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Research of rail traction shafts and axles fractures towards impact of service conditions and fatigue damage accumulation

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ABSTRACT

Traction shafts and axles of railway vehicles are designed to be safe and reliable in normal service conditions. Accidental and unpredictable conditions including bad exploitation (rail tracks, maintenance and extreme long service life) make the probability of shaft and axle fracture realistic. This article contains the experience and analysis of the traction shafts and axles fractures and fracture processes. Research also shows service conditions with results presented in the form of service stress spectrums. Besides normal service conditions, the results also include unpredictable phenomenon such as natural torsion vibrations of the shaft and wheels caused by stick–slip processes at the moment of the set in motion of a full-loaded train or at the moment of braking. These vibrations create an extremely high level of torque which is the main cause of cracks initialization. The next part of the article contains the results of the traction shafts and axles endurance research. The results of testing are transformed using the results of calculation by the FE method and by statistical estimation of the failure probability distribution. The main part refers to the interaction (impact) of service stress probability and failure (endurance) probability, which leads to the traction shaft (axle) reliability definition. Using the established model, locomotive traction shaft reliability is calculated and analyzed. The final part of the article contains suggestions for the traction shafts (axles) failure prevention.

1. Introduction

Traction shafts and axles of railway vehicles are designed to be very safe in normal service conditions. The shape and dimensions are optimized according to expected loads (and harmonized with load distribution), to stress concentration and to other design characteristics of those components. The service life is anticipated to be unlimited and it is a quite common occurrence that those railway components work 40 years without failures. However, some of them break on their own accord after a much shorter service time. Axle and wheel fracture can cause big traffic accidents and produce serious damages of railway vehicles and railway track. In numerous fracture cases the mentioned issues were avoided and prevented by correct vehicle damage monitoring. This problem is not new; traction shafts and axles fractures were analyzed as well as great efforts made to define the causes of those fractures and to improve the monitoring systems. This article intends to present a review of the authors' experiences with railway traction shafts and axles fractures and to define causes and processes of those failures. The main hypothesis of this approach is the impact of service conditions on railway vehicles and fatigue damage accumulation along the fatigue life. The types of fracture and fracture causes are various.

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State-of-the-art research in the area of railway traction shafts and axles fracture can be presented by the cited articles. Article [1] presents one kind of wagon axle fracture caused by progressive bearing damages. Without permanent condition monitoring and maintenance, the axle bearing can cause progressive brake or interrupt axle rotation and produce axle fracture. This article shows the relation between bearing conditions and railway axle fracture. The locomotive traction shafts failures, influence of stick–sleep process in wheel and rail track contact, together with the shaft reliability assessment is analyzed in article [2]. Railway wheels are components which can also be fractured by fatigue damage accumulation [3]. Reliability against damage accumulation and fracture propagation in the wheels is investigated in article [4]. The complex multiaxial stress state in the wheel and the probability of crack initiation is experimentally proved and identified. Similar machine parts, such as traction shafts of agriculture machines [5] are tested in order to establish fatigue life, endurance limit or failure probability. Specifically, steel endurance limit and failure probability for railway shafts are tested and results presented in article [6]. The size effect and effect of surface degradation at failure probability is included in the presented *S–N* curves. The effect of surface degradation in the range of super-long life (10^6–10^{10} stress cycles and more) is significant. There is no infinite fatigue life and endurance limit slightly decreases. It can be one of the reasons for cracks occurrence and axles fracture after a long service life. Article [7] also discusses the problems of railway axles fracture and considers the crack initiation, especially the size effect and fracture probability of the axles. Besides crack initialization, crack propagation through the section is also important for research of the railway traction shafts and axles fracture. Steels for these components are sensitive to the stress concentration caused by a crack, and crack propagation is very fast. Article [8] offers very important test results for crack propagation in real railway shafts–axles. Stress cycles number of 10^5 can be sufficient for axle fracture after the crack initiation. This is a very short part of the shaft–axle service life and they can be fractured in a relatively short exploitation period after the crack initiation. Monitoring of the crack initiation in the axles and traction shafts has to be permanent and systematic. The problems related to these aspects are discussed in articles [9,10].

2. Analysis of railway traction shafts and axles fractures

Fracture position in railway traction shafts and axles is various. In Fig. 1 the railway traction shaft and axles are both presented. Two types of railway axles are taken into consideration, the axle with disc brakes and the one with wheel brakes. The five areas of the shaft–axle fracture are defined. Position 1 is the area between the wheel and traction gear hub or hub of the disc brake. This area has significant stress concentration caused by the two hubs (wheel hub and gear or disc hub). In order to

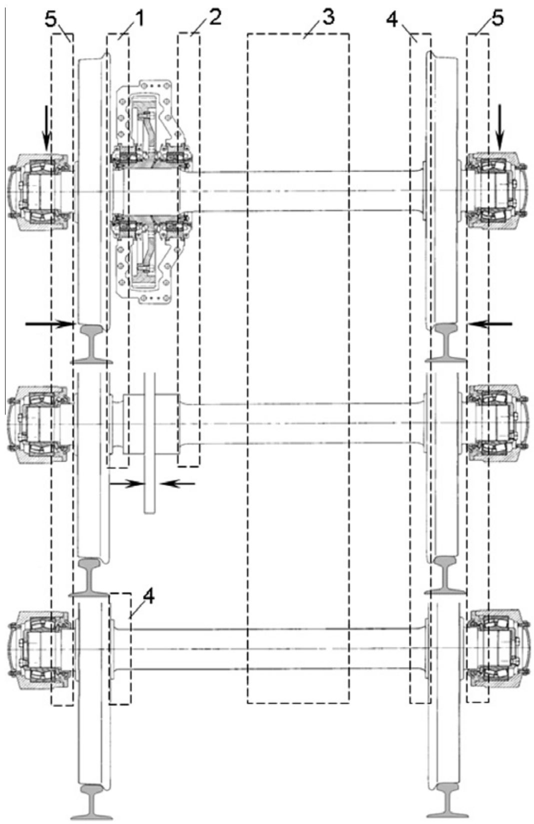

Fig. 1. Distribution of fracture places in the railway traction shafts and axles.