

Literature Review of Current Motorcycle Dynamic Studies

Advanced Motorcycle Performance ACEA7001

Joshua Edward Watson

MSc Motorcycle Engineering

1900149

University of Wales Trinity Saint David, School of Engineering

1900149@student.uwtsd.ac.uk

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Abstract

This paper reviews current or recent studies surrounding motorcycles and their dynamics. There are three topics of discussion within this paper including integrated safety systems, all-wheel drive (AWD) systems and exposure to handlebar vibration causing Hand-transmitted Vibration (HAV) syndrome. Each topic has been reviewed in context of their original reports which have been referenced through IEEE formatting.

Keywords: motorcycle; dynamics; safety; vibration; awd

Introduction

Motorcycles are constantly evolving, along with the technology and systems that drive them. In recent years there have been significant findings and developments in this area. Motorcycle dynamics is the science of the motion of a motorcycle and its components due to forces acting on them. [1]

Integrated Safety Systems

There are some safety related developments that have been suggested involving the implementation of various on-board control systems optimised to improve the general safety and performance level of the motorcycle industry. Similar methodologies have been successfully implemented in four wheeled vehicles, 'For other vehicle types, such as passenger cars, substantial investment in improved vehicle safety systems has resulted in significant reductions in death and injury.' [2]

Some technologies that have been suggested are improved stability, braking and driver control systems. It is thought that the inclusion of such suggested systems would prevent crashes occurring. [2]

Alternative reports have also assessed the feasibility of including such systems into motorcycles and have provided some of the following results based on studies into real world crash data. This data then led to the inclusion of additional integrated safety systems on two different motorcycles for testing purposes.

For ease of reading purposes, the report that these results originate from abbreviate the names of the integrated safety systems, these abbreviations will be defined below: [3]

- ABS – Anti-Lock Braking System
- EB – Enhanced Braking System
- CB – Combined Braking System
- AB – Active Braking System
- DS – Distance Support
- THW – Time Head Way
- TTC – Time to Collision

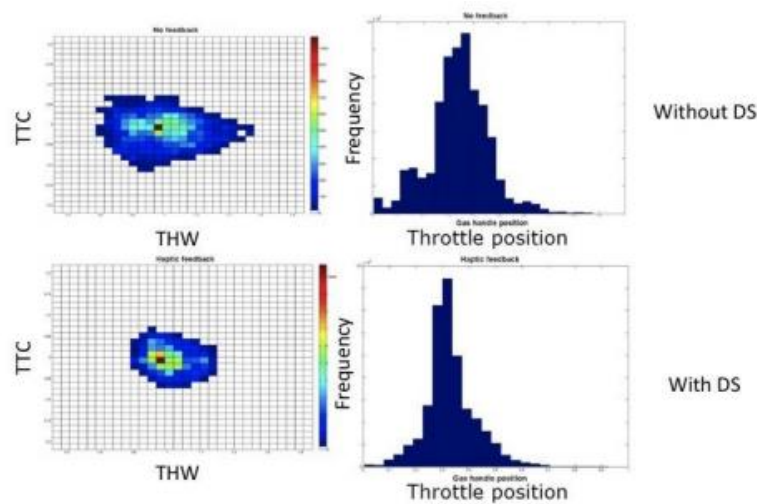


Figure 1 : Comparison with and without Distance Support. [3]

Figure 1 shows that the DS system significantly improved the ability to maintain a safe distance, in this case shown as THW, to a vehicle in front. It also shows much more stable throttle positions compared to tests without DS systems [3].

Suggesting that these DS systems would be a beneficial introduction to the motorcycle industry.

AB trigger setting	Mean speed (km/h)	Mean trigger dist (m)	Mean speed after AB (km/h)	Mean speed reduction (%)	Mean kinetic energy reduction (%)
3	46.7	23.3	24.1	48.5	73.0
5	46.6	14.8	29.9	35.9	56.2
7	47.0	7.8	34.7	26.2	44.9
9	46.3	6.2	37.0	20.2	36.0

Figure 2 : Comparison of AB results. [3]

Figure 2 shows results from AB system tests at 3, 5, 7, and 9 m/s² as a threshold of deceleration for activation of the system. The figure shows that speed reduction and kinetic energy reduction are totally dependent on initial of the vehicle. The results from these tests showed some inaccuracy due to equipment failure whilst attempting to record results. Of the results that were successful, the AB system was adequately able to provide enough deceleration to the machine without the rider losing control of the machine, therefore not crashing as a result. [3]

Given that a proportion of the tests were considered unsuccessful, it would seem appropriate to improve the test methodology and equipment for AB systems to re-evaluate the possibility of its inclusion on motorcycles. The early successful results could be considered as an indication that such a system may work but requires more thorough testing with higher success rates.

