Analysis of High speed instability of Weave Mode in Motorcycle by Using Energy Flow Method

YAMAHA Revs Your Heart

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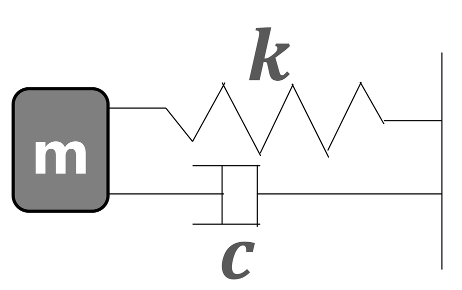
Introduction

In this report, we investigate the cause of the decrease in the stability of weave mode in high speed region using Energy Flow Method.

Degree of freedom in weave mode



Equation of motion

$$m\ddot{x} + c\dot{x} + kx = 0$$

Eigenvalue

$$\lambda = \frac{-c \pm \sqrt{c^2 - 4mk}}{2m}$$

Characteristics of damped vibration system

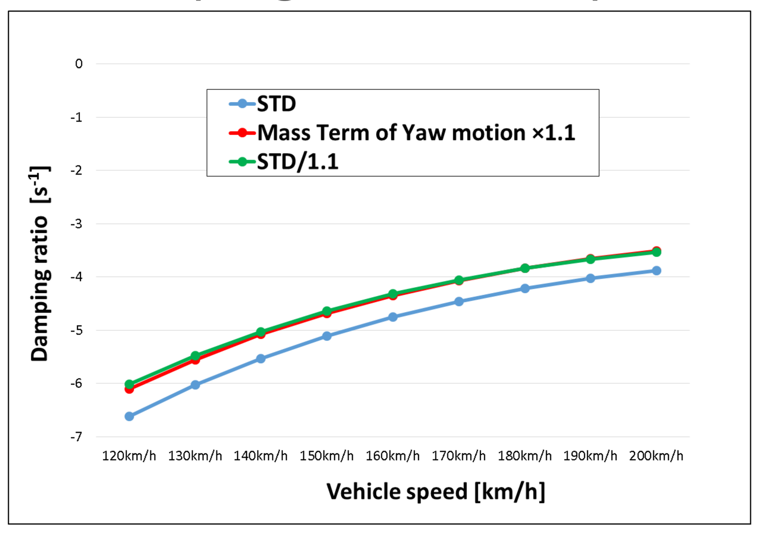
Real part of eigenvalue $\propto 1/m$
Imaginary part of eigenvalue $\propto 1/\sqrt{m}$

Given the vibration system with **one degree of freedom**, Which degree of freedom is the weave mode?

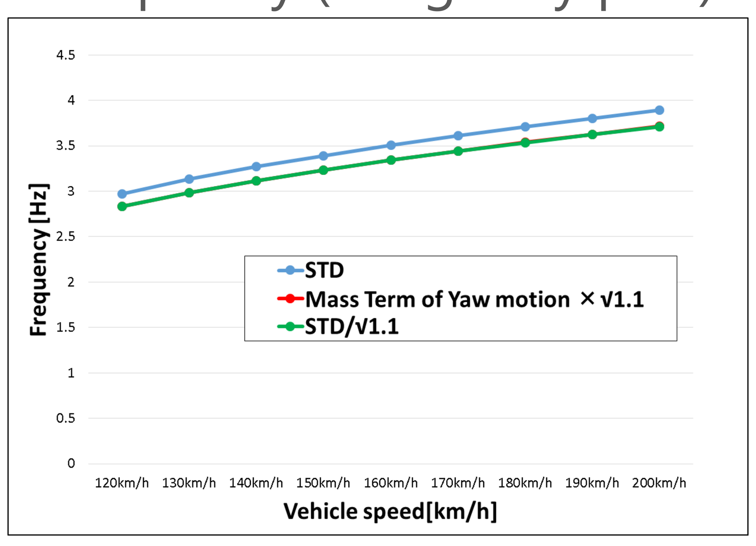
$$m\ddot{x} = -c\dot{x} - kx$$

×1.1

Damping ratio (Real part)



Frequency (Imaginary part)



Only the Yaw system almost matches !

