"Motorcycle Steering Oscillation Measurements to Detect Instability Behaviour during Tyre Testing on Straight Road at Constant Speed Using IMU and Steering Angle Sensor through 2D Data Recording System"

Mr. Sharad D. Mugale[1], Mr. Mahesh H Khude [2], Mr. Kishor D. Satpute[3] , Prof. Swapnil R. Dumbre[4]

[1]*Mechanical Department & Sharadchandra Pawar college of Engg, Otur*
[2]*Mechanical Department & Sharadchandra Pawar college of Engg, Otur*
[3]*Mechanical Department & Sharadchandra Pawar college of Engg, Otur*
[4]*Mechanical Department & Sharadchandra Pawar college of Engg, Otur*

---***---

Abstract - Motorcycle stability is crucial for rider safety, especially at high speeds where issues such as weaving oscillations may occur. Traditional evaluations that depend on rider perception are subjective and inconsistent. This project aims to create an objective method for detecting and analyzing motorcycle stability during tire testing on straight roads at constant speeds. The approach employs an Inertial Measurement Unit (IMU) along with a steering angle sensor, integrated into a 2D data recording system to simultaneously capture steering oscillations and vehicle dynamics. Tests will be conducted at various steady speeds without rider input or external steering influences, addressing a gap found in current research. The collected data will be filtered and analyzed in both frequency and time domains to measure the amplitude, frequency, and timing of weave oscillations. The results will establish quantitative instability thresholds and will be compared with riders' subjective feedback regarding tire performance. The expected outcome is a validated measurement technique for evaluating motorcycle stability that aids in tire development, safety evaluations, and aligns objective metrics with rider experiences. This project, sponsored by industry, guarantees the practical relevance and application of the research findings.

Key Words: Motorcycle stability, weaving oscillations, Traditional evaluations, Inertial Measurement Unit (IMU), steering oscillations, vehicle dynamics, amplitude, frequency.

1. INTRODUCTION

Motorcycle dynamics is an area of critical importance for both rider safety and vehicle performance. Unlike four-wheeled vehicles, motorcycles rely on a delicate balance between tyre grip, steering geometry, suspension setup, and rider control. At high speeds, this balance may be disturbed, leading to instability phenomena such as weave and wobble oscillations. Weave oscillations are low-frequency lateral oscillations (2–6 Hz) where the entire motorcycle ways side-to-side in a snake-like motion. They usually occur at higher speeds and are strongly influenced by tyre characteristics, frame stiffness, mass distribution, and aerodynamic effects. Wobble oscillations are higher frequency steering vibrations (~8–12 Hz) mainly involving the handlebars, often triggered by road inputs or tyre irregularities. For tyre manufacturers and vehicle developers, understanding and quantifying these oscillations is essential for product development, homologation, and safety evaluation. Traditionally, subjective rider feedback has been the main method of assessing stability. While valuable, it has inherent limitations: it is qualitative, varies between riders, and lacks repeatability. To overcome this, objective measurement techniques have been introduced in recent years. The use of Inertial Measurement Units (IMU) allows precise capture of yaw rate, lateral acceleration, and roll dynamics, while steering angle sensors provide direct measurement of handlebar oscillations. When synchronized using a data recording system, these measurements enable a scientific evaluation of instability phenomena. This project therefore focuses on developing an experimental methodology to measure and analyse motorcycle weave oscillations under straight-line conditions at different constant speeds, using IMU and steering angle sensors. The outcome will provide quantifiable insights into tyre-induced instability and contribute to objective tyre testing methods.

