Creep analyses of a steam pipe system

Jan Storesund[1], Kristin Steingrimsdottir[1], Juhani Rantala[2] & Tobias Bolinder[1]
[1] Inspecta Technology Sweden, [2] VTT Finland **SEBRA konferens 15/6 2016**

Introduction

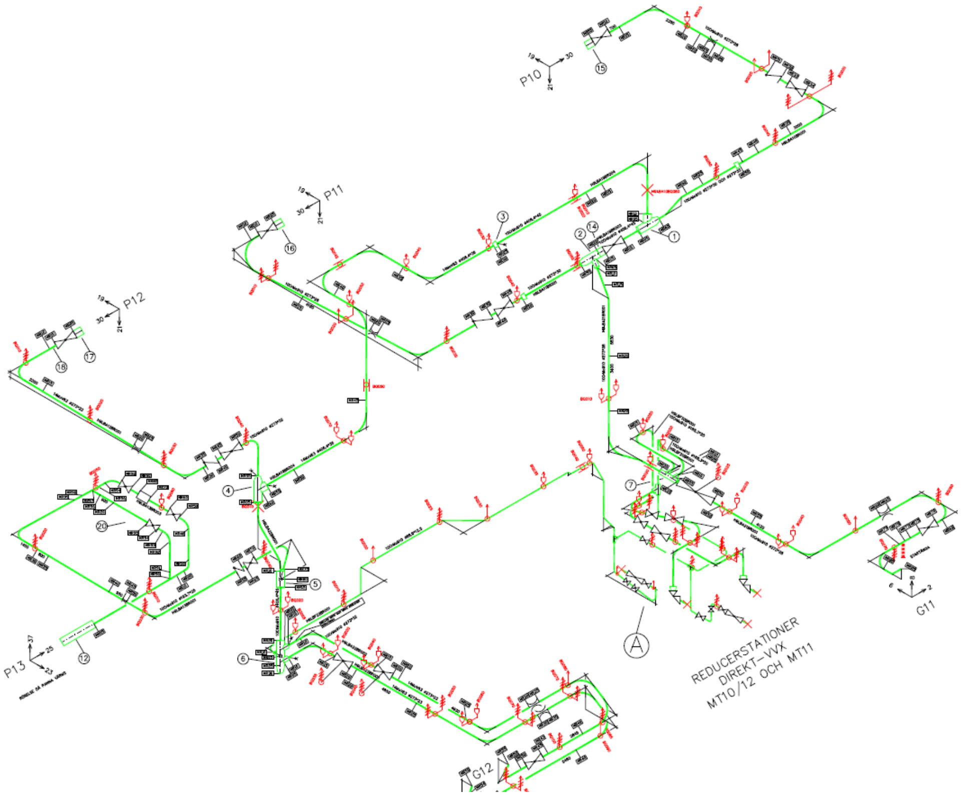
- Creep design of steam piping normally involves 100,000 h or 200,000 h design life time based on average creep data.
- Applied safety factors are 1.25 and 1.5 for 100,000 h and 200,000 h design life time, respectively, which are supposed to take account for lower creep strength than average, welds, system stresses, etc.
- The design rules are by formulae and therefore not precise.
- Hence, it is not possible to know the status with respect to consumed creep life in any detail after long-term operation without inspection and monitor of the system.

Introduction

- The present study aims to further develop:
  - analyses that can pinpoint critical positions for NDT correctly and in detail,
  - analysis methods that can be used for creep life assessment in live steam pipe system components,
  - the use of creep data of weld constituents from results of miniature creep testing,
  - and to make comparisons between analyses by use of tabled data and those where creep test data for the analysed component is used.

