Experimental report

01/02/2021

Proposal: **1-01-174**

Council: 4/2019

Title: Study of creep induced cavitation in a novel hourglass test specimen

Research area: Engineering

This proposal is a new proposal

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Samples: 316H Stainless Steel

Instrument	Requested days	Allocated days	From	To
D11	2	1	28/01/2020	29/01/2020

Abstract:

Studies of creep behaviour in structures that operate at elevated temperatures such as nuclear power plants are important for structural integrity assessments. In the current proposed SANS experiment the isothermal creep behaviour of type AISI 316H steel will be investigated experimentally. Due to the hourglass design of the sample it is possible to measure variety of creep strain rates within a single test. The creep ruptured test specimen will be examined using small angle neutron scattering to measure the creep cavitation around the failure position. The MAXE analysis method (using maximum entropy algorithm) will be used to calculate the distribution of defects from scattering data obtained by SANS.

Study of creep induced cavitation in a novel hourglass test specimen

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Introduction

Creep cavitation is a major degradation mechanism for material that is experiencing tensile stress at elevated temperatures. Since AISI 316H stainless steel is widely used for boiler tubes, steam pipework and steam headers in the UK's Advanced Gas-cooled Reactor (AGR) fleet a good understanding of its creep properties is necessary. For this study, measurements were carried out on a crept hourglass test specimen that due to its shape provided a varying stress and creep strain along its gauge length. Using this novel approach, it is possible to measure multiple creep strain curves along the gauge section in just one creep test specimen. The objective of this study is to quantify the amount of creep cavitation damage as a function of stress and creep strain for specimen made of 316H stainless steel.

Experimental procedure

SANS experiments were carried out along the hourglass section of a failed creep test specimen using an aperture of 2x4 mm. A 1 mm thick longitudinal slice was extracted from the hourglass test specimen and each point was measured with an acquisition time of 60 min over three different sample to detector distances of 1.5m, 8m and 28m. Four points along the gauge section were measured with an additional point within the grip area which is used as a reference measurement. Here, it is reasonable to assume that the amount of second phase particles is similar as in the gauge section but since this part is stress free no creep cavitation damage is expected. The obtained data have been analysed using a Maximum Entropy (MAXE) routine under the assumption that the scattering particles are spherical.

Results

The results from four measurements along the gauge section of the hourglass sample gave a clear indication of a rise of the volume fraction of creep cavities as a function of stress. This is illustrated in Figure 1 where the distribution of creep cavities is plotted. Two populations of cavities can be identified. A population of small creep cavities with a mean diameter of less than 50 nm and population of larger cavities with a mean diameter of around 220 nm.

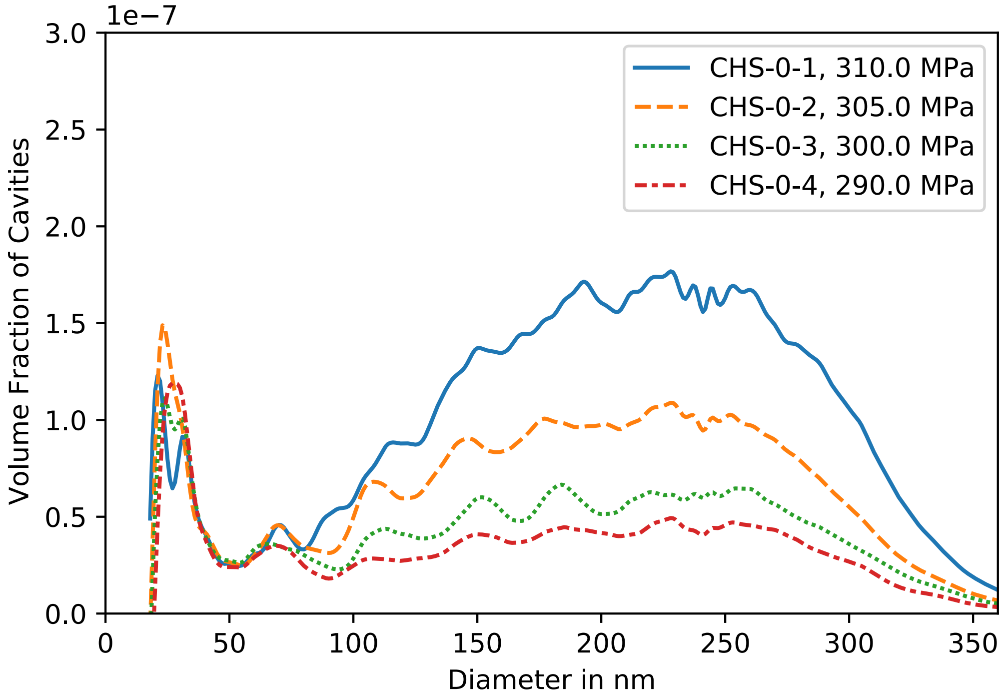

Figure 1 SANS results showing the distribution of cavities and increase in the volume fraction of cavities for four positions along the gauge section of the hourglass test specimen. The sample crept to failure at a temperature of 550°C and a net engineering stress of 305 MPa

Figure 2 illustrates the integrated volume fraction of creep cavities over the whole size distribution of creep cavities as a function of true stress. It can be found that the total volume fraction of cavities increases as stress increases.

