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Wear and Fatigue Behaviour of Wheel and Rail under Operational Conditions and Consideration of Future Developments in Material Use

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Abstract

This paper shows that ÖBB Infrastruktur AG operates a very diverse network of lines, ranging from straight sections to very tight curves across the Alps, which are subjected to very high loads. Rolling contact fatigue or wear can occur under different operating conditions. Due to the increasing shift of a wide variety of transports to rail, the requirements are increasing. For this reason, the effects of the material selection of wheel and rail have been analyzed several times, e.g. [1, 2, 3]. ÖBB Infrastruktur AG and the R&D service provider AC2T research GmbH have investigated the optimal rail quality depending on curve radii, load and wheel materials used. This should enable the infrastructure manager to develop a rail laying strategy during track maintenance that takes into account the change frequency of different wheel qualities.

Keywords: wear, fatigue, wheel-rail contact

1 Introduction

Application of ÖBB Infrastruktur AG operates a route network that varies greatly in terms of routing. Predominantly straight sections are used by the same vehicles as the very narrow curves over the Alps, some of which are subject to very high loads. Depending on the required alignment parameters, either rolling contact fatigue or wear predominates on the rail.

The demands on the wheel-rail system are becoming ever higher. The loads on the track are increasing, and the costs of maintenance must be optimized to an ever greater extent. This is achieved through permanent further development of the maintenance system via process considerations, but the technical design of the track also influences its maintenance costs. For this reason, the effects of the material selection of wheel and rail have already been analyzed several times (e.g. [1, 2, 3]).

Now, together with the Austrian Center of Competence for Tribology (AC²T research GmbH), investigations have been carried out into the optimum hardness of rails as a function of curve radii and wheel materials used. This will enable the infrastructure manager to evolutionarily develop his rail laying strategy in the maintenance of the track, taking into account the changing frequency of different wheel qualities in the future.

Within the scope of this project, a trend analysis will be carried out on the wheel-rail model test system (TOG2) already existing at AC²T [3], so that a wheel-rail material selection catalog for different conditions relevant in the ÖBB rail network will be developed on the basis of selected tests. These results are to be used as further information for the future material selection for rails in curves for the Austrian rail network and thus increase the operating time of wheels and the service life of rails and thus contribute to a sustainable cost saving.

The following project priorities have been defined:

- Wheel and rail hardness on wear and crack initiation.
- Influence of curve radius on wear and crack initiation
- Trend analysis for the real system

The following objectives were defined:

- Deepening the knowledge regarding wheel and rail hardness on wear and crack initiation/early damage using selected wheel and rail material pairings on the AC²T rail tribometer (comparison R260, R350HT, R400HT; comparison R7 and R9).
- Determination of plastic deformation zones or depths (shape retention of wheel and rail)
- Verification of selected influencing variables on wear and crack initiation and their periodic formation
- Influence of the curve radius

2 Methods

Using the realistic TOG2 laboratory model test rig with online track width measurement and test specimens machined from the rail and wheel, different operating conditions were experimentally simulated by comparing them with contact simulations and contact surface analyses of real rail and wheel specimens.

In the literature [5, 6], 3 different wear phases are described within the product life of contact-stressed components: Increased plastic deformation and wear occur in the run-in phase, which are reduced in the stability phase. After the stability phase, the failure phase begins, whereby wear and vibration are increased due to surface damage. The product life basically ends at the beginning of the failure phase.

In the case of wheel-rail contact, there is also a run-in and stability phase. On the model test rig, the run-in and stability phases are precisely determined by online track width measurement, which records every cycle. From the data obtained, the duration of the run-in phase and the average wear rate in the stability phase are determined for the different wheel-rail material pairings under different operating conditions.

The contact simulation and the contact surface analysis on real wheel-rail samples allow the comparison (tendencies) of the wear behavior of the real system with the wear behavior on the model test rig.

The concept of the methodological approach is shown schematically in Figure 1.

