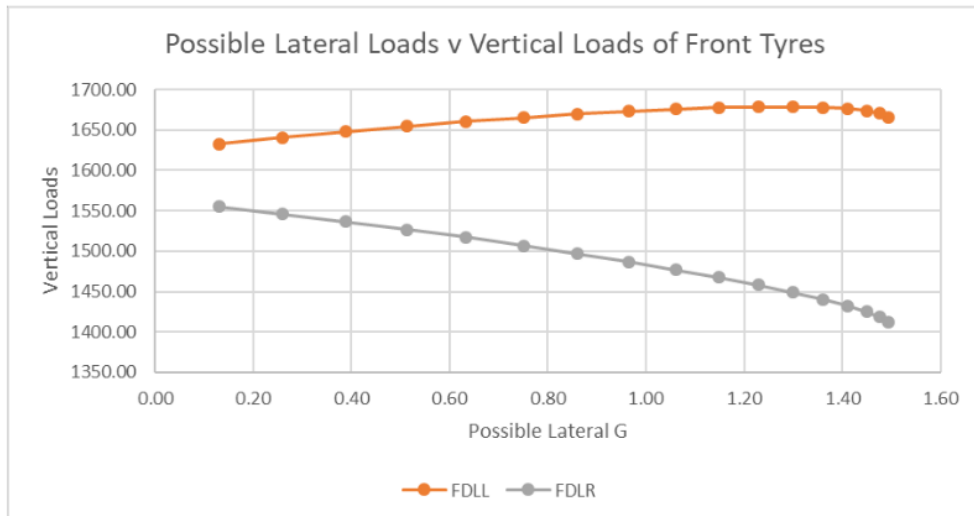
Graph 4:Lateral G v Vertical Loads of Rear Tyres



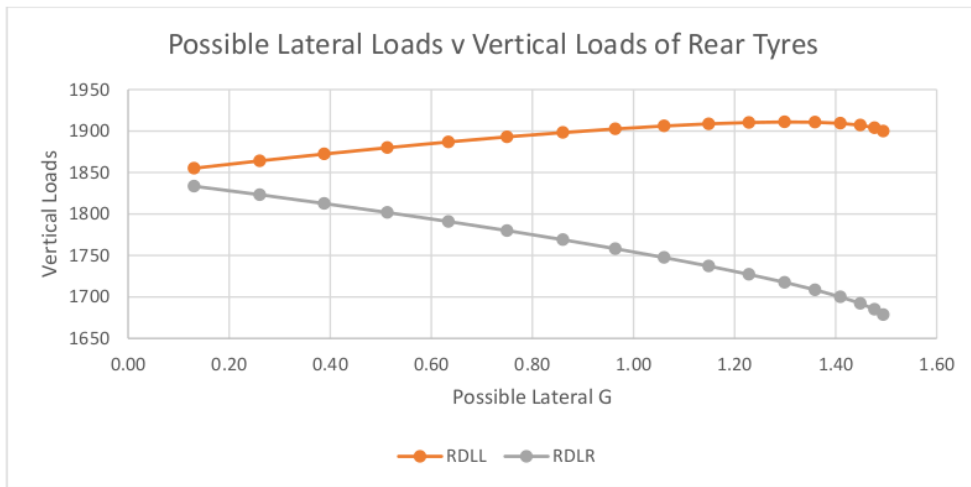
Graph 5:Velocity v Vertical Loads of Front Tyres



