

Development and Validation of PitBike Model in VI Grade

Joshua Edward Watson 1900149

Mr Joshua Edward Watson, MSc Motorcycle Engineering, University of Wales Trinity Saint David, Swansea, SA1 8PH

Abstract – *The aim of this report is to construct a VI-BikeRealTime simulation model representative of a M2R Racing RF140SM pit bike and validate the results against a real-world 2D Datarecording data set from Kinsham Raceway. The report aims to fairly evaluate both sets of data and provide reasonable comparisons and discuss any problems found.*



Figure 2 - M2R Racing RF140SM pit bike that was used.

1. INTRODUCTION

There were several stages that contributed to the overall completion of this report. Each stage will be shown, and its importance explained. The use of 2D Datarecording [1], VI-BikeRealTime [2], and Microsoft Excel were used through the entire process.

Kinsham Raceway [3] was used for the tests as it was accessible to the author and the circuit is perfect for pit bike use. The circuit offered a suitable number of corners both left and right, paired with some straight sections where the speed of the pit bike could be measured through the data logging apparatus.



Figure 1 - Kinsham Raceway, image taken from Google Earth Pro.

The pit bike used for this process was a M2R RF140SM. A 4-speed, 140cc pit bike with 12-inch wheels and slick tyres. Due to the pit bike being small, Kinsham Raceway was decided to be the perfect testing location to obtain initial, real-world data that could later be used to validate the model created in VI-BikeRealTime.

2. 2D Datarecording Hardware

So that the tests could be completed, a data acquisition package was fitted. The package was manufactured by 2D Datarecording and consisted of a range of sensors and potentiometers across the bike that fed their information back to a logging unit which stored the measured data until it was downloaded via USB cable to be analysed on 2D WinARace [4] analysis software.

The bike was equipped with the following:

- Front and rear wheel speed
- Front and rear tyre temperature
- Front brake pressure
- Front and rear suspension position
- Throttle position
- Dashboard

More generic information like RPM were measured through Controller Area Network (CAN) which could then also be viewed in the analysis software.

3. Physical Measurements

Before any comparison or validation of data could take place, full measurement of the pit bike was needed so that all input parameters were known for use in VI-BikeRealTime. The program required a range of chassis, brake, aerodynamic, and wheel measurements so that an accurate representation of the motorcycle could be generated in VI-BikeRealTime.

CHASSIS			
Fork Angle	22.40	deg	
Fork Length	735.00	mm	
Tube Length	449.00	mm	
Tube Diameter	39.00	mm	
F Axle Offset	30.00	mm	
Fork Position	19.00	mm	
Yoke Offset	23.00	mm	
Main Spring	2.50	N/mm	
F Rider Sag	35.00	mm	
Swingarm Pivot Hor (F Axle)	800.00	mm	
Swingarm Pivot Vert (Ground)	375.00	mm	
Swingarm Length	430.00	mm	
Swingarm Angle	12.38	deg	
SA Shock Mount Hor (Pivot)	110.00	mm	
SA Shock Mount Vert (Pivot)	54.00	mm	
Frame Shock Mount Hor (Pivot)	0.00	mm	
Frame Shock Mount Vert (Pivot)	275.38	mm	
F Sprocket Hor (Pivot)	84.00	mm	
F Sprocket Vert (Pivot)	28.00	mm	
Shock Length	320.00	mm	
Shock Main Spring	90.40	N/mm	
R Rider Sag (Shock)	20.00	mm	
Wheelbase Unladen	1200.00	mm	
Wheelbase Laden	1220.00	mm	

Figure 3 - Chassis measurements taken from the pit bike to be used in VI-BikeRealTime.

Using a spare engine that was dismantled, it was possible to check the individual gear ratios that the pit bike has, from which individual gear ratio could be calculated by using the following equation.

$$\text{Gear Ratio} = \frac{\text{Num. Output Teeth}}{\text{Num. Input Teeth}}$$

Equation 1 - Gear ratio equation.

GEARING			
	Primary	Counter	Ratio
1st	11	36	3.27
2nd	16	31	1.94
3rd	20	27	1.35
4th	23	24	1.04
Primary Drive	18	67	3.72
Final Drive	15	38	2.53
Chain Pitch	0.500	inch	
Chain Links	106	Ne	

Figure 4 - M2R Pit bike gearbox ratios.