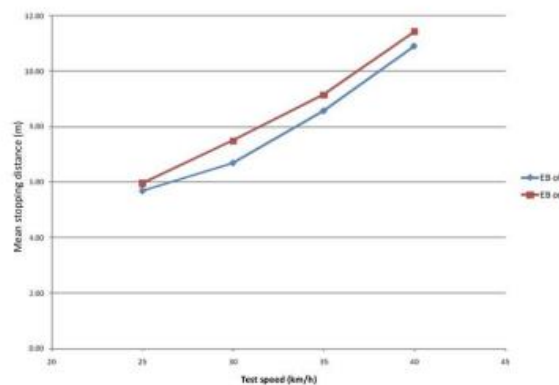


Figure 3 : Mean stopping distance with and without EB . [3]

Figure 3 shows comparative results of an EB system in terms of mean stopping distance in metres. The system was successful in increasing braking deceleration in the event of an imminent collision during the tests. These results were achieved with significantly less braking input, however produced similar results to that of a test with maximum braking input. This therefore suggesting that EB systems would be a success. [3]

All Wheel Drive Motorcycles

All Wheel Drive (AWD) systems are commonly associated with cars and other 4-wheel minimum vehicles. At present, there is only known to be one AWD motorcycle. Rokon Motorcycles produce 'the world's only true all-terrain vehicle' [4]. The Rokon motorcycle is a low powered machine designed for off-road use, this therefore proving that there are very few actual AWD road-going motorcycles.



Figure 4 : Rokon AWD motorcycle . [5]

Bonci, Longhi, and Scala [6] published a report analysing the issues surrounding previous AWD motorcycle attempts and aimed to 'find a proper mathematical representation of the motorcycle which describes the essential dynamics issues of the AWD'. [6]

The report modelled an AWD motorcycle using a range of symbolic equations of motion derived using the Lagrangian function. The analysis was conducted through a range of simple operating conditions of the motorcycle. This process allowed the authors to determine basic dynamic principles of an AWD motorcycle under development.

These tests also highlighted the impact that front wheel drive has on the overall dynamics of the AWD motorcycle with torque distribution via the front wheel. [6]

The report compared the simulated results to a validation model generated in MATLAB Simulink. Tests were mainly carried out to simulate cornering characteristics of the motorcycle, including corner entrance and corner exit whilst looking at roll angle and yaw speed. These results can be seen below.

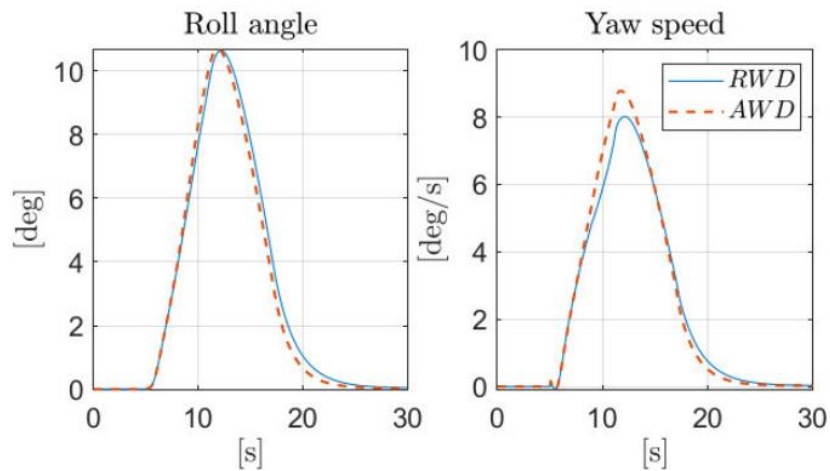


Figure 5 : Corner entrance results comparing RWD and AWD roll angle and yaw speed. [6]

