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SENSITIVITY TO DAMPING OF SELF-EXCITED VIBRATIONS IN CIRCULATORY AND PARAMETRICALLY EXCITED SYSTEMS

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Abstract. In mechanical engineering systems, self-excited vibrations are in general unwanted and sometimes dangerous. In most of these the linearized equations of motion the self-excitation terms are given by non-conservative, circulatory forces and/or parametric excitation. The presentation will discuss some recent results in linear and nonlinear systems of this type. Self-excited vibrations have of course been mathematically modelled and studied at least since the times of van der Pol. The van der Pol oscillator is a one degree of freedom system; its linearized equations of motion correspond to an oscillator with negative damping. Sometimes also other self-excited systems present negative damping, which can be made responsible for self-excited vibrations. In all the engineering systems mentioned above however, the self-excitation mechanism is mainly related to the interaction between different degrees of freedom (modes), and the linearized equations of motions contain circulatory terms. This together with parametric resonance is the main excitation mechanism discussed in this paper. Destabilization by ‘negative damping’ will not be considered. Also stick-slip phenomena are not in the focus of this presentation; they also do not seem to play an important role in all the examples given above. The systems analyzed in this presentation therefore are characterized by the M, D, G, K, N matrices (mass, damping, gyroscopic, stiffness and circulatory matrices, respectively) which may all be time-dependent. In the case of instability of the trivial solution, additional nonlinear terms do of course limit the vibration amplitudes. In the first part, MDGKN-systems with constant coefficients will be discussed. For a long time it has been well known, that the stability of such systems can be very sensitive to damping, and also to the symmetry properties of the mechanical structure. Recently, several new theorems were proved concerning the effect of damping on the stability and on the self-excited vibrations of the linearized systems. The importance of these results for practical mechanical engineering systems will be discussed. It turns out that the structure of the damping matrix is of utmost importance, and the common assumption, namely representing the damping matrix as a linear combination of the mass and the damping matrices, may give completely misleading results for the problem of instability and the onset of self-excited vibrations. The second part deals with MDGKN-systems with time-periodic coefficients. The stability of these systems can be studied via Floquet theory. A typical property of parametric instability behavior is the existence of combination resonances. However, if parametric excitation in the system is simultaneously present in the K and the N matrices and/or there are excitation terms which are not all in phase, an atypical behavior may occur: The linear system may then for example be unstable for all frequencies of the parametric excitation, and not only in the neighborhood of certain discrete frequencies. In both cases, with constant or time-periodic coefficients, the system dynamics may be highly sensitive do damping. The suppression of unwanted self-excited vibrations should therefore be robust with respect to changes in the damping matrix.