

VISITOR RESEARCH REPORT

Visitor Name: Mr. Pankaj Joshi

Area of Research: Computational Design Optimization Framework
(known as *EBF3PanelOpt*) for Multi-objective Design Optimization

Period of Visit: Feb 8, 2011 to May 15, 2011

Goal: Perform Experimental work at LARC

Strategy:

Accomplishments: Experimental work is completed at NASA Langley

Future Work: Simulation results validation

Pending Publications:

Seminar Presented:

Vibro-acoustic work at Unitized Structures Group

With the development of manufacturing techniques such as the Electron Beam Free Form Fabrication (EBF3 [1]), a metal deposition technique which deposits metal in complex shapes on a metallic base plate, it has become easy to manufacture complex shapes such as panels with curvilinear stiffeners. Designing and optimizing stiffened panels with predefined structural and acoustic response is the focus of the research work being conducted at the unitized structures group in Aerospace and Ocean Engineering Department of Virginia Tech. Researchers have dealt with sizing optimization of panels with straight/curvilinear stiffeners for many years and it has been proven that in some cases the mass of a panel with curvilinear stiffeners is lesser than the mass of a panel with straight stiffeners for a complex loading such as bi-axial compression with shear and transverse pressure. The vibro-acoustic research work performed at the unitized structures group deals with sizing as well as placement optimization of panel with straight and curvilinear stiffeners for desired structural and acoustic response.

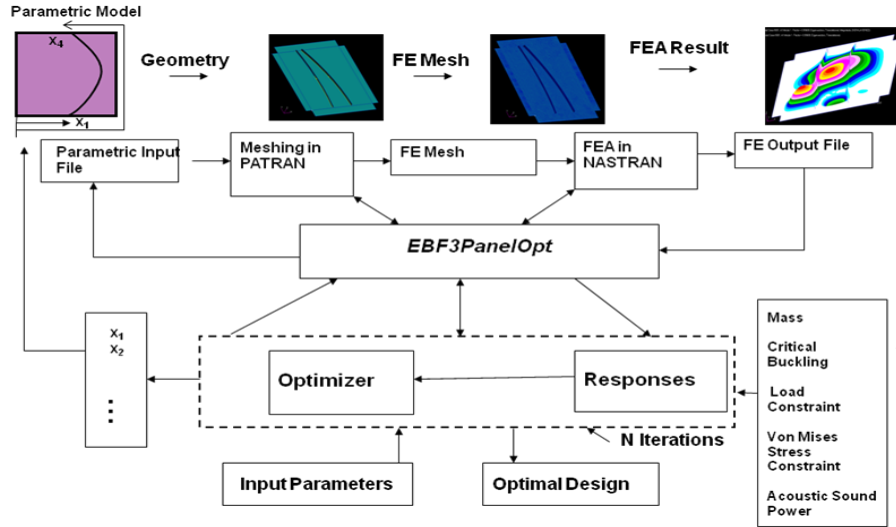


Figure 1 Developed vibro-acoustic design optimization framework

For acoustic optimization, point-excited stiffened panels are designed for minimal sound radiation given the constraint on total mass of the structure. This framework is extended to a multi-objective design optimization framework with mass and the radiated acoustic power as two objectives with constraint on buckling eigenvalue, von Mises stress and crippling stress. The developed framework is shown in Fig. 1. The developed framework, named *EBF3PanelOpt* for structural-acoustic optimization of point excited stiffened panels is also extended to multi point excitation to capture the realistic excitations such as turbulent boundary layer pressure fluctuations. Finite Element Method (FEM) is used for structural response of the structure for the excitation and acoustic response is calculated using Rayleigh integral. This vibro-acoustic research addresses the sound radiation in the acoustic medium due to structural vibration where the acoustic medium is air. The effect of air on the vibrating structure is considered to be very small. Therefore, coupling between structural and acoustic response is neglected. To reduce the computational expense of structural-acoustic optimization, a new methodology for the objective function evaluation is also proposed and optimal design for minimum radiated acoustic power is discussed.

To address the vibro-acoustic design optimization study of straight or curvilinearly stiffened panels excited by turbulent boundary layer (TBL) pressure fluctuation, the Corcos model of representing TBL is used to capture correlation of TBL pressure excitation. Validation of the approach using Corcos TBL model, implemented in *EBF3PanelOpt* is performed using fast multi-pole boundary element method in *FastBEM* [2] and a conventional boundary element code, *HELM3D* [3]. The optimal designs are obtained for a panel with two and four stiffeners, respectively. The minimization of both, the mass and the acoustic response during structural-acoustic optimization is conflicting in nature. Therefore, a multi-objective design optimization using non-dominated sorting genetic algorithm-II (NSGA-II) [4] in VisualDoc [5] is performed. The pareto optimal designs, obtained using multi-objective design optimization approach has reduced the acoustic response significantly with a minor mass penalty of the structure when compared to a baseline design while meeting all the constraints such as buckling eigenvalue, von Mises, and crippling stresses. One such panel with TBL excitation is shown in Fig. 2 and the radiated mean square pressure from this optimal design is shown in Fig. 3.

