CHAPTER 6

GENERAL DISCUSSION, CONCLUSIONS AND FURTHER WORK

6.1 GENERAL DISCUSSION AND CONCLUSIONS

6.1.1 Three-Layer Plates—Half-Sine Pulse

The transient transverse displacement response to a half-sine shock pulse has been analyzed for undamped, viscoelastically damped and internally damped three-layer unsymmetric laminated plates with simply supported end conditions. Taken into consideration are the effects of rotary and longitudinal inertias in addition to that of the transverse inertia (generalised theory). Analyses of these plates have also been carried out while taking into account the effect of transverse inertia only (simplified theory). In the case of viscoelastically damped plate, the dynamic shear properties of the core material have been represented by a four-element viscoelastic model. For internally damped sandwich plate, internal (structural) damping based on Constant Q hypothesis of Mindlin et al. has been introduced in the core and face layers of the plate. No restriction has been imposed on the geometrical and physical parameters of different layers of a plate. Numerical results for the transient transverse displacement response have been obtained by varying the values of these parameters over a wide range of practical interest.

For the three types of laminated plates (undamped, viscoelastically damped and internally damped) studied, it is
observed that if the duration of the shock pulse is large, the inclusion of rotary and longitudinal inertias in the analyses has no significant effect on the shock response of these plates; but, when the shock duration is relatively small, there is a marked decline in the response of such plates due to the inclusion of these inertia terms. This deviation between the predictions of the theory considering all inertias (transverse, rotary and longitudinal) and the one considering only transverse inertia tends to increase with decrease in pulse duration, signifying the importance of higher inertias in the case of sharp transients.

The effects of different parameters on the peak displacement response behaviour of the above referred types of three-layer plates have been investigated using both the theories. With a change in each parameter examined, these plates exhibit a qualitatively similar pattern of variation in their peak responses. As such, the conclusions regarding the peak response characteristics given in this section are qualitatively applicable to both the undamped as well as the damped laminated plates studied.

From the time-history curves of these plates, it is inferred that the peak value of transverse displacement response occurs earlier in time when the core material is more rigid. Further, for a relatively large duration of shock pulse, the maximum value of displacement response occurs within the excitation era; whereas, for a sharper transient, the maximum value of the displacement response is attained after the excitation era.
In all the cases, a symmetric configuration of the plate is found to give the least value of peak transverse displacement response which rises with an increase in unsymmetry of the cross-section. Similar adverse effect is noticed when the density of elastic, viscoelastic or elasto-dissipative core material of the respective type of sandwich is increased.

For the wide range of parameters studied, it is seen that increases in face thickness ratio and core thickness ratio result in reduction of the peak displacement shock response.

In the case of undamped as well as damped three-layer plates investigated, a rectangular configuration with a higher aspect ratio gives a better displacement response effectiveness.

The effect of varying the value of core shear modulus of undamped and internally damped three-layer plates reveals that the maximum displacement response of the concerned plate decreases rapidly as the said modulus is increased up to a certain limit, beyond which any further increase in the value of the shear modulus becomes less and less effective in reducing the peak response. Similar observations are made when the static shear modulus of the viscoelastic material is increased in the case of a laminated plate with a viscoelastic core.

As expected, there is no decay of shock response of undamped laminated plate; whereas, both the viscoelastically damped and internally damped plates (Chapters 3 and 4 respectively) show continuous decay of vibrations after the pulse era. For both types of damped plates, the rate of decay of residual vibrations
has been evaluated in terms of the logarithmic decrement.

In case of a viscoelastically damped plate, it is found that a softer or thicker layer of viscoelastic core gives a faster decay of shock response during the residual vibration era. Further, the decay rate is observed to increase with increase of face thickness ratio for higher values of static shear modulus of the core; whereas, for lower values of the said modulus, the decay rate increases initially but falls after attaining a peak value. In addition, the effect of increasing the aspect ratio shows that the damping increases till it reaches a maximum value and thereafter it decreases.

For internally damped three-layer plate, an investigation of the effect of core thickness ratio on the logarithmic decrement (Chapter 4) reveals that higher values of the core thickness ratio are beneficial for achieving greater values of the system damping. Further, the use of an elasto-dissipative core with a higher value of loss factor enhances the damping capacity of the internally damped sandwich, as expected.

