Fracture simulation in a steel connection in fire

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Introduction

Actual developments in the simulation of structural behaviour in fire are focussed on taking into consideration the interaction of all structural members in a global numerical approach. Therefore it is necessary to describe the load bearing behaviour of connections in detail.

To investigate the behaviour of a bolted steel endplate connection at ambient temperatures and in fire, a detailed 3D numerical model has been developed. The simulation is validated by experiments conducted at the University of Sheffield in 2008.

Methods and Parameters

In addition to other nonlinearities in FEM simulations, like temperature dependant material behaviour, methods for fracture simulation have been tested. One promising method of simulating fracture has been found to be a general fracture algorithm for ductile damage. The algorithm is described by the following equation:

$$\sigma = (1-D) \cdot \overline{\sigma}$$

The included damage-parameter D is defined as strain dependant. Until a damage initiation strain is reached, the value is 0. From the initiation strain, the parameter increases linearly till it reaches the value of 1 at a defined failure strain.

The material properties for beam and column and the properties for the bolts have been defined according to descriptions of the experiments. They are shown in Fig. 1 for structural steel. Obviously, the region within decreasing stress has not been included to the stress-strain-relationship, as this part is simulated using “ductile damage”.

The damage initiation strain has been set to the maximum strain described in Fig. 1 for each temperature. The fracture strain has been defined to 0.5.

