

Analysis of Influence of Tire F&M on Improvement of Vehicle On-Center Steering

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ABSTRACT

In this research, the influence of tire force and moment (F&M) characteristics on vehicle on-center steering performance was analyzed and then how to improve vehicle on-center performance was studied through controlling tire structure design parameter, tread pattern shape and tread grip characteristics.

First, the relationship between vehicle on-center steering performance and tire F&M characteristics was identified by comparing vehicle steering measurements and tire F&M measurements. It was found that key factor of tire related with on-center performance is aligning torque at lower slip angles. As the aligning torque at slip angle 1° increases, on-center feel is improved.

Second, the influence of tire design parameters on tire aligning torque was studied through F&M finite element (FE) analysis and measurement. It was found that the aligning torque at lower slip angle increases as stiffness of the tread and sidewall decreases. However, it shows trade-off with tire cornering force stiffness. It is necessary to optimize cornering force stiffness and aligning torque stiffness in tire structural design. In addition, as tread contact area to ground and viscosity of tread compound increase, both cornering force and aligning torque at lower slip angles increase together.

Finally on-center steering performance of an Europe mid-size wagon was improved by increasing tire aligning torque at lower slip angle based on these research results.

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INTRODUCTION

Sophisticated on-center steering response is one of important factors in premium vehicle driving. Recently vehicle manufacturers have been considering improving on-center steering response. On-center steering response is mainly dependent on steering system and suspension geometry. Steering system specification and suspension geometry in the initial stage of vehicle development are very important for better on-center steering. Tire dynamic characteristics also have an effect on on-center steering so on-center steering feel is evaluated in vehicle during tire development.

The first objective of this research is to identify the influence of tire dynamic force & moment (F&M) characteristics on vehicle on-center steering feel. First, vehicle steering response was measured using two tires with different F&M characteristics. Then the relationship of tire F&M characteristics and on-center steering response was analyzed and the tire aligning torque at low slip angle was found to control vehicle on-center steering response.

The second objective is to investigate tire design parameters to control aligning torque at a slip angle of 1° . F&M FE analysis was performed for several tire models with different structure design.

Then F&M were measured for tire samples with different tread compound and different tread pattern in order to study the effect of viscoelastic properties of tread compound and tread pattern shape on aligning torque.

Finally the tire design to optimize on-center steering response and limited handling was suggested and verified through tire F&M measurement and vehicle R&H test.

RELATIONSHIP BETWEEN VEHICLE ON-CENTER STEERING RESPONSE AND TIRE F&M CHARACTERISTICS

Vehicle On-Center Measurement

In order to study vehicle on-center steering response with respect to the tire, two kinds of tire samples with different specifications were prepared for subjective vehicle steering test. Tire A and Tire B have same tire size 215/55R17 and different all season tread pattern.

A Sine Wave Test method was used for vehicle on-center steering measurement. Yaw response and lateral acceleration of mid-size sedan were measured by inputting steering angle $\pm 28^\circ$ as an sine

wave with 0.3 Hz at the vehicle speed 80 kph. Figure 1 shows evaluation results of steering wheel torques relative to steering wheel angle and lateral acceleration for two tires.

Steering torque at 0° slip angle is related with tightness of on-center steering response. Steering torque at 0° slip angle of Tire A is higher than that of Tire B by 64%. Steering stiffness is defined as the slope from -0.02g to +0.02g in the graph of lateral acceleration and steering wheel torque. Steering torque slope of Tire A is also higher than that of Tire B by 48%. Namely Tire A is better than Tire B in overall objective on-center response measurement. In addition, Tire A showed better on-center feel than Tire B by one step in subjective vehicle steering test.