Pipe system modelling

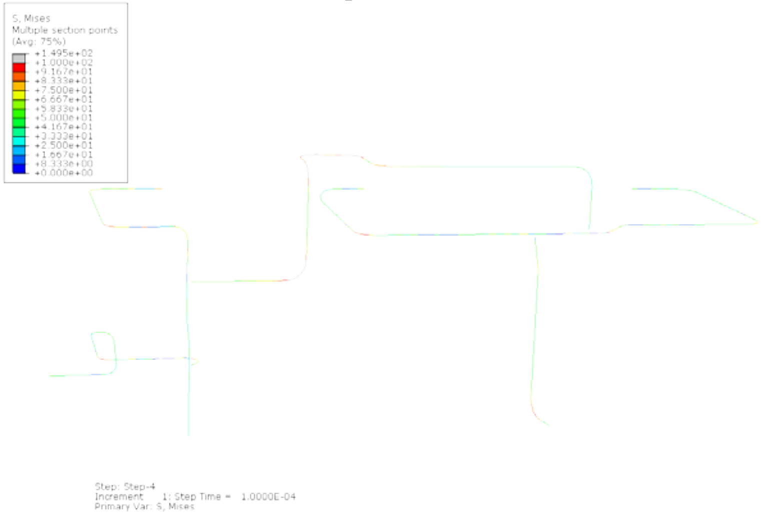
- A script for translating a Caepipe model to an Abaqus model was developed.
- Norton creep law was used for creep evaluation i Abaqus
- The constants B and n were determined from 1 % creep strain data of 10CrMo9-10 in EN10028-2:2009.



Caepipe model of the studied main steam pipe for elastic analysis

Influence of creep relaxation and starts and stops

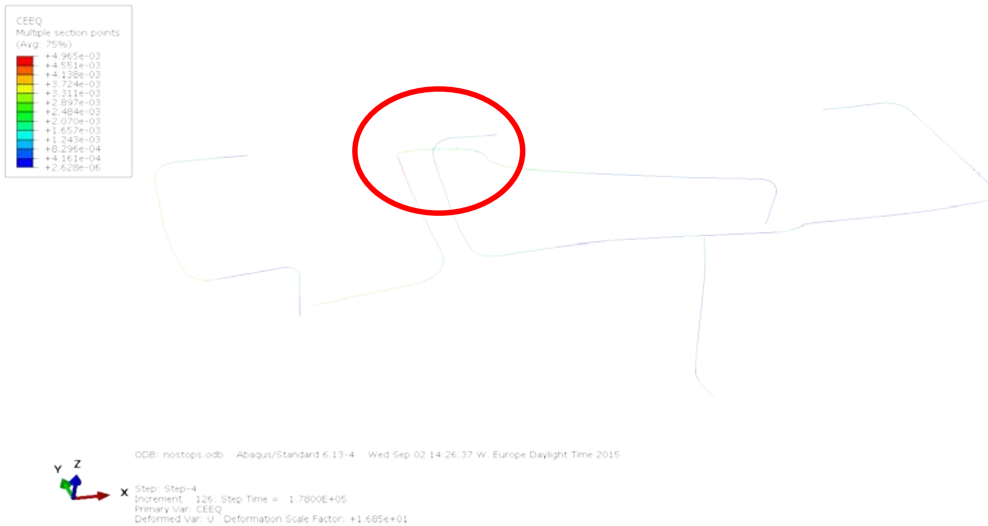
- A part of the system was modelled i Abaqus in the past.
- The same part of system was therfore considered in the elastic model translation to the creep model for verification reasons



