MECHANISM OF FRICTIONAL CONTACT INDUCED VIBRATION OF TBM CUTTERHEAD-CUTTER SYSTEM

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ABSTRACT
The cutterhead system of a tunnel boring machine (TBM) experiences violent vibrations due to the friction between the cutter and rock during operation, this phenomenon is a potential cause of abnormal damage accidents in TBMs[1]. The formation of cutter vibration is a complex process that involves dynamic contact, elastic brittle fracture, inhomogeneous materials. Failure to consider any of these factors may result in incomplete analysis results that do not fully reflect the actual situation. Most of the existing researches focus on the key factors affecting cutter vibration, adopt the "one-way coupling" method, ignoring the interrelation and influence of the frictional contact between the cutter and rock and the vibration of the cutterhead-cutter system[2],[3]. Aiming at the above problems, this paper presents a simple but effective coupled discrete element (DEM)-multi-body dynamics (MBD) analysis method to link the rock cutting process and the vibration of the cutterhead-cutter system in real time. And attempts are made to analyze the influence and mechanism by which the various factors(rock formation properties, rotational speed of the cutterhead, and cutter profiles) have an effect on the force and vibration of the cutterhead-cutter system. Finally, the correctness of the influence trend of each factor in the model on the vibration of the cutterhead-cutter system is verified by experiments.

The results show that the total power of the cutterhead-cutter system is a determining factor in its vibration intensity. Higher rock strength and higher rotational speed of the cutterhead will increase the energy required to break the rock per unit time, resulting in a rise in the work done by the cutter and a higher cutting force; and as the cutterhead-cutter system of the main external excitation, the cutting force increases will inevitably lead to more violent vibration. The equivalent damping (caused by cutter-rock contact friction) between the cutter and the rock can reduce the vibration of the cutter. The flat-top cutter has a larger contact area and range of force compared to the circular-top cutter, resulting in a larger volume of the crushed zone area and more rock powder. Therefore, the damping effect caused by friction energy consumption is stronger, and the vibration energy is effectively reduced, resulting in lower vibration intensity for the flat-top cutter under the same level of normal force.

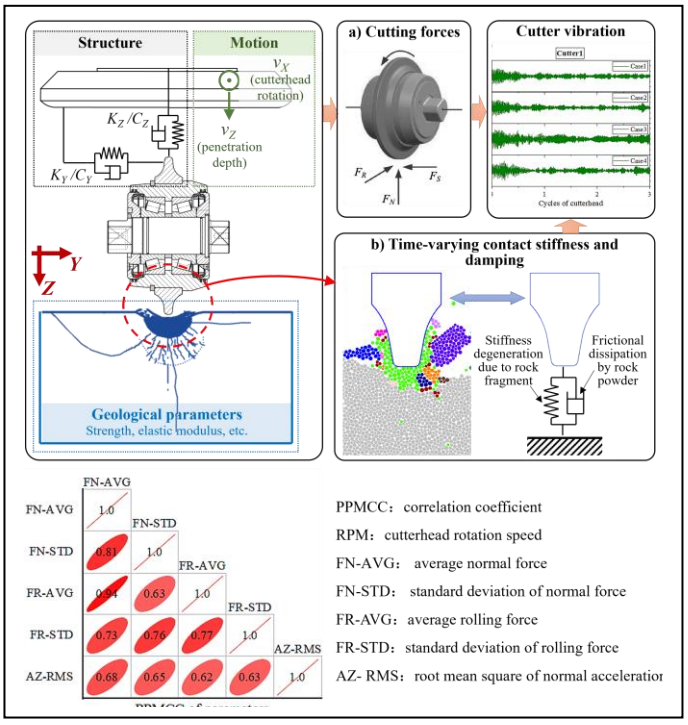

Fig.1 Correlation between cutter vibration and various factors.

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