Open-Source Data for Small Ring Tensile Test performed on SS316L at multiple displacement rates

Aniket Joshi, Alex Forsey, Richard Moat, Salih Güngör

School of Engineering & Innovation, Faculty of STEM, The Open University, Milton Keynes MK7 6AA, United Kingdom

Abstract

This document describes the experiments done at The Open University for the Small Ring Tensile Testing of SS316L performed at various displacement rates. This document delineates the experimental set-up, the experimental procedure, the material information, the image acquisition system, the organisation of the open-source data, the image conversion system to TIF file format, the cleaning up of the numerical CSV data obtained from the experiments, and the motivations, implications, and potential use-cases of this dataset.

Keywords: Small Ring Test; SS316L; Open-Source Data; Machine Learning

1. Introduction

The Small Ring Test was initially proposed as a novel high sensitivity creep test by Hyde et al [1]. The test involves a ring (either circular or elliptical) which is pulled by a fixed load with the help of loading pins on diametrically opposite ends. Conversion relationships have been established for this to translate this test to an equivalent uniaxial creep test [2].

This test methodology has recently been extended to perform tensile testing as well [3], with promising research being performed on additive materials [4].

There is, however, a dearth of research in this nascent testing method, especially for different materials [3]. Steel and nickel superalloys were specifically highlighted in the original study.

The current study lays groundwork for this testing on Stainless Steel (Grade 316L). Multiple tests at different rates, from 0.02 mm/min to 4.0 mm/min, have been performed on circular SS316L ring specimens. The study aims to make all the test data open-source, including the images taken for digital image correlation (DIC) and the raw data.

The study also involves testing data of uniaxial tensile tests on SS316L which were performed to benchmark the small ring tests. This is in addition to 3 "unknown" test datasets of rate 0.3333 mm/min, 0.6667 mm/min, and 1.1111 mm/min which will help future scientists verify their models. It must be noted that the isolation of these 3 displacement rates is only a guideline.

2. Methodology

2.1. Experiment Details

The small ring tests were performed on an Instron 8982 Universal Testing Machine. These tests were performed on a specially made grip fixture for this testing programme. The pins were painted with a speckle-pattern for optical strain and displacement measurement via DIC. A rectangular slab was also painted and fixed alongside the moving pin to provide a broader reference for vertical displacement. This would prove to be more reliable of a measure to plot the force-displacement curve than the conventionally used testing machine readings. A picture of the test is shown in fig. 1. The sub-size conventional uniaxial tests were performed on an Instron 5969 Universal Testing Machine.

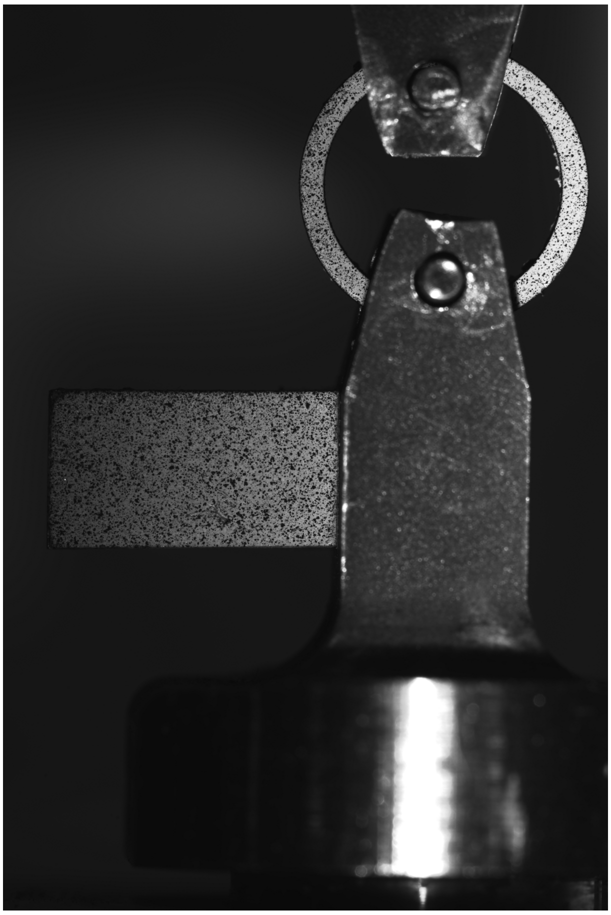

Figure 1: Picture of the loaded experimental setup

The folders divided in the source repository are divided by the displacements rates of the test and the type of the test (Uniaxial tensile test or small ring tensile test). The "mmMin" notation refers to the millimetres (mm) travelled by the bottom screw-head (and subsequently the bottom pin in the test) in a minute.