It was necessary to run the pit bike on a rolling road dynamometer on the university premises to determine power and torque readings for the entire rpm range. This data would be used then to generate a power map that was inserted into VI-BikeRealTime. The data was manipulated using MATLAB, and two plots were generated for display purposes within this report.

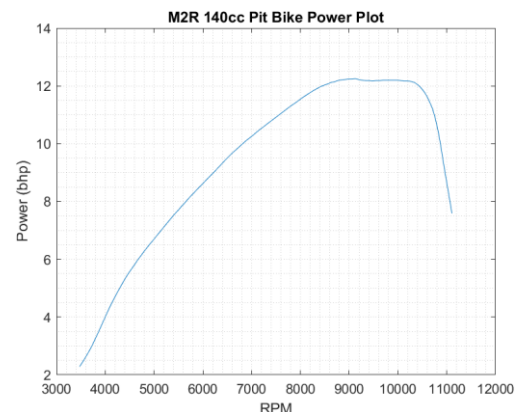


Figure 5 - M2R pit bike power plot from MATLAB using dynamometer data.

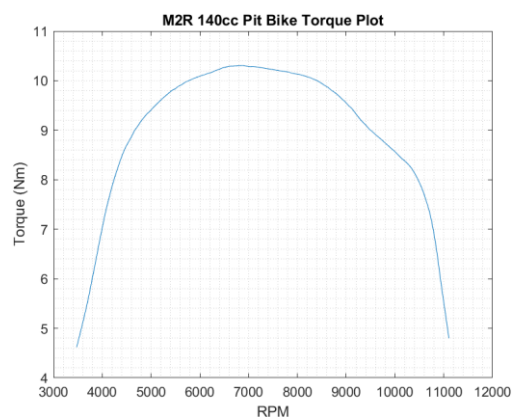


Figure 6 - M2R pit bike torque plot from MATLAB using dynamometer data.

Both front and rear wheel inertia were measured using an experimental setup which can be seen below where the wheel would be mounted and released. Stop watches were used to measure the time taken for the wheel to reach the end of the rig. With this measurement, and the mass of the wheels it was then possible to calculate wheel inertia.



Figure 7 - Experimental setup for measuring front and rear wheel inertia.

For accuracy purposes, timings were taken three times and then an average of those three values were taken. Thus, to reduce the chance of any anomalous results.

WHEEL INERTIA			
Platform Height	144	mm	
Platform Length	1000	mm	
F Spindle Radius	12.00	mm	
F Wheel Radius	235.00	mm	
F Wheel Mass	5.45	kg	
1st Trial	34.77	sec	
2nd Trial	34.02	sec	
3rd Trial	33.94	sec	
F Wheel Inertia	0.65	kg.m ²	
R Spindle Radius	12.00	mm	
R Wheel Radius	240.00	mm	
R Wheel Mass	7.15	kg	
1st Trial	36.71	sec	
2nd Trial	37.52	sec	
3rd Trial	36.75	sec	
R Wheel Inertia	0.99	kg.m ²	

Figure 8 - Front and rear wheel inertia data and calculated values.

Using a damper dynamometer in the university workshop, both the front and rear suspension systems were tested to gain data that could be used to generate damping files that would be necessary for use within the VI-BikeRealTime model.

Due to the data collection on every individual adjustment position, the following figure shows data for one position on both front and rear suspension. The same data was collected for each adjustment position.

Fork Damping Shock Damping

	1st Click (Fully out)			1st Click (Fully out)	
	Force	Velocity		Force	Velocity
COMPRESSION	180.60	0.000	COMPRESSION	131.36	0.00
	101.83	0.020		444.19	0.02
	155.49	0.040		487.27	0.04
	113.89	0.060		523.54	0.06
	157.65	0.080		548.88	0.08
	113.89	0.101		604.23	0.10
	151.07	0.120		634.37	0.12
	86.52	0.140		697.20	0.14
	148.92	0.160		734.81	0.16
	179.52	0.180		769.63	0.18
	116.05	0.200		831.13	0.20
	157.65	0.220		873.43	0.22
	239.76	0.240		920.52	0.24
REBOUND	165.30	0.000	REBOUND	-86.61	0.00
	149.99	0.021		-964.83	0.02
	108.40	0.040		-2400.53	0.04
	135.77	0.059		-3666.47	0.06
	79.95	0.080		-4869.02	0.08
	76.62	0.100		-5965.43	0.10
	18.64	0.121		-6985.62	0.12
	31.78	0.141		-8142.97	0.14
	-38.36	0.160		-9153.11	0.16
	-83.19	0.180		-10381.00	0.18
	-39.44	0.200		-11594.93	0.20
	-61.31	0.220		-13124.26	0.22
	-93.10	0.240		-13379.06	0.22

Figure 9 - Front and rear damper data collected from the damper dynamometer.