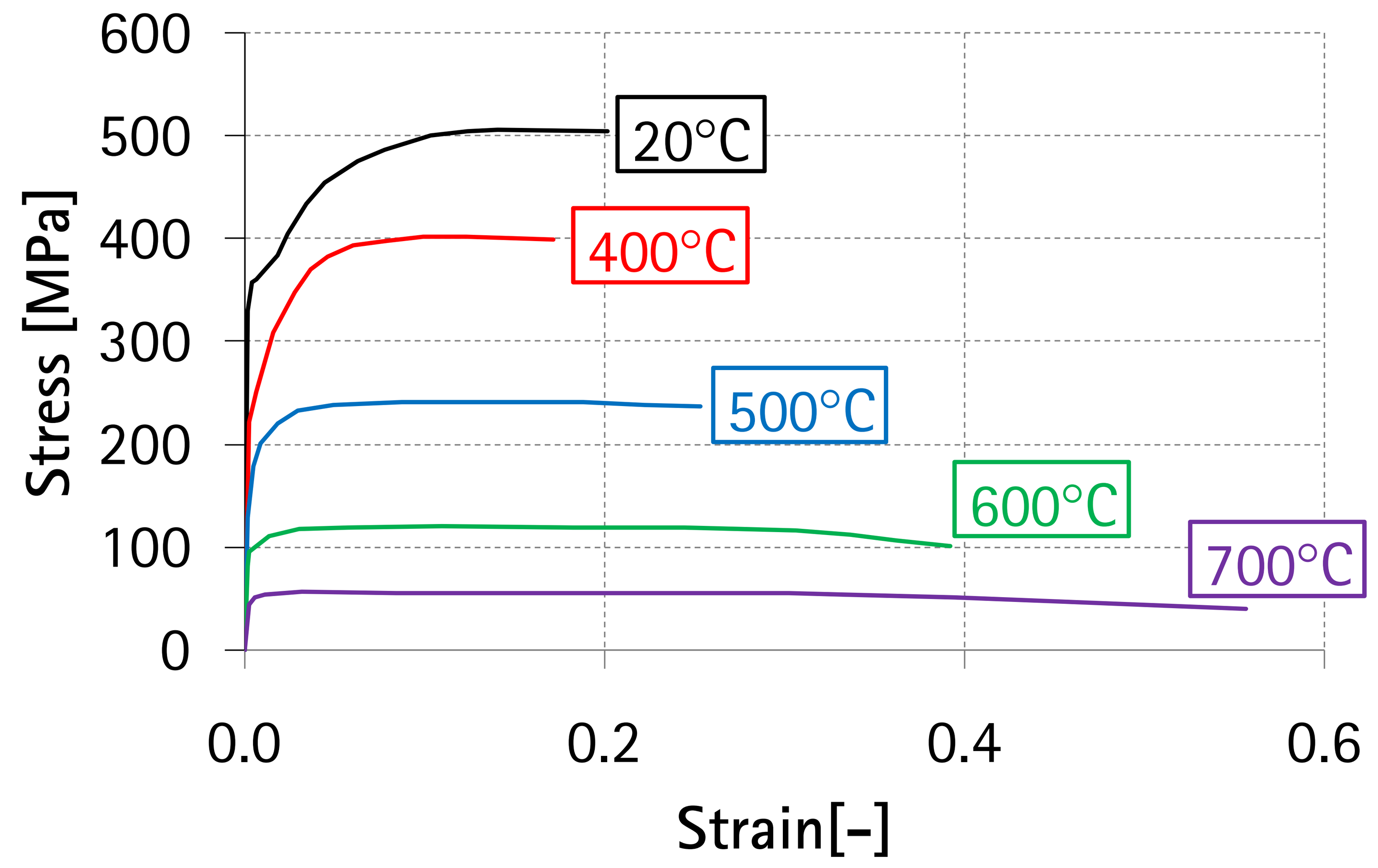

Fig. 1: Stress-strain-behaviour for structural steel

Results

As can be seen in Fig. 2, the fracture in the test at 20°C is simulated very well. In addition, stress in beam direction is shown. It is obvious, that high stresses occur at the end of the crack, which lead to a progressive fracture.

The results of the numerical simulation were compared to test results using the load-rotation-relationship, as well. Fig. 3 shows the relationship for tests at different temperatures.

