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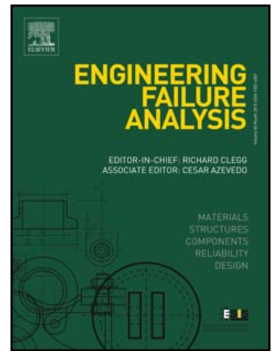

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Junzhou Huo, Dong Zhu, Nan Hou, Wei Sun, Jianghui Dong

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Application of a small-timescale fatigue, crack-growth model to the plane stress/strain transition in predicting the lifetime of a tunnel-boring-machine cutter head

Junzhou Huo[1], Dong Zhu[1], Nan Hou[1], Wei Sun[1,*], Jianghui Dong[2,*]

[1]School of mechanical engineering, Dalian University of Technology, Dalian 116024, China

[2]School of Natural and Built Environments, University of South Australia, Adelaide, SA 5095, Australia

Abstract: The crack-growth lifetime of a tunnel-boring-machine (TBM) cutter head accounts for more than 80% of a TBM cutter head's entire lifetime. Considering the ultrathick plate of a TBM cutter head, a small-timescale crack-growth model is modified to predict crack-growth lifetime based on the plane stress/strain transition condition. An improved quasistatic method is proposed to calculate the dynamic stress of the weak points of the cutter head, which is used as the input load. A plastic constraint factor α is introduced to change the yield stress value of the material. The transition of the stress/strain state in the crack tip is simulated, and the modified model is verified by a fatigue crack-growth test of the characteristic substructure, giving better prediction results. Finally, this method is applied to predict the crack-growth lifetime of a TBM cutter head in the Water Diversion Project in Northwest Liaoning Province, China, and the results show that when the crack of the cutter head's vulnerable part grows from 0.1 mm to 60 mm in depth, the TBM's useful driving distance is about 11.2 km.

Keywords: TBM cutter head; System dynamics; Crack-tip opening angle; Small-timescale fatigue crack-growth model

1 Introduction

A tunnel-boring machine (TBM) is a high-end, complex piece of construction machinery that has the functions of tunneling, mucking, guidance, and support within an entire section of tunnel [1]. The cutter head is the interface between the TBM and the rock to be excavated, and it operates under the pressure of surrounding rock and spatial multipoint distributed rock-breaking loads. Its working conditions are extremely harsh, and the unique wear of the cutter head's disc cutters results in violent vibrations of the entire cutter head, including the main girder. This kind of strong vibration may cause cutter-ring fracture, main bearing seal failure, cutter-head body structure fatigue failure, etc., thus reducing the efficiency and security of TBM construction [2 ,3]. By investigating the engineering of the Qinling, Taohuapu, and Zhongtianshan tunnels, it was found that TBM cutter-head cracking occurs most frequently and severely due to severe vibration and shock. The structural failure is caused by the long-time accumulation of crack damage, and fatigue fracture can be considered as the main reason for the structural damage.. The physical working condition of a cutter-head is very important to cutter-head effectiveness and efficiency, and once fracturing occurs, it will seriously affect the construction schedule, and can even cause the collapse of the tunnel, resulting in casualties and other damage. Therefore, it is of great value and significance to reasonably