All rings are approximately 2 mm thick, with an inner diameter of approximately 10 mm and an outer diameter of approximately 12 mm. The specific thickness for each sample tested can be found within its tested displacement rate folder in a separate CSV file with the 'INFO' prefix.

The experimental files are also divided into 'CLEAN' and 'RAW' folders. 'RAW' folders contain the raw and uncompressed images in .NEF format, along with the unprocessed CSV numerical data of the test. Folders are named appropriately and intuitively. The first part of a folder name is 'CLEAN' or 'RAW'. This is followed by the material name ('StainlessSteel316L'). Lastly, this is followed by the crosshead displacement rate. For instance, 'ExtensionRate0_65mmMin' denotes a crosshead displacement rate of 0.65 mm/min.

The raw images are taken from a Nikon D810 camera. The ISO is kept at 100 in most experiments, and the camera capture interval rate is also noted. The shutter speed is kept as 1/3" (one-third of a second) as well in most experiments.

The Cleaned folder contains the same images as the Raw folder, but in .TIF format. The images were converted with the help of the techniques delineated in [5] via MATLAB. Fig 1 is also the image as seen by the DIC camera and is in .TIF format.

After some preliminary testing, the tests were set to automatically shut-off once a reading of 2500N was reached. Some specimens fail before this limit is reached, but largely all the samples follow very similar trends.

The CSV files have a significant sampling noise and in the 'Cleaned' folder these files have been smoothed out with the help of the Butterworth filter in the SciPy python package [6]. The input values of 'N' (filter order) and 'Wn' (cut-off frequency) are 2 and 0.05. Some displacement rate tests have more than 1 CSV raw data file. This is due to a machine error (data logger memory overflow issue) that cause the test to stop midway. The test was promptly restarted, and all efforts have been made to ensure that there is no significant loss in data and quality. These multiple CSV files have been combined into a single file for the ease of the user in the "Cleaned" folders under the affected displacement rate experiment.

3. Discussion of Results and Conclusion

This study showcases the wide array of small ring tensile test experiments that have been performed at The Open University.

This open-source dataset can be used by researchers to better understand this novel testing technique while also allowing for a comparison to the standard uniaxial test as a benchmark. Given the huge dataset available here, a lot of potential applications are open in the materials science sphere. Users can train different neural networks to expedite material testing and understand the deformation behaviour undergone by the circular geometry. Users can also use the numerical CSV raw data and combine it with the images for machine-learning powered inverse finite element analyses.

The possibilities opened up with this dataset are huge and we hope that researchers find this dataset useful. More materials testing is planned for different materials to understand this testing method further. The materials being investigated next are Copper, Aluminium, and Nimonic-75.

References

[1] T. Hyde, W. Sun, A novel, high-sensitivity, small specimen creep test, The Journal of Strain Analysis for Engineering Design 44 (3) (2009) 171–185.

[2] T. H. Hyde, B. S. Ali, W. Sun, Interpretation of small ring creep test data, The Journal of Strain Analysis for Engineering Design 48 (4) (2013) 269–278.

[3] J. Kazakeviciute, J. Rouse, D. De Focatiis, C. Hyde, The development of a novel technique for small ring specimen tensile testing, Theoretical and Applied Fracture Mechanics 99 (2019) 131–139.

[4] J. Rouse, M. Simonelli, C. Hyde, On the use of small ring testing for the characterisation of elastic and yield material property variation in additively manufactured materials, Additive Manufacturing 36 (2020) 101589.

[5] A. Forsey, S. Gungor, Demosaicing images from colour cameras for digital image correlation, Optics and lasers in engineering 86 (2016) 20–28.

[6] P. Virtanen, R. Gommers, T. E. Oliphant, M. Haberland, T. Reddy, D. Cournapeau, E. Burovski, P. Peterson, W. Weckesser, J. Bright, S. J. van der Walt, M. Brett, J. Wilson, K. J. Millman, N. Mayorov, A. R. J. Nelson, E. Jones, R. Kern, E. Larson, C. J. Carey, İ. Polat, Y. Feng, E. W. Moore, J. VanderPlas, D. Laxalde, J. Perktold, R. Cimrman, I. Henriksen, E. A. Quintero, C. R. Harris, A. M. Archibald, A. H. Ribeiro, F. Pedregosa, P. van Mulbregt, SciPy 1.0 Contributors, SciPy 1.0: Fundamental Algorithms for Scientific Computing in Python, Nature Methods 17 (2020) 261–272. doi:10.1038/s41592-019-0686-2.