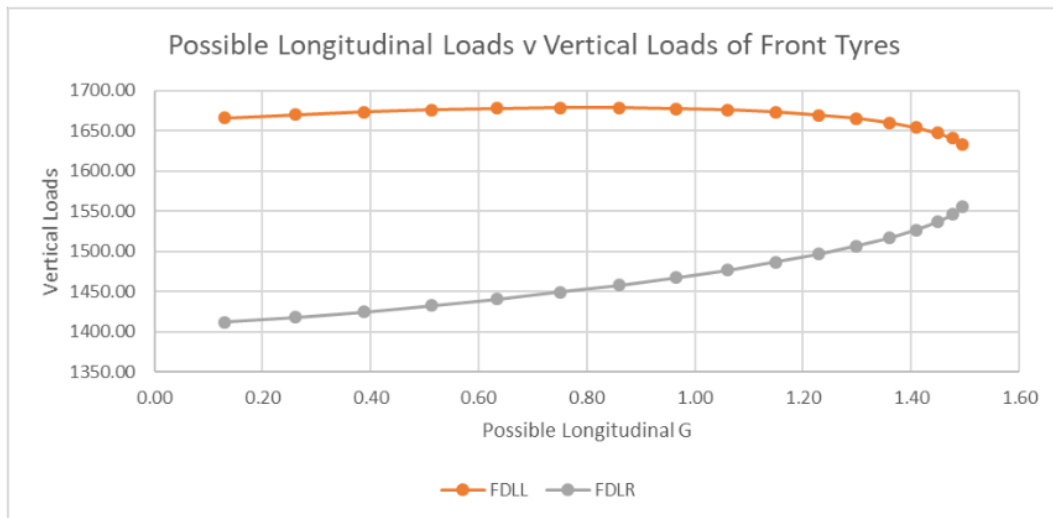
Graph 6: Velocity v Vertical Loads of Rear Tyres



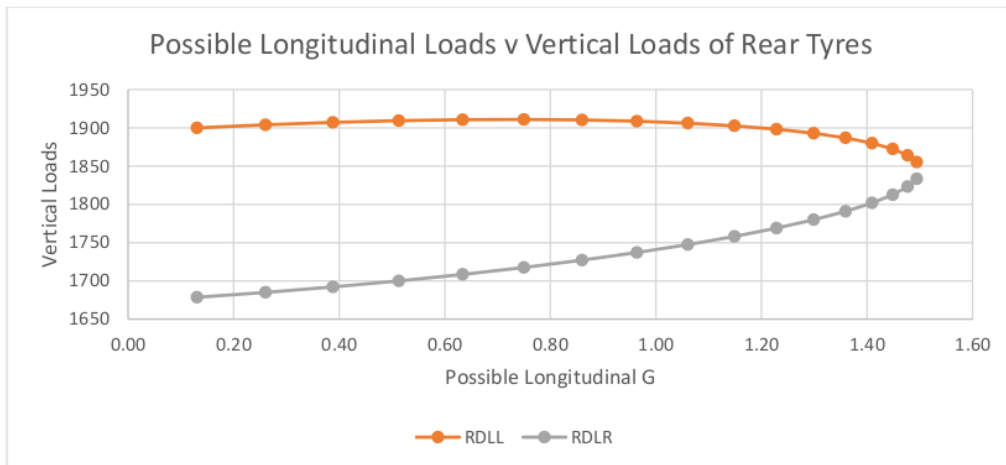
Graph 7: Possible Lateral Loads v Vertical Loads of Front Tyres