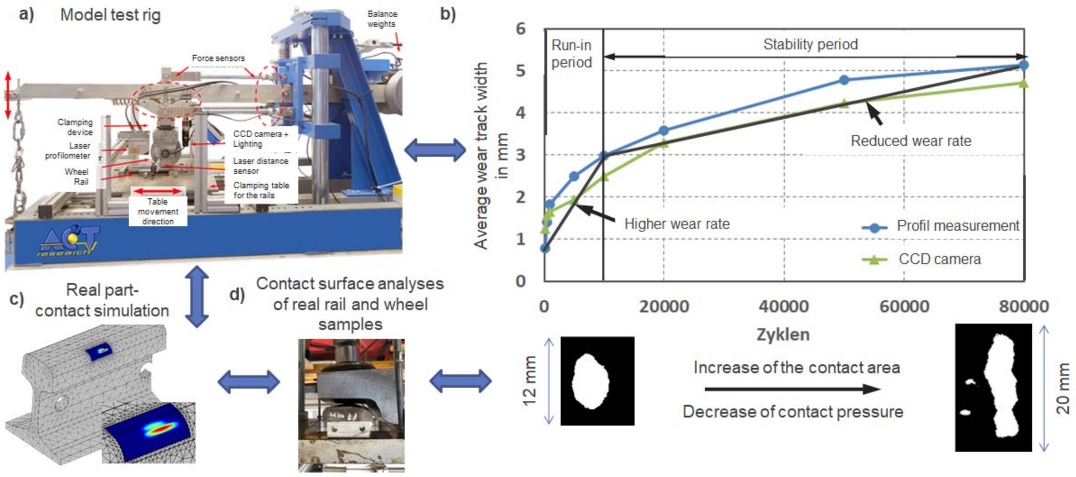

Figure 1: Methodical procedure of the study of wheel-rail interaction at AC²T: (a) laboratory model test rig TOG2, (b) online track width measurement for targeted characterization of the different wear phases, (c) real part contact simulation in wear condition, (d) real part contact area analysis wheel-rail.

This methodology, which has been expanded to include the separation of running-in and stability phases as well as contact simulations of real surfaces, is particularly suitable for the detailed investigation of the following questions:

- Influence of wheel and rail quality (different material pairings) on wear and development of fatigue cracks (rail materials: R260, R350HT, R400HT; wheel flange materials: R7, R9) in straight running and at different curve radii (radii 2000 m, 1000 m, 750 m, 500 m).
- Description of the causes of wear, crack initiation and crack propagation by combining the experimental results with online measurements, microstructural investigations (SEM, FIB, EBSD) and FEM calculations.

3 Results

The influence of different wheel (ER7G, ER7H and ER9H) and rail grades (R260, R350HT and R400HT) on wheel-rail wear under different operating conditions (e.g. variation of arc radius and axle load) were investigated in the experiment. ER7G corresponds to a used wheel made of ER7 with a hardness of ~250 HV1, where the service life was almost reached. ER7H and ER9H correspond to new wheels from ER7 (~300 HV1) and ER9 (~340 HV1).

Complementary comparisons were made with literature data regarding wear to wheel to rail hardness ratio [1, 2, 3] for straight running. Very good agreement was found between the model test rig and the real system.

The rail wear remains approximately the same despite different wheel mating bodies with different hardnesses. This was observed for both R260 and R400HT. As the wheel hardness increases, the wheel wear decreases. The wheel wear of different wheel grades is only slightly higher when using the rail made of R400HT.

With regard to plastically deformed zones and crack characterization, longitudinal transverse cross-sections were performed on the rail and the wheel for all test variants. It can be clearly seen that with increasing hardness, the contact area and the plastically deformed zone decrease in depth for both the rail and the wheels. With increasing wheel contact angle, i.e. decreasing arc radius, the wear increases nonlinearly and the crack length also decreases nonlinearly. The plastic zone forms within the first 4,000 cycles at the beginning of the run-in phase [5]. It can also be seen in the longitudinal transverse section that the average crack length, crack depth and the number of cracks per cm decrease with increasing hardness in both the rail and the wheels.

4 Conclusions and Contributions

The very heterogeneous ÖBB-Infrastruktur AG track network has a high proportion of curves with severe wear. For highly loaded small curve radii, higher-grade rail steels are therefore used in long-standing practice. The increasing use of likewise harder wheel material leads to the question of the optimum choice of rail grade in the future, depending on curve radius and rail stress.

Here, the objective of the analyses plays an essential role in the modeling of the test stand trials. The contact angles, angles of attack and detailed documentation have a significant influence on the results or their significance. A high level of detailed information was achieved through extensive test series with variation of the main influencing variables. With the creation of a material grade map as a function of the angle of attack (sheet radius) and "wheel grade mix", well-founded decision-making bases are now available for the individual assessment of sheets in the draw frame network.

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