The Effect of Human Inputs on Motorcycle Vehicle Dynamics

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The deliberate conscious action of riding a motorcycle is employed by a small percentage of riders, with misunderstood theories present amongst operators of all levels from novices through to professional racers. Many people ride with a level of unconscious awareness through feeling the vehicle and are unable to describe the response of the system and deliberate action they will introduce to counter a given dynamic situation. The aim of this project is to investigate some effects of human inputs on motorcycle vehicle dynamics through the use of a purpose designed data acquisition system to dispel some myths that exist amongst the riding population. This investigation was achieved by developing a data acquisition system to instrument a motorcycle and obtain experimental data around the Sydney Motorsport Park – Eastern Creek circuit. The specific topics investigated included an investigation into the transient phase of cornering where physical data was obtained to characterise the vehicle dynamics for future validation with an existing theoretical model. An investigation into the effect of the applied load on the foot pegs during cornering was explored, with the data set inconclusively supporting the notion that an applied load on the outside foot peg provides a perceived increase in stability during cornering. The investigation into the effect of applied steering input provided a data set to confirm that at high speed, most of the cornering effort is produced as a product of the counter steering input of ± two degrees to move the centre of gravity and induce the roll action of the motorcycle. This investigation validates some of the existing theoretical modeling concepts conducted by other authors in this field and was required to provide further understanding to the riding population on the effect of their conscious inputs into the motorcycle-rider system. This will ultimately lead to a more precise level of control and avoidance of serious injuries from a lack of knowledge by the rider.

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II. Introduction

In 2013, the Australian Bureau of Statistics revealed that there were 744,732 registered motorcycles operating in Australia, accounting for 4.3% of all vehicles registered in the country. This statistic reflects an average annual growth of 5.8% in motorcycle registrations across the population in the past five years, indicating a larger population is riding motorcycles on Australian roads. To account for the population of motorcycle riders that operate unregistered motorcycles on trails or the race track we can estimate that this figure could reasonably be doubled to account for those that ride motorcycles regularly. 15% of transport accidents involving motorcycles resulted in death to the rider where some of these instances may have been reduced through rider education [1].

Many riders don’t deliberately control the vehicle through a conscious effort and are unable to describe and articulate what actions they conduct in a scenario and the likely reaction from the system in response to those inputs [1]. There are instances where top level racing riders have been interviewed about control methods and don’t actually know exactly what deliberate inputs they are employing, leaving an element of guess and feel to their style. As the motorcycle is significantly influenced by the slightest changes and influences to the system, it is important for the rider to understand the cause and effect of conscious and subconscious inputs into the complete rider-motorcycle system [2].

A limited number of authors have investigated the topic of motorcycle vehicle dynamics with a distinct level of rigor orientated towards numerical analysis, multi-body kinematic modeling of complex arrangements to emulate the characteristics of the motorcycle with an appropriate experimental apparatus. Extensive efforts in mathematical modeling of the kinematics of how a motorcycle operates have been conducted, but there are only a limited number of recorded analytical cases where authors have taken the next step to obtain the data and correlate the model with the physical condition.

III. Project Outline

A. Aims

The aim of this project is to investigate some of the effects of human inputs on motorcycle vehicle dynamics. The investigation was achieved by instrumenting a motorcycle with an appropriate Data Acquisition System (DAQS) to obtain physical experimental data to use for further analysis in an effort to validate and quantify some of the theoretical concepts proposed by other authors and professional riders in this field.

B. Project Resources

The primary resources provided consisted of loaned instrumentation and data logging equipment. Reference material and electronic resources accessible through the university were used to conduct research to determine the likely approach of developing the DAQS. The SEIT TSG provided manufacturing and technical support for the manufacture of brackets and placement of strain gauges. All other consumable components such as the twisted pair data cable, Deutsch Connector system and Heat Shrink were funded and obtained by the author in an effort to deliver the required outcomes in an efficient manner. Time was the one resource that was seldom wasted and was constantly in short supply throughout all phases of this project.

