



PRIFYSGOL CYMRU
Y Drindod Dewi Sant
UNIVERSITY OF WALES
Trinity Saint David



**An investigation into how simulation can be used
to evaluate setup ahead of a race weekend.**

**BSc Motorsport Engineering
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Luke Atkinson P146166

Abstract.

This project has two main aims. The first aim of the project is to use motec in conjunction with the BPS simulator to statically test various setups. The second aim of the project is to analyze the tested setups using motec and conclude which setup is the most viable for a race.

Vigorous research has been conducted into testing methods such as design of experiment to better understand the most effective way of testing. Using design of experiment four setup changes were chosen to be tested, these being anti-roll bars, spring stiffness, front toe and finally rear toe. These setups have been critically analyzed using motec and other various software packages to deduce which setup was the most effective.

The conclusion was made that the high anti-roll bar setting, softer spring stiffness, front toe out and rear toe out were the most effective setups for a race. The setups were chosen based on race day rather than qualifying because in many categories of racing points are awarded on race day rather than qualifying.

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1. Introduction.

Data acquisition is a proven way for athletes to be successful. A common sporting discipline, and form of data acquisition, is for them to record their performance, analyze what has happened and draw conclusions from factors that influence their performance.

Sophisticated recording devices are used to collect, store and correlate data. These devices are fed by numerous sensors placed statically within a race car to give race times all the data they need. These sensors could range from G sensors which record lateral/ longitudinal G force, tire temperature sensors to gearbox oil temperature sensors. All the sensors in the car are used to assist engineers and drivers into getting the absolute maximum out of a race over a race weekend or test session. (Segers, 2008)

Motor racing has always been known for its use of high end technology. Simulators have become extremely sophisticated in the past 20 years of racing. Gerhard Berger explained that on his Formula one debut that he did not know the track so he went out and looked at the braking points of the “*quick drivers*”. (Sky Sports, 2013). In modern racing however, simulators are king. All formula one teams have simulation packages to help develop new parts, engine packages and even pit stops. Drivers use simulators for different reasons however. A racing driver’s main aim is to win. With the advancement in driving simulations being quick in a racing car is more about skill than bravery.

This project has two main aims. The first aim of the project is to use motec in conjunction with the BPS simulator to statically test various setups. The second aim of the project is to analyze the tested setups using motec and conclude which setup is the most viable for a race.

2. Literature Review.

2.1. Simulation.

2.1.1. Design of Experiment.

Design of experiment is a popular method used for simulation. It is a systematic method used to determine the relationship between factors affecting a process and the output of that process. Design of experiment has been used in this project to assist in the setup testing. The use of design of experiment made it possible to cut the amount of testing required to achieve the goals of the project.

2.1.2. Simulators.

Driving simulators are often referred to as ‘glorified video games’. *“It would be too easy and in fact, lazy to compare using a professional sim to playing a video game, because the physicality of driving a racing car really comes across. The environment you sit in, with a fully kitted out cockpit, and the driving model gives you a sense of immersion which has to be experienced to be believed.”* Simulators are used to allow drivers to pump in lap after in order to learn a track, the best racing lines and the latest possible point to break without damaging himself, the car or the track. (Kilbey, 2016). The university has a base performance simulator which has been used to conduct the testing necessary for the project.

2.2. Data Acquisition.

Data acquisition in race cars is an electronic memory unit that stores user defined parameters while the car is on track. The stored data can then be downloaded and analysed using software packages such as motec. Data acquisition can be broken down into six categories. These are 1. Vehicle performance analysis. 2. Driver performance analysis. 3. Vehicle development. 4. Reliability and safety. 5. Determining vehicle parameters. 6. Running logs. (Segers, 2008) Data acquisition has been used in the project as a way of ensuring that tests being run have value. Without data acquisition software such as motec the testing procedure would have been extremely long.

