2021-02-12

DRAFT

Project Plan for the CEN Workshop on The Standardisation of the Impression Creep Test

(to be approved during the Kick-off meeting on 2021-04-20)

1. Status of the Project Plan

- Draft Project Plan to be approved at the Kick-off meeting of the Workshop. The Impression Creep Standard Working Group, an interest group formed from companies actively developing and applying this technique, and comprising the participants listed in Section 3, has already started work and has been holding regular Webex meetings since May 16 2019. It is proposed that the Workshop will be open to everyone.

2. Background to the Workshop

- The market environment

Small sample testing in general, and impression creep in particular, offers the opportunity for owner/operators of power generation equipment to perform non-invasive testing of their high value equipment to determine risk or risk-ranking as they look to prioritize maintenance activities. Small sample concepts such as impression creep afford the opportunity to quantify high temperature creep behaviour relevant to high energy piping; high temperature valves; high pressure steam turbines; gas compressor, combustor, and turbine; and other critical components. However, in order to use this data in a consistent manner and have confidence in the determination of risk – either through comparative ranking or through component-specific life prediction, this test method needs to be internationally recognized and demonstrated to be consistent.

The paper by T Gallacher et al in the list of publications in Section 5 below discusses the commercial application of this test technique. Assessment of in-service plant to determine remnant life is of obvious significant industrial interest, particularly to high temperature plant operators, where plant life extension or confirmation of existing plant life is needed. As more power plants operate beyond their design life, the requirement for these services increases.

There are significant commercial benefits of using impression creep testing over conventional uniaxial creep testing. These include the ability to produce results relatively quickly; the small specimen size makes extraction feasible without significantly affecting the structural integrity of plant; the possibility to test a single specimen at several stresses or temperatures enables multiple assessments; and, increasingly, the maturity of underlying technical understanding and quality of results increases confidence in the technique. T Gallacher et all has presented several examples to the effective use of impression creep testing and has shown the technique to be a commercially viable.

- Existing standards and standard related activities and documents

European Creep Collaborative Committee RECOMMENDATIONS - VOLUME 3 Part III [Issue 5]: 3b Supplement - ECCC Guidelines for Impression Creep Testing 2014.

Electric Power Research Institute Report 3002009055 - A Guide to In-Service High Temperature Headers and Piping Materials Evaluation by Impression Creep Testing 2016. Currently only available to purchase, but will eventually become freely available, in line with EPRI procedures.

- Motivation for the creation of this Workshop

The primary objective is to agree a common test methodology and data interpretation for the impression creep test, to be applied by the laboratories using this specialised technique, in preparation for a future standard.

3. Workshop proposers and Workshop participants

- Original proposers of the Workshop:

  Nottingham University, UK

  Jacobs (formerly Wood plc), UK

  VTT, Finland

  EPRI, USA

  JRC Petten

  RWE, UK

  Jülich, Germany

  UTM, Czech Republic

- Participants at the Kick-off meeting:

  Nottingham University, UK

  Wood plc, UK

  VTT, Finland

  EPRI, USA

  JRC Petten

RWE UK

Jülich, Germany

UTM, Czech Republic

The Workshop is open to any interested party or entity that is willing to support the aims of the project plan. The participation will be free of charge.

- CEN/CENELEC national member holding the Workshop secretariat:

  BSI (UK) will act as the National Standards Body.

4. Workshop scope and objectives

Impression creep testing was originally developed at Nottingham University in the UK primarily to obtain creep data from different microstructural regions within weldments to be used in finite element modelling. As a result, the technique is supported by a substantial body of theoretical work and full details about specimen preparation and the testing technique are available. The test technique, in which the indentation rate of a rectangular indenter typically measured over the last 100 hours of a 350-400hour test, can be converted into equivalent creep strain rate using conversion factors calculated from a finite element model developed by Nottingham University.

In recent years the test method has become an established small-scale testing technique. It is a versatile technique in that, once a stable indentation rate is established, either the stress, temperature, or both, can be varied to provide data under multiple test conditions on the same specimen.

The impression creep test does not however produce a specimen failure. In order to overcome this limitation, use can be made of an empirical relationship between the creep strain rate obtained in the impression test and the rupture life obtained in a conventional uniaxial creep test at the same stress and temperature, where such data are available.

This relationship, termed the Impression Monkman Grant relationship, has been applied successfully for example to grade 91 steel where it has been shown that rupture life predicted from impression testing is in good agreement with actual rupture life obtained by conventional uniaxial testing. The relationship has proved particularly useful for plant application in situations where mis-heat treated grade 91 pipework with lower than expected creep strength has been encountered, requiring an estimate of creep strength to justify continued operation in service.

