Combining the Small Punch Test with the Small Ring Test

A. Joshi[1], A. Forsey[1], R. Moat[1], S. Güngör[1a]

[1]Faculty of STEM, School of Engineering & Innovation, The Open University, Walton Hall, Milton Keynes MK7 6AA, United Kingdom

[a] salih.gungor@open.ac.uk

Abstract

The Small Punch Test (SPT) and the Small Ring Test (SRT) are forms of miniature-specimen testing techniques that can be used to measure material properties. The SPT makes use of a disc that is 8 mm in diameter and 0.5 mm in thickness, while the SRT can make use of any ellipsoid shape, but rings of inner diameter 10 mm, outer diameter 12 mm, and thickness 2 mm have been tested previously. Given the sizes conventionally used for these tests, this study explores the feasibility of combining these two testing modes performed on a same parent specimen. From this parent specimen, the ring is extracted, and from the residual space of the extracted ring (for the SRT), a disc is machined for the SPT.

This study explores this combination of the SPT and SRT from a single specimen, with tests performed on SS316L and Nimonic-75. Tensile tests are performed on SS316L for both the tests, while SPT has tensile tests performed with Nimonic-75 and SRT has creep tests performed with the same Nimonic-75.

The results showcase the versatility of combining both the test forms, given that 1 parent sample yields 1 ring and 2 discs. This provides a volumetric material saving of 97.8%, compared to using standard uniaxial samples for 3 tests. While the results don't match with each other (SPT and SRT), they match well within the same testing type (ie, SRT matches with SRT) and with a control group of testing. Given this, it makes sense to recommend that this avenue of test combination be explored further.

Possible Sessions

16 (Novel Experimental Techniques), 22 (Structural Health Monitoring).

Introduction

The Small Punch and the Small Ring Tests are miniature-specimen testing techniques that can be used to measure creep, tensile, or fatigue properties from a material specimen. The Small Punch Test, or the SPT, is an evolution of the Miniature Disk Bend Test and has recently been codified by the European Code of Practice [1, 2]. The Small Ring Test, or the SRT, was originally designed to measure Creep properties of a material and was originally proposed by Hyde and Sun [3]. Recently, the SRT was also extended to tensile testing for circular rings by Kazakeviciute et al [4].

Given the sizes required for each specimen in this test, a combination of the testing methodologies is possible. The disc used in the SPT is 8 mm in diameter and 0.5 mm in thickness, while the ring used in the SRT is 2 mm in thickness, with an internal diameter of 10 mm and an external diameter of 12 mm in this study. The combination of both is proposed by extracting the discs from the blank space of the rings, which are extracted for the SRT. Thus, from 1 parent sample, multiple testing specimens can be extracted. This can be visualised better with the aid of Fig. 1, which showcases the extraction methodology.

To better understand how a combination of these tests would work, two research avenues are explored:

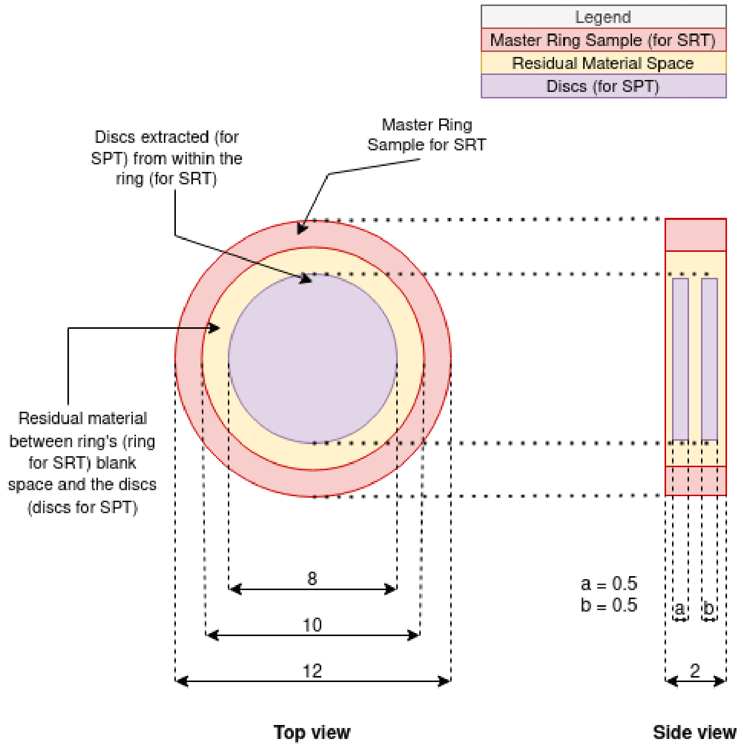
1. Phase 1: Combining the SRT (tensile) and the SPT (tensile) for SS316L.
2. Phase 2: Combining the SRT (Creep) and the SPT (tensile) for Nimonic-75.