2.3. MoTeC.

MoTeC has been one of the world leaders when it comes to data acquisition with its distinctive gold ECUs and a philosophy of engineering excellence. MoTeC has grown from a modest home workshop producing a screwdriver-adjusted ECU in the late 1980s to world leaders. MoTeC now has over two hundred dealers worldwide. MoTeC has become synonymous with motor racing success in almost every category across the globe.

MoTeC was initially adopted by sport sedans and road-registered vehicles but has since been picked up by the majority of motorsport categories worldwide such series as Le Mans, ALMS, NASCAR, FIA GT, Australian V8 Supercars, Indy Car, Dakar Rally, World Superbikes, Professional Drag Racing including Top Fuel and Sport Compact, Porsche Carrera Cup, Star Mazda USA, TC2000 Argentina, World Rally, Group N Rally, GP Masters, Formula 4000 and Formula Ford. MoTeC systems have also been put to use in military vehicles and commercial automotive test facilities. - (*Motec.com, 2017*) Motec is the chosen software package used for the project. Motec is an easy software package to learn and really assisted with the analysis of the data collected.

2.4. Weight Transfer.

Vehicle weight transfer is an unavoidable side effect of cornering. It occurs as a result of the chassis twisting around the car's roll center, which is determined by the setup of the suspension. When accelerating, braking or steering the body of the car rotates in the opposite direction, when the car is accelerating the car will rotate rearwards because the car is moving forwards for example. - (*Drivingfast.net*)

2.5. Suspension.

2.5.1. Anti-Roll Bars.

“The function of the anti-roll bar in preventing roll and, more importantly, transferring part of the cars weight from side to side and one end to another during cornering is taken over to the remarkable extent that it becomes not simply adjustable but also infinitely variable all the way through any particular corner in any manner the driver or road might demand.” (Staniforth, 1994)

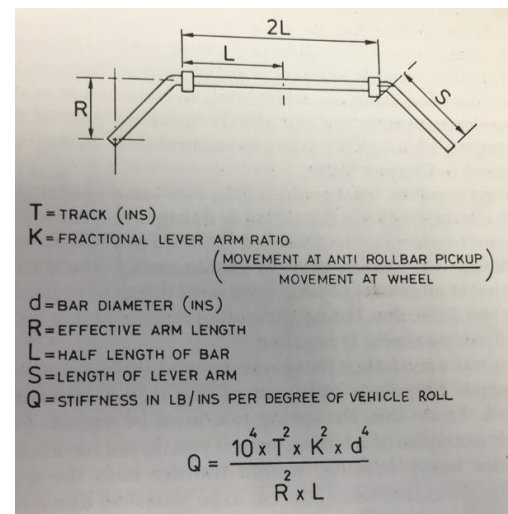


Figure 1; Image illustrating the parts and calculations of an anti-roll bar. (Staniforth, 1994)

2.5.2. Toe.

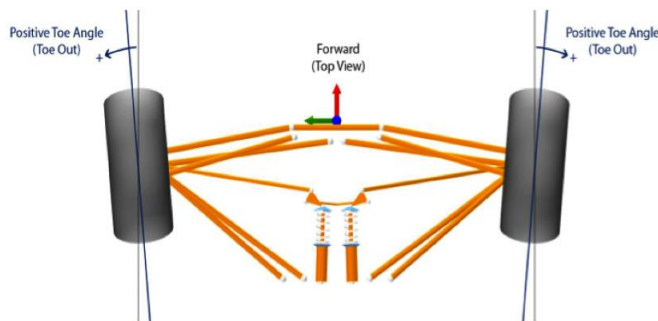


Figure 2; Image illustrating toe in and toe out. (Carengineer.com, 2013)

Toe angle categorizes the exact direction the tires are pointed compared to the centerline of a vehicle when viewed from above. Toe can be expressed in degrees or fractions of an inch. An axle is said to have positive toe in when the imaginary lines running through the centerlines of the tires intersect. They have negative toe out when they diverge. Vehicles can also have zero toe when the imaginary lines are parallel. Toe settings are typically

used to help compensate for suspension bushes compliance to enhance tire wear. Toe is also commonly adjusted to alter a vehicles handling characteristics. (Tirerack.com)

