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Effect of Measurement Method Differences on the Evaluation of Tire Lateral Relaxation Length

Taichi Murakami [1)] Akio Uesaka [1)] Naohiro Ishigami [1)] Hiroshi Nashio [1)]

1) TOYO TIRE Corporation, 2-2-13 Fujinoki, Itami, Hyogo, 664-0847, Japan

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This study focuses on the lateral relaxation length of tires and presents a systematic comparison of the effects of different measurement methods on its evaluation results. The lateral relaxation length is defined as the distance traveled by a tire until the lateral force response reaches 1−1/e (approximately 63.2%) of its steady-state value following a change in slip angle, and it represents the time delay of the lateral force response to steering input expressed in terms of distance. This lateral relaxation length is known to influence vehicle yaw-rate response and steering responsiveness and is regarded as one of the important dynamic characteristics that govern vehicle handling and driving stability. Conventionally, multiple approaches have been proposed for measuring the lateral relaxation length. Representative methods include the CP/Ky-based method derived from the steady-state characteristics of lateral force, slip angle, and lateral displacement; step and rampstep inputs that directly evaluate the buildup of lateral force immediately after the onset of steering; and sinusoidal inputs based on steady-state frequency response. However, few studies have systematically compared the evaluation results obtained using these methods under identical tire and vertical load conditions. Therefore, this study applies four methods—the CP/Ky-based method, step input, ramp-step input, and sinusoidal input—and evaluates the lateral relaxation length based on a common framework in which the tire lateral force response is approximated as a first-order system.

Experiments were conducted using a flat-belt testing machine and a flat-type tire contact behavior measurement system. A summer tire of size 245/40R18 was used throughout the experiments, with the inflation pressure fixed at 250 kPa. Multiple vertical load conditions of 1206 N, 2412 N, 4825 N, and 7237 N were applied, and the lateral force responses were measured for each evaluation method. As a result, the lateral relaxation length exhibited an increasing trend with increasing vertical load for all methods, including the CP/Ky-based method, step input, rampstep input, and sinusoidal input. Within the same vertical load condition, the step and rampstep inputs showed a certain dependence of the lateral relaxation length on slip angle; however, its influence was small compared with the variations caused by changes in vertical load. For the sinusoidal input, it was confirmed that within the frequency range evaluated in this study, the lateral relaxation length did not exhibit a clear frequency dependence and could be summarized as a representative value for each vertical load condition.

These results indicate that, under identical vertical load conditions, the lateral relaxation length shows relatively limited dependence on input conditions and is primarily governed by vertical load. On the other hand, slight differences were observed among the CP/Ky-based method, step input, rampstep input, and sinusoidal input, because each evaluation method emphasizes a different state of the lateral force response when determining the relaxation length. Specifically, the CP/Ky-based method provides a theoretical estimate based on steady-state relations derived from a mathematical model, whereas the step and rampstep inputs experimentally identify the relaxation length from the transient lateral force response to steering inputs, and the sinusoidal input evaluates it based on steady periodic responses. From these findings, it can be concluded that although the lateral relaxation length is not a direct representation of the tire dynamic characteristics in a strict sense, it serves as an effective representative indicator of the tire's dynamic response under identical conditions. Furthermore, these results highlight the importance of selecting an appropriate measurement method according to the evaluation objective and test conditions.

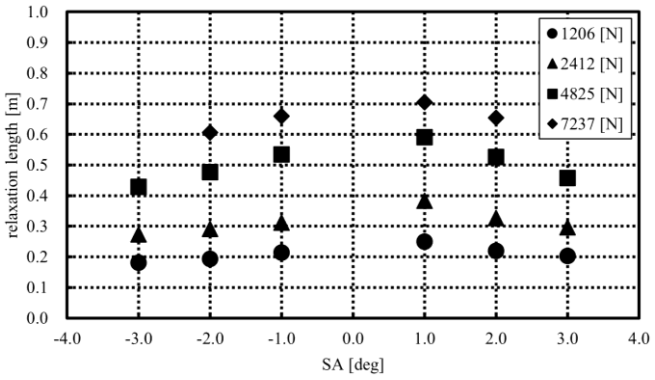

Fig.1 Lateral Relaxation Length under Step Input at 0.38 km/h

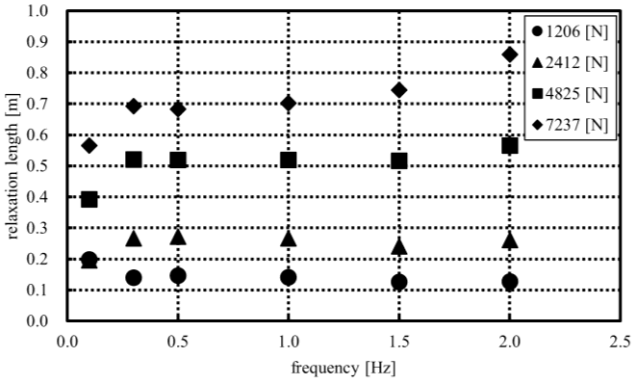

Fig.2 Lateral Relaxation Length under Sinusoidal Input at 20 km/h