Where, $\mathbf{I}_z$ and $\mathbf{I}_{zr}$ are of desired size with the identity matrices and are directly associated with the dissipation of $\{\mathbf{Z}_t\}$ and $\{\mathbf{Z}_r\}$ coordinates.

3. CLOSED LOOP

Now to activate the patches a law of velocity feedback control is imposed. The same can be shown in the form of equation

$$V^j = -K_d^j \dot{w} = -K_d^j [U^j]\{\dot{X}\} \tag{13}$$

where, K_d^j implies the control gain of the patches, $[U^j]$ implies the unit vector. Substituting the above equations, we get equation of motion as.)

$$[M^*]\{\ddot{X}\} + [C^*]\{\dot{X}\} + [K^*]\{X\} = \{F^*\} + \{F_t\} \tag{14}$$

In which, $[C_d^*] = [C^*] + \sum_{j=1}^{m} K_d^j \{F_p^*\}[U^j]$ implies the active damping matrix.

4. RESULTS

The model is developed in Matlab and analysis is carried out to minimise the non-linear vibrations which are generated by applying the load in the transverse direction. The square substrate is made up of smart composite material. The patches made up of PFRC/AFC material are attached to the substrate by ACLD treatment. The thickness of the patches & plate are taken as 250 μm and 3 mm. The values estimated for α, $\hat{\xi}$ and $\hat{\omega}$ by using GHM are 11.42, 1.0261e5 & 20. The load acting P in the transverse direction on the surface of the plate is given by 300. For simply supported beam the numerical outcomes which are obtained by the limiting conditions are given by

For Simply supported substrate (SSS):

$$v_0 = w_0 = \theta_y = \phi_y = \gamma_y = 0 \text{ at } x = 0, a$$
$$u_0 = w_0 = \theta_x = \phi_x = \gamma_x = 0 \text{ at } y = 0, b$$

The behaviour of the plate in the open and closed loop is understood by the deflection of the plate at the centre on the top layer of the surface. The load is uniformly distributed throughout the surface in the form of pulse. It is observed that the value of the non dimensional equation $\mathbf{Q} = \mathbf{pa}^4 / (\mathbf{E}_T\mathbf{h}^4)$ for the applied load exceeds 40 number, then the plate exhibits non linear deformation.

The validation is also done for the simply supported plate for open and closed loop which is included by two identical patches of PFRC/AFC for cross ply condition $(0^\circ / 90^\circ / 0^\circ)$. The results obtained are shown in figure 4 and 5 which reveal that the present results match with the existing one. Thus the validation is done for the present FE model with AFC material by using ACLD treatment.

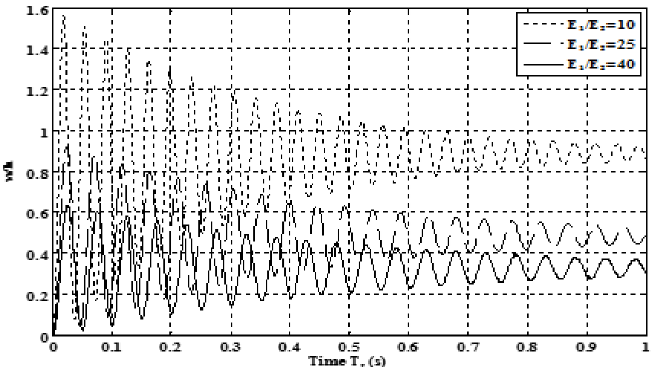

Figure 4: Effect of material anisotropy on controlled responses of a simply supported boundary condition (SS1) for symmetric cross ply $(0^\circ / 90^\circ / 0^\circ)$ square substrate plate undergoing geometrically nonlinear vibrations using AFC patches (for $a/h = 300$, Q=100, $K_d = 500$