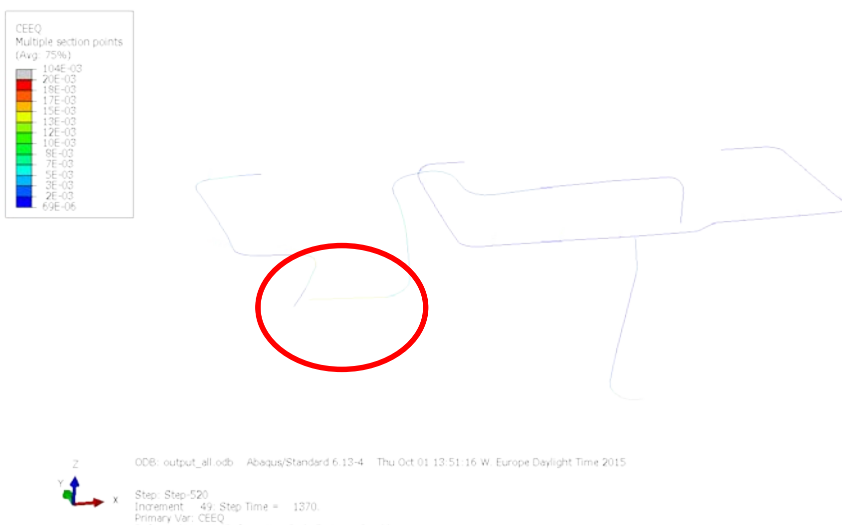
Elastic stress distribution att service temperature and pressure, t=0

Below: Stress distribution after 1 year service at 530°C.

Influence of creep relaxation and starts and stops



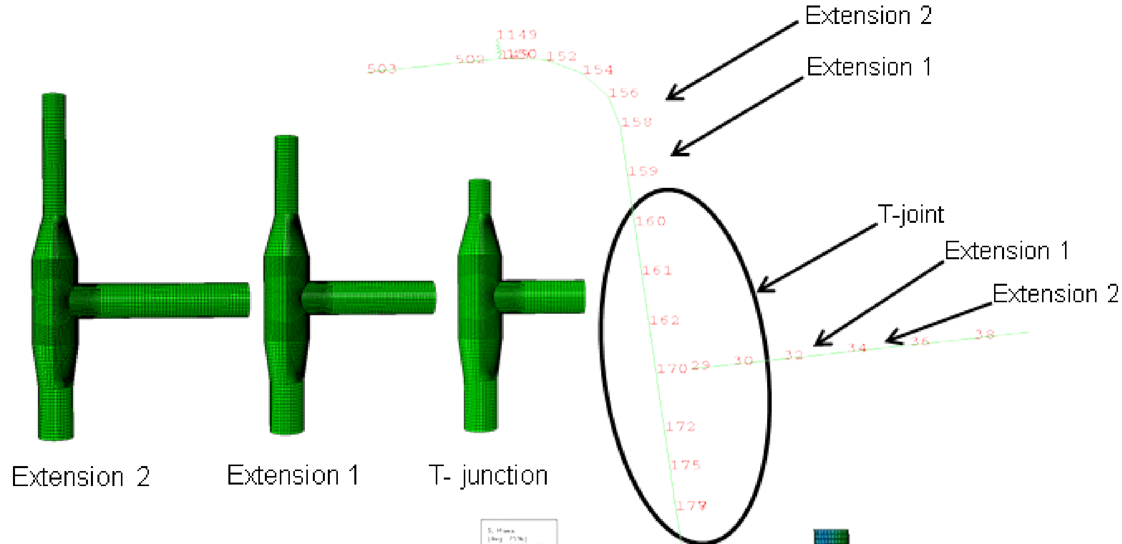
- Simulated service without stops for 178 000 hours. Maximum equivalent creep strain = 0.5%