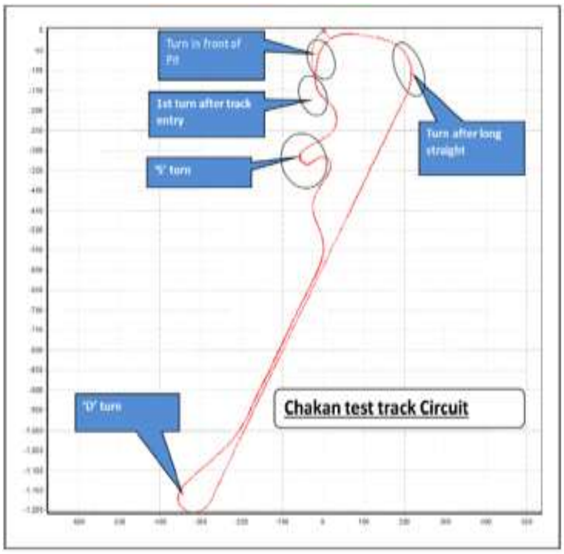

Fig. 1.1 Motorcycle Testing Track

Fig. 1.1 Form Drilling Stapes

2. OBJECTIVES:

The core aim of this project is to develop an objective and reliable methodology to detect motorcycle steering weave/oscillation behaviour during tyre testing using an IMU and steering angle sensor. The objectives can be defined in detail as follows: Objective Measurement of Instability: Capture steering oscillations and vehicle motions using high-resolution IMU and steering angle sensor data. Record yaw rates, and steering oscillation frequencies that indicate weave behaviour. Identification of Speed-Dependent Behaviour: Perform tests at different constant speeds (e.g., 100 km/h, 120 km/h, 140 km/h, 150 km/h) on straight roads. Determine the onset speed where weave instability becomes noticeable. Signal Processing and Filtering: Develop a data processing pipeline to remove noise and extract meaningful oscillation characteristics and apply frequency-domain analysis (FFT or spectral methods) to quantify weave frequency (2–6 Hz range). Correlation with Subjective Rider Feedback: Compare objective measurements with the rider's perception & establish an evaluation framework. Methodology Development for Tyre Testing: Propose a repeatable test procedure for tyre manufacturers. Industrial Application & Validation: Showcase applicability in a real-world tyre testing (industry collaboration). Provide a foundation for future research in motorcycle dynamics and tyre performance.

Weave instability is a low-frequency (2–6 Hz) side-to-side oscillation of a motorcycle occurring during straight-line travel at medium to high speeds (typically above 100 km/h). It is influenced by tyre stiffness, motorcycle geometry, speed, and tyre condition. The motion appears as a snake-like movement of the entire motorcycle, felt by the rider as steering "lightness" or instability. It can be triggered or amplified by road irregularities, aerodynamic forces, tyre-road interaction, and rider inputs.

3. CONCLUSIONS

The research trajectory clearly demonstrates a transition from purely theoretical and rider-subjective assessments toward robust, sensor-based objective measurements and active control strategies. This progression has enabled: • Accurate characterization of stability oscillations (wobble, weave) in terms of frequency, damping, and dynamic modes. • Development of advanced computational models which simulate and predict instability onset and evolution. • Incorporation of real-time sensor data in industrial applications to improve motorcycle safety and performance. • Exploration of structural design optimization and active control systems to mitigate instability across all operating conditions. Thus, the combined theoretical, experimental, and technological advances have significantly deepened understanding of motorcycle stability oscillations and paved the way for safer, more controllable motorcycles under high-speed conditions.

ACKNOWLEDGEMENT

The heading should be treated as a 3rd level heading and should not be assigned a number.

REFERENCES

1) Cossalter, Motorcycle Dynamics, 2nd ed., Lulu Press, 2006.
2) T. R. Kane, "The effect of frame flexibility on high speed weave of motorcycles," SAE Technical Paper 780306, 1978.
3) G. E. Roe and T. E. Thorpe, "The influence of frame structure on the dynamics of motorcycle stability," SAE Technical Paper 891772, 1989.
4) G. E. Roe and T. E. Thorpe, "Motorcycle instability on undulating road surfaces," SAE Technical Paper 911307, 1991.
5) R. S. Sharp, "The stability and control of motorcycles," Journal of Mechanical Engineering Science, 1971.
6) R. S. Sharp and D. J. N. Limebeer, "A motorcycle model for stability and control analysis," Vehicle System Dynamics, 2001.

7) D. J. N. Limebeer and R. S. Sharp, "Bicycles and motorcycles: Stability analysis," Vehicle System Dynamics, 2006.
8) S. A. Evangelou and D. J. N. Limebeer, "Control of motorcycle stability," IEEE Control Systems Magazine, 2007.
9) H. B. Pacejka, Tyre and Vehicle Dynamics, Elsevier, 2002.
10) T. D. Gillespie, Fundamentals of Vehicle Dynamics, SAE, 1992.
11) J. Y. Wong, Theory of Ground Vehicles, Wiley, 2008.
12) V. Cossalter and R. Lot, "A motorcycle multibody model for real-time simulations," Vehicle System Dynamics, 2002.
13) C. Koenen, "The dynamic behaviour of motorcycles," Delft University, 1983.
14) D. H. Weir, "Motorcycle handling dynamics and stability," SAE Paper, 1972.
15) H. Imaizumi and T. Fujioka, "Motorcycle-rider system dynamics by multibody analysis," SAE Technical Paper 978499, 1997.
16) T. Yoshino et al., "Stabilization compatibility between weave and wobble modes," JSAE Journal, 2021.