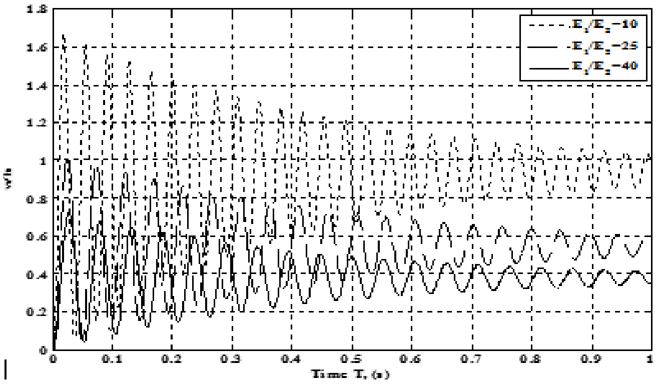

Figure 5: Effect of material anisotropy on controlled responses of a simply supported boundary condition (SS1) for symmetric cross ply $(0^\circ / 90^\circ / 0^\circ / 90^\circ)$ square substrate plate undergoing geometrically nonlinear vibrations using AFC patches (for $a/h = 300$, Q=100, $K_d = 500$)

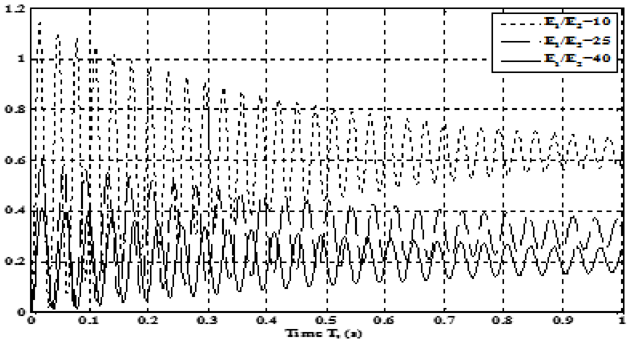

Figure 6: Effect of material anisotropy on controlled responses of a simply supported boundary condition (SS2) for anti-symmetric angle-ply $(-45^\circ / 45^\circ / -45^\circ / 45^\circ)$ square substrate plate undergoing geometrically nonlinear vibrations using AFC patches (for $a/h = 300$, Q=100, $K_d = 500$)

4.1 Validation

The results got from the experimentation are validated by the reference paper [16].

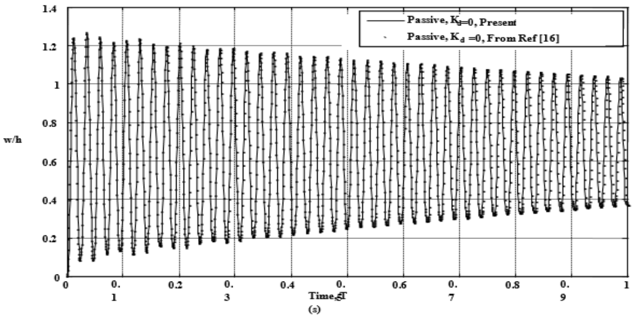

Figure 7: Present results are compared with Ref[16] for the dynamic

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behavior of simply supported symmetric cross ply $(0^o/90^o/0^o)$ of square plate for $a/h = 200$ under passive mode ($K_d = 0$)

5. CONCLUSIONS

In order to investigate the behavior of the substrate under active layer damping a three dimentional finite element model was developed. An anisotropic material of thin laminated composite plates as smart structure with distributed AFC patches using ACLD treatment was analyzed for geometrically nonlinear transient vibrations. The AFC material is used to make the constraining layer of the ACLD treatment. Golla-Hughes-McTavish (GHM) was used to model the constrained viscoelastic layer of the ACLD treatment in time domain. Along with a simple first-order shear deformation theory the Von Kármán type non-linear strain displacement relations are used for deriving this electromechanical coupled problem.
The results prove that the ACLD treatment using AFC material has a drastic improvement in the damping characteristics of the laminated plates as compared to the passive damping. The effect of material anisotropy on amplitude the vibration is examined and is observed that the value of **w/h** increases with decrease in the value of **E1/E2** due to decrease in overall stiffness of the plate. Also, the effect of non-dimensional load on response showed that as load increases the amplitude of the response increases. the phase plots reveal the aspect of stability in controlling the nonlinear transient vibrations. For symmetric cross-ply **(0°/90°/0°)** plates, the damping ability of the ACLD patch becomes maximum when the piezoelectric fiber orientation angle in the AFC constraining layer is 0 degrees.

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