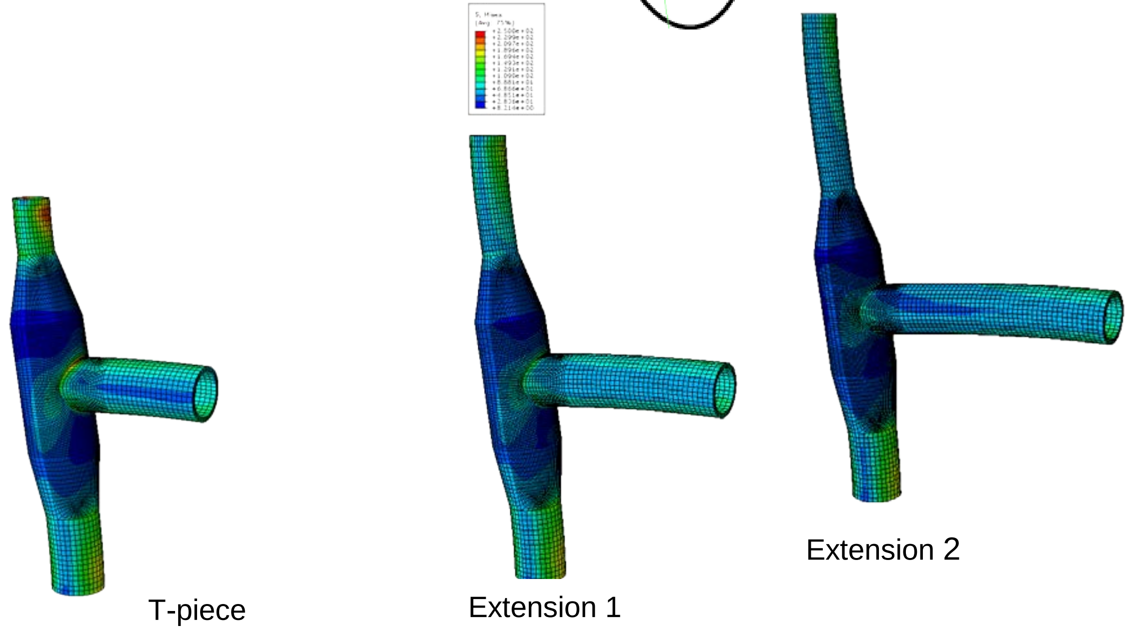


- Simulated service with 130 cold starts for 178 000 hours. The maximum equivalent creep strain is higher and in different locations compared to no starts.

Superposition of system stresses on component analyses

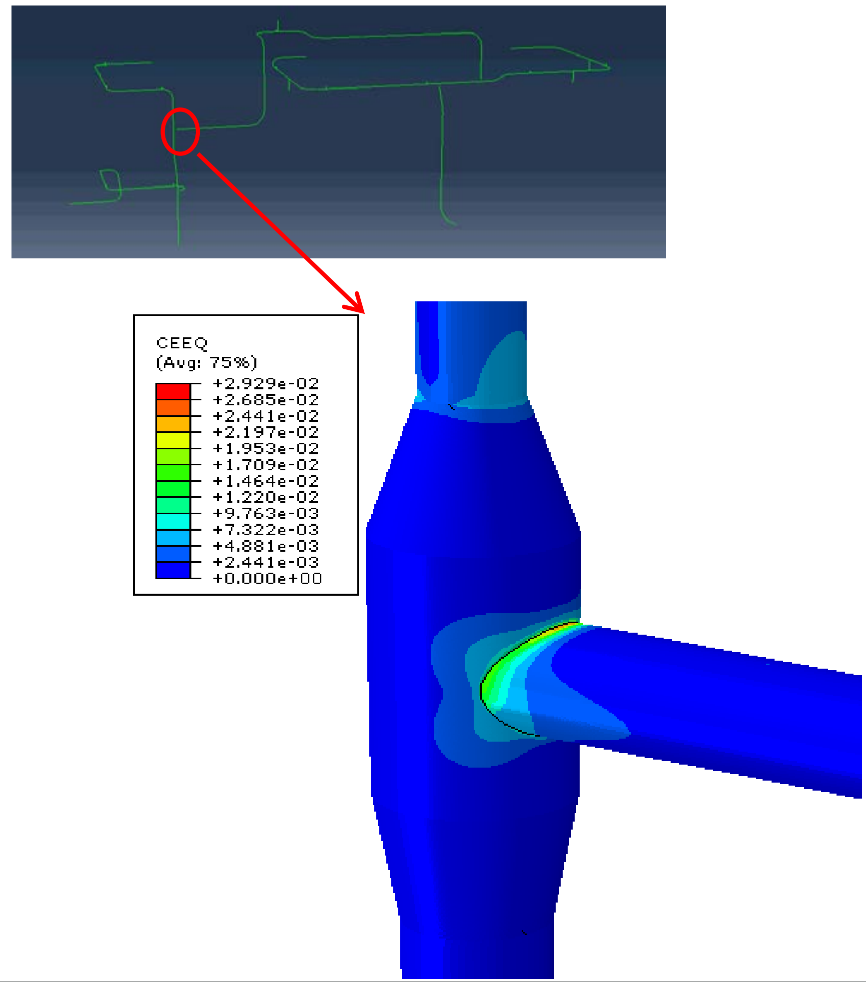
- Boundary conditions and loading for the component models consist of displacements obtained from the pipe system models.
- Internal pressure is also applied to the component models.
- The temperature is applied on the entire model to get correct displacements due to thermal expansions.
- The stiffness of the Abaqus pipe model and the actual T-piece differ.
- The difference decreases with increased extension of the component model.
- The extension should be at least two pipe diameters in length.