The initial phases relating to DAQS configuration was achieved through online academic resources, personal texts and several leading industry websites. The software resources required consist of access to the CATIA computer aided design package and the MoTec data analysis software. Limited access to the student workshop facility was required for the manufacture, modification and fitment of component brackets.

The DAQS was fitted to a 2007 Suzuki GSXR 1000 motorcycle, which was employed for all data collection phases and was supplied and ridden by the author as pictured below in Figure 1.

C. Goals

During the consideration and establishment of this project topic three primary goals were proposed and achieved with varying levels of success:

1. Design, construct and establish a suitable DAQS to obtain appropriate data for evaluation during dynamic testing and experimentation;
2. Evaluate the data obtained and conduct a comparative analysis with available theoretical modelling for the dynamic condition being investigated; and
3. Translate the data obtained during analysis into a meaningful result to enhance the rider’s understanding of how to consciously control aspects of a motorcycle.

Figure 1: The instrumented motorcycle used for testing

Final Project Report 2013, SEIT, UNSW@ADFA
There were many conditions and scenarios that this investigative approach could of explored; however, this project employed the DAQS developed to investigate the following motorcycle vehicle dynamic topics revolving around the way the vehicle negotiates high speed corners:

1. The transient phase on initial turn in before steady state cornering is established;
2. Exploration of the applied load into the foot pegs while cornering; and
3. The influence of the steering rate through the handlebars while cornering.

The final goal related to this project was to produce an ‘Instruction Manual for Implementing a Motorcycle Data Acquisition System’ to capture lessons learnt with the components and resources utilised for this project.

D. Methodology

The approach undertaken to complete this project topic was executed in the following sequence with several tasks operating concurrently to improve efficiency across the project.

The initial analysis identified that the outcomes for this project were reliant on the establishment of a reliable and robust DAQS before any investigations could be conducted. The research and development into sensor technology available, interfacing, programming and wiring loom construction became the main focus for the initial phase of the project.

Once the DAQS parameters were determined and the components had been purchased, the construction phase commenced. This is where all of the system components were laid out on a test board and the wiring loom construction began.

The installation phase commenced as components and sub-systems became available and were deemed fit for use. Integration of the constructed DAQS, mounting brackets and software with the motorcycle occurred progressively as the installation was carried out. As the system evolved it was trialed and utilised to collect data for analysis with whichever components were functioning and available at the pre-designated test session.

An analytical evaluation of the data set was conducted upon successful collection of the relevant data for the conditions as outlined within the topic goals. A comparison between the existing theoretical modeling and the experimental data was conducted to extrapolate the relevant factors and inputs required for deliberate conscious control of the motorcycle.

E. Literature Review Findings

Throughout the conduct of the literature review there was a significant amount of research discussing modeling of multi-body kinematics for the motorcycle negotiating a corner without experimental results published to support the theoretical concepts explored. This observation was the motivation to further contribute to the discussed theory by capturing appropriate data of the given condition. This would further validate such theories with physically quantified data for future analysis and comparison.

There was a reasonable amount of literature revolving around the rider’s upper torso affects, redistribution of weight by leaning and unintentional dampening effects through the link on the handlebars. However, no published research was able to be found discussing the connection point of the feet, the forces generated through the pegs and if the rider is generating lateral stability, holding on or influencing the rate of roll through the corner. The only literature discovered was a video demonstrating the limitations of lean steering versus counter steering by applying the riders weight through the pegs on a modified motorcycle.

The steering input on a motorcycle has a limited range of motion and there were a variety of research papers that revealed details on the complexity involved in developing the conditions to investigate steering input effect factors. The authors of these academic papers stated that in order to explore this topic in detail it would require a carefully considered approach to be applied to an investigation relating to the human input effects of the system.

