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Tests and FEM Calculations for the Screw Coupling 1MN

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Abstract The article describes mandatory requirements for screw couplings in the service release. Additionally, the test results for the coupling and their comparison with FEM calculations are presented.

Introduction

Screw couplings are universal connections for railway vehicles. The safety of the integrity of the train composition in operating conditions depends on these devices, understood as a combination of various types of wagons and locomotives. Not only are these devices subjected to very high loads, but also must be resistant to long-term influence of changing weather conditions. Approval of this type of equipment for operation requires carrying out tests in the scope described in current European standards and the following directives: EN 15566: 2016 [1]; EN15566: 2011[2]; Rolling Stock TSI - Freight Wagons WAG / Commission Regulation (EU) No. 321/2013[3]; TSI - Rolling stock - Locomotives and passenger rolling stock / Commission Regulation (EU) No. 1302/2014 [4].

The EN 15566 standard defines the range of forces to be applied for screw couplings operating in load ranges of 1MN; 1.2 MN; 1.5 MN, depending on the time of use (20 or 30 years).

Table 1. Condition of dynamic tests for screw coupling [1]

Operational requirements	Range of forces to be applied		
Lifecycle in years	Designation	Step 1	Step 2
	1 MN	ΔF1 = 170 kN	ΔF2 = 575 kN
	1,2 MN	ΔF1 = 205 kN	ΔF2 = 690 kN
	1,5 MN	ΔF1 = 270 kN	ΔF2 = 910 kN
		N_1 in cycles	N_2 in cycles
20	all	10^6	$1{,}45 \times 10^3$
30	all	$1{,}5 \times 10^6$	$2{,}15 \times 10^3$

The area (surface) of the shackle-hook interaction is the crucial place in the screw coupling. In this area, there is a surface contact of the coupling and hook elements, as well as force transmission, including high surface pressure. The following are the results of tests for 1MN screw coupling in the 30-year operation variant.

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Fatigue test

Fatigue tests of screw coupling 1MN (part of the required tests) were carried out on a LFV testing machine with a maximum tensile force of 2.5 MN Fig.2. An example of a fragmentary graph of fatigue history is presented in Fig.3. The maximum tensile forces for the coupling were 575 kN during this study. The number of the highest loads F = 575 kN in the entire fatigue tests was 2150 cycles.

Fig. 1. Screw coupling 1MN on the testing machine during tests

After the completion of fatigue tests, the screw coupling was subjected to destructive tests, using a magnetic powder method to assess the surface condition of the bow (screw coupling) in the area of surface contact with the hook. The NDT tests revealed cracks on the shackle of the 1MN screw coupling. The results of the tests (Fig.4) are presented below. Regarding the requirements and assessment criteria described in standard EN 15566:2016, discontinuities / fractures up to 20 mm are allowed.

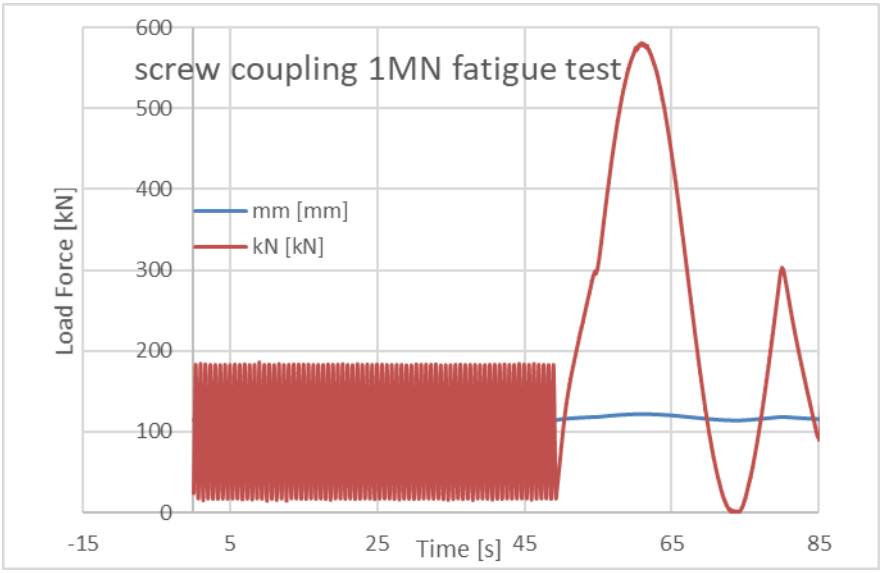

Fig. 2. The course of fatigue loads for the screw coupling

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Fig. 3 Non-destructive testing NDT - magnetic-powder method, observations of the shackle screw coupling 1MN after fatigue tests. Visible cracks in the marked area.

In order to accurately assess cracks in the shackle screw coupling 1MN, it was subjected to further examinations.

