NON-LINEAR VIBRATION.

An Analytical and Analogue Investigation of the Effects of Non-Linearity in the Suspension of Modern Road Vehicles .

by

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Except where specific reference is made to the work of others, this work is original, and has not been submitted to any other university in any form .

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1. INTRODUCTION.

The modern road vehicle presents an extremely complicated dynamic system, as it possesses a great number of modes of vibration which can be excited under the action of both transient and repeated loading conditions. Nevertheless, a vehicle can only be regarded as satisfactory if it gives acceptable performance under all reasonable conditions of operation to which it is subjected.

This is particularly true of the suspension system, which is responsible for providing a safe, stable, and comfortable ride for all combinations of live load, road surface, and forward speed that may be encountered. Unfortunately, these criteria are in many ways conflicting, each requiring different parameters of the suspension elements to provide the optimum results. Thus vehicle suspension design is always concerned with the degree of compromise which is desirable with respect to the conditions of the particular application. Furthermore, the development of suspension design has, till the present time, been almost entirely experimental, with successive modifications as these became apparent from actual operating performance. Consequently, although based essentially on linear vibration theory, practical suspensions have invariably been modified to possess some degree of non-linearity in the components of springing and damping, however the trends are by no means consistent, indicating that selection is still primarily a compromise.

Recently, the proven use of magnetic liquids as a controllable force-transmitting medium, suggested that these might be employed in the vehicle suspension damper to relate its characteristic in some way to the operating conditions, so that the overall performance could be optimised.

Thus, this thesis describes an analytical and experimental analogue study of the effects of non-linearity in the damping and springing components of a modern road vehicle suspension. In this respect, the term "non-linear" is used in its broadest meaning, as it implies only that spring forces are not proportional to deflection, and damping forces are not proportional to the magnitude of relative velocity between the elements.

The aim of the project, is to investigate the possibility of using magnetic liquid dampers in such a way, that their performance is controlled by some characteristic of the resultant motions of the vehicle suspension, to be the optimum required for the particular operating conditions, so that the overall performance can be considerably improved.

Thus, although it is the determination of an optimum controlled non-linear damping characteristic which is of prime importance, it is necessary to investigate the interacting effects of the more standard spring non-linearities in order to ensure an optimum solution for the complete suspension.

With this in view, the thesis has been arranged to first present the criteria of performance of the vehicle suspension and the range of operating variables to which the road vehicle can be subjected. The overall performance of the complete vehicle is then reviewed in order to indicate those characteristics which are of greatest influence in satisfying the performance criteria, and the average suspension parameters employed in the modern road vehicle are also included.

Chapter 5, introduces a two mass system which is recognised to be the greatest degree of simplification which is allowable if dynamic responses are to be compared with those of the whole vehicle, and the complete transient and harmonic responses of this system are determined from linear vibration theory, as a basis of comparison for the succeeding non-linear effects.

Then, after introducing the concepts of non-linear damping and springing in the suspension, and reviewing the current literature on the solution of non-linear vibration problems, an analytical method is developed to enable the harmonic response of the simplified system to be calculated for conditions of controlled non-linearity in the magnitude of damper effort.

Then, from these results, an optimum form of controlled damping is suggested.

Chapter 7, gives a detailed description of the mechanical analogue which was designed and constructed especially for this project. The following chapter presents in detail the experimental work conducted on the analogue, thereby proving the validity of the earlier analytical work, and indicating the effects of non-linearity of suspension springing.

Finally, the conclusions are drawn from both the experimental and analytical work, and recommendations made for a composite non-linear control of damping effort based on the relative motion between axle and body, and the recorded axle acceleration, which achieves the desired object of successfully relating damper effort to the prevailing excitation conditions.