Methodology

With a required thickness of 0.5 mm for each SPT disc, theoretically, 4 discs can be extracted from the blank space of a ring that is 2 mm thick. However, given the material losses associated with machining the discs, 2 discs were extracted from each blank of the SRT ring specimen. The narrow circumferential allowance was also another challenge, given the ring had an internal diameter of 10 mm, thus giving the blank the dimensions of 10 mm and 2 mm thickness.

For the testing programme, rings and discs were extracted via normal procedure (that is, not from the blank space of the rings used for SRT), and via the combination hypothesis procedure proposed here. This holds true for the first phase of testing SRT and SPT in tensile modes for SS316L and for the second phase of Nimonic-75 testing that involved SRT (in Creep testing mode) and SPT (tensile mode).

Fig. 1. Schematic of the hypothesis, showcasing the combination of the SRT and the SPT. All dimensions are in mm and representative only for visualisation purposes. Not to scale. Pictured adapted from [5].



The results from the specimen obtained via combination hypothesis are compared to the results from the specimen obtained via conventional machining procedures.

For phase 1, 5 rings are extracted from a parent sample, which results in 10 subsequent discs extracted for the hypothesis testing. All these specimens are tested at different crosshead displacement rates. The control group of normally extracted rings and discs are tested at the same rates to maintain consistency.

For phase 2, 1 ring is extracted from a parent sample, which results in 2 discs extracted for the hypothesis testing. This ring is used in a Small Ring Creep Test, which is compared against a normally extracted ring at the same load (160 MPa) and temperature (600°C). The extracted discs are also compared against normally extracted discs at the same crosshead displacement rate to maintain consistency.

Results and Conclusions

Although the results were not a perfect match for the SRT and SPT, they promise a strong research avenue to pursue for materials testing in situations where material is scarce. The SPT results don't match well with each other, but they match well with the control group of rings for both phase 1 and phase 2. Similarly, the SRT results match well with the control groups in phase 1 and phase 2, while not matching well with the SPT. This is a remark on the testing techniques and not on the hypothesis, which could likely be attributed to the nascency of the SRT and the rig compliance issues (for the SPT) faced in this study.

References

[1] European Committee for Standardization. Small punch test method for metallic materials. Technical Report CWA 15627:2007, European Committee for Standard- ization, 36 rue de Stassart, B-1050 Brussels, 2007.

[2] Matthias Bruchhausen, Tim Austin, Stefan Holmström, Eberhard Altstadt, Petr Dymacek, Spencer Jeffs, Robert Lancaster, Roberto Lacalle, Karel Matocha, and Jana Petzová. European standard on small punch testing of metallic materials. In Pressure Vessels and Piping Conference, volume 57908, page V01AT01A065. American Society of Mechanical Engineers, 2017.

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

[4] J. Kazakeviciute, J. P. Rouse, D. S. A. De Focatiis, and C. J. Hyde. The development of a novel technique for small ring specimen tensile testing. Theoretical and Applied Fracture Mechanics, 99:131–139, February 2019.

[5] Aniket Joshi. Evaluation and optimisation of the Small Ring Test and its amalgamation with the Small Punch Test. PhD thesis, The Open University, Walton Hall, Milton Keynes MK7 6AA, United Kingdom, 2023.