Superposition of system stresses on component analyses

- The highest stresses/ strains appear at one of the right angel positions.
- 2,6 % creep strain in the critical area after 42 000 h in operation.
- Tabled creep data, no weld included in the model.



Assessment of creep strains the steam pipe system

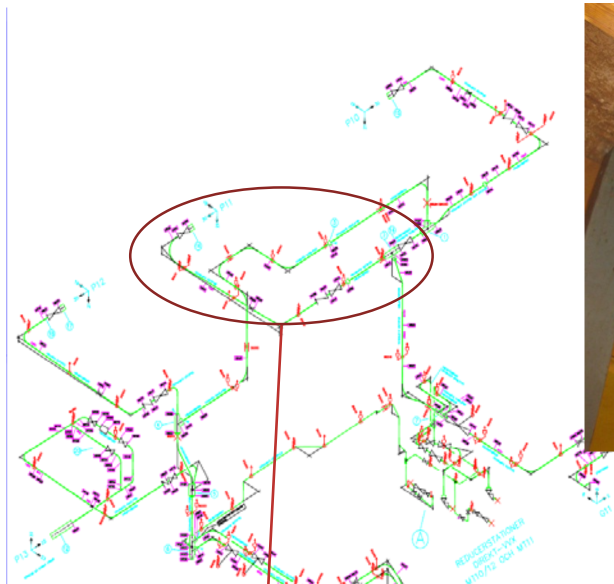
Exchanged part of the system including two original butt welds (180 000 hrs) and a T-piece (73 000) hrs.

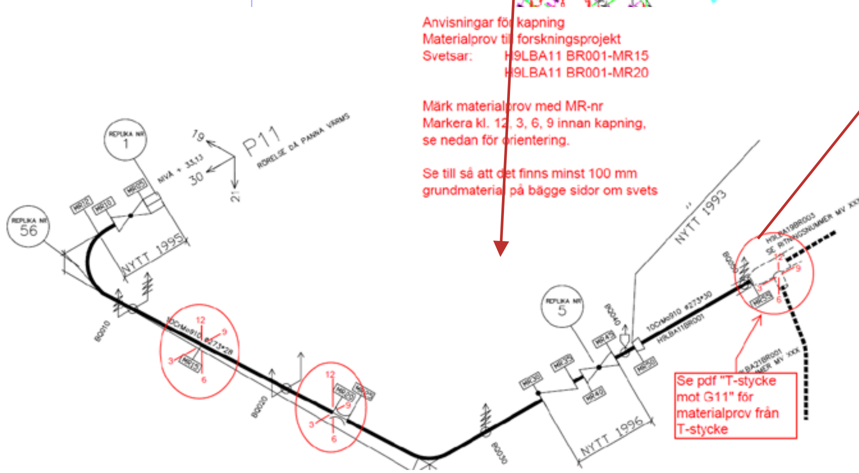
Creep damage ratings:

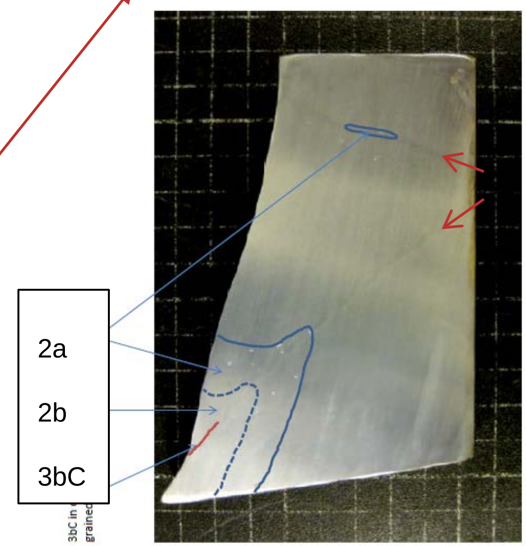
MR15: 5/2a

MR20: 2a-3bC

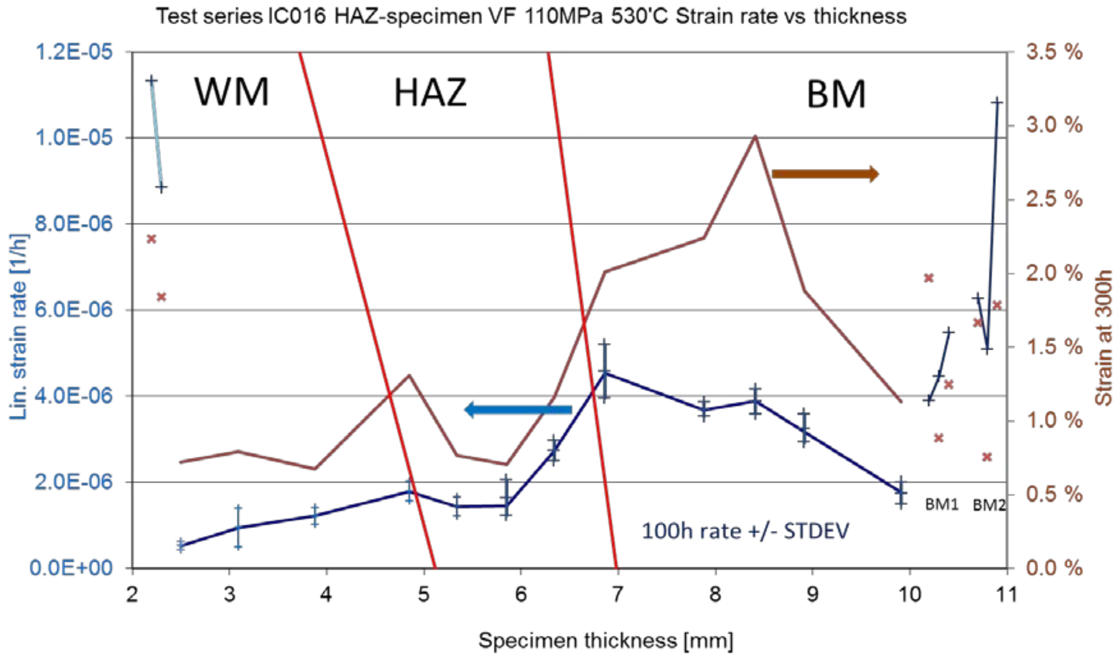
MR05: 1-3bC







Weld creep data from Impression Creep (IC) testing



- Linear creep rate and strain at 300 h vs. impression creep specimen thickness.