Center of gravity was also measured both with and without a rider to gain a greater level of accuracy. It was measured with a rider of 89.7kg while wearing full riding equipment including helmet, leathers, and boots.

CG BIKE			
Bike Levelled F R	36.00	36.30	kg
Bike Lifted F R	40.00	32.30	kg
Bike Levelled + Rider F R	58.00	104.00	kg
Bike Lifted + Rider F R	77.00	85.00	kg
Stool Height	300		mm
Rider Weight	89.7		kg
CG Hor Vert	783.21	801.52	mm

Figure 10 - Center of gravity data and calculated values.

Using mathematical methods, it was possible to calculate center of gravity of front and rear suspension systems, as well as the inertia of internal engine components like the crankshaft, clutch basket, and final drive sprockets.

The final measurement that had to be taken to contribute toward the VI-BikeRealTime model was frontal area of the pit bike, measured in m². This was completed using an image of the front of the pit bike with the rider sat in an upright riding position whilst in full riding gear. Using a transparent grid overlay it was possible to scale the grid and count the number of squares that the pit bike and rider took up, which from that allowed the frontal area to be calculated.



Figure 11 - Frontal area image with transparent grid overlayed for calculations.

4. Real World Data

Data logged from the test session at Kinsham Raceway has been analysed for use within this report. Important channels were gathered onto one worksheet and laid out clearly so that analysis was effective.

Over the whole test session, there were eight 'runs' recorded with the rider completing around 10 laps per 'run'. Over a lap distance of 0.747km the best recorded lap time of the test session was 0m 49.600s. For comparison and validation within this report, this lap was considered as the 'ideal' lap time. Over the rest of the laps recorded, an average lap time of around 0m 51.000s was observed. This report aimed to replicate that lap time through the VI-BikeRealTime model, and it was deemed that if the model could achieve a time close to the 'ideal' then it could be deemed a significant success.

Measuring values	
	323-PITBIKE-04
Lap	12
Time tot	0:49.600
m total	11:47.679
Time Lap	9735
m Lap	0:49.599
	747

Figure 12 - 'Ideal' lap time taken from the real data recorded by the 2D data recording system.

Data collected at the Kinsham Raceway test had some slight issues with sensor reading irregularities, which provided some clearly inaccurate information. However, it was possible to identify a specific lap of 0m 50.752s, this was done using lap triggers and provided a lap that had comprehensive information that could be used for comparison.

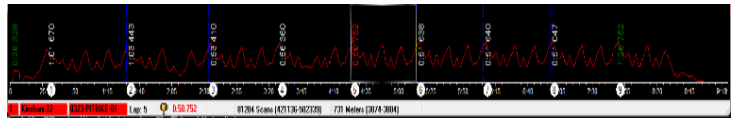


Figure 13 - 2D Datarecording lap triggers were used to identify laps within the data set.

The following figure presents the lap that was utilized for comparison against the VI-BikeRealTime model.

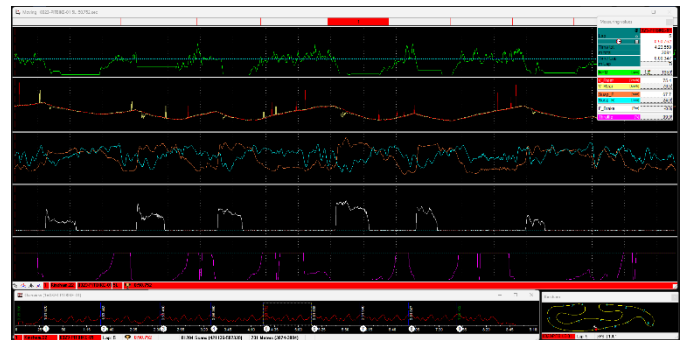


Figure 14 - 0m 50.7s lap chosen to use for comparison with VI-BikeRealTime model results.

Using the export tool within 2D WinARace, it was possible to export the channels shown in figure 14 to a Comma-Separated Values (CSV) file to be opened and manipulated within Microsoft Excel.