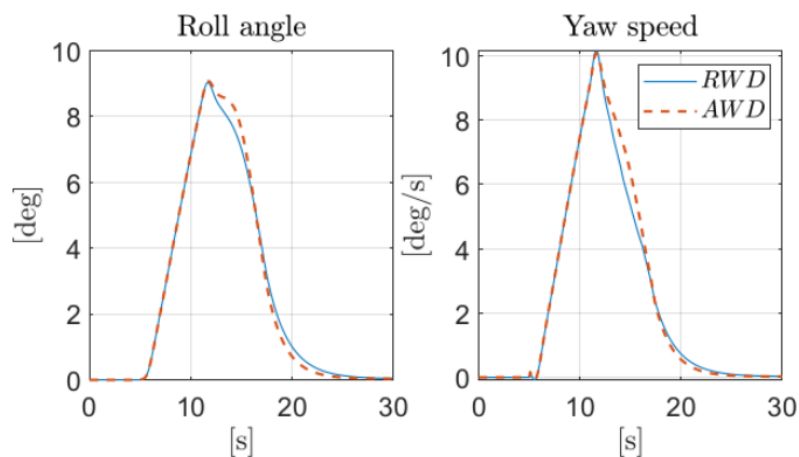


Figure 6 : Corner exit results comparing RWD and AWD roll angle and yaw speed. [6]

The report concludes that an AWD model has been successfully outlined through the methods discussed previous, and results have been compared and validated through a multibody software. The work showed little differences between AWD and RWD systems which can be seen as a positive starting point for further development.

It is apparent that based on the information presented within this paper that AWD motorcycles could be a success. However further work would be required to evaluate how an AWD motorcycle would behave in varying scenarios and performance levels.

Rubber Mounted Suspended Handlebars

Due to natural characteristics of a motorcycle, specifically their engine and their connection to the road through tyres, users are exposed to high levels of constant vibration, which can lead to hand/arm problems.

A report written by Nabil Mohamad Usamah, Ahmad Zhafran Ahmad Mazlan, and Zaidi Mohd Ripin [7] evaluates a possible solution to reduce the amount of vibration a rider is exposed to whilst riding a motorcycle. It investigated the possibility of utilizing rubber mounts to make the handlebars suspended.

Tests were conducted using an accelerometer and an impact hammer to accurately record results where the rider's hand would be gripping the handlebar. Comparative tests were carried out between stock, metallically mounted handlebars, and rubber suspended systems. The report looks at four different variations of rubber mounts made from natural rubber and steel. [7]

A test was conducted to analyse each of the suspended iterations which would record the model acceleration response at varying frequency rates. Figure 7 below shows results obtained from the tests and highlights that iterations B and D have the lowest acceleration response when compared to the stock design. This therefore showed that iterations B and D would be suitable for further analysis.

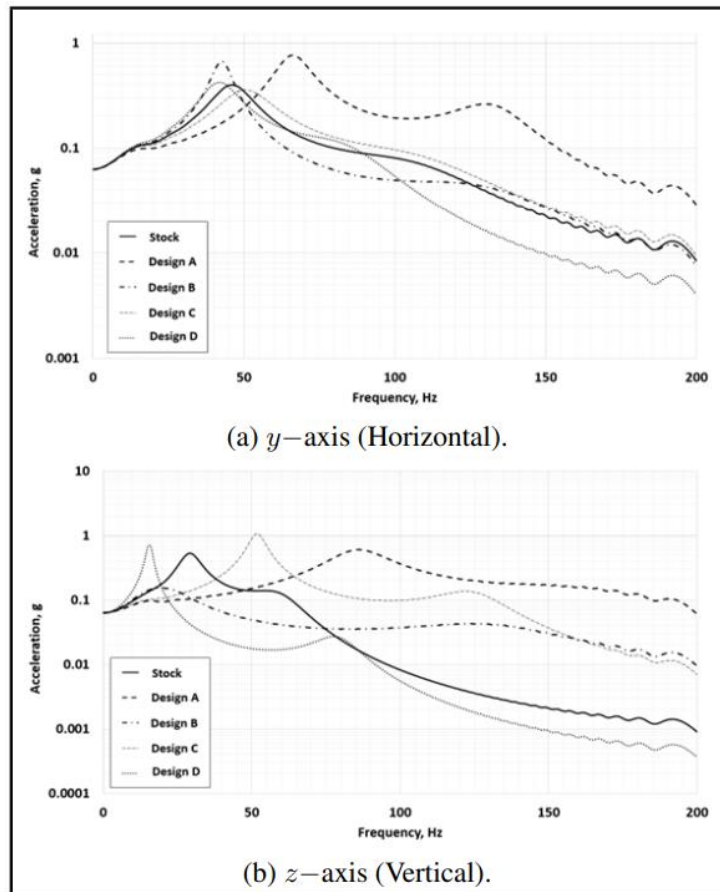


Figure 7 : Acceleration frequency response for each design iteration compared with stock design.