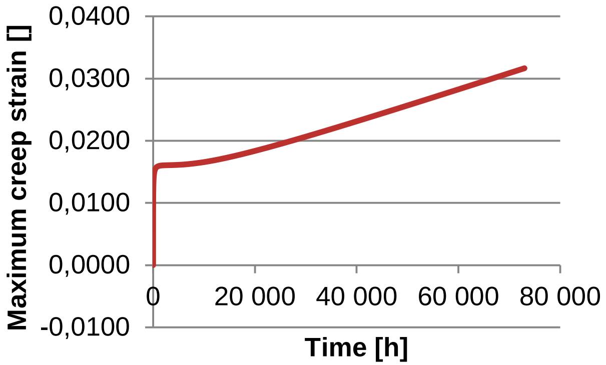
System analysis – creep life evaluation with different material models

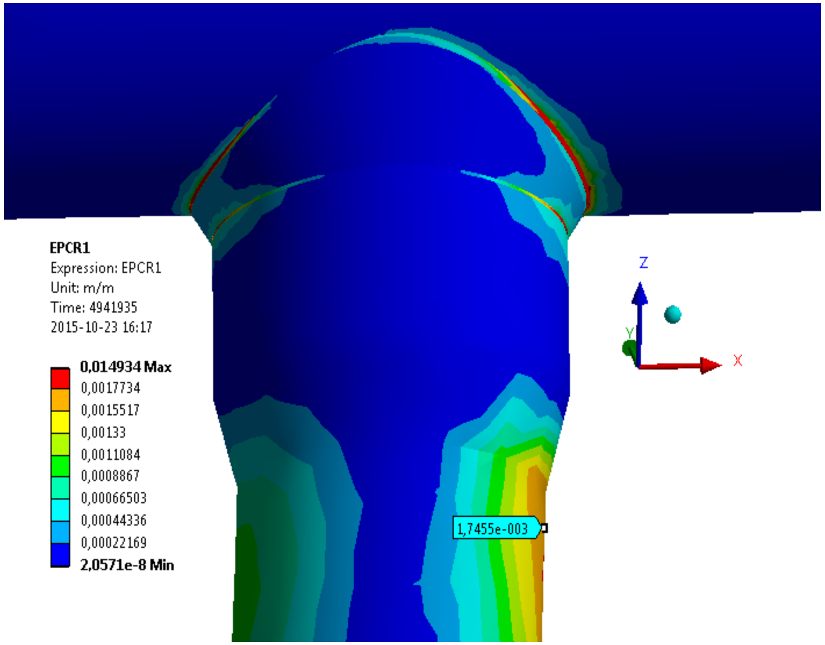
Model No.	Description	B	n
1	EN 10028-2	4.92E -17	5.08
2	EN 10028-2 – lower bound (20 %)	1.53E -16	5.08
3	LSCP data (logistic creep strain prediction)	2.16E -17	5
4	IC testing- new unused material, base material data. Modell is assumed to have the same n value as evaluated from EN 10028-2.	7.46E -17	5.08
5	IC testing for a base material that has been in operation in Heleneholmsverket for 73 000 hours of operation.	1.64E -16	5.08

