Dr. Raouf A. Raouf (1960 – 1997)

Selected Publications:

Ali H. Nayfeh and Raouf A. Raouf (Department of Engineering Science and Mechanics, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, U.S.A.), "Non-linear oscillation of circular cylindrical shells", International Journal of Solids and Structures, Vol. 23, No. 12, 1987, pp. 1625-1638, doi:10.1016/0020-7683(87)90113-2
ABSTRACT: The method of multiple scales is used to analyze the non-linear forced response of circular cylindrical shells in the presence of a two-to-one internal (autoparametric) resonance to a harmonic excitation having the frequency OMEGA. If omegar and ar denote the frequency and amplitude of a flexural mode and omegab and ab denote the frequency and amplitude of the breathing mode, the steady-state response exhibits a saturation phenomenon when omegab is almost equal to 2omegar, if the excitation frequency OMEGA is near omegab. As the amplitude "f" of the excitation increases from zero, ab increases linearly whereas ar remains zero until a threshold is reached. This threshold is a function of the damping coefficients and omegab minus 2omegar. Beyond this threshold ab remains constant (i.e. the breathing mode saturates) and the extra energy spills over into the flexural mode. In other words, although the breathing mode is directly excited by the load, it absorbs a small amount of the input energy (responds with a small amplitude) and passes the rest of the input energy into the flexural mode (responds with a large amplitude). For small damping coefficients and depending on the detunings of the internal resonance and the excitation, the response exhibits a Hopf bifurcation and consequently there are no steady state periodic responses. Instead, the responses are amplitude- and phase-modulated motions. When OMEGA is almost equal to omegar, there is no saturation phenomenon and at close to perfect resonance, the response exhibits a Hopf bifurcation, leading again to amplitude- and phase-modulated or chaotic motions

Nayfeh, A.H. and Raouf, R.A., 1987, "Nonlinear forced response of infinitely long circular cylindrical shells," Journal of Applied Mechanics 54, pp. 571–577.

Raouf, R. A. (1989). Modal Interaction in Shell Dynamics. Doctoral Thesis. Virginia Tech, Blacksburg, VA.

Raouf, R. A. and Nayfeh, A. H. (1990). One-to-One Autoparametric Resonance in Infinitely Long Cylindrical Shells. Computers & Structures, 35(2):163–173.

Raouf A. Raouf and Anthony N. Palazotto (Department of Aeronautics and Astronautics, Air Force Institute of Technology, Wright-Patterson AFB, OH 45433, USA), "Nonlinear dynamic response of anisotropic, arbitrarily laminated shell panels: An asymptotic analysis", Composite Structures, Vol. 18, No. 2, 1991, pp. 163-192, doi:10.1016/0263-8223(91)90049-5
ABSTRACT: An asymptotic procedure is used to derive the nonlinear equations of motion governing the forced dynamic response of an arbitrarily laminated slightly compressible composite shell panel in cylindrical bending. A combination of the Galerkin procedure and the method of multiple time scales is used to construct a uniformly valid asymptotic expansion for the dynamic response of the panel under near-resonant external excitation, and in the presence of a two-to-one internal resonance condition. A qualitative analysis shows that there is a threshold value for the amplitude of excitation, above which the panel exhibits the saturation phenomenon in which the amplitude of the directly excited mode saturates and the coupled mode starts to

respond nonlinearly and eventually dominates the response. The force-response curve also exhibits the jump phenomenon.

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"Non-linear free vibrations of symmetrically laminated, slightly compressible cylindrical shell panels",
Composite Structures, Vol. 20, No. 4, 1992, pp. 249-257, doi:10.1016/0263-8223(92)90030-G
ABSTRACT: A geometrically non-linear dynamic shell theory presented by the authors in an earlier work is used to study the non-linear free vibrations of symmetrically laminated cylindrical shell panels. The theory accounts for arbitrary lamination constructions, anisotropy, and slight compression across the thickness. In this paper, this theory is used to derive the equation of motion of the panel with quadratic and cubic non-linearities and symmetric lamination schemes. The symbolic manipulator Mathematica™ is used to perform the Rayleigh-Ritz procedure and derive a single-mode approximation to the vibration of the panel. The Lindstedt-Poincare perturbation technique is used to analyze the resulting non-linear differential equation of motion and study the effects of non-linearities on the dynamics of free vibrations of the panel. A numerical example of a symmetrically laminated graphite/epoxy shell panel is used to demonstrate the procedure. The numerical example shows that non-linearities are of the hardening type and are more pronounced for smaller opening angles. Moreover, it shows that the larger-amplitude motions are dominated by the lower modes.

Raouf A. Raouf (Department of Mechanical Engineering, United States Naval Academy, Annapolis, MD 21402, U.S.A.), "A qualitative analysis of the nonlinear dynamic characteristics of curved orthotropic panels",
Composites Engineering, Vol. 3, No. 12, 1993, pp. 1101-1110, doi:10.1016/0961-9526(93)90067-T
ABSTRACT: This paper presents a qualitative study of the nonlinear free vibration characteristics of curved, simply supported orthotropic panels. The panels are modeled using the Donnell-Mushtari-Vlasov shell relationships. An approximate solution to the resulting nonlinear equations is constructed using the Galerkin procedure in the spatial domain and the Lindstedt-Poincaré perturbation technique in the temporal domain. The combination of these procedures is implemented using the symbolic manipulator Mathematica. The analysis shows that although the transverse displacement may be assumed to have a single mode, the compatibility condition forces the in-plane stress resultants to be multi-modal. It is shown that the type of nonlinearity that the panel exhibits is strictly cubic if either of the axial or circumferential modes is asymmetric. On the other hand, the nonlinearity is both quadratic and cubic for axisymmetric modes. Numerical simulations using various geometric and material properties show that the reponse of the first modes of the panel could be either hardening or softening depending on the geometric and material properties of the panel. On the other hand, the response of the higher modes for the studies cases is always hardening. Numerical results also suggest that it is possible to tailor the dynamic response of some panels to produce softening or hardening behaviors.

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"On the non-linear free vibrations of curved orthotropic panels", International Journal of Non-Linear
Mechanics, Vol. 29, No. 4, July 1994, pp. 507-514, doi:10.1016/0020-7462(94)90019-1
ABSTRACT: This paper studies the non-linear free vibrations of simply supported curved orthotropic panels. The panels are modeled using the Donnell-Mushtari-Vlasov shell relationships. A combination of the Galerkin

procedure and the Lindstedt-Poincaré perturbation technique is used to construct an approximate solution to the resulting non-linear equations of motion. Algebraic manipulations show that the panel exhibits a non-linear response only when both the involved axial and circumferential modes are axisymmetric. Numerical studies of a Graphite/Epoxy panel show that its response is softening, i.e. the non-linear natural frequency decreases as the amplitude of motion increases. They also show that the lower modes are more non-linear than the higher, mainly flexural modes. The presented results also show that for the studied panels, the non-linear effects are the strongest for shallow, thin, and short panels.