Comparisons

The displacement response effectiveness of a three-layer undamped (elastic-cored) plate has been investigated (Chapter 2) by comparing its response with that of an undamped (elastic) homogeneous plate. The comparisons have been done on the basis of constant size, constant weight and constant static stiffness criteria. The faces of the laminated plate have been taken to be
of the same material as that of the homogeneous plate. For each criterion, an undamped laminated plate with a core of relatively high shear modulus and of suitably greater thickness ratio is found to give a displacement response which is much lower than that of a corresponding homogeneous plate. However, a quantitative study of the size, weight and static stiffness ratios reveals that when a particular ratio is kept as unity, an increase in core thickness ratio brings about a change in the remaining two ratios which is unfavourable to one of them. This means that a high value of core thickness ratio can only be used at the cost of some other factor such as size, weight or static stiffness. Thus, the choice of the particular criterion out of the above referred three criteria, and the choice of core thickness ratio and other parameters of the system may be optimised within the constraints of a particular situation so as to evolve a design of the sandwich plate that would give a much better displacement response effectiveness vis-à-vis a reference homogeneous plate.

A comparative study of the vibration response characteristics of viscoelastically damped and undamped three-layer plates has been done (Chapter 3) on the criterion of identical dimensions of the corresponding layers of these plates, same material for their faces, and equal static shear moduli and densities of their core materials. For the wide range of various parameters investigated, a laminated plate with a viscoelastic core shows a better displacement response effectiveness than that of a corresponding plate with an elastic core.
The effect of inclusion of internal damping in the analysis has been examined (Chapter 4) by comparing the detailed results obtained for the internally damped and the undamped three-layer plates. It is seen that the transient displacement response in all the cases of internally damped laminated plates is lower than that of the corresponding cases of undamped laminated plates.

As already mentioned, the viscoelastically and internally damped three-layer plates have the added advantage over the undamped three-layer plate because in case of the damped plates the shock response continues to decay after the excitation era.

6.1.2 Three-Layer Plate—Rectangular Pulse

The governing equations for the shock response of a simply supported three-layer undamped plate subjected to a rectangular shock pulse of a finite duration have been derived (Chapter 5), with account taken of the transverse inertia effects only. Laplace transformation technique has been used to find the solution for the transverse displacement response. Numerical results have been plotted to study the effects of various parameters on the shock response behaviour of the plate.

From the time-history curves, it is noticed that a single peak occurs within the excitation period when the core shear modulus is low; but, for higher values of the said modulus more than one peaks show up and the number of such peaks increases as the core shear modulus increases.
The geometrical and physical parameters which have been varied to investigate the peak transverse displacement response characteristics are the coefficient of unsymmetry, face thickness ratio, core thickness ratio, aspect ratio and core shear modulus ratio. The study of the shock response behaviour due to the variation of these parameters reveals that qualitatively the shock response behaviour follows the pattern similar to that observed in the study of three-layer plates subjected to half-sine shock pulse.

Effect of the pulse duration has been examined on the basis of constant input impulse as well as on the basis of constant pulse height. When the area of the rectangular pulse is kept constant, a reduction in the duration of the pulse increases the peak transverse displacement response of the plate. Investigations based on constant pulse height reveal that, for the case of short duration pulses, the response increases with increase in pulse duration. As a result, the amplification factor increases and is maximum (= 2.0) when the period ratio (ratio of the pulse duration to the fundamental period of the sandwich plate) approaches a value of about one-half. A further increase in pulse duration brings about no change in the peak response and the amplification factor remains two for a rectangular pulse of any longer duration.

6.1.3 Effect of Pulse Shape

The comparative study (Chapter 5) of the shock response of an undamped three-layer plate to differently shaped pulses (rectangular and half-sine types) has been summed up in the form
of shock response spectra drawn on the basis of equal input impulse, taking the two types of pulses to be of the same duration. From the illustration given, it is observed that the peak transverse displacement response due to half-sine pulse is nearly equal to that due to the corresponding rectangular pulse for period ratio up to nearly 1/5; is higher when this ratio is from about 1/5 to 2; and is lower for period ratio beyond this value. This shows that for period ratios larger than a certain value, the shape of the pulse (on equal impulse basis) has a considerable effect on the shock response character of the laminated plate studied.

6.2 FURTHER WORK

The analyses and results presented in the current work are expected to be helpful in the design of undamped, visco-elastically damped and internally damped three-layer plates. However, in order to make available a complete set of design curves covering a wider range of geometrical and physical parameters, a further computational work is needed on a large scale.

Present investigations deal with simply supported boundaries of the laminated plates. A similar study of these laminated plates with other types of end conditions would be of much interest.

For multilayer plates subjected to random excitation, the vibration response analysis taking into consideration the
effects of all inertias remains to be done as yet.

The present work deals with shock response of the laminated plates having 3-layers only. This work should be extended to the laminated plates with higher number of layers. In fact, it would be an ideal goal to develop and investigate similar analyses for n-layer laminated plates subjected to differently shaped pulses and ultimately subjected to the random excitation, which is of great practical value.