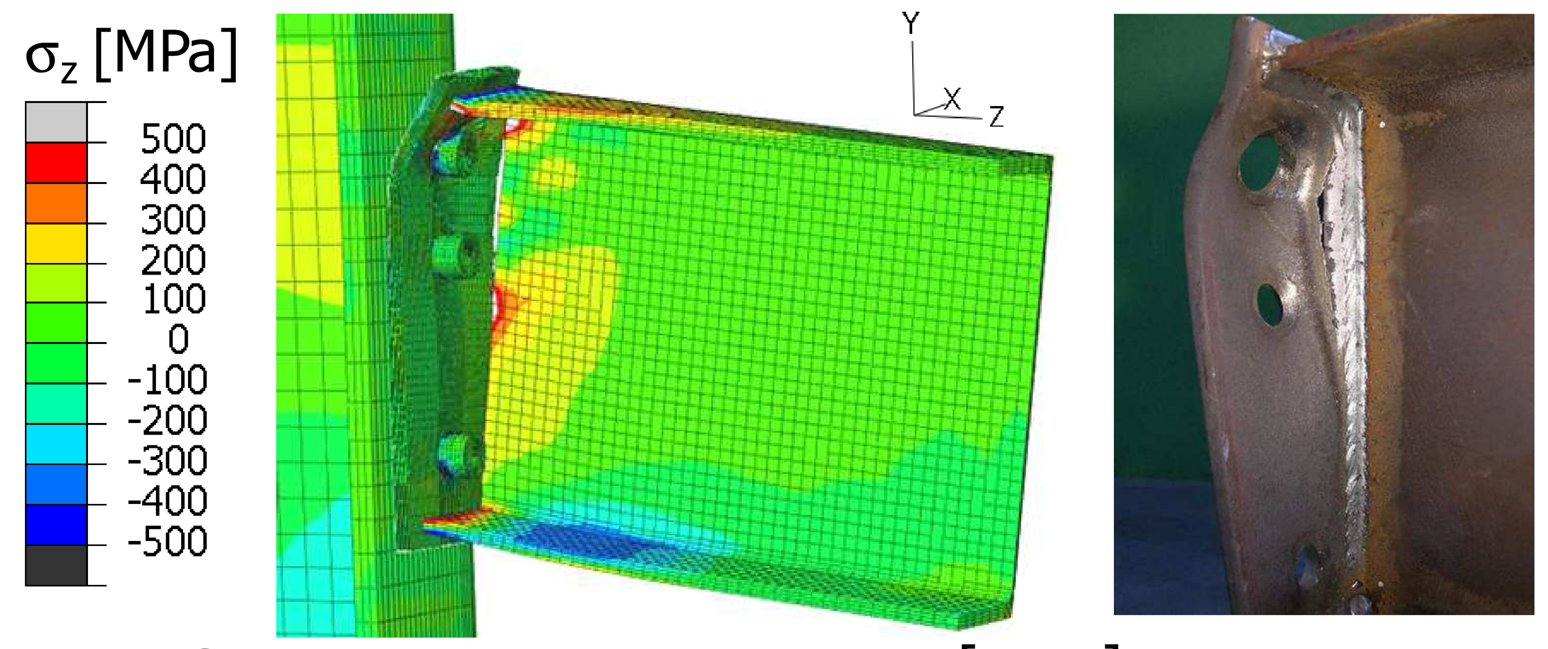

Fig. 2: Stresses in beam direction [MPa] in deformed FEM-model at rotation of 7.5° and 20°C

As shown, the results of numerical calculation and experiment are correlating very well. Even at large deformations and decreasing forces, the connection behaviour can be described by the numerical model.

