Radiation-induced instability of a finite-chord Nemtsov membrane

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We consider the stability problem of a membrane of an infinite span and a finite chord length that is submerged in a uniform flow of finite depth with free surface. In the shallow water approximation, Nemtsov [1] has shown that an infinite-chord membrane is susceptible to flutter instability due to excitation of long gravity waves on the free surface if the velocity of the flow exceeds the phase velocity of the elastic waves and placed this phenomenon into the general physical context of the anomalous Doppler effect. Subsequently, Labarbe and Kirillov [2] extended the former result to the general configuration of a layer with arbitrary depth. They successfully managed to obtain new dispersion relation and stability diagrams from the application of sensitivity analysis and perturbation theory. In the present work [3], we derive a full nonlinear eigenvalue problem for an integro-differential equation in the case of the finite-chord Nemtsov membrane in the finite-depth flow. In the shallow- and deep water limits we develop a perturbation theory in the small added mass ratio parameter acting as an effective dissipation parameter in the system, to find explicit analytical expressions for the frequencies and the growth rates of the membrane modes coupled to the surface waves. This result reveals a new intricate pattern of instability pockets in the parameter space and allows for its analytical description (cf Fig.1). The case of an arbitrary depth flow with free surface requires numerical solution of a new non-polynomial nonlinear eigenvalue problem. We propose an original approach combining methods of complex analysis and residue calculus, Galerkin discretization and Newton method to produce high-accuracy stability diagrams within an unprecedentedly wide range of system's parameters (cf. Fig.2). We believe that the Nemtsov membrane appears to play the same paradigmatic role for understanding radiation-induced instabilities as the famous Lamb oscillator coupled to a string has played for understanding radiation damping [4].

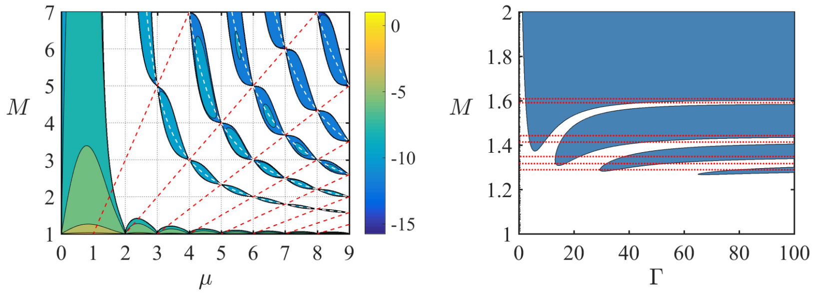

Fig. 1: Left: Shallow-water analysis. Right: Finite-depth computation.

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