Channels used for comparison were:

- RPM
- V_Front (front wheel speed in Kmh)
- V_Rear (rear wheel speed in Kmh)
- Susp_F (front suspension position in mm)
- Susp_R (rear suspension position in mm)
- F_Brake (front brake pressure in bar)
- Throttle (%)

With the data accessible in Microsoft Excel, a plot for each of the channels listed above was created over the entire lap.

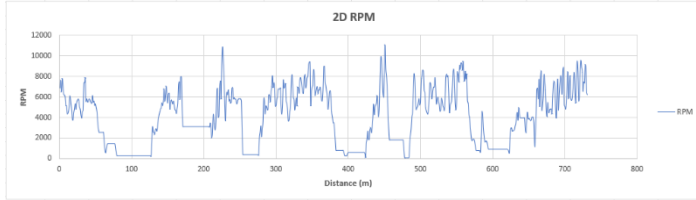


Figure 11 - RPM plot from the exported 2D lap of Kinsham Raceway.

It can be observed that the RPM trace shown in the above figure is relatively loud and contains multiple peaks and fluctuations in reading. This could be due to the method of reading RPM on the bike may not have been suitable. A 50Hz filter was applied to the trace which reduced some fluctuation. Filtering the trace has helped slightly in a visual sense, however this obviously has no effect on the physical RPM values. It is also unknown why RPM drops to around 100 in some areas. This is deemed to be highly unlikely due to the pit bike having an idle RPM of around 1000.

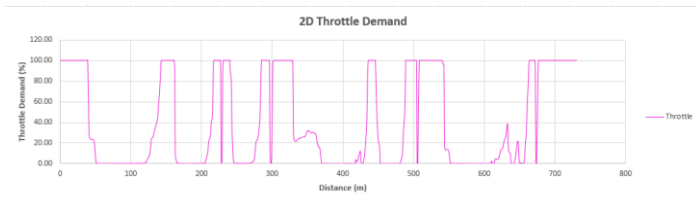


Figure 16 - Throttle demand plot from the exported 2D lap of Kinsham Raceway. Values are measured in percent.

As would be expected, the throttle demand trace aligns with RPM.

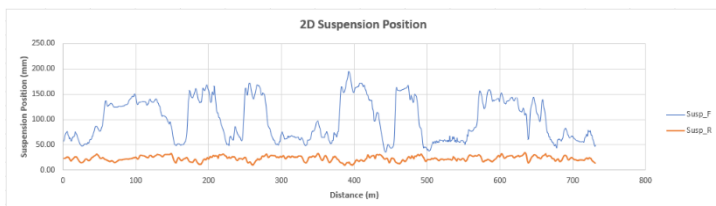


Figure 17 - Suspension position plot front (blue) and rear (orange) from the exported 2D lap of Kinsham Raceway. Values are measured in mm.

Both suspension traces have been collected through linear potentiometers mounted on the front fork and rear shock of the pit bike. The traces are acceptable and will be suitable for comparison of their trends, the front suspension trace reaches values of around 180mm, which is representative of the 190mm fork travel of the pit bike.



Figure 18 - Front (blue) and rear (orange) wheel speed traces from the exported 2D lap of Kinsham Raceway. Values are measured in Kmh.

Both front and rear wheel speeds were perfectly suitable for comparison against the VI-BikeRealTime model. Thin 'spikes' in a positive direction were disregarded from comparison. The reason for such 'spikes' could be due to vibration affecting sensor reading. It was encouraging that both wheel speeds followed a general trend and matched each other, suggesting that both sensors were working suitably for the majority of the session.

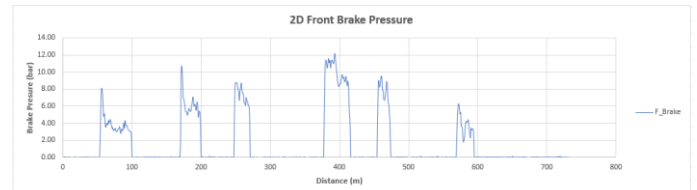


Figure 19 - Front brake pressure plot from the exported 2D lap of Kinsham Raceway. Values are measured in bar.

Data gathered regarding front brake pressure was taken to be successful. Peak readings of around 12 bar were observed, which is possible when the rider applies front brake while approaching a turn.

