Load collective design for fatigue analysis of railway vehicle components

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Background

Current standards for fatigue analysis of railway components determine the stress history based on measured or simulated load histories. For dynamically loaded components, where the vehicle type and track conditions can leads to multiaxial loading and variable load sequences. Cumulative damage approaches can be used to assess the fatigue life of these components if the whole load collective is measured or simulated however in cases where the load histories are unavailable, simplified load collectives, like those outlined in the VDV 152 standards for low-floor rail vehicles, are used to estimate the fatigue life of components. These standardized load collectives simulate tangent and curved track conditions however the load collectives do not integrate in the effect of track irregularities on component loading. While these standardized load collectives provide an adequate estimation of fatigue life, these load collective neglect the effects of higher frequency loading and load sequencing effects on fatigue life and do not guide the explicit handling of multiaxial loading on fatigue life and crack propagation within components.

This study investigates the impact of higher frequency loadings and multiaxial loading sequences on fatigue life for low-floor vehicles. It comprises of two parts: (1) a comparative analysis and explanation of current fatigue estimation methodologies for rail vehicles, and (2) the evaluation of fatigue life for a simulated low-floor tram system under in-service running conditions.

The comparative analysis focuses on the standardized fatigue life estimation method for low-floor rail vehicles (VDV 152) and compares it with alternative time-based and frequency-based fatigue estimation methods. Using these methods, the running gear components' fatigue life is computed analytically and compared to the measured fatigue life. The load histories for the analytical calculations are derived from multibody simulations of an articulated 70% low-floor tram running on track with measured lateral and vertical track irregularities, simulating current in-service conditions.

It is anticipated that these results will provide clarity on the impact of different fatigue life estimation methods on the calculated fatigue life and the difference between standardized approaches versus time and frequency-based load collectives. Furthermore, this work can provide guidance on appropriate cumulative damage methods to assess fatigue life when using non-standard load collectives.

An abnormal vibration phenomenon and the control strategies of vehicle-mounted motor cooling system in a high-speed train

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Introduction

The motor cooling system is a typical piece of vibration-inducing equipment in a high-speed train [1], which consists of a wind fan suspended under floor, and a long wind transportation duct with several different cross-sections due to the limited mounting space in the bogie area. However, an abnormal vibration phenomenon occurred in a Chinese high-speed train with several octave frequencies of 38Hz induced by the motor cooling system. Passenger even felt numb while standing on the floor in the upper region of wind duct. Moreover, cracks were found on few wind ducts after removing the bogies in the maintenance stage. In this paper, the abnormal vibration characteristics are investigated by both the specialized and long-term monitoring test. A simultaneous proportion test bench is designed to study the vibration mechanism. Finally, different control strategies for both the existing operational and the newly manufactured trains are proposed and validated.

Analysis

1) **Phenomenon descriptions**. The occurrence of 38 Hz and its octave frequencies show a strong correlation with the train velocity threshold on 70 km/h, which is the trigger point of the high-speed mode of wind fan. It means that the source of abnormal vibration is the wind cooling system. According to the monitoring test on a high-speed train operated in Beijing-Shanghai railway line for 20 days, the approximate mileages percentage of failure mode is 6.77%.

2) **Cause analysis**. The abnormal frequency of 38Hz and its octaves reappeared in the simultaneous proportion test bench by blocking about 80% area of the fan inlet or the motor air inlet. Several main frequencies, such as 35Hz, 70Hz, 88Hz and 110Hz, were analyzed from the aerodynamic turbulence characteristics in the wind duct using CFD method. Therefore, the vibration of the motor cooling system increases exponentially because of the turbulence in wind duct while the frequency of 38Hz occurs.

3) **Optimization approaches**. Two approaches are proposed regarding the wind fan and duct respectively. The technical specification of the wind fan is updated to optimize the flow-pressure characteristics to extend the stabilization workspace in the condition of low-flow rate. With respect of the wind duct, the cross section is optimized to reduce the flow induced vibration, avoiding the octave frequencies of 38Hz. In addition, the cracked welded part is replaced by the integrated aluminum profile structure to increase the structural strength.