Main freedom of weave mode is Yaw system

Energy Flow Method (EFM)

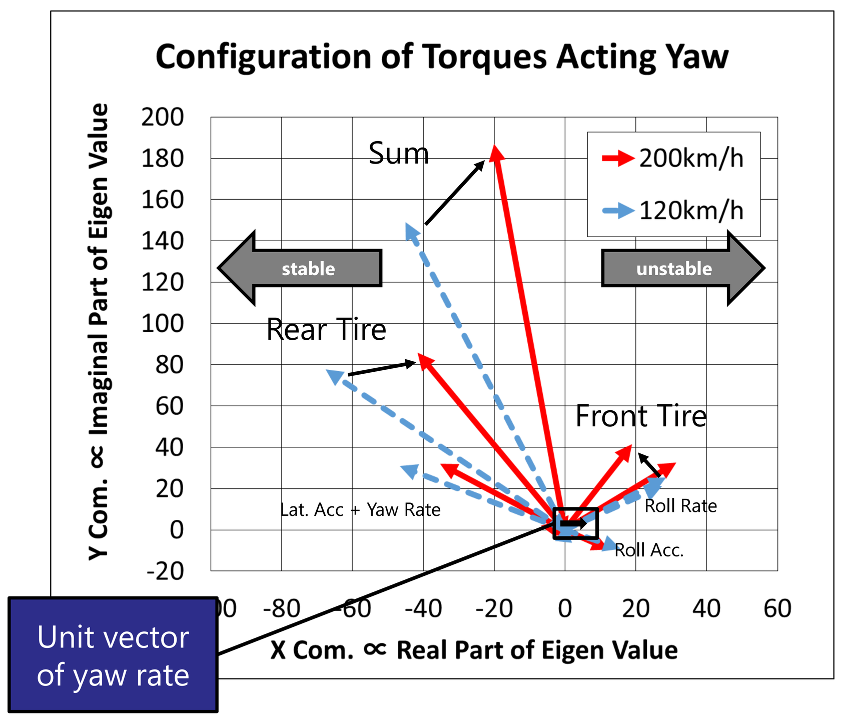
Yaw system equation

$$(M_f k^2 + I_{rz} + I_{fx}\sin^2\varepsilon + I_{fz}\cos^2\varepsilon)\ddot{\psi} = - M_f k\ddot{y}_1 - \{M_f jk - C_{rxz} + (I_{fz}-I_{fx})\sin\varepsilon\cos\varepsilon\}\ddot{\varphi} - (M_f ek + I_{fz}\cos\varepsilon)\ddot{\delta} + \{i_{fy}/R_f + (i_{ry}+\lambda i)/R_r\}\dot{x}_1\dot{\varphi} - M_f k\dot{x}_1\dot{\psi} + i_{fy}/R_f\sin\varepsilon\,\dot{x}_1\dot{\delta} + l_1 Y_f - l_2 Y_r$$

Eigenvectors normalized with yaw rate

$$X = \begin{bmatrix} \dot{y} \\ \dot{\psi} \\ \dot{\phi} \\ \dot{\delta} \\ Y_f \\ Y_r \end{bmatrix}$$

Eigenvector ×Coefficient



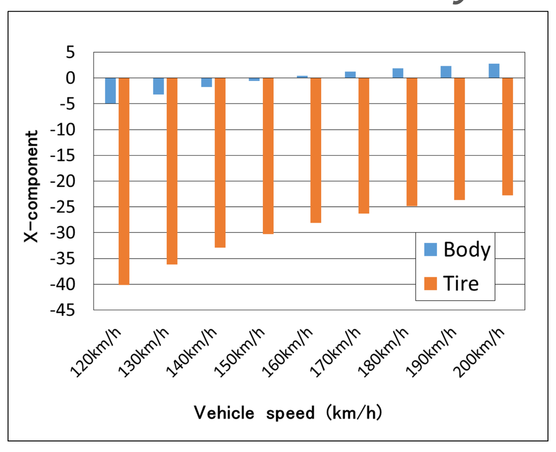
The contribution to the stable direction of Sum ⇒ Larger at 120km/h than at 200km/h

X Component : Proportional to real part of eigenvalue
Y Component : Proportional to imaginary part of eigenvalue