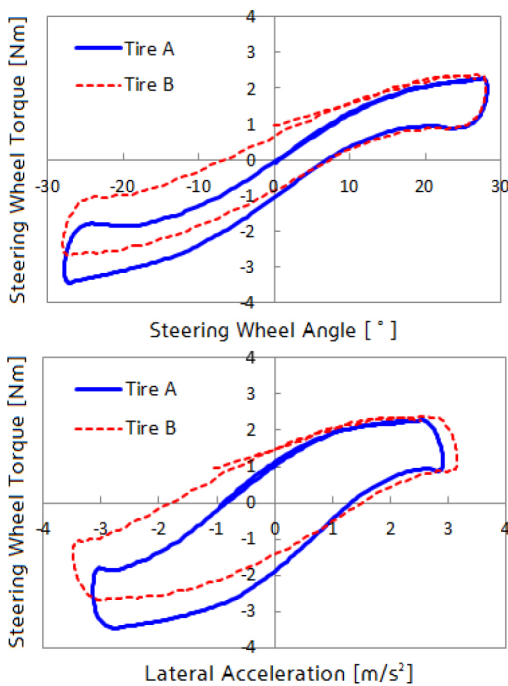


Figure 1. Measurement results of vehicle on-center steering response

Relationship between On-Center Steering Response and Tire Aligning Torque

Cornering force and aligning torque relative to slip angle were measured by using Flat Trac for two tire samples which were used in vehicle on-center steering measurement. Here four load conditions (60%, 100%, 140% and 180%) were applied at the rolling speed 80 kph. Figure 2 shows the cornering force and the aligning moment in 100% load condition for both Tire A and Tire B.

Tire A has higher cornering force by 2~5% up to 4° slip angle than Tire B. However Tire B shows higher aligning torque by 9~25% up to 4° slip angle than Tire A. Especially cornering force at 1° slip angle (cornering stiffness) of Tire A is higher by 5% than Tire B but aligning torque at 1° slip angle (aligning stiffness) of Tire A is lower by 25%. In addition, Tire B is higher than Tire A in H-Function and G-Function which shows change rate of torque and force according to

load variation. Here Tire A which shows better on-center steering performance is superior to Tire B only in aligning stiffness at lower slip angles. Tire A is considered to have on-center tightness by providing steering system with greater aligning torque at the ground contact area.

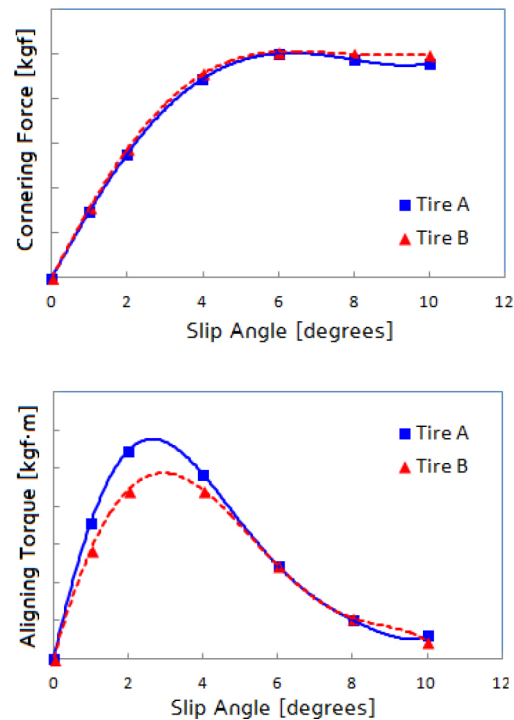


Figure 2. Tire Force & Moment measurement results

The case that aligning torque in lower slip angle is higher than Tire A was not been tested in this measurement. So it cannot be clearly defined that on-center steering response increases as aligning torque at lower angles increases. However, it is necessary to have equivalent or higher aligning stiffness based on the performance reference tire (Control Tire) during tire development.

INFLUENCE STUDY OF TIRE DESIGN PARAMETER ON ONCENTER PERFORMANCE

It is necessary to understand how tire design parameters have an effect on aligning torque stiffness to control on-center steering response during tire development. In this research, several studies to show the effect of tire structure, tread pattern and tread compound property were performed by using F&M FE analysis and F&M measurement.

Effect of Tire Structural Design Parameter

Several tire tunings to control tire structural design parameters in tread and sidewall are performed in order to match with vehicle R&H (ride and handling) and NVH performance during tire development. Table 1 shows available range of structural design parameters in tread and sidewall in 215/50R17 tire development for Europe mid-size wagon.