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Analysis of High Speed Wobble Mode using Energy Flow Method

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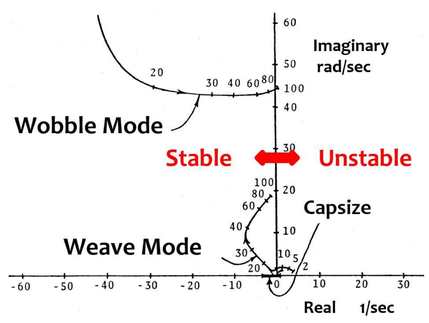
Introduction & Objectives : Detailed mechanism of high speed instability of wobble mode

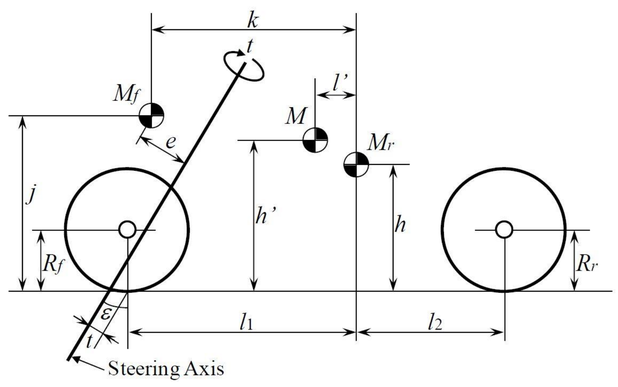
Motorcycles have instability modes at high speed range. These are called wobble and weave modes. The reasons of the **high speed instabilities** have not been understood by now.



Shows that the detailed mechanism of high speed instability of wobble mode **in a context of equations of motion**.

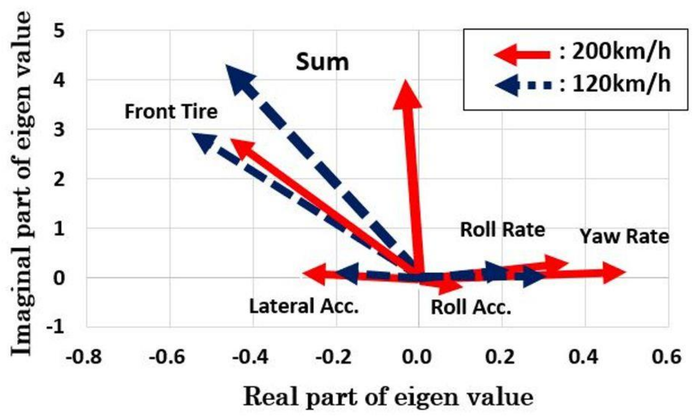
Method : Energy flow method using eigenvectors

(1) Computation Model [1]

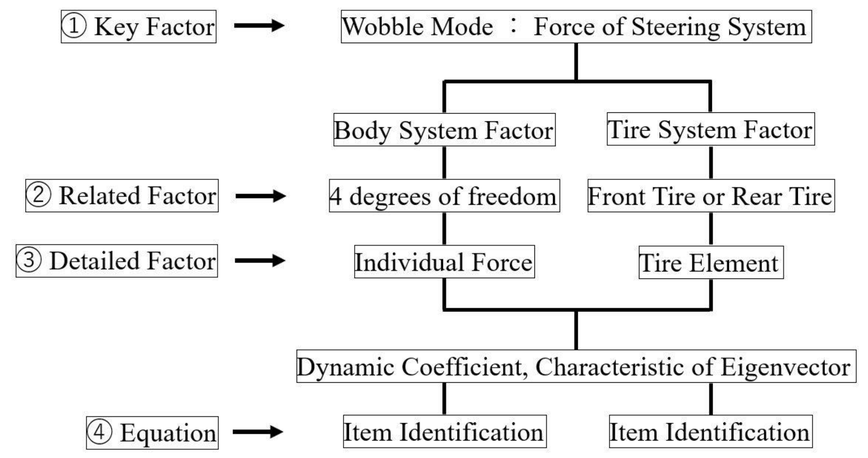


Mathematical model

(2) Configuration of Torques Acting on Steer [2,3]



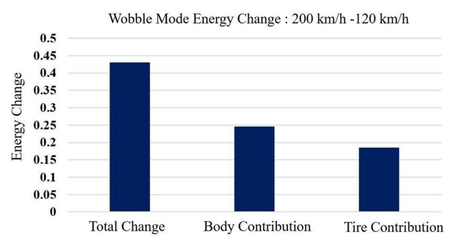
(3) Flow of Methods to Find the Cause of Straight-line Stability Change



Result : Analysis of High Speed Wobble Modes

(1) Key Factor

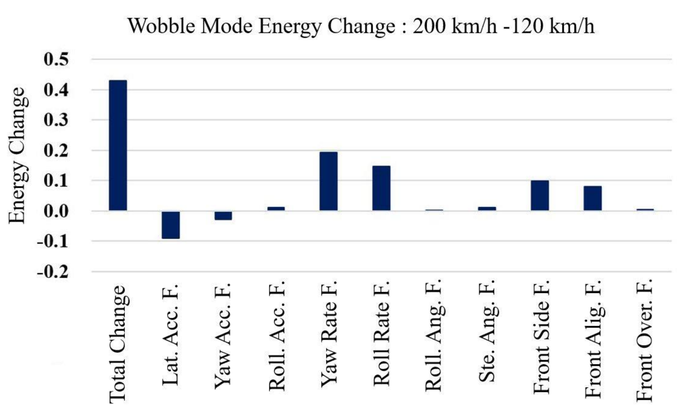
Increased **body system energy**.



