CHAPTER 6

Discussion and conclusions

6.1 As the title of the thesis indicates this work was directed to study the effect of various parameters of an air-spring. Expression for natural frequencies of these mounts are well-known. But damping characteristics are not available in explict expression form. Also as pointed out earlier numerical solution for the capillary damping has not been available in literature. Hence more attention was concentrated on numerical solutions and damping characteristics.

After obtaining numerical solutions for a large number of cases with different sets of parameters for free vibrations it was observed that effect of nonlinearity is small and effect of air friction in capillary can be thought of in terms of equivalent viscous damping. This was found to be the cases ever when amplitudes were quite high. However effect of nonlinearities is not completely absent as ratio of amplitudes of successive cycles does vary by a small amount. But for practical purposes this can be neglected. In the case of steady state analysis for low damping value a drift in the mean position of the solution was observed. Reason for the same could not be found out.

6.2 Dual Frequency Characteristics

Dual frequency characteristics of tank connected airspring as mentioned in various papers is found here also. However thereare not only two natural frequencies but natural frequency varies continuously from the case where complete tank volume is effective (no capillary resistance) to the situation where tank is completely cut off. (capillary resistance is infinite). This has been clearly brought out in steady state solution graphs. This variation from one natural frequency value to other is in the region of critical capillary coefficient and results found in this thesis are similar to those presented in reference(12).

6.3 Damping Characteristics

As discussed in chapter Five load deflection curve shows hysterisis loop which represents inherent damping in the air bellow. Stiffness of rubber bellow is nonlinear w.r.t. load and is also a function of airpressure. These observations agree with those mentioned in reference(8). Thus in practice auxiliary spring stiffness will be nonlinear. For the purpose of experimentation in this thesis only a small part of the load deflection curve is used which can be treated as linear. Thus theoretical assumption of linear auxiliary spring is achieved to some extent.

For damping due to capillary flow explicit relations have been derived and validated by experiment as shown in chapter 4 and 5. Since such relations are not available in literature only qualitative comparision is possible. Variation of maximum transmissibilty with stiffness ratio shown in in reference(11) is similar to the one obtained in this thesis. Variation of damping ratio with capillary resistance as found experimentally in this reference almost coincide exactly with the formula given in this thesis. However variation of damping with volume ratio though indicates similar trend does not coincide with the formula. But since other parameters are not given direct comparision is not possible.

Bachrach and Rivin(17) have considered $\omega_c = \frac{n C_r p_c}{V_c}$ and N= Volume ratio as important parameters affecting system characteristics. In this thesis as mentioned in chapter Four parameter ϵ is the most effective parameter which is similar to ω_c

of this reference. This may be taken as supporting fact for the results presented here. Maximum loss factor in this reference is given by $V_t/\sqrt{V_t - 1}$ while in this thesis it is shown that maximum damping factor depends on the quantity $\sqrt{V_t - 1}$

Regarding time step in Runge Kutta method observations in this thesis are similar to reference(22). Variation of pressure lags behind the motion which is similar to observed in this work also. Though this reference deals with orifice damping it is interesting to note that effect of area on damping shows two different regions clearly.

6.4 Conclusions

1. Dual frequency characteristics of air spring is verified and variation of resonance frequency with damping is presented.

2. Effect of variation in damping ratio with parameters like volume, Area, Mass, Volume ratio and capillary coefficient is given as explict expressions. Two different regions are shown to exist for two different expressions. Effect of auxiliary spring on damping is presented.

3. Expression for critical capillary coefficient has been derived and it is shown that two regions mentioned above lie on either side of critical capillary coefficient.

4. It is shown that maximum possible value of damping is entirely governed by volume ratio.

5. Expression for damping in pure pitch mode has been given again in explicit form.

6. A vehicle suspension system with airsprings as a two degrees of freedom system with air springs connected to each other has been analysed. Linearised equations are presented Effect of capillary passage has been studied and it is shown that acritical damping value exists for overall best performance. Effect of phase angle between front and rear excitations has been considered for the first time in this thesis.

7.Theoretical results have been verified through experiments.

6.5 Scope for future Work

Since very little work has benn done in the field of airsprings(practically no work in India so far) a large scope for work exists. Following few fields are suggested.

1. Effect of other dampings like material damping on capillary damping.

2.Variation of resonance frequency in the region of critical damping.

3. Damping in the case of orifice connections combined with capillary connections.

4. Vehicle suspension system taking roll mode also into account.

5. Variation in ground reaction in case of a vehicle with airspring suspension.

6. Active suspensions for vehicle.