Non-linear dynamics of an Disc Brake System under Moving Loads

Xin SUI and Qian DING

Department of Mechanics, Tianjin University, Tianjin 300354, China

A disc braking system is modeled as that two moving loads act symmetrically on an annular beam with flexible boundary condition. A friction model with Stribeck effect is adopted to estimate the tangential interaction, resulted from the normal interactions between the contacting parts. A simulation procedure is proposed to deal with the moving interactions and calculation is carried out by using the finite difference method, which shows that only the first-order mode vibration of the beam can be induced. Then the partial differential equation of motion of the disk is reduced to a first-order mode vibration system with time-varying stiffness. Numerical simulations are then carried out to investigate the dynamics of the 7 DOF coupling braking system. Influences of the internal resonant conditions, initial pressures and acceleration of the disk motion on the frictional instability are investigated. Bifurcation diagrams, time histories, phase portraits and frequency spectra of vibrations of the pads in all directions, before and after occurrence of the frictional instability, are provided reveal the dynamical behavior of the braking system.

The critical speeds under 1:1 and 1:2 internal resonances are 0.6 m/s and 0.0081 m/s respectively, which means that the higher the critical speed is, the earlier the instability occurs. Obviously, the strong movement coupling between the moving elements brings earlier occurrence of the frictional instability. As the disk speed is below the critical speeds, the relative equilibrium of the pad on the disk loses its stability and stick-slip type limit cycle vibrations are resulted in all directions' movements. As a counterpart of the pads, the disk vibrates also with large amplitude transversely.

In case there is no pressure difference between the upper and underneath pads, the larger the initial pressure is, the earlier the instability appears. In addition, the frequency of the limit cycle vibration increases with that of the initial pressure. If there is pressure difference, the critical speeds are different for the upper and underneath pads.

Higher braking deceleration will bring the disk speed reach to zero faster and the period of stick-slip vibration with large amplitude will be shortened. But calculation shows that the stick-slip vibration is more extensively in this case, and small "jitter" phenomena happens many times during process.