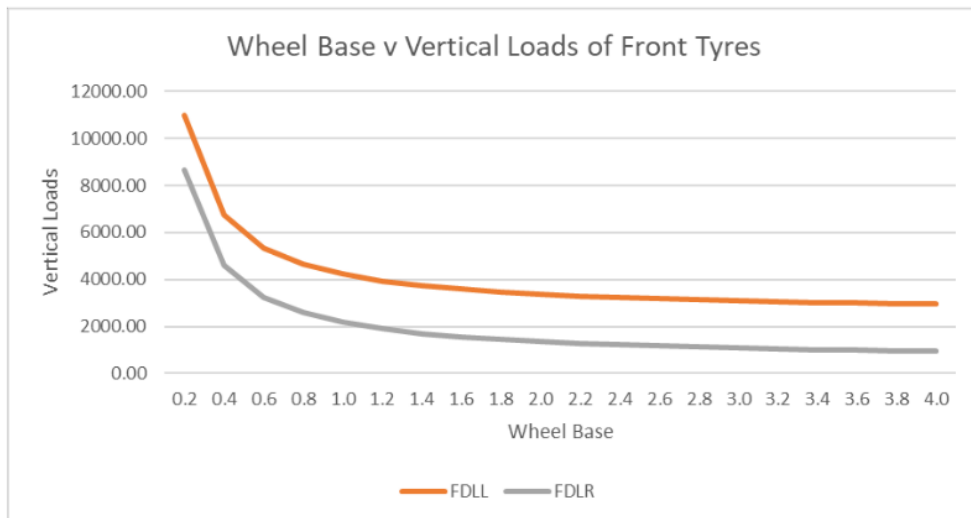
Graph 8: Possible Lateral Loads v Vertical Loads of Rear Tyres



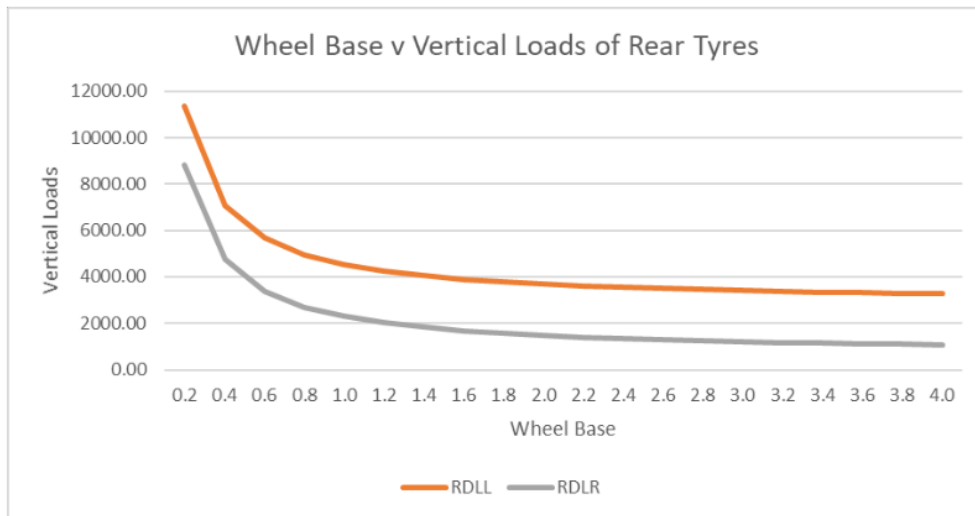
Graph 9: Possible Longitudinal Loads v Vertical Loads of Front Tyres



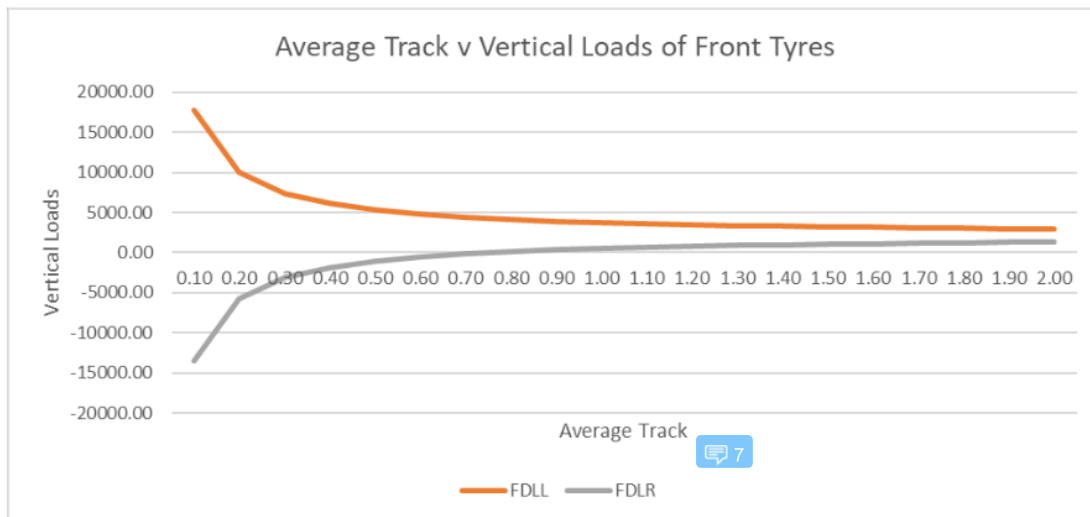
Graph 10: Possible Longitudinal Loads v Vertical Loads of Rear Tyres



