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THE PARAMETRIC EXCITATION VIBRATION ANALYSIS OF DRILL STRING ON LUNAR REGOLITH SAMPLER

Abstract

The lunar regolith sampler, which has long drill string with outer spiral and inner hollow core, need to drill into dense lunar soil with impact-rotate mode. The lateral vibration will happen on the slender drill string under periodic axial excitation stem from drill pressure and impact when the drill bit contact lunar rock in lunar regolith. The lateral vibration will alleviate the impact energy, which propagates from the top of the drill string to the drill bit through the slender drill string. Especially in some harsh conditions, the drill string will buckle laterally. The instable domain under parametric excitation is determined by the physical parameters of the dynamic system. To study the lateral vibration on the drill string, the dynamic system was considered as simple supported beam with axial excitation, and the dynamic equations of the dynamic system were established. The axial excitation includes two parts. The first part is drill pressure, which is constant and can be combined into the term related to the natural frequency of rod. And the second part is periodic impact force which is described as harmonic function, considering the effect of small damping. The boundaries of stable domain and instable resonance domain were determined by some parameters, such as excitation frequency, structure of system and dynamic parameter. The dynamic equations of damping system and no-damping system can be rewritten as standard Mathieu equations by the method of separation of variables. The first order asymptotic steady state solution can be achieved by solving the vibration equations of damping system with perturbation theory. The stable domain and instable resonance domain were found, and the magnitude-frequency characteristic was also obtained. The analysis indicates that the axial drill pressure can reduce the natural frequency of the dynamic system and enlarge the instable domain; the small damping will alleviate the instability. With rational parameters, such as excitation frequency, axial impact force, material of the slender drill string, flexural modulus, natural frequency and so on, the state of drilling string will be away from the instable domain, and the lunar regolith sampler can drill into lunar regolith more safely.