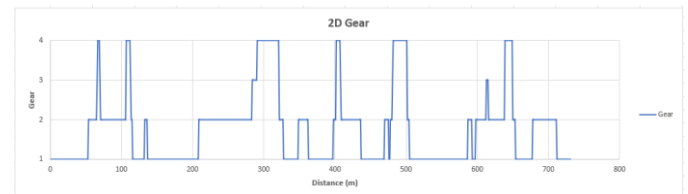


Figure 20 - Gear plot from the exported 2D lap of Kinsham Raceway.

5. VI-BikeRealTime Simulation

Using information discussed within section three of this report, a VI-BikeRealTime model was constructed.

5.1 VI-Road

To accompany the bike/rider model, it was necessary to create a track using VI-Road [5]. VI-Road is a circuit building software that works from a line generated as a KML/KMZ file. In this case to ensure accuracy, the exact GPS line that the rider followed on the exported lap was exported to Google Earth Pro, where the line could be exported as KMZ to VI-Road to be used as the path that the VI-BikeRealTime model would follow.



Figure 21 – GPS path that the rider followed on the exported lap from 2D, which was converted to a KMZ file for use in VI-Road.

Once the KMZ file had been exported to VI-Road, a circuit was then built around this path which resulted in a circuit that would be used in the simulations. This simulation circuit provided high accuracy and would provide the best possible chance of achieving comparable lap times.

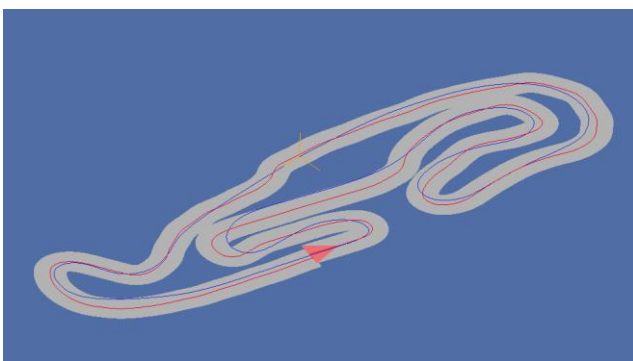


Figure 22 – Kinsham Raceway created in VI-Road using GPS path from exported 2D lap.

It is worth noting that in a visual sense, the circuit could have been improved with kerbs, and surface textures. However due to time constraints and the prioritization of actual simulation results, the circuit shown in figure 21 was suitable for use.

5.2 Simulation Initial Parameters

Once the bike model had been generated, and the circuit was complete, it was possible to begin setting up a simulation.

There are various choices of simulation that VI-Road contains, however it was decided early that for this simulation, a MaxPerfMoto simulation type would be used.

The reasoning for this was since the MaxPerfMoto simulation is iteration based, meaning that the simulation solver will continue to attempt to solve the simulation until it finds a feasible result. This works from a set of pre-defined parameters that are shown in the following figure.

VI Grade MaxPerfMoto Simulation Input Parameters							
Laptime: 0m 53.7s							
Initial Speed	Initial Gear	Long. Accel. Performance Factor	Long. Brake Performance Factor	Lateral Performance Factor	Correction Step	Max Allowable Path Distance	Max Iterations
mm/s						mm	
30,000	4	1.5	1.5	1.8	0.01	1050	200

Figure 23 – VI-BikeRealTime simulation input parameters that provided the best lap time of the simulation runs at 0m 53.7s.

Figure 23 shows the simulation parameters that were used to achieve the fastest lap time of all simulation runs completed. In total there were around 75 runs attempted. Each run was completed with slightly different input parameters, resulting in varying lap times with 0m 67.2s being the slowest and 0m 53.7s the fastest. Three runs were conducted at almost identical input parameters to those shown in figure 23 to confirm the lap time. At this point, no simulation run had achieved a better result, so this was taken to be the lap that would be compared and validated with the 2D data.

Plots containing data like those taken from the 2D data export were automatically generated by VI-Road as the simulation was running, which are shown below.

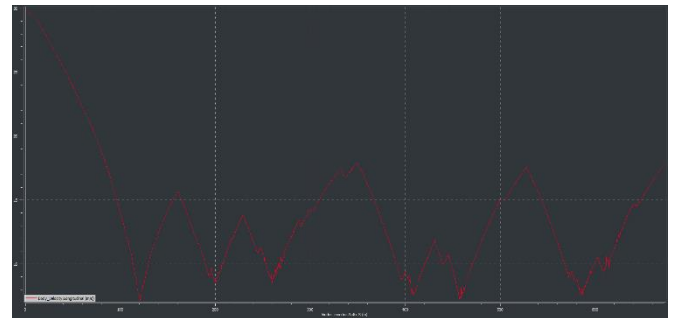


Figure 24 – Velocity trace taken from the VI-BikeRealTime simulation lap. Values are measured in m/s.