Computed tomography tests

CT examinations were performed on GEphoenix v/tome/x m tomograph with a panel detector using a 300 kV X-ray tube. The examples of spatial images of cracks propagation of shackle screw coupling 1MN are presented in Fig.4.

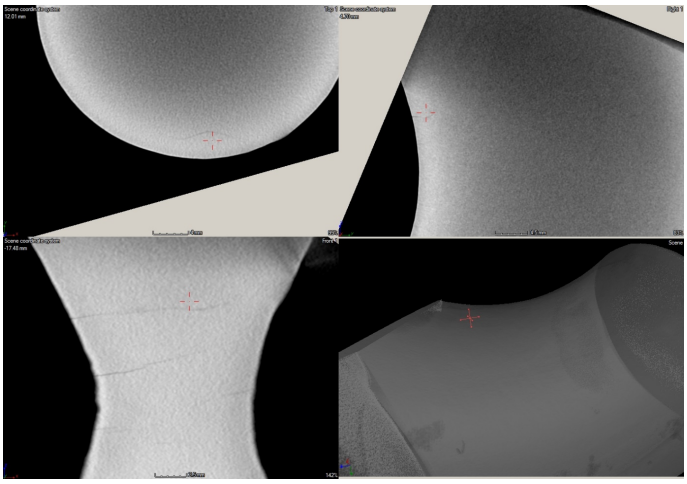

Fig. 4 The cracks propagation in the shackle screw coupling 1MN

The obtained CT images allow for observing the propagation course of cracks in 3D and determining their actual length and depth of occurrence below the surface.

Currently, the requirements of this standard only determine the surface length of the defect. According to the observations made, it was found that cracks could propagate to 5 mm even below the 1MN screw connection of the contact surface.

FEM Analyses

The shackle of 1MN screw coupling was modelled in the SolidWorks program. Boundary

conditions of FEM model were prepared in the HyperMesh program. The Altair Optistruct program was the calculation solver [5],[6].

FEM calculations are often a good support in the analysis of various events, damage and help to understand the causes of damage and destruction [7].

Literature data was used for 40CrMo4 steel [8], from which the shackle was made. The load was applied considering plastic deformations.

Sample results of FEM load simulation for the shackle of 1MN screw coupling model are shown in Fig.5, Fig.6 and Fig.7.

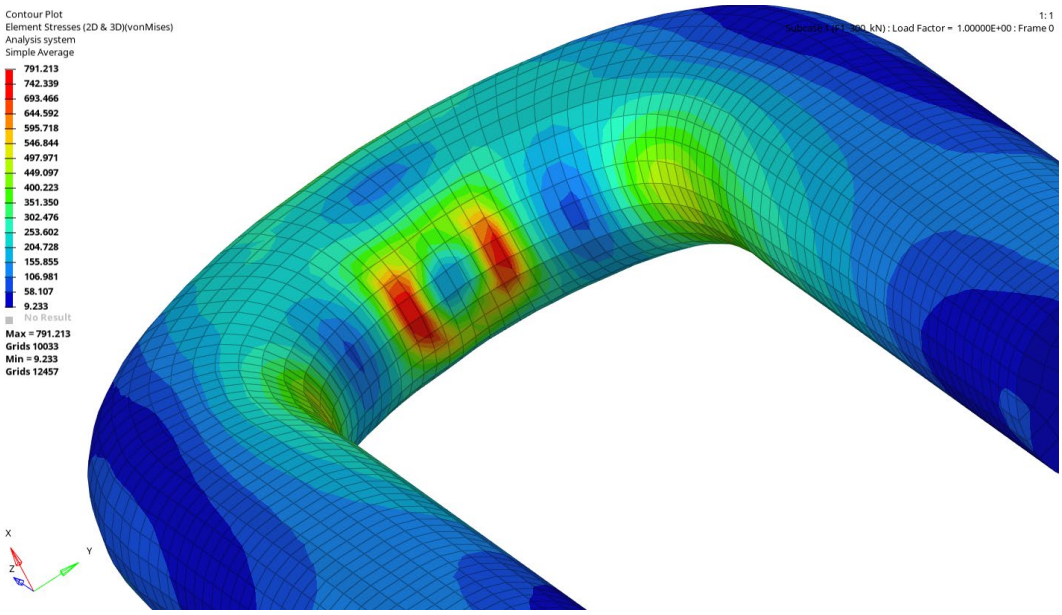

Fig. 5. Stress according to von Mises for a load of 575kN.

