1. Introduction

The metro wagon bogie tow bar consists of three main parts – the central tube part and two lugs. These parts are welded to each other. Metro tow bars cracks had appeared during the operation on the wagons near the welds. Metro operator assigned the examination of tow bars fatigue life.

Strain gauges were installed on the tow bar and the loading spectrum was measured during an operation. Two bars were loaded by means of hydraulic actuator and the initialisation and propagation of crack was monitored.

2. Measurement of the loading spectra

The places where strain gauges were installed can be seen in Fig. 1. Eight unidirectional strain gauges HBM LY11 6/120 and two strain gauge rosettes HBM RY91 6/120 were installed near the weld. Strain gauges were connected with measurement unit HBM Spider 8. The calibration of the bar was made in laboratory using hydraulic actuator IST 160 K, see Fig. 2. The prepared bar was then installed on metro wagon bogie, see Fig. 3.

Most measurements were performed during the morning rush hour, when maximal loading of tow bar was expected. Nonstandard situations, like emergency stop etc., were simulated and measured in the night time without a passenger loading. Example of measured dependency of the loading force versus the time can be seen in Fig. 4. All measured data were then analyzed and typical operational spectra were evaluated. The Rain-Flow method was applied to compose two parametric stress matrixes.
These were consequently used for prediction of the fatigue life of a new type of bogie tow bar.

Fig. 4: Force versus time during one ride between the end stations.

3. Fatigue life of the tow bars

Two tow bars were chosen by metro operator to determine the fatigue life. Three load levels were chosen to loading tow bar. The first lowest one corresponded to a design level of the safe operation. Five million cycles without failure was assumed. Loading was performed by hydraulic actuator IST PL160K, when alternate sinus loading was chosen with 10 Hz running frequency. Four strain gauges HBM LY11 6/120 were installed at places A, B, C and E, see Fig 1. Setup of the loading stand was similar as can be seen in Fig 2.

The first specimen was loaded on the first load level 5 million cycles without observing of cracks. Loading on the second load level was interrupted after cca 2⋅10⁵ cycles, when the crack was observed in the welded toe. It was suspected that the crack had been initiated during the first load level, but it should be hidden under layers of cement and paint. Therefore second tow bar was cleaned in such interesting places.

The crack initiation near the weld was also observed during the second test, when the bar was loaded on the lowest force level. Grow of this crack can be seen in Fig 5. Loading was finished when stiffness response prevented load controlled test. The tow bar was broken for possibility examine fracture surface. Fracture surface can be seen in Fig 6. The program for prediction of a fatigue life of the tow bar was compiled, when inputs were measured loading spectra, S-N curves of typical weld geometry. The operator can mixed loading spectra according the real operation in service and predict the fatigue life of the tow bar.

Fig. 5: Crack propagation on the second specimen

Fig. 6: Fracture surface on broken specimen 2

4. Conclusion

A measurement of the loading spectra of the metro wagon bogie tow bar showed high peaks in the operational loading, which can leads to the fatigue crack initialization. The fractography analysis showed that main problem was the technological indiscipline during a welding process. A new shape of the connection of the lugs to the central tube was than designed by operators to avoid the fatigue fracture.

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6. References