IV. Data Acquisition System Design

A. System Requirements

The approach to determine the requirements, constraints and system specifications was derived from a modified systems engineering approach where system level requirement drove a requirement breakdown structure for the whole project. Preliminary system design continued to identify the major components, instrumentation plan and define the preliminary physical architecture of the system. There are several components that make up the system primarily consisting of software, hardware, interfaces, testing facilities and the rider. Hardware refers to the physical sensor, wiring and logging components required to collect the data. The mounting brackets could arguably be considered a hardware item, but is also considered to be an interface item, as they are required to safely secure the equipment to the motorcycle and support the sensor. Software refers to the programs that allow the adjustment of configurations on the data logger and sensors as well as the analysis program to process the data collected. System level interfaces refer to the rider interfacing with the motorcycle, the existing motorcycle interfacing with the new data acquisition system and the software programs interfacing with the sensors to convert their signals into worthwhile data.
The next step towards establishing the DAQS required the determination of parameters to be measured, sensor and component selection, and their suitability for the application.

B. Hardware Components

The CDL3 used during this project had significant hardware limitations. A priority was placed on channels to log, which was determined from the requirement analysis. The CDL3 had a limited capacity to log hardwired channels, as there were only eleven input channels available. The limited amount of Analogue Voltage inputs available shaped the project direction to explore the use of CAN sensors to acquire the required amount of data for evaluation. These sensors exploited the dedicated CANBUS’s and RS232 channels available on the CDL3 mitigating some of the hardware constraints. The sensor channel allocation used for the project is outlined below at Table 1.

### i. Table 1: Sensor inputs and channel designation for the project variables.

<table>
<thead>
<tr>
<th>Channel Type</th>
<th>Channel No.</th>
<th>Physical Quantity</th>
<th>Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analogue Voltage</td>
<td>AV1</td>
<td>Steering Angle</td>
<td>Rotary position</td>
</tr>
<tr>
<td></td>
<td>AV2</td>
<td>AV Roll Rate</td>
<td>Bosch YRS3 AV</td>
</tr>
<tr>
<td></td>
<td>AV3</td>
<td>AV Lateral Acceleration</td>
<td>Bosch YRS3 AV</td>
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<tr>
<td></td>
<td>AV4</td>
<td>Throttle Position</td>
<td>OEM Throttle Position Sensor</td>
</tr>
<tr>
<td>Analogue Temp</td>
<td>AT1</td>
<td>Force input by rider: Left Peg/Bar</td>
<td>Load Cell / Strain Gauge Amp 1</td>
</tr>
<tr>
<td></td>
<td>AT2</td>
<td>Force input by rider: Right Peg/Bar</td>
<td>Load Cell / Strain Gauge Amp 2</td>
</tr>
<tr>
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<td>DIG1</td>
<td>Front Brake applied</td>
<td>Front Brake Switch</td>
</tr>
<tr>
<td></td>
<td>DIG2</td>
<td>Not used</td>
<td>N/A</td>
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<tr>
<td>Speed Inputs,</td>
<td>SPD1</td>
<td>Engine Revs</td>
<td>OEM RPM Sensor</td>
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<tr>
<td>(Voltage Capable)</td>
<td>SPD2</td>
<td>Front Wheel Speed</td>
<td>Magnetic hall effect &amp; trigger disc</td>
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<tr>
<td></td>
<td>SPD3</td>
<td>Rear Wheel Speed</td>
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<td>Vehicle x,y,z acceleration, yaw &amp; roll rates</td>
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<td></td>
<td>BAT-</td>
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<td>Battery/Voltage</td>
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Another key component of the hardware system was the wiring loom. The wire selected was the NEMA WC27500-22-TG-4-T14 being a 22 gauge tinned copper shielded twisted pair cable with four conductors. This cable was selected as other researchers have previously encountered excessive noise from ignition modules and rotating ferrous components. The intent of using this wire was to negate as many external noise sources as possible. The next component of the wiring loom to consider was the method of connecting the devices. The more expensive reusable Deutsch Autosport DTM connector system was selected due to its ability to be reconfigured quickly as the system develops, while maintaining a robust and weatherproof connection [3]. To terminate wires, gold plated pins were crimped with the correct DTM tool in conjunction with heat shrink and hot glue to join multiple cables while applying strain relief.