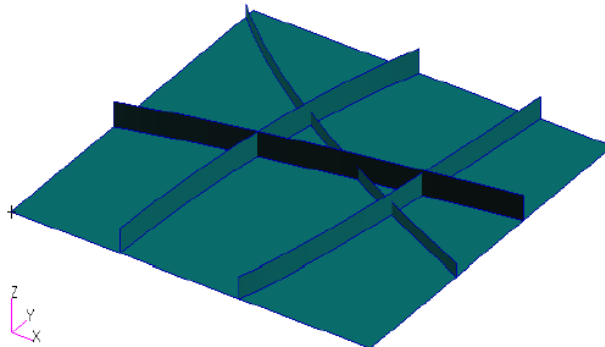


Figure 2 An optimal design for TBL excited stiffened panel

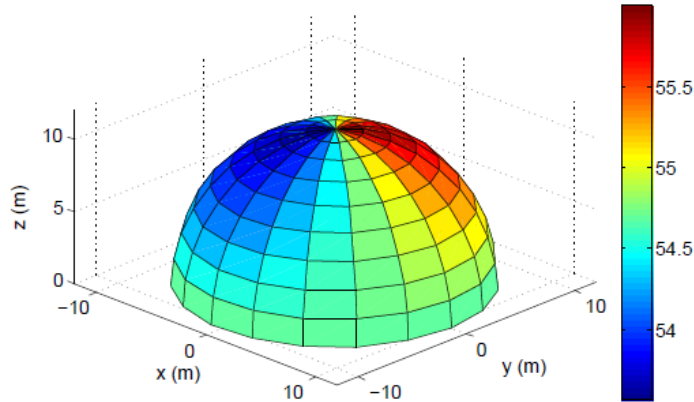


Figure 3 Mean square pressure (dB) radiated from the optimal design

A multi-objective design optimization framework is also developed for design optimization of diffuse field excited panels with straight and curvilinear stiffeners. A diffuse pressure field, assuming several plane waves coming from random directions and with random phase has been created. The obtained diffuse field is used as the source of excitation and radiated acoustic power is calculated for multi-objective structural-acoustic design optimization. The pareto optimal designs of panel with six stiffeners are obtained and a comparative study is performed with a baseline design with six stiffeners. The baseline design is obtained by performing structural optimization of a panel with six straight stiffeners. The developed framework is also extended to perform multi-objective design optimization of point excited complex structures such as curved panels with straight or curvilinear stiffeners. A fast multi-pole boundary element method is used to calculate the acoustic response of the curved panel with stiffeners and design optimization results of a curved panel with two and four stiffeners are discussed.

Experiments are also performed at Sound and Acoustic Load Transmission (SALT) facility of Langley Research Center to measure the sound radiation and transmission loss for two panels with straight and curvilinear stiffeners, respectively. The stiffened test panels have been designed using multi-objective design optimization framework for TBL excitation. The manufacturing constraint suggested by Lockheed Martin is used as the constraint in design space during multi-objective design optimization. The sound radiation is measured for point excited stiffened panels and transmission loss is measured for diffuse field excitation of the manufactured stiffened panels.

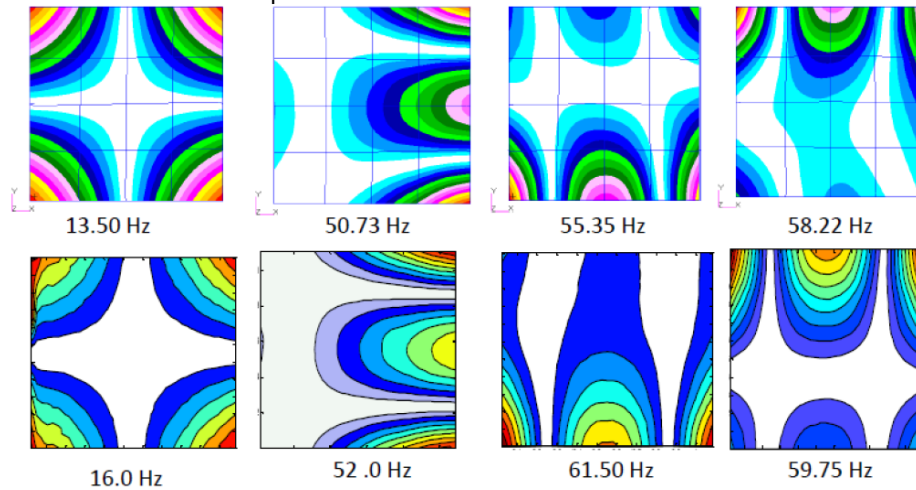


Figure 4 First four mode shape and eigen values of a panel with six stiffeners; FEM (top) and experiment (bottom)

The free vibration tests of the manufactured stiffened panels are also performed and mode shape and eigenvalues of the freely hung stiffened panels are compared with the mode shape and eigenvalues obtained using finite element analysis. The excited experimental mode shape and eigen frequencies match quite well with the finite element analysis results. This comparison is shown in Fig.4. Due to coupling of the stiffened test panels with the frame, a finite element model of the stiffened panels with frame is made. To capture the effect of the bolted joints in the test setup, bush elements with optimal values of rotational and translational stiffness are used.

References

1. Taminger, K. M. B., and Haey, R. A., "Electron Beam Freeform Fabrication: A Rapid Metal Deposition Process", Proceedings of 3rd Annual Automotive Composites Conference, September 9-10, 2003, Troy, MI. Society of Plastics Engineers (2003).
2. FastBEM Acoustics V.2.2.0 Advanced CAE Research, LLC (ACR), West Chester, Ohio 45069, U.S.A.
3. Wu, T. W., Boundary Element Acoustics: Fundamentals and Computer Codes, WIT press, 2000.
4. Deb, K., Pratap, A., Agarwal, S., and Meyerivan, T., "A Fast and Elitist Multiobjective Genetic Algorithm: NSGA-II", IEEE Transactions on Evolutionary Computation, Vol. 6, No. 2, April 2002.
5. VisualDOC 6.2, Vanderplaats Research and Development, Inc., Colorado Springs, CO 80906.