2.6. Driver Specimen.

There is a common misconception outside of the engineering world that racing drivers are not athletes. This is not true. When the word 'athlete' is uttered we immediately think of fit men and women who can run, hit hard, go for longer and are generally at the peak of physical fitness such as Usain Bolt and Dame Jessica Ennis-Hill and Cristiano Ronaldo. The driver selected needed to be able to cope with the extreme levels of concentration required to be a racing driver. It became apparent that this was not the case with the driver selected so the choice was made to convert the project into more of a test driver role than a race driver role.

3. Methodology.

3.1. Test Plan.

Test plans are crucial for any form of testing. A test plan can help reduce the amount of time used for testing, time is money after all and most companies do not want to expend money when it could be used in more valuable areas. Therefore most tests have a test plan. Test plans are used to ensure all aspects are tested during each phase of the process. Since the development process is constantly evolving, developers need to be aware of what was tested. (Bissonnette and & rarr;, 2017)

1.	Driver gets in car and has a few laps to find his feet, no data is being collected at this point.
2.	A setup change will be made, front anti roll bar will be put to its lowest setting for example, the driver will then do 5 laps trying to be as quick and consistent as he can be.
3.	Once the driver has completed his 5th lap he will be instructed to enter the pits to end the run.
4.	The driver will then answer a questionnaire to determine how the setup change effected the cars performance, handling and his performance.
5.	Another setup change will then be made and the process will be repeated.
6.	After all changes required have been made the driver will comment to the engineer on which setup he felt most comfortable with and which setup he would recommend.
7.	The data will then be collected from software by the engineer. The engineer will then analyze the data and show the driver where he is losing time in each setup.

Figure 3; the test plan.

3.2. Calculations.

The point at which the data is collected has to be accurate and conclusive. Therefore, the same point on the track will be selected for every setup. These points will be selected based on the theoretical potential of showing variable load split. The selection point for both corners is about 1/3 of the way through the corner. This method could have been more streamlined with further investigation. It became apparent that the point at which data was collected was not always accurate with how the car was behaving overall.

Turn 2.	Anti-Roll Bar	Spring Stiffness	Toe
Entry	9.221s.	8.862s.	8.785s.
Apex	10.656s.	10.597s.	10.559s.
Exit	13.723s.	12.826s.	13.089s.

Figure 4; Table with setup corner times for turn 2.

Turn 5.	Anti-Roll Bar	Spring Stiffness	Toe
Entry	37.184s.	35.885s.	36.378s.
Apex	38s.	36.678s.	37s.
Exit	38.687s.	37.487s.	38.088s.

Figure 5; Table with setup corner times for turn 5.

3.3. Motec math channels.

Motec uses a method called math channels to help correlate specific data. This feature has been extremely useful for the project because it has allowed for aspects of the car to be understood when under normal circumstances it would be impossible to access this data. The creation of the understeer/ oversteer channel has been extremely useful for the project because it has aided in understanding how the car is behaving under certain loads and conditions.

3.4. Excel spreadsheet.

The excel spreadsheet was created to create graphs to analyze the setups with. The spreadsheet consists of all the setups and three main vehicle characteristics, these being lateral G, corner speed and load split. The excel spreadsheet consists of the readings taken from the time in the lap discussed in **Calculations**. The graphs used in the **Discussion & Analysis**. Section of the report were created using these data figures. They were created by adding the setup on X axis and the setup characteristic on the Y axis. Axis titles were then added to assist in reading the graphs. Finally, each portion of the corner was given a specific color. Blue for entry, orange for apex and grey for exit.

4. Discussion & Analysis.

The discussion & analysis section of the report has been split into four main categories. These categories are for the setups. Anti-roll bars, spring stiffness, front toe and rear toe. Each of these categories then has a sub category. These sub categories are labelled after the data analyzed within the setups. These sub categories are lateral G, corner speed and load split. The setup changes have all been statically analyzed in order to conclude what is the best setup for each category.