C. Software Components

The DAQS software interface utilised was MoTec’s CDL3 Dash Manager V1.5 and the I2 Pro Analysis Software V1.0, available online [4].

The first task in establishing the software component of the DAQS was to write the configuration file for the dash to align with the hardware parameters established. The easiest way to write a new configuration file is to start at ‘Connections’ and work through every screen available from top to bottom and then work across the headings from left to right.
After working through several configuration variations, it became quicker to write a new configuration file for big changes rather than adjusting old templates, as there were functions that relate to one another and cause errors when loading the file to the dash. The importance of understanding the technical data sheet parameters became prevalent when writing CAN protocol files for selected sensors.

D. Mounting Bracket Design

During the development of this system it was necessary to design and manufacture mounting arrangements on the motorcycle for several sensors and components to integrate with the existing infrastructure. Some of the many considerations during the bracket design process were to ensure the modifications are safe, secure and suitable for use in the environment of operation. The precision, accuracy, and clearances of components varied considerably depending on their application and location; however, all tolerances were set to ± 0.1mm. As most of the project was prototype work there was a reasonable amount of modification and maintenance fitting applied to designed components to ensure they functioned correctly with the system.

The material used in most components was 6061 Aluminum plate, sheet or extrusion sections for its lightweight properties. The wheel speed trigger discs were made from mild steel to allow the GT101 Magnetic Hall effect sensor to detect the ferrous material. Vibration dampening rubber material was considered for the dash and the inertial sensor unit to minimise excessive noise in the signals from the vibration of the engine. It was noted that the integration of new components should always be tested with the existing paneling and functional control mechanisms on the motorcycle operating. It proved easy to develop mounting solutions for sensors when the bike was stripped down and stationary but a different story when in race trim.

The components that had the greatest risk of causing serious injury or even death to the rider if they failed had a rigorous design criteria applied to them to ensure safety could be maintained for the motorcycle to travel up to 250km/h during testing.

E. System Proving, Validation and Testing

Once the details surrounding the design of the DAQS were determined, relevant components, sensors, wiring, connectors and software was acquired to commence the physical build by generating a test board as shown in Figure 2.

Familiarisation with operating the software was trialed with a similar existing racecar system on a public road test loop. The car configuration file was downloaded and the data was monitored live in the CDL3 Dash Manager program during the test drive and analysed upon completion with the I2 Analysis software.

The inherit nature of having a limited amount of time to complete the build took its effect and dynamic proving of the DAQS only took place on track at SMSP-EC. Unfortunately the system was still evolving and developing when the first track session date was upon us, and testing commenced. During the commencement of the building phase, the approach used was to adapt the pre-configured harness to suit the project’s needs and leave it in a condition to be able to be restored and returned to the university upon completion. This approach was employed during the initial testing session and only successfully logged the GPS data with a basic configuration file. The excessive cables that cluttered the motorcycle were the primary reason a custom loom was developed prior to the next test session, which later induced its own set of complications.

During the second testing session, the progress of the system had been slow and although there were gains made by obtaining logged data for front and rear wheel speeds, steering angle, throttle position and applied load through the foot pegs, unfortunately the GPS failed to work with the new loom and configuration. After this session the issues encountered with the GPS were rectified and the CAN network issues including protocol settings and software configuration for the sensors were developed to enable the whole system to function prior to the final test session. Other issues related to the calibration of sensors, identified from the previous set of data were rectified and reprogrammed within the software.

During the third testing session, the motorcycle and all components of the DAQS operated as designed and intended to produce the data set used to investigate and analyse the stated motorcycle vehicle dynamic conditions.