[7]

The report found that engine induced vibrations were the most significant vibration being experienced by the rider. It was also found that this level of vibration increased with engine speed, however this is to be expected.

Hand-arm Vibration (HAV) syndrome can be a result of exposure to high levels of vibration on motorcycles, hence the aim of this report is to identify a suitable solution to reduce this issue. The test carried out evaluated the motorcycle (assumed to be a small capacity motorcycle/scooter) to be running from 2000-4000rpm. Within this range of rpm sites, an average HAV value was 8.18m/s^2 , which based on the European Directive (2002/44/EC) it would take the rider around 45 minutes to reach this vibration action limit, and a much longer exposure period would be needed to reach the exposure limit value. [7]

Average HAV (cruising)	Stock (m/s ²)	Design A (m/s ²)	Design B (m/s ²)	Design C (m/s ²)	Design D (m/s ²)
Handlebar	8.276	5.823	5.398	6.135	4.082

Figure 8 : HAV results compared between each design and stock. [7]

As figure 8 shows, design iteration D significantly reduced average HAV exposure which further supports the suggestion that rubber mounted suspended handlebar systems could be a significant motorcycle dynamics improvement. Results showed that the suspended handlebar design could increase the time taken to reach vibration action limit from around 40 minutes to 200 minutes, which is significantly under the average amount of time spent on a motorcycle per day, this therefore reducing risk of HAV for motorcycle users using rubber mounted suspended handlebar systems. [7]

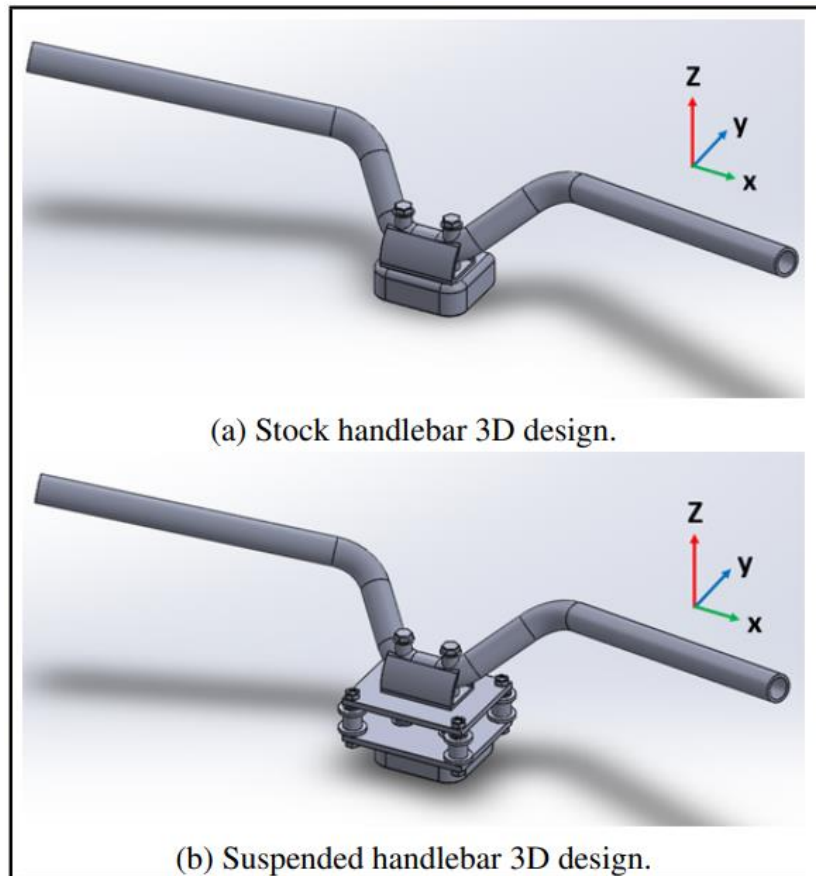


Figure 9 : Design comparison of stock and suspended handlebar design from CAD software. [7]

Conclusions

Of the three recent papers that have been reviewed within this paper, there are clear positive indicators that each of their representative areas could be a success. For both integrated safety systems and AWD systems, it is felt that further work is needed to effectively utilise the technology, however it is clear from results gathered that both could be a success.

The utilisation of rubber mounted handlebars proved that it would be a success and significantly reduce the chances of HAVs. This was especially the case for riders who use their motorcycle for short periods each day, however for longer exposure periods, further work is needed to continually reduce this issue.

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