5. Conclusion.

Based on all the findings from the project it is possible to come to three recommendations for setups. The first setup to be recommended is the high anti-roll bar setup. On the face of it the standard setting for anti-roll bars is the most balanced through the corners. The standard setting was however the slowest setup with a time of 1;09.225, over 2 seconds slower than the higher setting with a time of 1;07.094. With more testing however, a happy medium could be found between these two setups.

The next setup to recommend is the softer spring stiffness setup. This setup is the slower setup, but it seems to be the more balanced and more forgiving setup of the two setups tested. The higher setting would be a good qualifying setup, but in many categories of racing cars enter parc ferme where no setup changes are allowed. Therefore, it is logical to choose a setup that is more forgiving and better for tire wear relative to lap time. This is the softer setting.

The front toe out setup is the next to be recommended. This is because it is the most balanced of the two setups tested. This setup also allows the driver to turn in earlier and carry more speed through corners due to there being less mechanical understeer in the car. This is especially important at Brands hatch due to the large number of fast corners this track possess.

The final setup to be recommended is the rear toe out setup. This setup has been selected for many of the same reasons as the front toe setup. It is a balanced setup and allows the driver to push the car more on the exit of corners. It is important for racing drivers to feel comfortable in the car and many racing drivers will suffer over the course of a race if the rear of the vehicle feels unstable.

The 4 setups recommended will all have to be applied to the car at the same time in the simulator to truly discover weather it can be considered as a race setup. Even if the results in the simulator are positive this does not guarantee that the car and driver will gather the same results in on track. Simulators are beautiful tools that allow us to test endless possibilities in setup throughout the course of a day. If these setups were all to be tested on track it would take days rather than hours, so it is important to condemn possible weak setups now rather than waste precious track time testing these setups.

Of course, more setup changes could have been tested. This project focused solely on suspension but GP2 cars are known for downforce. It is possible that if the front and rear wing angles were to change then the car would behave differently with these setups that have been tested. In future projects it will be the goal to test as many variations in setup as possible to gather the clearest picture of how the car is behaving.

6. References.

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7. Appendices.