Further work and refinement would be required to improve the accuracy and performance of some of the sensors and their calibration; however, the existing project time constraints and track availability prevented any further developments to improve the quality of the data set obtained.

![Figure 2: The data acquisition testing board](image)
Figure 3 details the SMSP-EC complex with each turn labeled with the prefix T before the corner number.

The relevant DAQS technical data sheets and specifications can be found in the “Instruction Manual for Implementing a Motorcycle Data Acquisition System” developed by the author as a specific deliverable for Mr. Alan Fien from SEIT.

The focus for this investigation will be orientated around T1 for the transient phase of cornering and T4 through to T5 for exploring the applied load on the foot pegs. The effect of the applied steering input will be evaluated throughout the variety of corners on the circuit.

V. Investigation into the Transient Phase of Cornering

A. Introduction

The art of cornering a motorcycle through a turn is something that takes professionals years to perfect. Several authors have investigated the complicated arrangement of multi-body kinematics in an effort to understand the mechanics of how a motorcycle conducts such a manoeuvre. This area of research has generated theoretical models to simulate the conditions during the transient phase on approach to the corner and once steady state cornering has commenced. The aim of this investigation is to capture experimental data to describe the transient phase on initial turn in before steady state cornering is established.

B. Background

Professor Vittore Cossalter describes in his research the modeling representation of the wheel velocity in a turn. Cossalter implies that there is a difference between the modeling of the transient conditions compared to what physically happens during this condition as the model assumes that there is no longitudinal slippage between the rear wheel and the road [5]. The paper also discusses how the velocity of the vehicle is represented by the forward velocity of the contact point on the rear wheel and is expressed as the yaw velocity equation:

\[ \Omega = \frac{V}{R_{Gr}} \]

where \( V \) represents the forward velocity and \( R_{Gr} \) represents the path radius of the rear wheel.

Theoretically assuming there is no longitudinal slippage between the tires and the road surface, the spin velocity of the wheels in reference to the forward velocity of the vehicle for roll angle and kinematic steering angle is represented as:

\[ \omega_r = \frac{V}{\rho_r + t_r \cos \varphi} \]

\[ \omega_f = \frac{V}{(\rho_f + t_f \cos \beta) \cos \Delta} \]

Cossalter indicates in his analysis, that in reality it is expected that during the thrust and braking phases there is always longitudinal slippage. The slippage of the front wheel exists in the braking phase but is considered negligible in the steady state conditions model and generally unnoticed by the rider due to the rolling resistance that exists in the system. During this transient phase upon entry to the turn, when the vehicle is encountering longitudinal slip the vehicle is starting to roll at the turn in point. This phase sees the circumference of the tyres reduce due to the profile of the tyre and the velocity of the wheel increase, theoretically increasing the revolutions per minute of the vehicle, which drives the slip for the turn [6,7].

C. Physical Results

A selection of the data obtained experimentally from the DAQS at SMSP-EC is pictured below at Figure 4. The green vertical marker represents the start of the transient phase, which lasts until the blue vertical line where steady state conditions begin to be present. If we refer to the ‘Front and Rear Wheel Speed’ plot denoted by the marker arrow at A, we can see how the rear wheel speed begins to increase as it slips and approaches the stability of steady state cornering. This can also be seen by the plot labeled ‘Wheel Speed Difference’, where the front wheel speed is subtracted from the rear wheel speed to indicate any pronounced rate of change. This channel shows a uniformed increase in rear wheel speed as it slips through the transient phase until steady state cornering is established.

