CHAPTER 1

INTRODUCTION

1.1 Vibrations are excited either because of the inertial forces present into the system or the movement of the base of the system. Vibration amplitudes should be kept within limits for various reasons like to improve fatigue life of the machinery, to provide passenger comforts or to isolate force being transmitted to neighbouring machines etc.

1.2 Reduction in vibration amplitudes can be achieved by keeping natural frequency of the system atleast three times less than the lowest excitation frequency. This requires a spring of very low stiffness. With conventional metal springs lower stiffness requires a tall spring giving rise to space stability problems. In vehicles this introduces shock at high road inputs. If resonance is unavoidable damping is necessary but undesirable at higher frequencies. Moreover conventional metal or rubber springs cannot provide for stiffness or damping variations.

1.3 Airsprings have distinct advantages over the conventional springs. They can be designed to give natural frequencies of the order of 1 Hz. Same natural frequency can be maintained for different loads and heights of spring. Damping can be introduced easily. Natural frequency can be easily changed. Stiffness characteristic can be made to vary with the deflection so as to avoid shocks as in vehicles. Airsprings offer enormous flexibility so that they can be used in active isolation systems.

In the simplest form an airspring can be considered as a piston supporting load and sliding in an airfilled cylinder or an airbellow. Stiffness of this airspring is inversely proportional to its volume. Hence for low natural frequency a larger volume is needed. This is provided by connecting it to a reservoir through a tube. The flow of air through the tube(capillary) gives rise to damping due to viscous friction.

Though airsprings offer so many advantages and concept of airspring is more than 100 years old comparatively very little work has been done in this area. As will be seen from literature review most of the work on capillary connected springs is based on linearised model and solution is by operator method. This has restricted the treatment to steady state vibrations. Effect of variation of parameters is mostly presented in a graphical form. Only 3 to 4 papers have dealt with nonlinear equations. But they have considered only shock response. Though airsprings are used on vehicles pitch mode has not been studied so far.

1.3 A detailed literature review has been carried out. 22 papers and one report have been reviewed and author feels confident that most of the available literature is covered. Papers are mostly reviewed in a chronological order. However continuity of the subject also is kept in mind. Hence papers dealing with shock motion are covered at a later stage.

Literature reviewed can be grouped as :- (i) Papers dealing with the use of airsprings on vehicles and their design considerations. (ii) Research papers on airsprings connected with a reservoir through capillary tube. As mentioned above all of them have considered a linearised model. All papers except two have considered a single degree of freedom system under steady state vibrations. Papers dealing with two degrees of freedom system have also considered only translation mode. (iii) Papers dealing with shock response. Nonlinear equations are numerically solved in terms of dimensionless parameters.

1.4 In the present work the following cases have been investigated which were not covered in the literature so far :-

(i) Non-linear differential equations for a single-degree of freedom system consisting of a mass supported on an air spring are formulated. Airspring is considered to be connected to a tank through a reservoir. Equations consists of equations of motion and equations of mass flow. These equations are converted into dimensionless variable form. Equations are solved numerically and effect of variation of each parameter is found out. Response of the system to initial displacement (free vibrations) has been analysed and effect of variation of each parameter on damping factor has been considered. An interesting closed form relation between damping factor and these parameters has been arrived at. It is felt that this relation will be very useful to the designers of airsprings for introducing damping into the system. Response to forced vibration has also been studied numerically and effect of capillary resistance on the resonance frequency is found out.

(ii) A similar relation has been arrived at for pitch mode motion. Here a mass supported on two airsprings as in a vehicle is considered. Choosing suitable parameters pitch mode is uncoupled from the translation mode so that effect of parameter variation on pitch can be calculated.

(iii) Equations for a vehicle suspension system considering it as a two-degrees of freedom system are formulated. The system considered is a rigid mass supported on two air springs. Each air spring is connected to its own tank and two springs are connected to each other. Numerical results have been given.

(iv) Following the available literature linearised system equations have been developed for the above case. However tank volume has not been considered. It may be pointed out here that no work on case (iii) and (iv) has been so far reported.

1.5 Experimentation :

Experimental work was carried out by using airbellows manufactured by Firestone Co., U.S.A. Though variation of parameters as covered into the numerical analysis could not be done because of practical and financial limitations effect of variation of two important parameters viz. capillary resistance and tank volume was observed experimentally. Trend observed experimentally is similar to the numerical analysis.

1.6. It can be concluded that some important aspects of airsprings have been studied and useful and interesting results have been brought out. Future scope of work has been indicated.