Constraints upon the Achievable Performance of Vehicle Suspension Systems

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In this thesis we examine the suspension design problem from the perspective of mechanical multi-port networks. By drawing on the concepts of passivity, reciprocity, invariant equations and symmetry we are able to investigate the freedom we have in specifying the behaviour of quarter-, half-, and full-car models.

The quarter-car model is cast as a mechanical multi-port network. A complete set of constraints upon the frequency responses of its transfer functions is derived which must be satisfied if the model is to be stable and passive. The full freedom available in suspensions consisting of springs, dampers and levers is derived. We demonstrate that an active suspension is required to achieve certain behaviours. It is shown that the responses obtainable by an active quarter-car measuring strut and tyre deflections, plus body and wheel accelerations can be approximated arbitrarily closely by an active suspension measuring just strut deflection and body acceleration.

The half-car model is developed as a mechanical multi-port network. The inputs and outputs of the model are decomposed into their vertical and angular components. Performance measures for the responses to road and load disturbances are developed. The constraints upon the responses of the model is then investigated under the assumptions of reciprocity, symmetry and various relationships amongst the vehicle parameters. The total number of independently specifiable impedances for the model is found . We show that if, and only if, the vehicle parameters satisfy certain relationships then we may design a suspension which decouples the vertical and angular motions of the half-car, and that the resulting model has the form of two independent quarter-cars. The case of active half-car models is considered, and a complete set of constraints upon the transfer functions of the half-car are derived.

It is shown that under the requirement for a vehicle to exhibit left-right symmetry the full-car model decomposes into two sub-models. Each of these models is analysed along similar lines to those given for the half-car model. The total number of independently specifiable impedances of the full-car model is derived under various assumptions. It is demonstrated that a conventional passive suspension fails to exploit the full freedom available in passive suspensions. We briefly discuss the warping behaviour of the model and how it varies with suspension configuration.