

Structural Optimization for Vehicle Dynamics Loadcases

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ABSTRACT

As mass reduction becomes an increasingly important enabler for fuel economy improvement, having a robust structural development process that can comprehend Vehicle Dynamics-specific requirements is correspondingly important. There is a correlation between the stiffness of the body structure and the performance of the vehicle when evaluated for ride and handling. However, an unconstrained approach to body stiffening will result in an overly-massive body structure. In this paper, the authors employ loads generated from simulation of quasi-static and dynamic vehicle events in ADAMS, and exercise structural finite element models to recover displacements and deflected shapes. In doing so, a quantitative basis for considering structural vehicle dynamics requirements can be established early in the design/development process. The objective of the authors was to develop more comprehensive structural optimization loadcases by utilizing analysis of the suspension and the loads it imparts on the chassis structure during a handling maneuver. This paper illustrates two new methods of developing vehicle structure for vehicle dynamics: inertia relief step steer and statically constrained roll.

INTRODUCTION

One aspect of global vehicle structural development for stiffness involves tuning the response of the body to suspension and powertrain input. From the customers' perspective these responses are often perceived as vibrations and/or noise. However, there are also circumstances when the response, although transient, is more static in nature. In other words, there are gross elastic body deflections associated with variable quasi-static loads. One such circumstance occurs during a cornering maneuver^{1,2,3} (another example might be a ride swell). Naturally, the efficient reaction to

these loads by the body structure allows for a lighter weight design that also provides the foundation for a high quality handling feel.

Since there are many, often competing, structural requirements - Crashworthiness, Durability, NVH considerations, etc, it becomes increasingly important to understand the mass and cost implications of improved performance within a discipline like vehicle dynamics. If the relationship between performance, mass, and cost within each discipline can be understood then the requisite balance can be achieved.

By using structural optimization analysis^{4,5} together with vehicle dynamics simulation the vehicle body can be developed to react to loads in a very specific and targeted manner. For example, both the linearity and magnitude of global body deformation at a stabilizer mount during a cornering event can be adjusted. In this case chassis tuning capability would be enhanced by setting and achieving appropriate roll stiffness distribution targets.

Additionally, by optimizing across different loadcases and response locations, design synergy (or efficiency) is maximized.

THE STEP-STEER APPROACH

An event that can provide much insight within the Vehicle Dynamic's regime is a step-steer input. Once steady state is attained at the conclusion of the event, the loading on the vehicle is similar to a typical cornering maneuver. However by its nature, the step-steer event generates a lot of transient information. Observation of the deformed shapes of the body in conjunction with inspection of the tire force plots suggests that it may be convenient to divide the event into three

distinct phases: turn-in, roll, and transition to steady state. [Figure 1](#) indicates the steering wheel angle relative to time through the event. The step-steer maneuver is idealized over a finite period of time, moving from the straight ahead position to 40 degrees over a 0.1 second period. The forward velocity of the vehicle in this case is 100 kph.

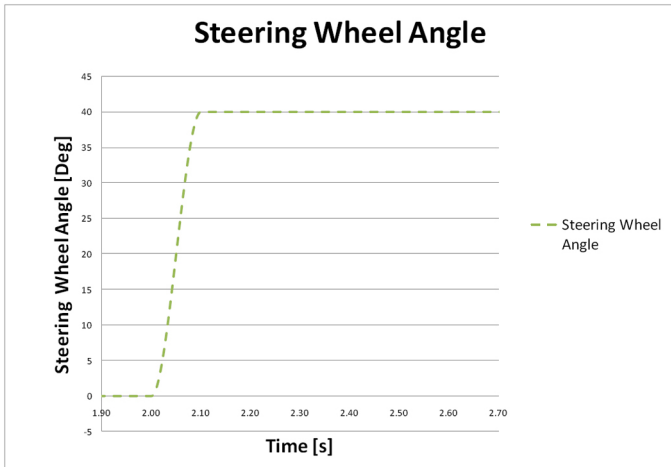


Figure 1. The steering wheel turn-in step steer event is idealized over a finite time.

Examining [Figures 2 and 3](#) provides insight into how the tires react to the dynamics of the vehicle body through the event. Phases 1, 2 and 3 are indicated on the charts. Phase 1 (Turn-In) has a duration of approximately 0.06 seconds. At the start of the event, the front tires generate lateral force because of the slip angles generated by the driver input. Due to body inertia and various system compliances the rear tires have not responded at this point. Phase 2 is considered to have started when the vehicle body begins to roll, as evidenced by the change in vertical force in [Figure 3](#). The lateral force in the front tires continues to build through Phase 2. Phase 3 is defined as starting when the rear tires begin to generate a lateral force. The front tires have an inflection in the lateral force at this instant. Phase 3 continues until steady state cornering is achieved. (For illustrative purposes, the event has the steering wheel rotation begin arbitrarily at time = 2 seconds)

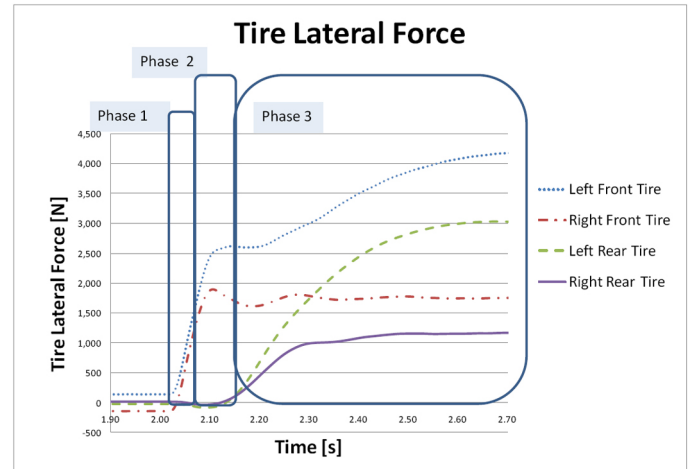


Figure 2. The lateral forces generated by each tire over the step steer event.

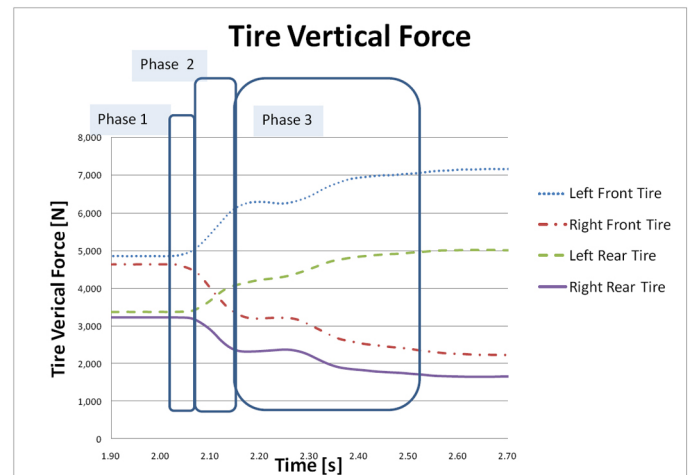


Figure 3. The vertical forces acting on each tire over the step steer event.

An ADAMS flexbody model is used to extract loads at the suspension interface points and at points where significant masses are attached to the body (the powertrain for example). These loads are then employed in a Vanderplaats Research & Development Genesis⁶ model to generate a structural optimization loadcase for each one of these phases. [Figures 4, 5, and 6](#) show the response of the ADAMS model for each one of the cornering phases.