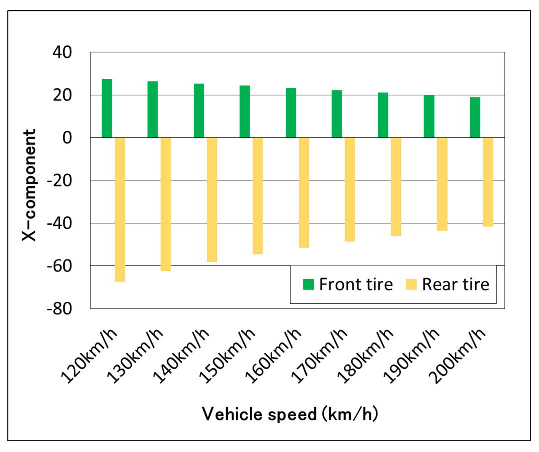
Analysis result

【Analysis using the Yaw system equation】

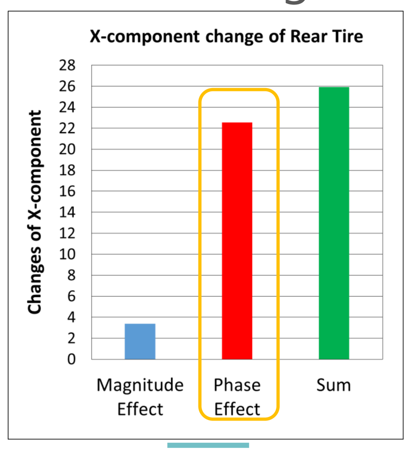
X-component divided Into *Tire* and *Body*



X-component divided into *Front tire* and *Rear tire*



The change of Phase and Magnitude



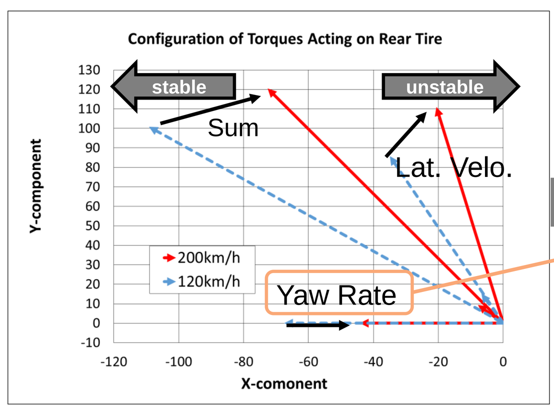
The main factor determining stability is ***Energy Flow of tire***

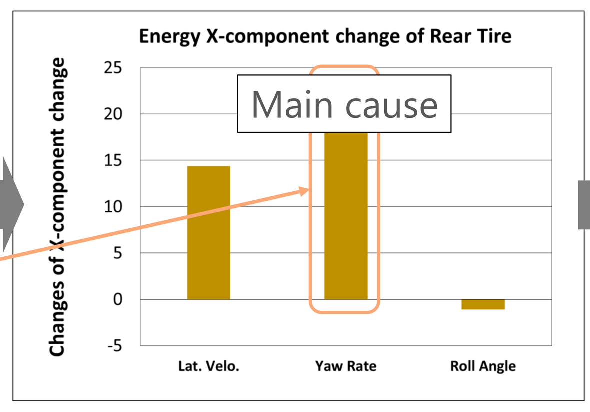
In *Front and Rear tire*, the ratio of ***Rear tire is larger***

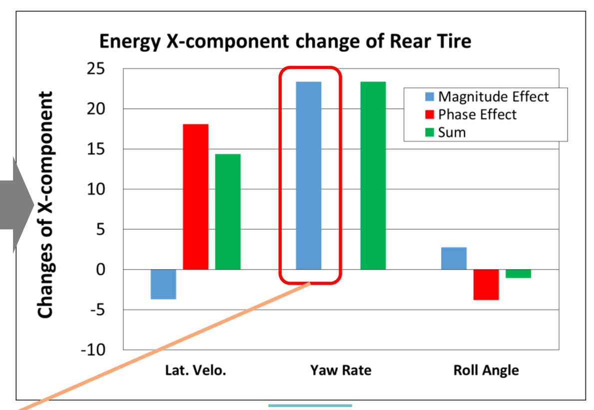
***Rear tire* gives most influence on the weave mode**

Most of the breakdown of change is the *delay in the Phase of the Rear tire*

【Analysis using the Rear tire equation】







Rear tire equation

$$Y_r = -C_{Ys2}/\dot{x}_1\,\dot{y}_1 + C_{Ys2}l_2/\dot{x}_1\,\dot{\psi} + C_{Yc2}\varphi$$

Lat. Velo. Yaw Rate Roll Angle

※l_2 is unchanged

Yaw Rate ⇒ *Reduction of coefficient*

The cause is C_{Ys2} or $\dot{x}_1$

Change rate of C_{Ys2} and $\dot{x}_1$

	120km/h	200km/h	Rate of change [%]
$\dot{x}_1$	120.00	200.00	166.67
C_{Ys2}	3.34E+03	3.65E+03	109.07

Main factor!

Main factor of the decrease in the Yaw rate coefficient is the *increase in the vehicle speed*

Summary

- ✓ **Rear tire force that most affects the stability of the weave mode.**
- ✓ **The main reason why the rear tire force decreases is a phase delay.**
- ✓ **Cause of the phase delay is the decrease of the Yaw Rate coefficient.**
- ✓ **Main factor of the decrease in the Yaw rate coefficient is the increase in the vehicle speed.**

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