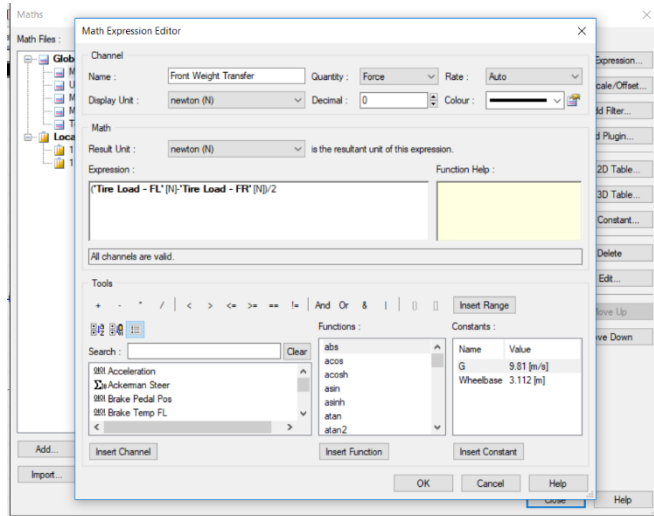


Figure 9; Front weight transfer channel

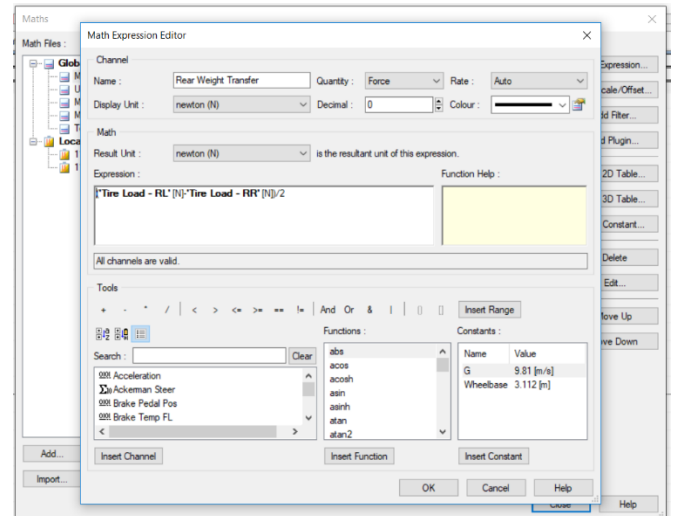


Figure 8; Rear weight transfer channel

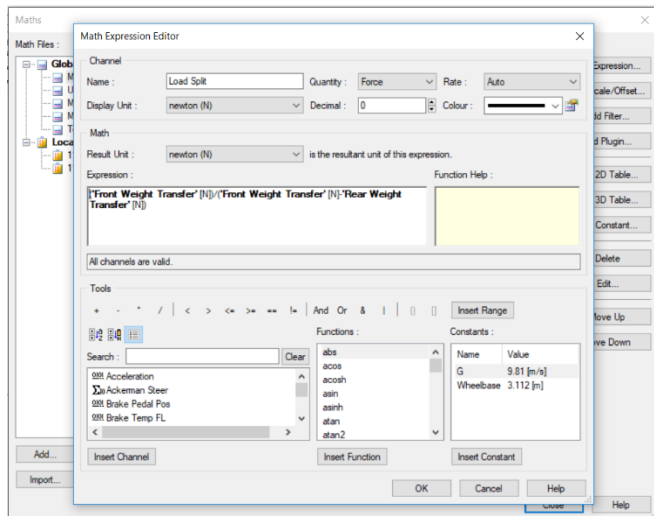


Figure 7; Load split channel

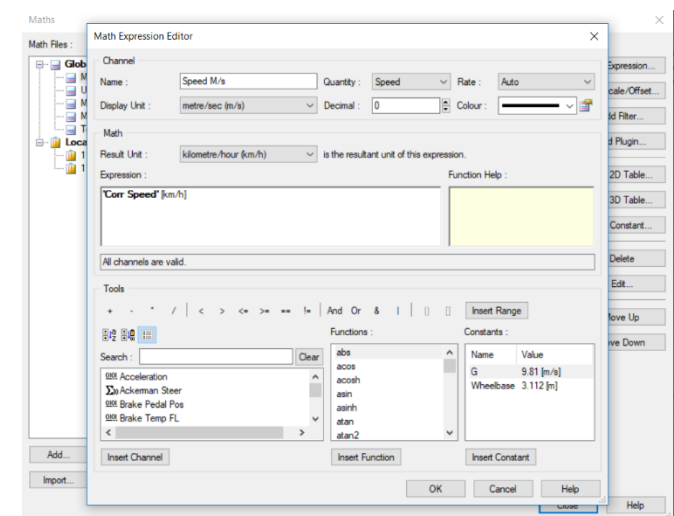


Figure 6; Speed M/s channel