The WS Secretariat may also indicate in this section its intentions as regards the distribution and dissemination of the resulting CWA. BSI to comment.

5. Workshop programme

The CWA shall be drafted and published in English, unless the Project Plan defines otherwise.

Work plan

The planned CEN/CENELEC Workshop on the Standardisation of the Impression Creep Test is intended to establish a common test methodology and data interpretation for the impression creep test amongst laboratories using, or planning to use, this specialised technique.

In broad outline the activities are:

- Review of testing details (test rig, specimen, indenter, etc) in the existing ECCC guidelines, updating them as necessary.
- Agreement on the detailed testing procedure and the way creep strain value is to be extracted and subsequently used (eg by conversion to rupture life).
- Demonstration by Round Robin testing on selected materials. The details of the initial Round Robin proposed are shown in Annex A and Annex B below.
- It is intended to complete inter-laboratory testing by the end of June 2021, with analysis of data and finalisation of the documentation by the end of September 2021.

The timescale for the development of work items stated in the Project Plan at the time of its adoption must remain visible in later versions/revisions of the Project Plan. The timescale originally envisaged having been disrupted by the COVID-19 pandemic, this will be subject to review.

In accordance with the CEN and CENELEC rules for the development of a CWA, an open commenting phase is highly recommended for all CWAs, as a means of enhancing the transparency of the Workshop process. An open commenting phase is mandatory if the CWA deals with safety aspects The Project Plan shall record the intention for such external comment phase together with an explanation how this phase will be organized and how the feedback will be processed. The minimum duration of the comment phase is 60 days.

Work already delivered

The following selection of recent papers by Impression Creep Standard Working Group participants constitute work already delivered in this area:

A BRIDGES & D PURDY: Post-Test Impression Creep Evaluation Methods and Findings for Improved Code of Practice. 5^{th} International Conference: Small Sample Test Techniques, Swansea, Wales, July 10-12, 2018.

A BRIDGES & D PURDY: Potential Implications of Step Loading in Impression Creep Testing. 5^{h} International Conference: Small Sample Test Techniques, Swansea, Wales, July 10-12, 2018.

J RANTALA & T ANDERSSON: Application of Impression Creep Testing for Measuring Creep Properties of Heat Affected Zone. 5th International Conference: Small Sample Test Techniques, Swansea, Wales, July 10-12, 2018.

S J BRETT: The Impression Creep Monkman Grant Relationship. 5th International Conference: Small Sample Test Techniques, Swansea, Wales, July 10-12, 2018.

T GALLACHER, J EATON-MCKAY, S BRETT, S JACQUES, C AUSTIN & A WISBEY: Commercialisation of Impression Creep Testing. 5th International Conference: Small Sample Test Techniques, Swansea, Wales, July 10-12, 2018.

A BRIDGES, J SHINGLEDECKER, J SIEFERT, D PURDY, J FOULDS & C FERGUSON: Impression Creep Testing for Evaluation of Grade 22 Ex-Service Hot Reheat Piping Seam Weld. 5th International Conference: Small Sample Test Techniques, Swansea, Wales, July 10-12, 2018.

J RANTALA: Technical Note: Experimental Techniques for Impression Creep and Small Punch Testing. 5th International Conference: Small Sample Test Techniques, Swansea, Wales, July 10-12, 2018.

S J BRETT, C N C DYSON, D PURDY, J SHINGLEDECKER, J RANTALA, J EATON-MCKAY & W SUN: Impression Creep Test of a P91 Steel: a Round Robin Programme. Materials at High Temperatures, published on line December 13, 2017.

K BRENNAN, S J BRETT & J EATON-MCKAY: Impression Creep Testing of Aberrant Grade 91 Material Removed from Piping in Service. 4th ECCC Conference: Creep & Fracture 2017, Dusseldorf, Germany, September 10-14, 2017.

T LANT, S J BRETT, A CLARK & R WALTON: Creep Testing of a Seam Welded Grade 91 Hot Reheat Bend with Aberrant Microstructure. 4th ECCC Conference: Creep & Fracture 2017, Dusseldorf, Germany, September 10-14, 2017.

S J BRETT, B KUHN, J H RANTALA & C J HYDE: Impression Creep Testing for Material Characterization in Development and Application. 10th Liège Conference on Materials for Advanced Power Engineering, Liège, Belgium, September 14-17, 2014.

W SUN, T H HYDE & S J BRETT: Use of Impression Creep Test Method for Determining Minimum Creep Strain Rate Data. 2nd International Conference: Determination of Mechanical Properties of Materials by Small Punch and other Miniature Testing Techniques, Ostrava, Czech Republic, October 2 - 4, 2012.