4) **Validations and applications**. The optimized wind fan and the new duct structure are validated on the test bench. The approach of updating wind fan is suitable for the existing operational trains, which has been validated by the operational assessment of about 0.3 million km without occurrence of the failure frequencies. The approach of optimizing wind duct is implemented in the newly manufacturing trains to enhance the product quality.

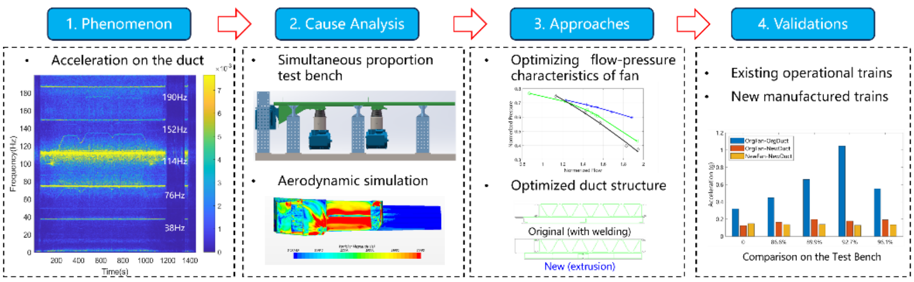

Fig. 1 Analysis workflow and results

Conclusions

The abnormal vibrations on the motor cooling system with 38Hz and its octave frequencies originate from the wind fan since the unstable state in low-flow rate. The flow induced vibrations in the wind duct increase structural mechanic vibration exponentially. Thus, an optimized wind fan with wider stable workspace and the alternative wind duct with integrated profile structure are validated to be the effective strategies for the existing operational and newly manufactured trains respectively.

References

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Life extension of a cracked tram carbody

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Introduction

Tram fleet M32 has been in operation on the tramway system in Gothenburg since 2004. Fatigue cracks were found in the upper door openings. The unexpected appearance of the fatigue cracks threatens Västtrafik's long term plans for these vehicles. Therefore, Västtrafik initiated an investigation with the aim to develop and implement measures to ensure life extension.

Analysis

A previous strain gauge measurement was available to DEKRA. These strain gauges had been positioned locally in the vicinity of the corners near the cracks. The signal patterns and the track properties were simultaneously analysed, complemented by a vehicle dynamics simulation, see Figure 1. It could be concluded that torsion of the carbody was the dominant fatigue load behind the fatigue cracks.

The corners were reanalysed with a fatigue design analysis in a FE model, which concluded that the design life was too short. Most probably, torsion was not considered during design. In order to a to enable the life extension a damage tolerant program was introduced. This consists of crack repair, a minor reinforcement and recurrent inspections, based on fracture mechanics.

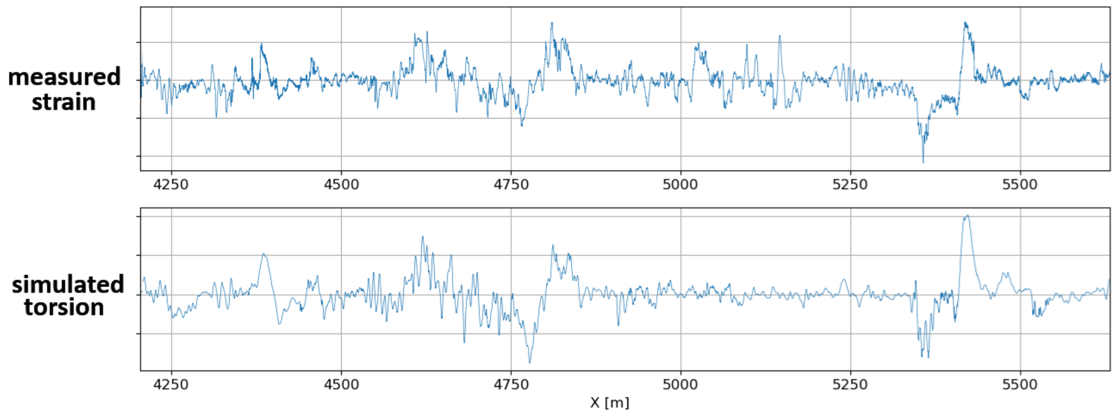

Figure 1. Upper diagram: measured strain from field test. Lower diagram: torsional moment on the carbody from multibody simulation.