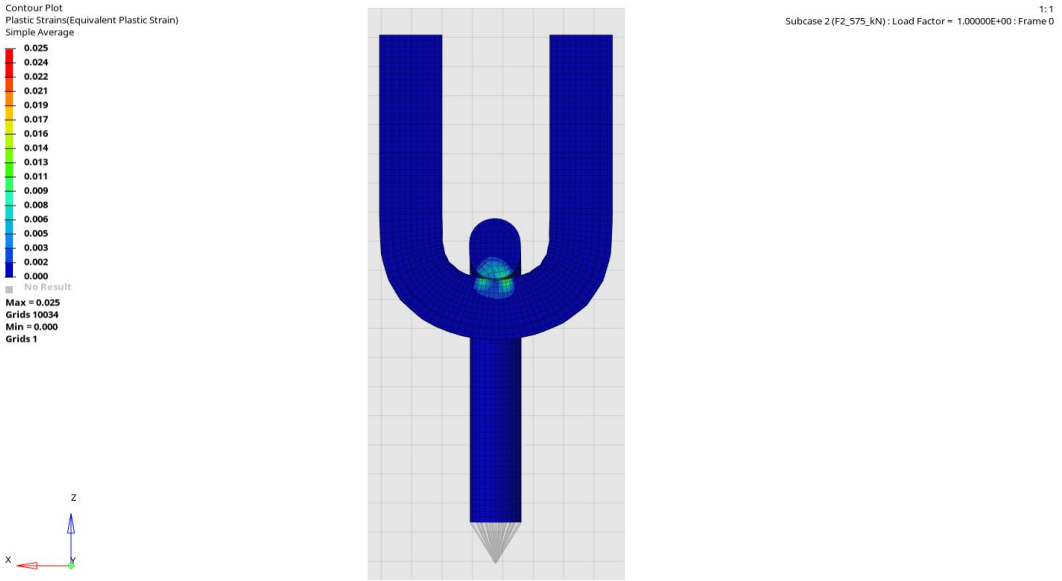

Fig. 6. Plastic strains for a load of 575kN.

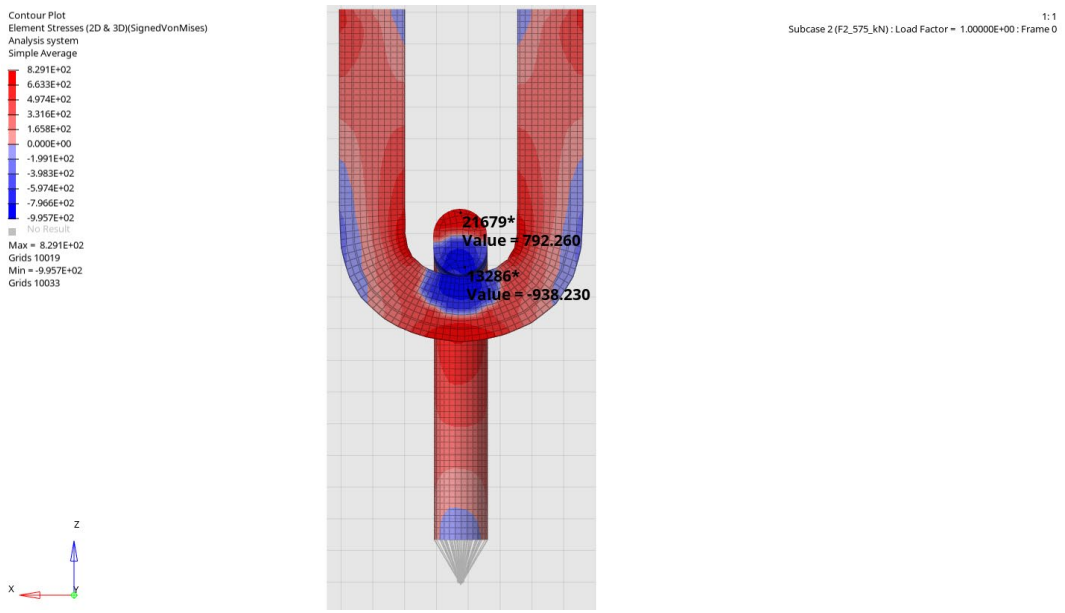

Fig. 7. Graphic representation of stress distribution in the shackle of screw coupling. Tensile and compressive stresses according to Signed/von Mises for a load of 575kN.

FEM calculation results

As it results from FEM calculations, plastic deformation may already occur at the load of 575 kN at the highest load in fatigue tests repeated up to 2150. These deformations may occur in the area of contact and near-surface areas of shackle of 1MN crew coupling shown in Fig.6.

In the contact hook/shackle area, mainly compressive stresses (blue colour) occur, which is shown in Fig. 7.

Summary

The NDT (non-destructive testing) and CT (computed tomography) tests performed after fatigue loads of 1M screw coupling confirm that the contact surface of the shackle / hook is a critical area of crack occurrence. CT studies show that in the analyzed case the crack propagated up to 5 mm below the surface of the bow. As it results from FEM calculations, plastic deformation may already occur at the load of 575 kN.

References

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