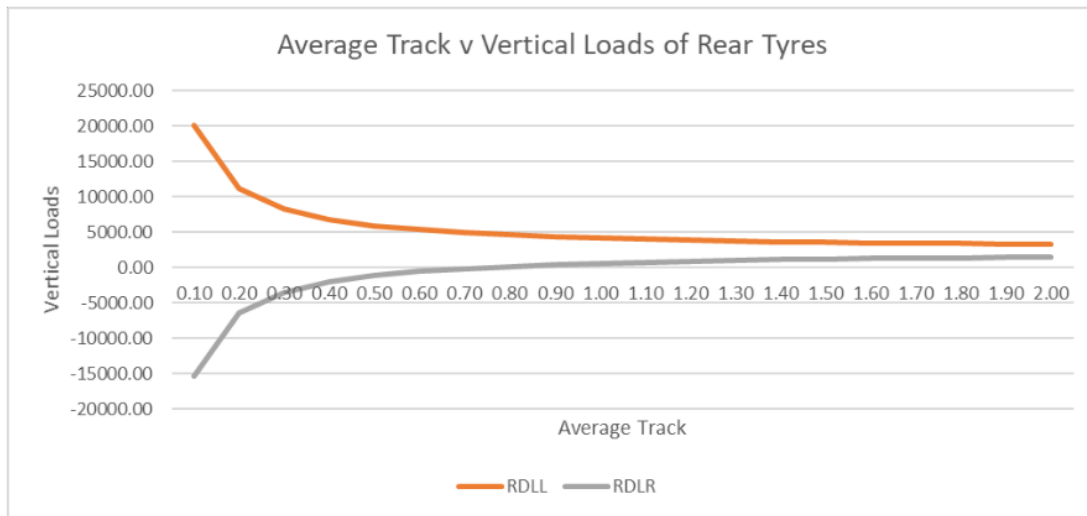
Graph 11: Wheel Base v Vertical Loads of Front Tyres



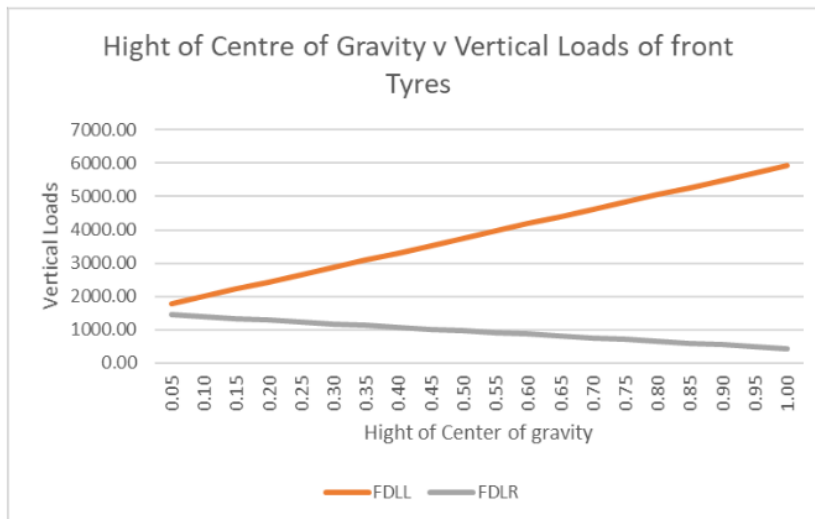
Graph 12: Wheel Base v Vertical Loads of Rear Tyres



