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On the surface scratch and thermal fatigue damage of wheel material under different braking speed conditions

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ABSTRACT

The surface scratch and thermal fatigue damage of wheel and rail materials are imperative problems affecting safety and stable operation of railway transportation. This study is to explore the surface scratch damage and thermal fatigue cracks for wheel material at different braking speeds. The results indicate that surface scratch morphology presents marked thermal fatigue cracks and plowing damage with an increase in braking speed. The shallow thermal fatigue cracks initiate on wheel roller surface and then propagate parallel with the contact surface at low braking speed. However, serious thermal fatigue cracks tend to branch and propagate toward inner material at high braking speed. The frictional heat makes the yield strength of wheel materials decrease, which aggravates the thermal fatigue damage as braking speed increasing.

1. Introduction

Railway components such as wheel and rail play an important role in the stable operating and safety of railway transportation [1–4]. It is well known that the train braking system is the most important equipment as the daily and emergency braking operations. The tread braking system is widely used owing to its simple structure and great reliability [5]. When the brakes are applied on wheel treads, the frictional heat is distributed with the obvious thermal gradients on the near wheel surface and the temperature of wheel tread will rise [6–7]. The temperature corresponds with those causing the yield strength and fatigue strength of wheel/rail materials decrease, which may result in abnormal wear, thermal fatigue cracks and surface scratch in the wheel and rail surface [8–10]. Therefore, the initiation and propagation of surface fatigue cracks are closely related to the braking thermal loads [11]. The braking thermal damage is classified into two major categories by Kwon [12]. The damage distributes around circumference of wheel tread during the tread braking process, and that occurs locally between wheels and rails when the wheels skid caused by wheels locking [12]. Fig. 1 shows the typical thermal damage on the high-speed wheel tread.

The studies on the thermal load include: experimental evaluation on thermal fatigue resistance of wheel materials, analysis of the stress and strain owing to mechanical and thermal load, experiment investigation on the effect of wheel tread braking on thermal fatigue [11,13–15]. Widiyarta et al. [16] investigated the influence of frictional heat on rail wear by means of ratcheting failure-based computer simulations and found that the accumulated plastic shear strain increases as both the friction coefficient and slip rate increasing and the wear rate is around 11 times higher than the condition without thermal stress and thermal softening. Lewis et al. [8,10,17] studied the effect of temperature on the wheel and rail wear using a twin-disc machine, and they found that the bulk temperature rises owing to frictional heat and the temperature rise can noticeably influence the wear transitions from mild wear to severe wear. The evidence shows that the thermal cracks initiate on the wheel surface as the consequence for the wheel partial sliding or full sliding, which leads to bulk frictional heat on the interface. The thermal fatigue cracks will start to initiate and propagate when

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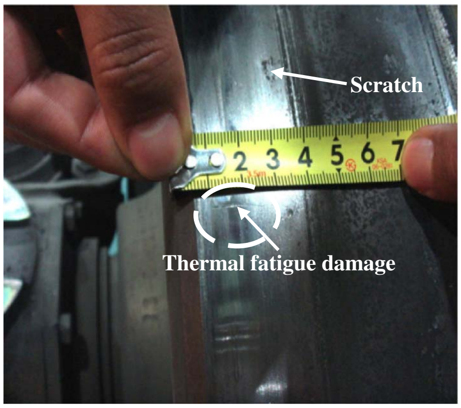


Fig. 1. Typical thermal damage on the high-speed wheel tread [12].

the thermal stress exceeds the fracture stress of wheel materials.

Reviewing previous studies about the damage of wheel materials, the braking speed is a vital factor which will influence the damage properties of wheel materials and has not been explored sufficiently. This study is to explore the surface scratch damage and thermal fatigue characteristics of wheel materials under different braking speeds using a wheel/rail simulation apparatus. Particularly, the development of thermal fatigue cracks and branch cracks on the wheel roller were investigated by multifarious micro-examinations.

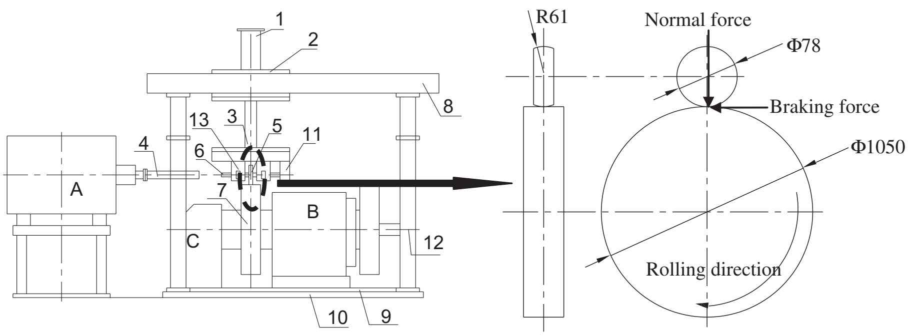
2. Experimental details

2.1. Wheel/rail simulation apparatus

All experiments were carried out using a wheel/rail simulation apparatus under the different braking speed conditions (Fig. 2). The detailed capabilities and usage had been introduced previously [4]. The tester is composed of a small roller served as the wheel roller (upper roller) (5) and a larger roller served as the rail roller (lower roller) (7). The rail roller acts as the driving roller and is powered and controlled using a DC motor (B), and the wheel roller is drove by the friction force in the wheel/rail contact interface. The braking force in the wheel/rail contact interface is obtained via a magnetic powder brake (11) that was installed to the wheel roller shaft (6) during the experiment process. The magnetic powder brake is a transmission device using the magnetic powder as transmission medium to produce resistance moment. The power of magnetic powder brake is changeable to generate different braking resistance moment. Therefore, different braking forces could be applied to the wheel roller and the experiments simulate normal braking.

2.2. Experimental materials and parameters

The rail roller used in this study was made of rail material and the wheel rollers were cut from the real wheel tread. The rail roller



1.Normal loading cylinder; 2.Loading carriage; 3.Spindle and yoke; 4.Univesal shaft; 5.Wheel roller; 6.Wheel shaft; 7.Rail roller; 8.Lateral loading cylinder; 9.Turning plate; 10.Base plate; 11.Magnetic powder brake; 12.Speed measuring motor; A,B.ZQDR-204 DC motor; C.Gear box

Fig. 2. Wheel/rail simulation apparatus and simulating wheel and rail rollers. 1. Normal loading cylinder; 2. Loading carriage; 3. Spindle and yoke; 4. Universal shaft; 5. Wheel roller; 6. Wheel shaft; 7. Rail roller; 8. Lateral loading cylinder; 9. Turning plate; 10. Base plate; 11. Magnetic powder brake; 12. Speed measuring motor; A, B. ZQDR-204 DC motor; C.·Gear box.