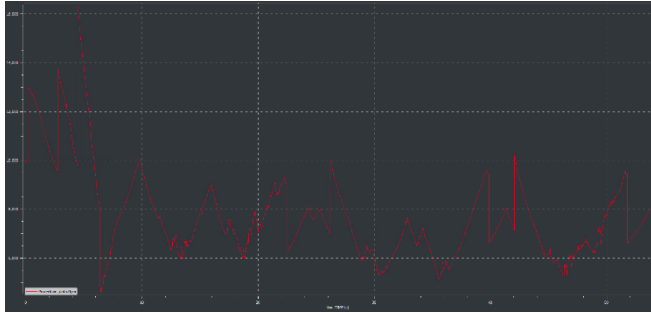


Figure 25 – RPM trace taken from the VI-BikeRealTime simulation lap.

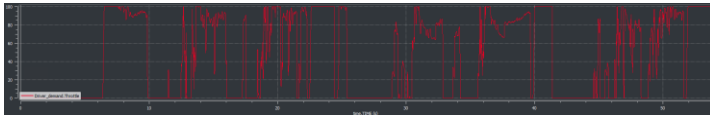


Figure 26 – Throttle trace taken from the VI-BikeRealTime simulation lap. Values are measured in percent.



Figure 27 – Front (red) and rear (blue) brake pressure trace taken from the VI-BikeRealTime simulation lap. Values are measured in N/m^2 .

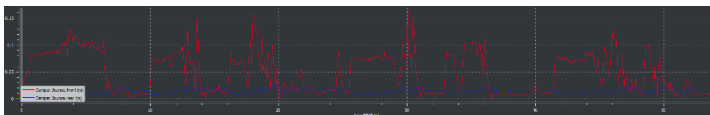


Figure 28 – Front (red) and rear (blue) suspension position trace taken from the VI-BikeRealTime simulation lap. Values are measured in m/s.



Figure 29 – Front (red) and rear (blue) wheel speed trace taken from the VI-BikeRealTime simulation lap. Values are measured in m/s.

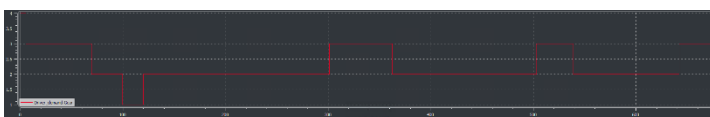


Figure 30 – Gear position trace taken from the VI-BikeRealTime simulation lap.

Upon completion of the simulation and the collection of results, as shown in previous figures. The entire result file was exported to a CSV file. Using Microsoft Excel, raw data was organized and a series of plots, identical to those shown in figures 24-30 were created.

Quick analysis of the results from the VI-BikeRealTime simulation showed that most of the data followed general trends similar to what had been observed from the 2D data. This was an encouraging observation and gave early indications that the model had successfully generated results that could be feasibly compared with a real-world data set.

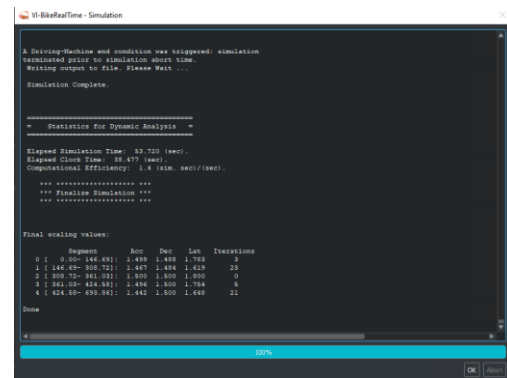


Figure 31 – Simulation dialogue window showing completion of simulation.

As figure 31 shows, the simulation was complete after 53 iterations, completing a lap time of 0m 53.7s.



Figure 32 – View of the simulation as it was completing in VI-BikeRealTime.

Full comparison and validation will be conducted within following sections of this report with conclusions drawn on any findings.

6. Comparison and Validity of Results

Microsoft Excel was used to combine both sets of results and produce a full set of overlaid plots. The plots are shown and discussed below.

Note: Larger sized overlaid figures are provided at the end of this report for referencing to.