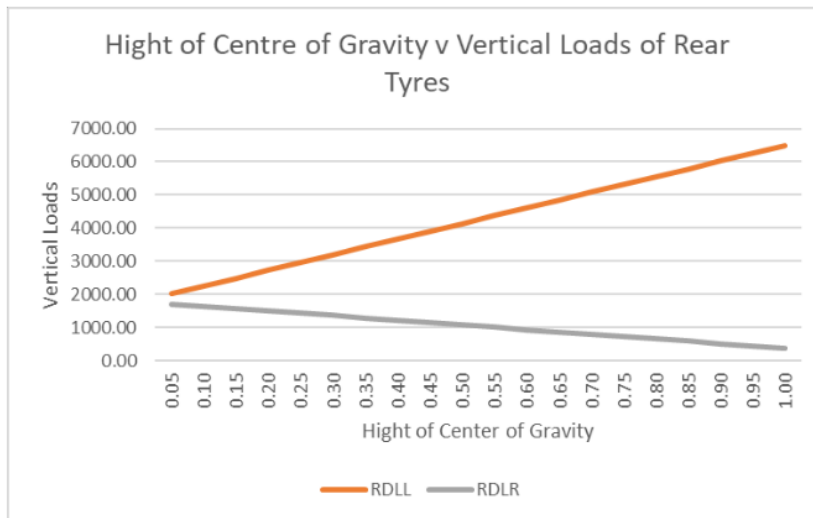
Graph 13: Average Track v Vertical Loads of Front Tyres



Graph 14: Average Track v Vertical Loads of Rear Tyres



Graph 15: Hight of CoG v Vertical Loads and Front Tyres



Graph 16: Hight of CoG v Vertical Loads of Rear Tyres

Analysis

The values for vertical load increases as the longitudinal G rises, this is shown in graphs 1 and 2. Graphs show that the four corners of the vehicle have an equal increase in vertical load, with the back wheels experiencing a slightly higher load due to pitch. This increase is due to a rise in longitudinal G and aero load. These factors **cause** an increase in vehicle speed, this decreases the time available to displace the air, this results in the air flowing over the vehicle to be slower than that traveling underneath; **causing** down force resulting in vertical load (Tudor, 5th March).

The lateral G increases or decreases depending on the direction of steer, this can be seen in graphs 3 and 4. Graphs show the load displacement of a vehicle turning right. As lateral G increases so does the vertical load on the left side of the vehicle, in response to this rise a drop can be seen on the right side of the vehicle. This is due to the mass of the vehicle shifting when cornering due to roll, yaw and centripetal forces, this shift places more load on the side opposite to the direction of steer. **10**

Graphs 5 and 6 shows an equal increase in vertical load over the four corners of the vehicle as the velocity increases. The reason for this increase is the same as what is shown in graphs 1 and 2.

Aero load is the load placed on to the vehicle due to air resistance. When a negative figure is calculated for Aero load it means a down force is produced, if the figure is positive it produces lift. From the graphs previously mentioned the impact of aero load can be seen when an increase in longitudinal G or velocity takes place, and an increase in vertical load is shown. **11**

1.5 G cannot be achieved along the longitudinal and lateral directions at the same time; this is because the longitudinal and lateral G expressed must add up to 1.5 G. if this calculation adds up to a figure greater than 1.5 the maximum G has been exceeded. The effect of changing these two figures can be seen in graphs 7-10. **12**

Graph 11 and 12 shows the impact of the wheelbase on the vertical load. The graphs show that as wheel base increase the vertical forces placed on the wheels lessens. With a wheel base of 0.2 meters there was a total vertical load of 9975.78 N, when increased to 4.0 meters the vertical load dropped

to 2058.33 N; this is a reduction of 7917.45 N. This reduction is due to a larger wheel base which helps reduce the influence of load distribution on the axle (Reimpell & Betzler, 2001).