If we refer to the marker arrow B, we can see a small increase in engine RPM just after the transient phase has commenced. The increase of 740 RPM reflects the action of the motorcycle’s rear wheel rolling into the corner as it changes circumference from the centre of the tyre to the shoulder. This is further supported by the ‘Throttle’ plot at the marker arrow C, which shows the throttle position progressively being closed; implying the motorcycle RPM should be decreasing uniformly. As we expected to see a small increase in RPM from the tyre circumference reducing, conversely there is a decrease of 532 RPM as the bike is rolling up to the vertical position after completing the corner as indicated by the marker arrow E.
Some of the data collected didn’t align, as we expected that the ‘Gyro Roll Rate’ would have a reasonably horizontal trajectory, which increased in gradient as the motorcycle reached the required lean angle for the corner before being restored to its horizontal trajectory once the motorcycle was restored to the upright position. Further inspection of the sensor after testing revealed that the mounting bracket had failed and the sensor was allowed to move within a limited range inducing noise and inaccuracies into the data logged. It was also expected that the ‘Steering Angle’ plot, would of demonstrated a more pronounced change in angle from the riders initiated input, during the transient phase at marker F; However, its trajectory was consistent with the results expected as the steady state cornering condition was achieved.

The data depicted at Figure 5 showed some interesting responses in the system that were unable to be explained convincingly while investigating the transient phase of the corner. The markers at A and B show a significant amount of noise occurring in the ‘Front Wheel Speed’ channel but it is also registering a greater wheel velocity than the rear which was not expected. After reviewing the configuration it showed that the calibration of the wheel speed sensors were not correct, which is likely to explain the inverted speed differences.

There was a suggestion of the characteristics of the tyre playing a part under severe acceleration and braking but this claim could not be supported by the data collected on 16 Dec 2013 with the correct calibration settings.

D. Findings
This investigation was able to correctly obtain data to define the transient phase as described in Cossalter’s research particularly the indicators of the RPM change proportionate to the motorcycle rolling and the difference in wheel speeds generated through the corner. It would have been ideal to use the physical data values obtained to qualitatively compare it with the theoretical model to evaluate the results. Unfortunately, converting the path radius of the wheel determined from the angular velocities and trajectory of the motorcycle in relation to the corner profile was beyond the scope of this investigation, so this comparison wasn’t completed.

VI. Investigation into the Effect of the Applied Load On the Foot Pegs

A. Introduction

The rider of a motorcycle has five key connection points with the vehicle, those being both hands at the handlebars, both feet on the foot pegs and the rider’s backside on the seat. The human input effects on the handle bars has been thoroughly investigated with some robust research generated around the connection point of the hands. The effect of the applied load on the foot pegs has been sparsely documented with very few academic references made to how the inputs are related to the dynamics of the motorcycle. There are many debated theories amongst professional riders on applying a load to certain foot pegs at different times through a given manoeuvre to generate additional stability whilst cornering. The aim of this paper is to investigate the effect of the load applied through the foot pegs during both a left and right cornering manoeuvre of a similar profile to determine the influence of the foot pegs on the stability of the motorcycle.

B. Background

This paper was motivated by an interview observed with professional riders discussing their understanding of the physics applied to controlling a motorcycle and the effect of deliberately loading the outside foot peg during a corner. It was claimed by the riders, that they could feel an improvement in the stability of the motorcycle by deliberately loading the inside foot peg upon entry into the corner to assist in turning the motorcycle in and then loading the outside foot peg upon exit to increase the vertical load on the tyre for additional grip and traction upon exit of the corner [2].

The Ducati MOTOGP team were observed conducting research and development within this area where pressure pads were placed in various locations and strain gauges were installed on the foot pegs and other selected components. It was assumed that the team was attempting to log data relating to the rider adjusting the systems centre of gravity to improve the stability and control of the motorcycle. Unfortunately, this information is Commercial-In-Confidence and there hasn’t been any findings published on their research.

Keith Code the author of ‘Twist of the Wrist’ discusses the concept of a rider having a limited amount of concentration they can spend. If the rider is concentrating on applying a load to the foot peg without obtaining any benefit it could be considered misspent concentration exerted in this action. If they spend too much on one particular action then they will have nothing left to use if an unlikely situation arises [8].