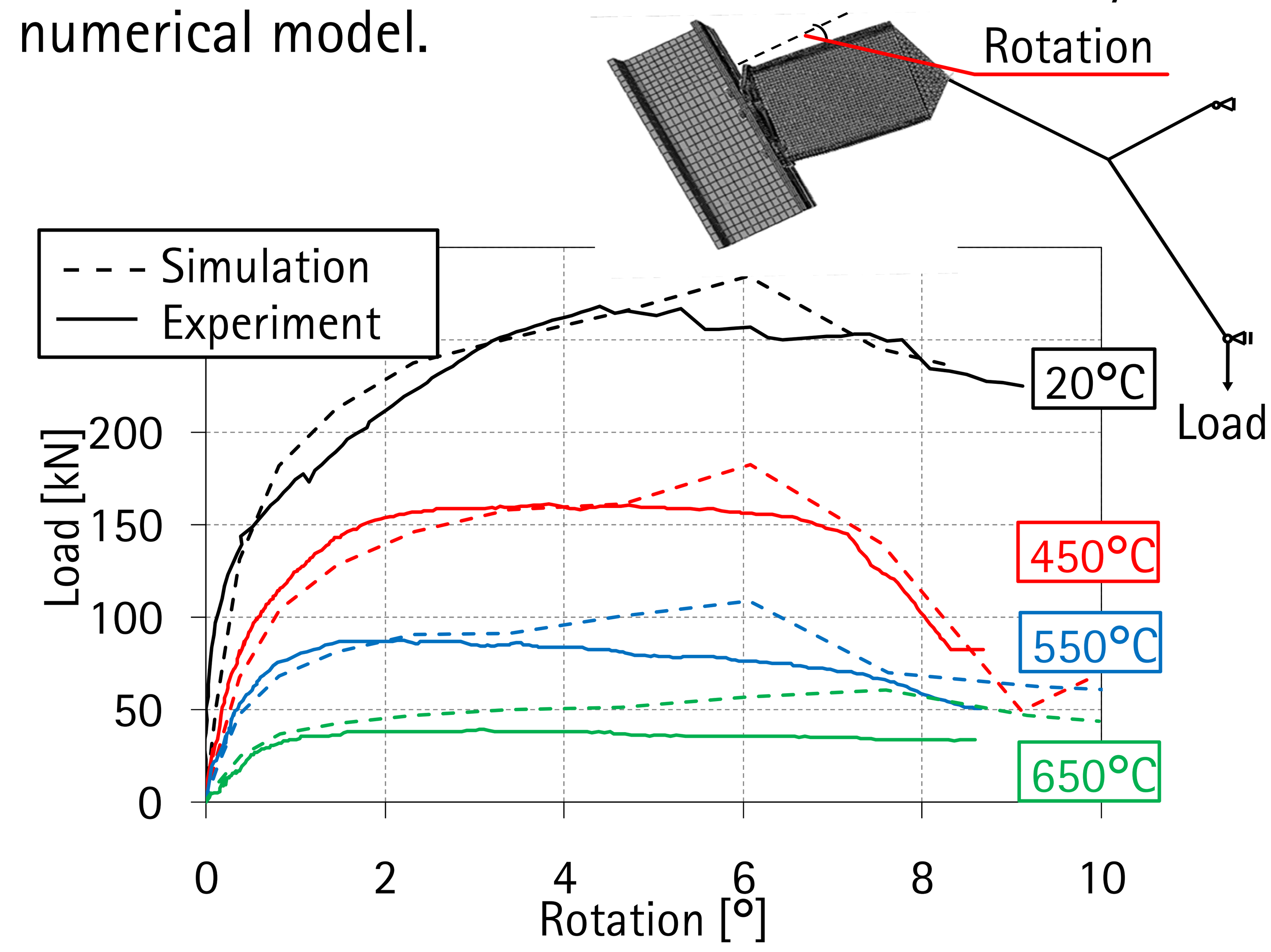

Fig. 3: Force-rotation-relationship in different tests

From Fig. 4 it may be seen, that bolts of the upper row are failing during the test at 550°C (blue bolt shaft). At the end of the test at 20°C, they are still bearing loads. This change of failure mode is correlating with the results of the experiments.

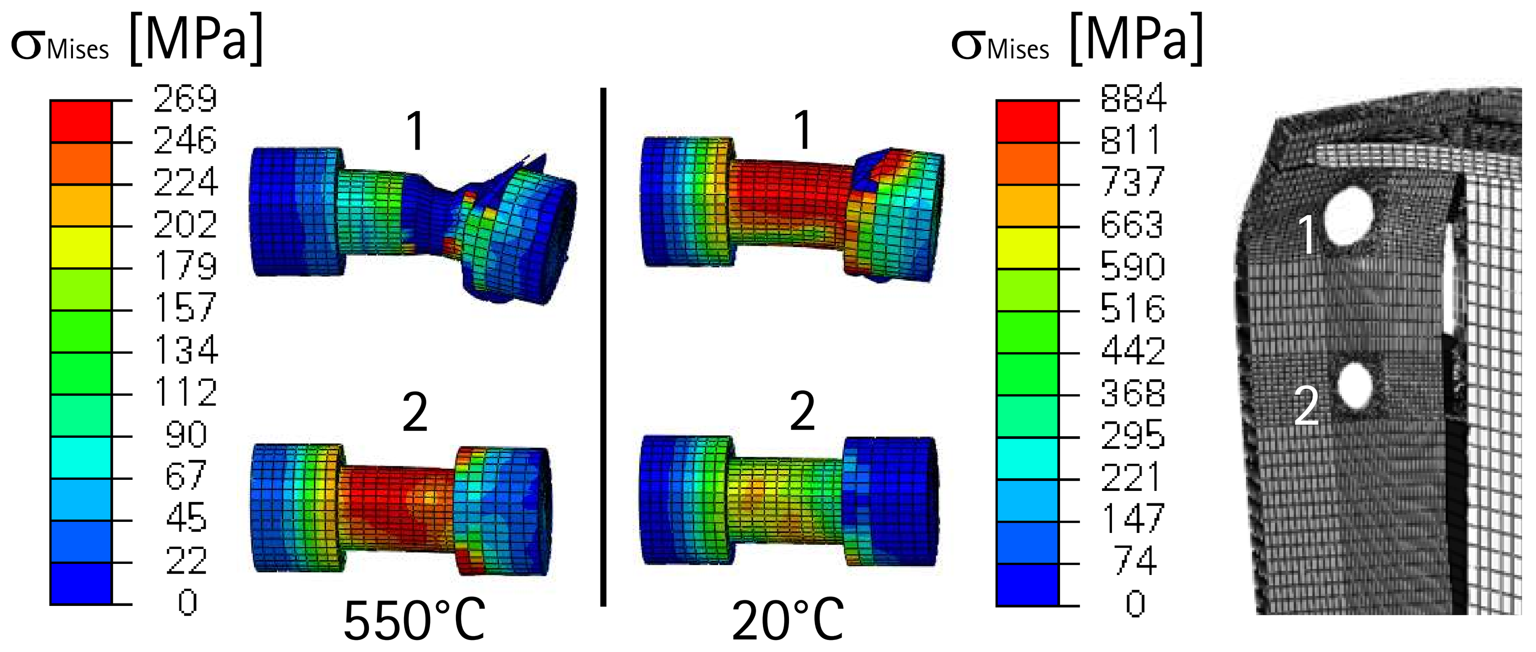

Fig. 4: Bolts at rotation of 7.5° at different tests

Conclusions

The developed numerical model was validated using the experimental tests and is able to describe the failure mechanism as well as the overall load-rotation-behaviour.

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