13

Graphs 13 and 14 show that as the track of the vehicle increases so does the vertical loads on the right side of the vehicle, in response to this the vertical loads on the left side of the vehicle decreases. This is due to the distance between the wheels increasing and the distribution of lateral G becoming equal over the four wheels, this distribution of load improves vehicle cornering. once the track reaches 1.50 m, both sides become parallel

Graphs 15 and 16 shows the effect of altering the CoG hight. As the hight of the CoG increases the vertical load on the left side of the vehicle rises as the load on the right-side of the vehicle drops. This is due to the centre of mass shifting more within the lateral directions as a result of the CoG being risen, this shift in mass can also be seen within graphs 3 and 4 when cornering. It is the shifting of mass which affects vertical load on the vehicle.

What has been learnt from this assignment is the large range of set up choices available and the impact these set ups have on vehicle balance between handling and comfort. This is best shown in the results from altering the wheel base, track and centre of gravity, this is also shown when looking at different race vehicle set ups compared to that of road vehicles/ super car and how they use the same components in different ways to achieve different out comes.

14

Conclusion

When looking through the collected data and research there are 3 main areas that stand out, these areas show the impact that vehicle set up has and how they are best suited for the vehicle.

The CoG affects how the load shifts around a vehicle when cornering and accelerating, this is shown in graphs 15 and 16. They show how the vertical loads can increase and decrees as the vehicle turns a corner and how it relates to the hight of the CoG, the higher the CoG the greater the vertical loads on the opposing side of the turn. This can be seen in the designs of road and race cars. Road vehicles have their CoG higher than that of a race car to allow for an overall better ride. This differs from a race car where the CoG is lower to reduce the amount of mass moved when cornering, this results in better cornering ability and an increase in aero load due to a rise in air flow over the vehicle during acceleration. On super cars their suspension set up counteracts this force allowing them to corner whilst staying flat.

Aero load is the result of there being negative air pressure on the top of the vehicle. This Is due to the decrease in time available to displaced the air, resulting in the air flowing over the vehicle to be slower than that traveling underneath; coursing down force resulting in vertical load. This affect can be seen in graphs 1,2,5 and 6 and is what race vehicles and super cars use to create down force and give them more grip.

Wheel base and track impact the vehicles cornering ability's and how well load is distributed between the 4 contact patches. By increasing the wheel base and track the vertical loads/weight of the vehicle is distributed over the four contact patches, this helps with the distribution of load when cornering. on race vehicles this is done just enough to allow load to be distributed equally without making the steering to bulky, on road vehicles this is increased to make the vehicle mor stable.

In conclusion the research and data collected shows a large range of vehicle set-ups and the impact these have on the vehicle (the 3 previous points), depending on the use of that vehicle and the required comfort and handling.

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Tudor, K. Load Transfer. M4X02198 Vehicle Systems. 27th February, University of Wales Trinity Saint Davids.

Vehicle Balance and Braking Report. Charles Sangster, 1902452

GRADEMARK REPORT

FINAL GRADE

57 / 70

GENERAL COMMENTS

Instructor

Really good references included and they are well embedded in the report. Both the reference list and citations are produced to a high standard. Well done.

Your research section is to a very high quality, with a great level of technical language and terminology used. It is clear that you understand this topic well. Some images might have been beneficial to help support some of the points you were making.

It would have been good to include all four contact patches on the same graph to show what was happening to the vehicle overall.

There is an issue with your longitudinal graphs due to an error on your spreadsheet. Therefore your analysis for this is not quite correct either. More explanation needed for the combined load section but you are onto the right path. Rest of the graphs are analysed well.