It’s proposed that the action of loading the outside foot peg provides an avenue to lock on and hold on to the motorcycle during cornering rather than increasing the vehicles stability.

An investigation into a multi body motorcycle model with eleven degrees of freedom published by Professor Vittore Cossalter discusses the requirement for this complex approach to provide an accurate representation of the motorcycles behavior. In line with this complex model, there is discussion about the manner that the tyre’s lateral and radial stiffness characteristics contribute to the location of the actual contact point with the ground where the motorcycles normal force would act through, illustrated at Figure 6 [9].

It’s proposed that the action of loading the outside foot peg contributes towards an adjustment in the tyre profile by influencing where the actual contact point axis acts, resulting in a perceived change of feel by the rider.

C. Physical Results

For the collection of data relating to the riders applied load, purpose built foot pegs were designed and machined to provide two flat surfaces, one hundred and eighty degrees apart for the placement of two strain gauge load cells as depicted in Figure 7.

A selection of the data obtained experimentally from the DAQS at SMSP-EC is pictured below at Figure 8. The green vertical marker represents the approach into T4 and the blue vertical line represents the exit at T5. Both of these corners were selected to investigate and evaluate the data obtained from the applied load in the foot pegs by comparison, as they have a similar corner profile defined by the radius, camber and length, but are in opposite directions.
If we refer to the ‘Peg Force’ plot between the vertical markers, we can see that the right foot peg has an applied load during the right hand corner, which is similar and proportionate to the force of the left hand foot peg during the left corner. The majority of force is placed on the inside foot peg, regardless of how much force the rider is consciously placing on the outside foot peg. We can see the data set doesn’t support the notion that an applied load to the outside foot peg contributes towards improving the stability of the motorcycle.

![Figure 8: Data collected from testing at Eastern Creek on 16 Dec 2013](image)

The rider as part of the motorcycle-rider system has a limited amount of force that they can apply on the vehicle. The variables that could possibly generate some additional force during a corner operating in steady state are the riders applied weight to the moment arm of the peg. The data obtained does not conclusively determine that loading the outside peg increases the stability of the vehicle; however, the data does show in this instance that up to 70% of the riders weight is applied through the inside foot peg during each corner.

It is likely that the rider experiences a perceived feeling of additional stability when they use the outside leg to lock in and hold on to the motorcycle during the turn. This concept is also supported by the video demonstration Keith Code conducts to explain the benefits of counter steering versus lean steering [10]. The demonstration shows the minimal effect an applied load has on the foot pegs to contribute towards turning a motorcycle, emphasising how slow the system reacts to the input. This provides an indication that any direct inputs on the foot pegs during a corner are likely to be negligible by the time they take effect and influence the system.

This investigation has limitations, which will preclude a conclusive stance to be obtained as the apparatus has some inherent errors associated with it that could be improved with additional time and resources. The rider used to collect the data was an amateur where a professional rider could be employed to improve the consistency of data collected for analysis. The adjustment dials on the strain gauge amplifiers were unable to be completely aligned resulting in a small gain offset from each of the signals. The foot peg design could be modified to reduce the varying effect of the applied moment arm, as the foot is unable to be consistently placed in the same spot to qualitatively assess the load applied. Alternatively, a camera could be placed to observe the foot placement with measured marks on the pegs to aide in omitting any induced errors.
E. Findings
Within the constraints of this data set, there is evidence to support the claim that the force generated by the rider through the peg is only used to hold on and lock off during cornering and doesn’t contribute to increasing the stability of the motorcycle. However, there is still a possibility that the applied load to the foot peg influences the tyre characteristics, which would require the tyre manufacturers data and further analysis.

VII. Investigation into the Effect of the Applied Steering Input

A. Introduction
The measured steering range of a modern sports motorcycle varies across models depending on the geometric rake and trail settings with a common range in the order of ten degrees from left lock to right lock. The manner in which a motorcycle counter steers to manoeuvre through a corner is widely published with some differing points of view existing on what the effect is from the steering input. This investigation aims to explore the steering input range of operation and how it contributes towards the vehicle negotiating a turn.