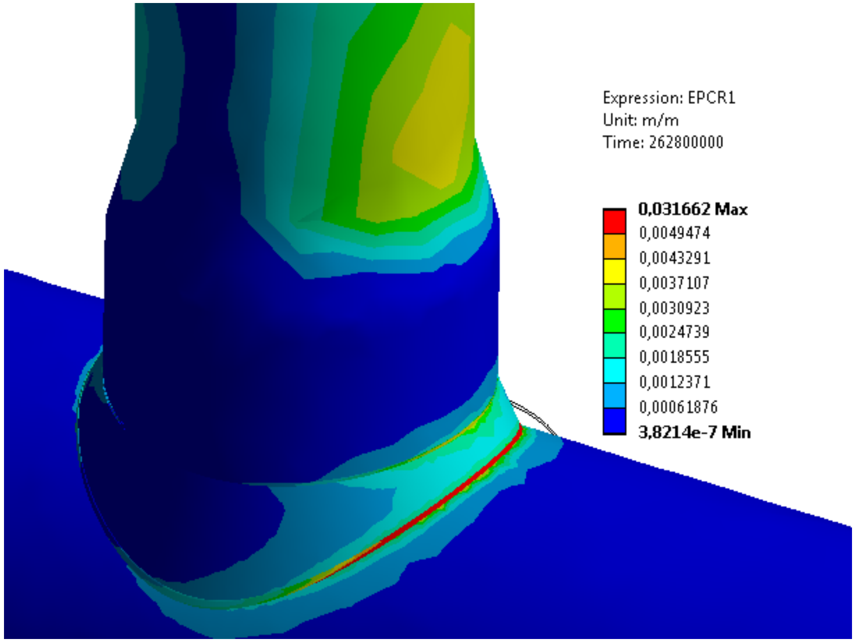
Model No. / Part in system	1	2	3	4	5
MR15	0.085 %	0.26 %	0.029 %	0.13 %	0.27 %
MR20	0.1 %	0.29 %	0.042 %	0.15 %	0.31 %

Component analysis

- Creep strain distribution after 73 000 hours.
- Data from IC testing
- Observed creep damage in HAZs: 2000 cavities/mm^2 at one right angle. 2000 and 3000 cavities/mm^2 at the saddle points.







a) virgin material: max 1,5 % creep strain

b) actual service expose material : max 3,2 % creep strain

Conclusions

The following conclusions can be drawn from the present study:

- A main steam pipe system with significant observed creep damage was tested and analysed.
- Impression creep testing with an innovative approach allowed the creep rates to be scanned from the base material across the HAZ to the weld metal by steps of 0.5 mm. The maximum creep rate was in the intercritical HAZ and 2.6 times higher than in the parent metal. The weld metal of the new weld was overmatching by a factor of two.
- Impression creep testing of parent and weld metals with 73 000 hours service exposure showed 3 and 6 times higher creep rates, respectively, than for corresponding materials in a virgin weld.
- The impression creep test results of virgin parent metal were consistent with uniaxial creep testing of the same material.
- Creep analysis of a main steam pipe system showed significant stress relaxation occurs after a relatively short service period. These effects cannot be covered by an elastic analysis, such as a Caepipe analysis.
- Creep analyses of a main steam pipe system including starts and stops resulted in higher levels of creep strain than without the starts and stops. In addition, the positions where the highest strains occurred were not the same. Identification of critical positions with critical positions by elastic pipe system analysis, which is quite common today, should therefore be carried out with some caution.

Conclusions

- Creep analysis of the main steam piping was carried out with creep data from standards and from the impression creep test results. Creep test results of new material and standard data gives similar creep strains in the system, approximately 0.1 % after 178 000 hours. The same analysis but with use of creep tests results of service exposed material and with lower bound standard data resulted in 0.3 % creep strain.
- A component model of a T-piece where system stress can be superimposed to internal pressure was developed successfully.
- A branch weld was then included in the model of the T-piece. The relative differences of creep rates between parent metal, HAZ and weld metal that was obtained by the impression creep testing was used in the model for simulations of service exposure.
- There was a quite good agreement between simulated creep strain distribution after 73 000 hours in service and observed creep damage in the real T-piece after the same time in service.

Future work

- Model of the entire pipe system for full verification of the models.
- Extend the testing of HAZ with small punsch testing to obtain tertiary creep and ductility data.
- Introduce primary creep in the model. In SEBRA project M39197 it was found that primary creep has a significant importance in case of creep relaxation.
- Integrate component modelling in to the system model.

Thank you for your attention

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