New chapters should start on a new page. You do need to proofread your work - either yourself or someone else. In a number of places you have course instead or cause etc. However generally this is a well produced report. Well done.

PAGE 1

PAGE 2

PAGE 3



Comment 1 | K & U Subject

Brief introduction but it does set the scene.



Comment 2 | Prof Prac

New chapters should start on a new page.



Comment 3 | Prof Prac

causes



Comment 4 | Prof Prac

Weight not wait



Comment 5 | K & U Subject

Really good explanation.

PAGE 4



Comment 6 | Prof Prac

Always add a sentence or two at a start of a chapter to explain what is being covered in that chapter.

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10



Comment 7 | Prof Prac

Units missing?

PAGE 11

PAGE 12



Comment 8 | Prof Prac

cause not course



Comment 9 | Prof Prac

causing not coursing



Comment 10 | C&I Skills

Good explanation.



Comment 11 | C&I Skills

Good



Comment 12 | C&I Skills

You should mentioned traction circle and Pythagoras at this point to help explain this point. Your explanation is not 100% accurate.

PAGE 13



Comment 13 | Literature

Really good that you have supported your analysis with references as well.



Comment 14 | C&I Skills

Good description of the effect of wheelbase, track width and COG height.



Comment 15 | C&I Skills

Really good conclusion.

PAGE 14

LITERATURE

Exceptional 85-100%

(including reading, referencing, academic conventions and academic honesty)

OUTRIGHT FAIL 0-29%	Little or no evidence of reading and/or reliance on inappropriate sources. Views and findings mostly unsupported and non-authoritative. Referencing conventions used incoherently or largely absent.
UNSATISFACTORY 30-39%	Poor engagement with essential reading. No evidence of wider reading. Reliance on inappropriate sources, and/or indiscriminate use of sources. Heavily reliant on information gained through class contact. Inconsistent and weak use of referencing.
SATISFACTORY 40-49%	Engagement with a limited range of mostly relevant and credible sources but with some reliance on information gained through class contact. Some omissions and minor errors. Referencing conventions evident though not always applied accurately or consistently.
GOOD 50-59%	Engagement with an appropriate range of literature, including sources retrieved independently. Some over-reliance on texts rather than other sources. Referencing may show minor inaccuracies or inconsistencies.
VERY GOOD 60-69%	Engagement with a wide range of literature, including sources retrieved independently. Selection of relevant and credible sources. Generally sound referencing, with no/very few inaccuracies or inconsistencies.
EXCELLENT 70-84%	Engagement with an extensive range of relevant and credible literature. Consistently accurate application of referencing.
EXCEPTIONAL 85-100%	Exceptional engagement with an extensive range of relevant and credible literature. High-level referencing skills consistently applied.

K & U SUBJECT

Exceptional 85-100%

Knowledge and Understanding of Subject. Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.

OUTRIGHT FAIL 0-29%	Major gaps in knowledge and understanding of the basic underlying concepts and principles of the subject matter. Inclusion of irrelevant material. Substantial inaccuracies
UNSATISFACTORY 30-39%	Gaps in knowledge of the basic underlying concepts and principles, with flawed or superficial understanding. Some significant inaccuracies and/or irrelevant material.
SATISFACTORY 40-49%	Limited knowledge and understanding of the basic underlying concepts and principles within the subject area. Some elements may be missing
GOOD 50-59%	Knowledge of the basic underlying concepts and principles is accurate with a good understanding of the field of study but lacks depth and/or breadth.
VERY GOOD 60-69%	Competent knowledge of the basic underlying concepts and principles. Exhibits very good understanding