6.1 RPM

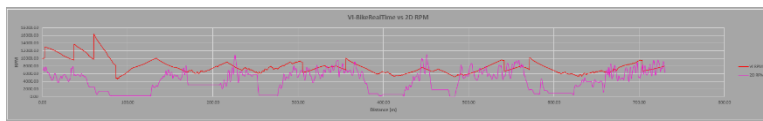


Figure 33 – Overlaid RPM data from 2D (pink) and VI-BikeRealTime (red).

Initially, the VI trace starts very high, with three ‘peaks’, this is due to simulation starting parameters being set to a high initial speed and starting in fourth gear. Each of those three ‘peaks’ is the downshift of the VI-BikeRealTime model.

Once those peaks had settled and the lap progresses, there are a series of progressive peaks and low points as it progressed through the lap. The first of these can be seen beginning at around 80m and ending around 160m. These are acceleration phases, and when cross referenced to the 2D track map, this correlated with the straight section of circuit on approach to turn 1.

In terms of general trend matching, the 2D RPM was much lower than the VI-BikeRealTime RPM. Potential reasons for this could be due to slight differences gear selection around the circuit, or a potential issue with the method in which the 2D RPM was measured.

Additionally, points at which the 2D RPM began to increase and decrease when compared with the VI-BikeRealTime RPM were slightly later. Reasoning for this could be due to the fact that there was no absolute definition within the simulation model as to where throttle should be opened and closed, this was controlled completely by the simulation AI.

6.2 Wheel Speeds

Three plots have been generated to illustrate wheel speed comparisons. A combination of front and rear wheel speeds from 2D and VI, along with separate plots for front and rear wheel speeds respectively.

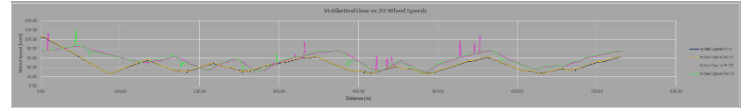


Figure 34 – Wheel speed comparison plot combining front and rear speeds from 2D and VI-BikeRealTime.



Figure 35 – Wheel speed comparison plot of front wheel speeds.

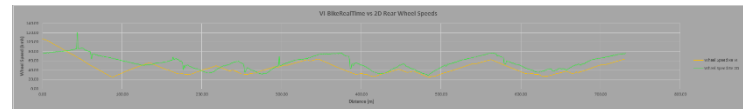


Figure 36 – Wheel speed comparison plot of rear wheel speeds.

Generally, all wheel speed traces followed a similar trend in the same areas of the lap. Similar to the point made when discussing RPM, the 2D data traces increase and decline at slightly later points in comparison to the simulation model. Again, it could be suitable to determine points at points on the circuit where the simulation model should pick up the throttle, and release.

As mentioned previous in this report also, there are some issues with ‘spikes’ in the 2D traces, which in this comparison have been disregarded. The reason for these ‘spikes’ could have been due to sensor issues when testing or mounting errors.

Across the lap, the 2D trace reached wheel speeds of around 80kmh, whereas the VI-BikeRealTime model had reached speeds of roughly 60kmh. This could have contributed to the deficit in lap time between the two sets of data.

6.3 Suspension Position

Like wheel speed, three plots have been generated to highlight suspension position comparison. One with both data sets combined, one with only front suspension position, and one with only rear suspension position.

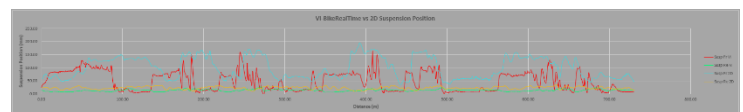


Figure 37 – Suspension position plot combining both front and rear 2D and VI-BikeRealTime data sets.

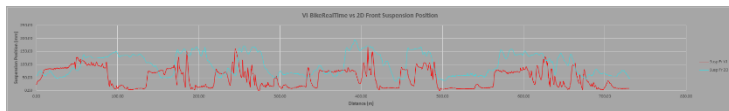


Figure 38 – Suspension position plot showing both front suspension position traces.

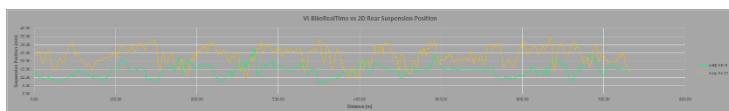


Figure 39 – Suspension position plot showing both rear suspension position traces.