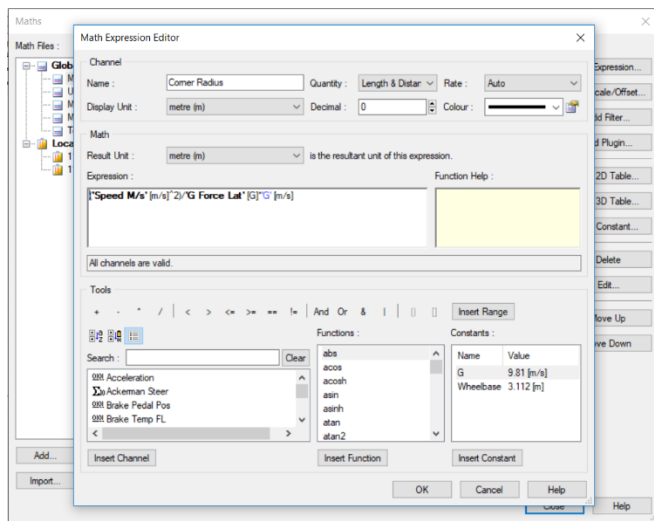


Figure 13; Corner radius channel

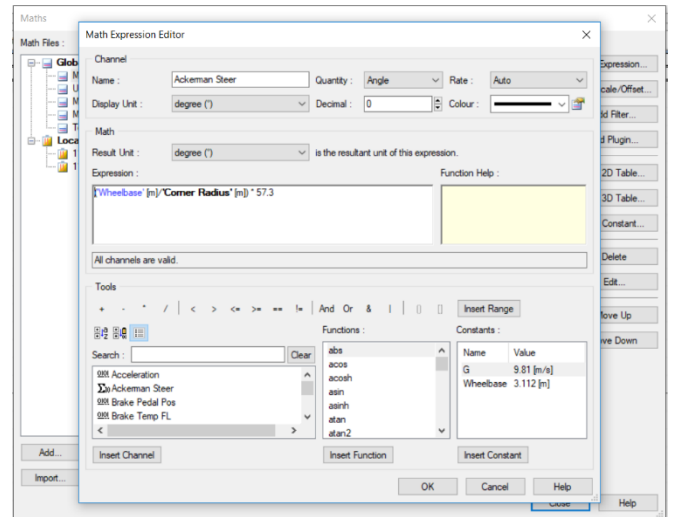


Figure 12; Ackerman steer channel

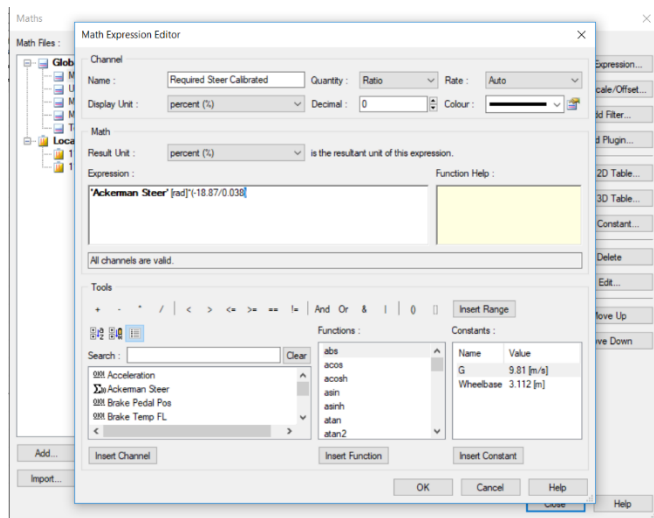


Figure 11; Required steering calibrated channel

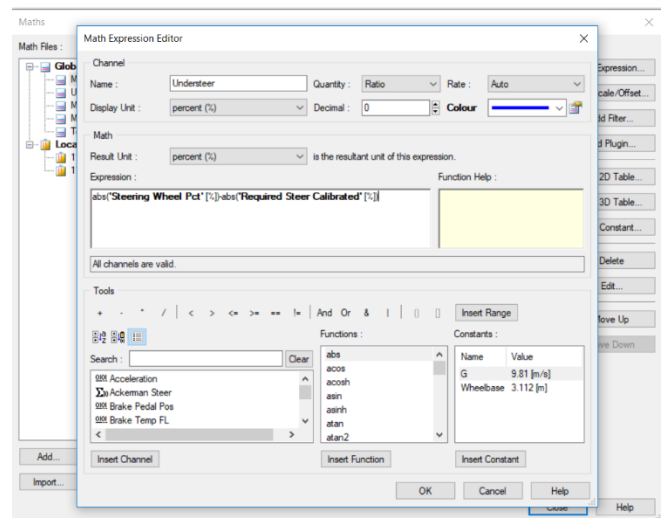


Figure 10; Understeer channel