EXCELLENT 70-84%	Excellent knowledge and understanding of the basic underlying concepts and principles of the subject.
EXCEPTIONAL 85-100%	Exceptional, detailed knowledge and understanding of the basic underlying concepts and principles
C&I SKILLS Excellent 70-84% (Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.)	
OUTRIGHT FAIL 0-29%	Wholly or almost wholly descriptive work. Little or no evaluation of the underlying concepts and principles. Failure to develop arguments, leading to illogical or invalid judgements. Minimal or no use of evidence to back up views.
UNSATISFACTORY 30-39%	Largely descriptive work, with superficial evaluation of the underlying concepts and principles. Weak interpretation of data, flawed development of arguments and judgements. Information accepted uncritically, uses generalised statements made with scant evidence and unsubstantiated opinions. Ideas sometimes illogical and contradictory
SATISFACTORY 40-49%	Limited attempt at evaluation of the underlying concepts and principles, tending towards description. Can interpret qualitative and quantitative data but with some errors. Some evidence to support emerging arguments and judgements but these may be underdeveloped or with a little inconsistency / mis-interpretation.
GOOD 50-59%	Good evaluation of the underlying concepts and principles. Can interpret qualitative and quantitative data, with minor errors. An emerging ability to use evidence to support the argument. Mostly valid arguments and logical judgements.
VERY GOOD 60-69%	Sound evaluation of the underlying concepts and principles. Can interpret qualitative and quantitative data accurately. Ability to devise arguments using evidence to make mostly appropriate and valid judgements.
EXCELLENT 70-84%	Excellent evaluation of the underlying concepts and principles. Can interpret qualitative and quantitative data accurately and with some insight. Excellent ability to devise arguments using evidence and make appropriate and valid judgements
EXCEPTIONAL 85-100%	Exceptional evaluation of the underlying concepts and principles based evidence. Outstanding interpretation of qualitative and quantitative data. Exceptional ability to devise arguments using evidence and make wholly appropriate and valid judgements
PROF PRAC Excellent 70-84% (Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.)	
OUTRIGHT FAIL 0-29%	Work is poorly structured, disorganised, inaccurate and/or confusingly expressed. Very weak use of language and/or very inappropriate style. Failure to work effectively individual or as part of a group. Little or no evidence of the skills for employment requiring the

exercise of some personal responsibility.

UNSATISFACTORY 30-39%	Work is poorly presented in a disjointed manner. It is loosely, and at times incoherently, structured, with information and ideas often poorly expressed. Weak use of language and/or inappropriate style. Flawed approach to individual or group work, meeting only partial obligations to others. Limited evidence of the skills for employment requiring the exercise of some personal responsibility.
SATISFACTORY 40-49%	Mostly ordered presentation and structure in which relevant ideas / concepts are reasonably expressed. Work may lack coherence and/or accuracy in places. Can work as part of a group, meeting most obligations to others but perhaps with limited involvement in group activities. Demonstrates the basic skills for employment requiring the exercise of some personal responsibility, with some areas of minor weakness.
GOOD 50-59%	Mostly coherent, organised and accurate work, in a suitable structure and is for the most part clearly expressed. Can work effectively independently and/or as part of a team, with clear contribution to group activities. Demonstrates the skills for employment requiring the exercise of some personal responsibility, with some areas of strength and some of minor weakness.
VERY GOOD 60-69%	Work is accurate, coherent, fluent, well-structured and organised. Can work effectively independently and/or as part of a team, with very good contribution to group activities. Demonstrates very good skills for employment requiring the exercise of some personal responsibility, with just occasional minor weakness.
EXCELLENT 70-84%	Work is coherent, very fluent and is presented professionally. Can work effectively independently and/or as part of a team, with an excellent contribution to group activities. Demonstrates excellent skills for employment requiring the exercise of some personal responsibility with an appetite for further development.
EXCEPTIONAL 85-100%	Work is accurate, exceptionally coherent, very fluent and presented well. Can work effectively independently and/or as part of a team, with an exceptional contribution to group activities. Demonstrates exceptional skills for employment requiring the exercise of some personal responsibility with an appetite for further development