Energy Change of Steering Freedom

(2) Related Factor

In the vehicle system, **yaw rate force** and **roll rate force** contribute to destabilization.

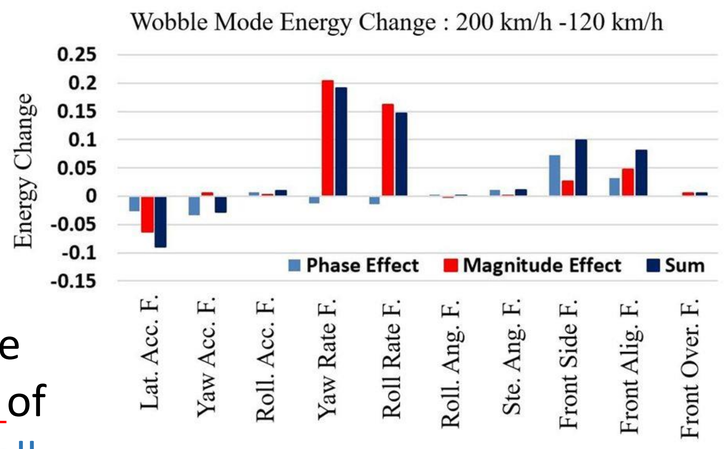


Detailed Energy Change of Steering Freedom

(3) Detailed Factor

Compare vehicle system contributions by effect. (Phase Effect and Magnitude Effect)

In the vehicle system, the **effect of the magnitude** of the yaw rate force and roll rate force is main.



Two Effects of Acting Forces on Steering Freedom (Phase Effect and Magnitude Effect)

(4) Equation

The reasons of the high speed instabilities

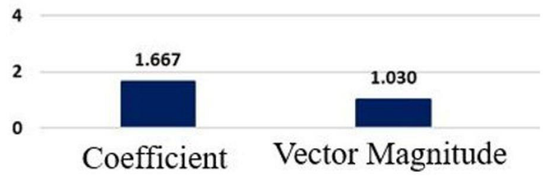
・Consideration of only **magnitude effect**

$$M_f e\ddot{y}_1 + \left(M_f ek + I_{fz}\cos\varepsilon\right)\ddot{\psi} + \left(M_f ej + I_{fz}\sin\varepsilon\right)\ddot{\phi}$$
$$+\left(I_{fz} + M_f e^2\right)\ddot{\delta} + \left(M_f e + i_{fy}/R_f \sin\varepsilon\right)\dot{x}_1\dot{\psi}$$
$$-i_{fy}/R_f \cos\varepsilon\,\dot{x}_1\dot{\phi} + \left(tZ_f - M_f eg\right)\phi$$
$$+\left(tZ_f - M_f eg\right)\sin\varepsilon\,\delta + tY_f - T_{zf}\cos\varepsilon - T_{xf}\sin\varepsilon = 0$$

Steering motion

・The magnitude effect is composed of **the coefficient** part of the equation and the **magnitude of the eigenvector**.

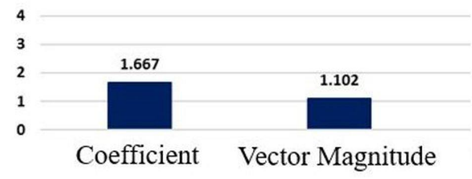
・The vehicle body factor is the speed term included in the coefficient of **yaw rate force** and **roll rate force**.



Coefficient and Eigen Vector Change Concerning Yaw Rate Force Acting to Steering Freedom

$$+\left(M_f e + i_{fy}/R_f \sin\varepsilon\right)\dot{x}_1\dot{\psi}$$

About 58%



Coefficient and Eigen Vector Change Concerning Roll Rate Rorce Acting to Steering Freedom

$$-i_{fy}/R_f \cos\varepsilon\,\dot{x}_1\dot{\phi}$$

100%

Physically, **gyro torque** increases as vehicle speed increases.

Conclusion

(1) A major factor for destabilization is the **increase in energy in the body system**.

(2) The **yaw rate force** and **roll rate force** acting on **the steering system** are increased.

(3) The reason is that the **gyro torque** increases included in the yaw rate force and roll rate force.

(4) At higher speeds, the gyro torque increases as the wheel speed increases.

References

(1) R. S. Sharp：The Stability and Control of Motorcycles, Journal of Mechanical Engineering Science, Vol.13, No.5, p.316-329 (1971)

(2) T. Katayama and T. Nishimi：Energy Flow Method for the Study of Motorcycle Wobble Mode, Vehicle System Dynamics, Vol.19, No.3, p.151-175 (1990)

(3) Y. Marumo and T. Katayama：Analysis of Motorcycle Weave Mode by Using Energy Flow Method, Transactions of the Japan society of mechanical engineers. C, Vol.77, No.781, p.3490-3501 (2011)