Conclusions

The identification of torsion enabled the establishment of a fracture mechanics based program for life extension. A firm understanding of the interaction between the vehicle and the track is necessary to determine the dominant fatigue load.

Long term on-track test with EPS wheel profile

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Introduction

Continuous measurements of ride comfort in terms of carbody accelerations provides new possibilites to investigate long-term trends and systematic events, and A-Train has made non-stop ride comfort measurements since 2017. A comfort issue occurs after reprofiling, see Figure 1. The upper diagram shows relative lateral ride comfort during three years of measurement, and the lower diagram shows equivalent conicity of the wheels. Reprofiling with the standard S1002 wheel profile results in a period with reduced ride comfort, before recovering to the level prior to reprofiling.

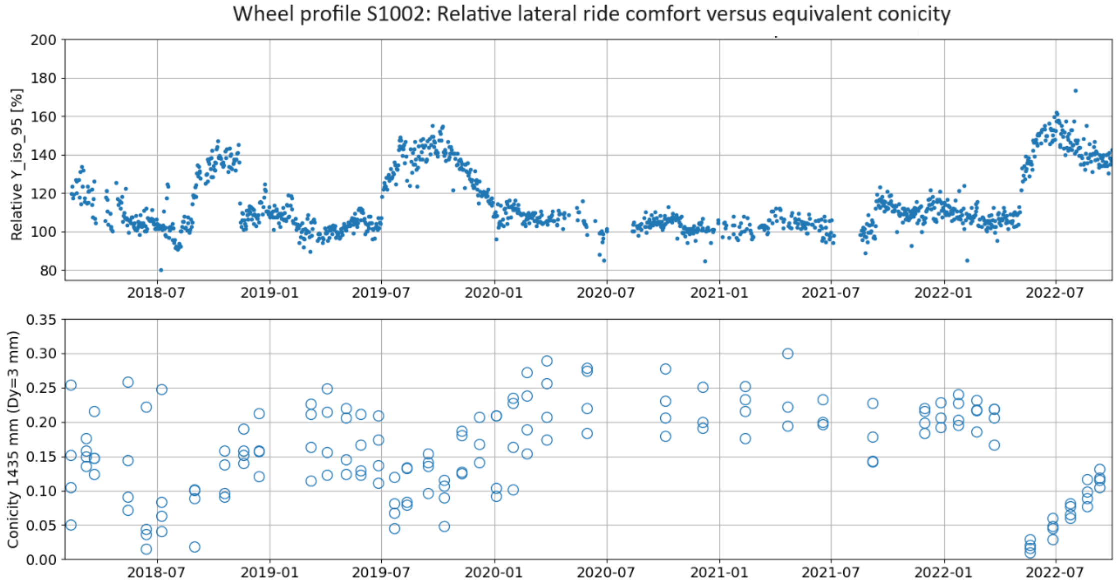

Figure 1. Problem description, current situation with S1002 wheel profile. Upper diagram: relative lateral ride comfort, comparison of daily 95% percentile rms values. Lower diagram: equivalent conicity of measured wheel profiles, rail profile 60E2 1/40 inclination, gauge 1435 mm.

Scope

The effect on ride comfort by reprofiling with the EPS wheel profiles, EN13715 (2010), which has a higher initial equivalent conicity than the S1002 profile, is demonstrated in a long term on-track test.

This work is part of the on-going research activities within the collaboration project "A systematic approach to improve passenger ride comfort" between the infrastructure manager Trafikverket and operators A-Train AB and SJ AB, together with external partners, Asplund et al. (2023).

References

M. Asplund et al., "Introduction to the Collaboration Project: A Systematic Approach to Improve Passenger Ride Comfort", Trafikverket 2023/113404: 178508100-001, 2023.