ABSTRACT

Acoustic analysis of vibrating cavities is of paramount importance due to immense impact of noise on the healthy existence of mankind. Excessive exposure to high sound pressure levels (SPL) causes severe health hazards like hearing damage, mental stress, physiological, endocrine, and cardiovascular damage, etc. and badly affects the quality of work and productivity. Conversely, good acoustic design can lead to contentment, pleasure, safety and sound health for people. Higher noise level poses a serious threat both for the passengers inside the automobiles and pedestrians on the road. Hence, over the past several years, customer's demand for acoustic comfort has become an important criterion for vehicle selection. There are strict legal regulations on noise emission levels too.

Because of the inflated cost of structural materials and scarcity of fossil fuel, it is important to make the vehicular cabin structures lighter and fuel-efficient. Consequently, designers prefer lightweight structural materials with high specific strength and stiffness, such as, laminated composites, over conventional materials. Unlike rigid walls, thin and flexible walls modify the noise and vibration level and thus alter the acoustic response both inside and outside of the vehicle considerably, thus necessitating coupled structural acoustic (CSA) analysis. Again, irregular geometry of the cavity and radiation of sound from fully or partially opened windows in vehicles make the analysis more challenging. As active noise cancellation escalates the overall cost, passive noise cancellation methods such as adding absorbent layer or stiffeners along with modifying the damping, can be adopted to control the sound pressure level for the comfort of passengers.

Hence, considering real-world scenarios, the present study adopts a multidomain framework that partitions the acoustic cavity into smaller subdomains interconnected by intermediate interface layers which facilitates a comprehensive analysis of the multi-domain Boundary Element Method (BEM) for coupled interior and exterior domains. An in-house software has been developed in MATLAB environment to investigate the vibroacoustic response of a three-dimensional vehicular acoustic cavity having a combination of rigid and flexible panels, with complex boundaries involving absorbent layers and opening, using coupled finite element and multi-domain boundary element analysis. Exact analysis of SPL at the exterior domain have been evaluated using continuity condition at the window surface. The program developed is

versatile enough to handle cavities of any shape and multiple interacting boundary panels with arbitrary position of opening.

The program has been verified with analytical and experimental data available in the literature to ensure accuracy. The finite element analysis of the flexible panels is done using first order shear deformation theory with an eight-noded isoparametric element and folded plate transformations are applied to modify the structural stiffness and mass matrices from local to global coordinates prior to assembly. The nodal sound pressure levels at flexible boundaries are determined using mobility relationship obtained from the finite element structural analysis.

The sound pressure levels have been evaluated both at the interior and exterior cavity and it has been demonstrated that the shape of the flexible acoustic domain along with the presence of opening alters the modal characteristics of the structure causing considerable modifications in the sound pressure level (SPL) pattern. The SPL inside the vehicle cavity can also be modified by judiciously stiffening the enclosure. Examples reveal that one can restrict the acoustic output at the resonant frequencies by suitably adding absorbents.