Dynamic Stability, Post-critical Behavior and Recovery of Systems in Engineering

Jiří Náprstek et al.

The Institute of Theoretical and Applied Mechanics, Czech Republic

Many structures encountered in civil, mechanical, naval or aerospace engineering can get in a state of the dynamic stability loss. Overstepping a certain limit of parameters specifying external action or mutual interaction of sub-systems involved, the system response exhibits a dramatic increase which can lead to a temporary excess or a final collapse. Consequently, the problem in question consists in determination of instability areas and system behavior in respective post-critical states. Except domain of technology various phenomena of stability loss can be also encountered in many areas of plasma or solid-state physics, chemistry and other natural sciences.

In the paper the most frequently used methods of dynamic stability investigation will be reminded in relation with dynamic systems widely discussed in various engineering branches. In particular Lyapunov function and exponent procedures, Routh-Hurwitz, Lienard and other theorems together with applications will be outlined. Analytical and numerical procedures are combined. Special experimental facilities have been used and also newly developed in order to jointly affect theoretical and experimental investigation.

Systems widely encountered in engineering will be introduced in a form of mathematical models. Their analysis of dynamic stability and post-critical behavior will be outlined. Stability limits, bifurcation points (Hopf, Poincarée, etc.), attractive/repulsive limit cycles, quasi-periodic response processes, chaotic regimes will be discussed. Two levels of stability loss (possible recovery, final inevitable collapse) as they can be observed at softening systems will be pointed out. Time limited excitation and respective transition effects (seismic excitation) will be also discussed together with evaluation of possible system reliability improvement.

To illustrate above phenomena two classes of (i) auto-parametric and (ii) self-excited systems and their post-critical behavior will be presented. The former one includes various types of non-linear pendulum (2DOF, 3DOF and more complicated), systems with heavy ball moving in spherical dish (holonomic) and others, all of them being used as vibration absorbers. Softening systems related with inverse pendulum modeling slender structures (combined 3DOF+continuous) under seismic excitation will be presented. The latter class will be focused to 2DOF aero-elastic systems in linear as well as non-linear versions using neutral and flutter derivative approaches. Further systems modeling problems arising in naval and railway engineering will be outlined as well.

A few hints for engineering applications are given. Some open problems and possible future research strategy are outlined.