B. Background
The authors of ‘Steering Characteristics of Motorcycles’ applied a significant amount of rigor and detail on behalf of the Yamaha Motor Company Ltd to validate some modeling developed by Cossalter and Kageyama et all. The team quantified the validity of two techniques used to accurately assess the slip angle of a motorcycle during steady state cornering. They achieved this by conducting a comparative study between data logged by an inertial GPS sensor and an optical slip sensor simultaneously, yielding similar results even at large roll angles. This group of researchers furthered their comprehensive study to determine stability factors such as the slip angle factors, steering torque factors, and diagrams for the acceleration index and the steering ratio which are factors that are not easily affected by the rider’s lean posture and inputs and could potentially be used as an index to characterise the motorcycle alone. They stated that the steering torque factors vary greatly depending on the rider’s lean posture and the testing method, which implies that a carefully considered approach must be employed when investigating the human input effects of the system revolving around steering inputs and present theories to accurately isolate the appropriate variables for consistent evaluation [11].

C. Physical Results
The data obtained from the steering inputs during a test session are depicted in the plot below at Figure 9. We can see from the data that throughout the majority of the session the operational range of ±2 degrees is all that is required to induce the appropriate roll angle to negotiate the variety of corners on the circuit. Within the data set there are two distinct peaks where the steering angle range approaches a maximum. The first peak at marker A, describes the slow maneuvering action of turning left out of the pit garages to line up at the grid. The second peak at marker B describes an instance where the rider ran deep in a corner and off track during a session and had to conduct a slow left hand turn to resume the session.

The fidelity of the data set could look to be improved as it was expected that there would have been more indicative data on the counter steer action input, to generate the roll of the motorcycle to negotiate the corner.

Figure 9: Data collected from testing at Eastern Creek on 28 Nov 2013
E. Findings

The steering input generated during high speed cornering is within the range of ± 2 degrees indicating most cornering effort is a product of the counter steer action to move the centre of gravity and induce the roll of the motorcycle.

VIII. Conclusions

During the conduct of this investigation there were varying levels of success obtained across the sub-topics explored. The design and development of a data acquisition system was definitely achieved enabling the subsequent investigations to commence for the project.

The data set collected to physically describe the transient phase of cornering, identified suitable indicators to describe the dynamics of the motorcycle with a positive development in defining the system through a corner. It also provides an avenue to support future theoretical modeling research and subsequent claims.

During the investigation into the effect of the applied load on the foot pegs, our findings inconclusively supported the claim that the applied load is a perceived stability generated by the rider, which allows the rider to lock in and hold on to the motorcycle. It also highlighted the requirement for additional research to be conducted with tyre modeling to validate the claim and produce a more definitive conclusion.

While exploring the applied steering input generated during high speed cornering it was discovered that most of the cornering effort is a product of the counter steer action induced by a steering input of ± 2 degrees to move the centre of gravity and initiate the roll of the motorcycle.

These investigation validate some of the existing theoretical modeling concepts conducted by other authors in the field and was required to provide further understanding to the riding population on the effect of their conscious inputs into the motorcycle-rider system. These findings will ultimately lead to a more precise level of control and avoidance of serious injuries from a lack of knowledge by the rider.

IX. Recommendations

It is recommended that subsequent investigations be conducted within the following topics related to this project to further evaluate the effect of human inputs on motorcycle vehicle dynamics:

1. How the combined rider-motorcycle system operate; particularly the dynamic effect and input of the rider moving the system’s centre of gravity to control the motorcycle;

2. The development of a mathematical model, to convert the theoretical path radius of the vehicle from physical data to create a practical road model to correlate theoretical and physical results; and

3. How the applied load to the foot peg influences the tyre characteristics during a corner with the use of the manufacturers tyre data to qualitatively evaluate if a change in the actual contact patch is evident.

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