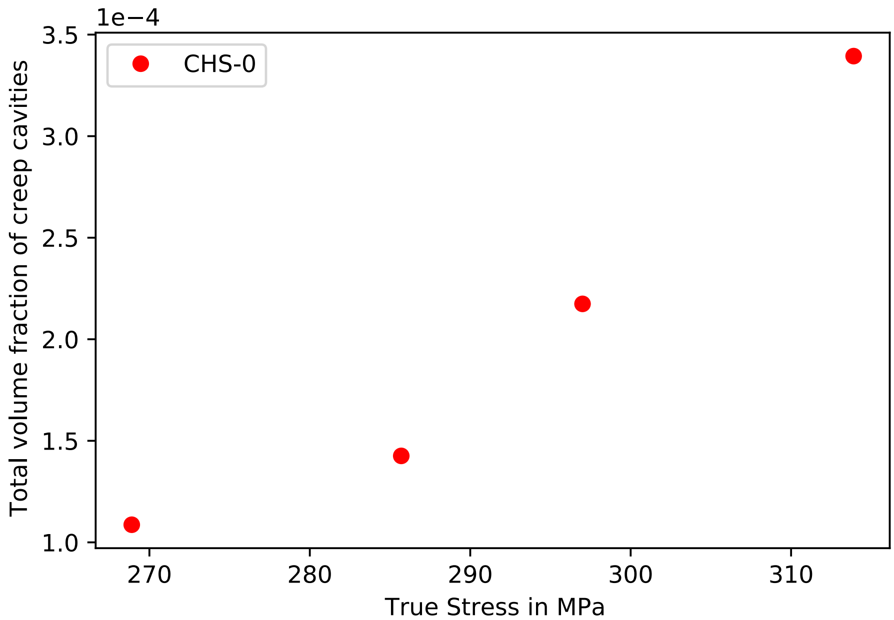

Figure 2 The integrated volume fraction of creep cavities for four positions along the gauge section of the hourglass test specimen as a function of true stress.

Under the assumption that creep cavities are spherical the number density could be calculated from the ratio of volume fraction and volume of spheres over each diameter interval. Subsequently, a distribution of the number density can be calculated as shown in . Figure 3. It can be seen that the number density is larger for small sized creep cavities and gets smaller for larger sized cavities.

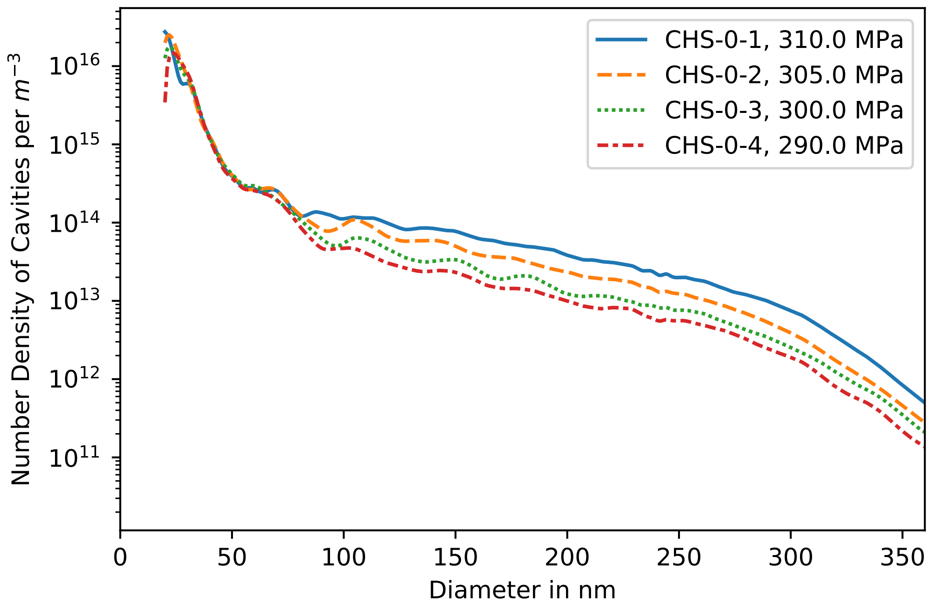

Figure 3 Distribution of the number density of creep cavities for four positions along the gauge section of the hourglass test specimen

Conclusion

From the data obtained at the ILL/D11 (proposal: 1-01-174) a correlation between the volume fraction of creep cavities and creep strain as well as stress can be established. Two different populations of creep cavities with mean diameter of <50 nm and about 220 nm can be identified from the small angle neutron scattering data. These findings have been verified using scanning electron microscopy (not reported here).