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Limitations of analytical strength verifications with local effects and nonlinearities: A case study on a failed high rack rail

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ABSTRACT

A standard rail of a high storage rack showed cracking after a few years of operation. The investigations first focussed on the support bearings of the rail that define the span for the dominant bending load. Potential defects in the butt welds and the material also had to be taken into consideration. Hence, metallographic analyses and a detailed stress analysis by means of the Finite Element Method (FEM) were performed. The FE simulations revealed dominant local effects in the contact zone between wheel and rail, where local bending exceeded the global rail bending stress, with additional transverse stress components due to the compliant rubber collar of the wheel. An improved rail profile was suggested, and an analytical proof of the rail's fatigue strength was performed according to DIN 15018 (comparable to ISO 8686), which additionally took into account the local stresses from the FE simulation.

The case exemplary shows the risk of analytical strength assessments based on nominal stresses, where local effects may be underestimated or even ignored. Analytical strength verifications are typically based on a few assumptions: one or several load cases should be identified as dominant cause for mechanical stress, which is in the ideal case predominantly uniaxial. Additionally, all preconditions for an analytical approach must be fulfilled such as typically linear behavior (no contact), small deformations compared to the structural dimensions, and linear elastic isotropic material. Local effects should be negligible or of lower order. Hence, analytically designed structures usually have to undergo a static loading test for verification. The paper discusses the difference of nominal stress, local stress or notch stress from FE models. It provides a guidance for the mixed approach in strength verifications, where local stresses from FE results can be used supplementary to analytical stress results for strength verifications which are based on nominal stresses.

1. Introduction

Many structures in transportation and industry are designed and dimensioned according to standards and guidelines which allow the strength verification based on analytical results, i.e. the stresses are assessed by means of nominal stresses

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which again are based on formulas and analytical results. The use of numerical results for example from finite element (FE) simulations is usually not intended. But local stresses due to model nonlinearities such as contact, large deformations, or nonlinear material are generally easier to grasp and quantify with numerical tools such as the finite element method (FEM) than with analytical approaches. It may therefore be reasonable to use numerical stress analysis results or at least components thereof in a classical strength verification (which still may be based on nominal stresses). A more modern and also established approach is clearly the strength assessment based on local stresses, *if* a numerical analysis tool is available where the simulations facilitate the considerations of all nonlinearities and notch effects.

In the present case the rail of a high storage rack showed fatigue cracks in the upper flange of its INP 240 standard section. The high rack operates with a monorail concept shelf feeder, where the stability is given by a second small rail at the upper end of the vertical beam, cf. the exemplary Figs. 1 and 2. The actually observed cracks in the running surface of the bottom rail are shown in Fig. 3.

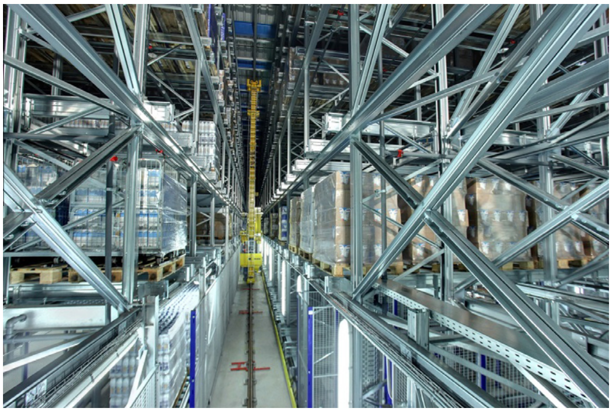

Fig. 1. Typical installation of a high rack with monorail shelf feeder. Source: http://group.emmi.com.

Fig. 2. Shelf or rack feeder with two bottom rollers and guiding pulleys (top). Source: http://www.mecalux.com.