Generally, the suspension traces are good and follow the same general trends throughout the lap. There are no excessive peaks shown in the 2D data, however the VI-BikeRealTime front trace is quite loud and has considerable fluctuation.

This could have been due to excessive amounts of brake being applied during the simulation. This was something that was observed when reviewing the simulation, the rider would apply aggressive amounts of brake often, which causes the front suspension to compress excessively. This point can be backed up further when comparing front brake pressure data.

It was also noted that upon observing figure 39 that the simulation model utilized less rear suspension travel. A potential reason for this is that the simulation model doesn't take into account rider mass, and therefore there is less load transfer causing the suspension to compress and rebound.

6.4 Front Brake Pressure

Due to the pit bike only having a front brake pressure sensor fitted, only the front brake pressure was compared within this sub-section.

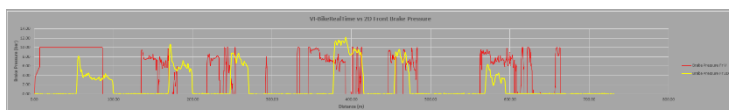


Figure 40 – Front brake pressure traces from 2D (yellow), and VI-BikeRealTime (red).

It was clear to see that both traces followed very similar patterns and reached almost identical peak values of around 10 bar, except for one small peak at around 400m into the lap where the 2D trace saw a peak of just over 12 bar. These data traces are representative of each other,

and it can be said that the simulation model replicated braking behaviour of the 2D trace accurately.

Like what has been noted in previous comparison sections, the 2D trace actually began braking at a later point in the lap compared to the simulation model. Again, this could have been due to their being no control over when braking occurred within the simulation model. Other than that, those braking traces shown in figure 40 compare accurately.

6.5 Gear Position

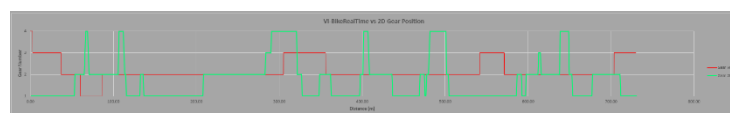


Figure 41 – Gear position traces from the 2D (green) and VI-BikeRealTime (red) data sets.

There were some obvious comparisons that could be drawn from the gear position data traces. From all the data that has been compared within this report, the gear data matches far worse, and accurate comparisons were hard to make.

It could be seen that the VI-BikeRealTime model does not utilize 4th gear through the main part of the lap. There is no clear reason as to why this happened, and if it were a real-world situation then it could have proved detrimental to the health of the engine. Instead the simulation model utilized 3rd gear for the majority of the lap.

Alternatively, the 2D data used 3rd gear very little and instead the rider utilized 4th gear much more often. It is also apparent when looking at the 2D gear data that changes between gears were very sudden. Reasoning for this could be due to the inaccuracy of the RPM reading, which is a crucial component for the calculation of gear position. If a better reading of RPM was taken, then there was confidence that the gear position trace would appear much more recognizable.

It is also clear to see that shift points were occurring at significantly different times within the lap. This was also observed when reviewing the simulation back, it appeared that the model changed gear in unsuitable locations like mid-corner which had significant impact on the corner maneuver, and ultimately the lap time.

7. Conclusions

Overall, a good-solid simulation model was created which was able to perform a lap time (0m 53.7s) that was three seconds off the lap chosen for comparison from 2D (0m 50.7s). Based on the findings that have been explored and discussed within this report, this can be taken as a success.

The majority of results that have been compared have shown generally sound comparisons, except for gear position and RPM, which their issues have both been discussed in their comparison sub-sections respectively.

The general feeling is that if there was more flexible control with VI-BikeRealTime, specifically within MaxPerfMoto simulations which allowed the possibility of defining when certain events occur, i.e., throttle increase/decrease, braking starting/stopping, and shift points around the circuit, then a faster lap time could have been achieved.

There were some issues with the 2D data set gathered from the test at Kinsham Raceway which have been discussed that could have contributed toward a difference in results. These are all things that could be explored again should the comparison occur again in future.

Generally, it is felt that the tests and simulation can be considered a success and the author is happy with the findings and comparisons made within this report.

8. References

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- [4] "WinARace — 2D Datarecording Documentation 1.0 documentation." https://help.2d-datarecording.com/WinARace_Main.html (accessed Mar. 15, 2023).
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Appendix