6. Workshop structure

The Workshop will be open to all, with its structure agreed at the Kick-off meeting. To date the Impression Creep Standard Working Group has constituted a single project team, providing its own administrative support. One sub-team activity carried out by Nottingham University and

EPRI, related to maximum acceptable indenter depth, has been completed. Notes of meetings are held on the Europa CIRCABC website.

The formal Secretariat role, normally taken by a National Standards Body, is provided by BSI in the UK.

7. Resource requirements

All costs related to the participation of interested parties in the Workshop's activities have to be borne by themselves. The participants have agreed that this is a self-funded activity.

8. Related activities, liaisons, etc.

ECCC WG1 – includes a subgroup on small scale creep testing.

CEN/TC459/SC1 – 'Test methods for steel (other than chemical analysis) - currently includes another small-scale test method, Small Punch.

9. Contact points

Administrative Contact:
Dr Steve Brett
Impression Creep Standard Working Group
e-mail: steve.brett456@btinternet.com

Secretariat:
Katherine Imbert
Standards Development Manager
BSI
389 Chiswick High Road
London, W4 4AL, UK
Tel: +44 20 8996 6450
e-mail: katherine.imbert@bsigroup.com

CEN-CENELEC Management Centre
Alessia Gaetani
Project Manager
Rue de la Science 23
1040 Brussels
Tel.: +32 2 550 09 56
Fax: +32 2 550 0819
e-mail: agaetani@cencenelec.eu

Annexes

Annex A

Proposed Standard Test Conditions and Proposals for the Impression Creep Testing Round Robin

The common test procedure will be a stepped stress procedure, but some laboratories have expressed interest in carrying out additional single step tests at selected stresses used in the stepped test.

Hysteresis Check

The purpose of the hysteresis check is to ensure the proper operation of the displacement measurement system. The hysteresis check will also help achieve a good contact between the specimen and the indenter by smoothing out surface roughness and reducing microscopic misalignment.

After positioning and aligning, the specimen is pre-loaded with a small controlled force (typically 10-100 N). The whole testing set-up is then subjected to several (3-5) loading cycles at room temperature up to the intended testing load or below the elastic limit of the tested material, whichever is lower, until the hysteresis between the cyclic loading and unloading curves becomes minimized. The loading can be done either at a constant loading rate (typically 2 MPa/s) or in a stepwise manner having 5-10 load steps between the minimum and maximum load. The displacement response is recorded and plotted as hysteresis loops of displacement versus load. In case of constant rate load ramp the operator has to make sure that the data logging system is fast enough to record the load and displacement in real time, otherwise the loading rate has to be lowered. In case of stepwise loading the operator has to make sure that all the signals have fully stabilised before taking the readings.

After the hysteresis check the test set-up is heated at a small pre-load (max 25% of the test load) to the test temperature without removing the specimen. Care must be taken that the compressive load is on all the time during heating up in order to maintain the contact between the indenter and the specimen.

After gaining confidence in the displacement measurement system the hysteresis check can be regarded as voluntary, but periodical checks are recommended in order to spot any malfunctioning of the extensometer system. The hysteresis check procedure is mandatory if such changes are made to the rig which could influence the displacement measurement.

Single Step Test

The test should aim to last 400hrs, but a duration of 400±50hrs is considered acceptable. A ±50hr margin has been chosen to enable test laboratories to continue testing over a weekend, if necessary. The indentation rate should be measured by linear regression over the last 100hrs of the test.

Stepped Stress Test

An initial step of 400±50hrs at the minimum stress, with the impression indentation rate measured by linear regression over the last 100hrs.

Subsequent steps at gradually increasing stress levels, each step lasting 150±50hrs with indentation rate again measured over the last 100hrs of each step. Provided the indenter is not disturbed between steps the initial stage of embedding the indenter in the specimen does not need to be repeated.

Specimen/Indenter Dimensions

The impression specimen/indenter dimensions will be 10mm x 10mm x 2.5mm with a 1.0mm wide indenter or 8mm x 8mm x 2mm with a 0.8mm wide indenter. All the test laboratories are believed to be able to test the larger configuration and some can test the smaller.

Material 1

The first common material for testing will be Bar 257.

The stock of this material currently held by EPRI was material supplied by SJB to Loughborough University. The images supplied indicate that this is in its original condition and has not been heat treated. The properties should therefore be the same as for previous Bar 257 material tested.

Test Conditions

The test temperature will be 600°C, the temperature at which most previous data has been obtained on Bar 257.

It is proposed to use a four-step stepped stress procedure at 100MPa, 110MPa, 120MPa and 130MPa. Based on the previous results for this material, the converted creep strain rates should fall within the optimum range of approximately log -5 to log -4/hr.

Conversion Factors

The impression creep strain rate will be obtained from the indentation rates using Wei Sun's 3D conversion factors:

$\eta = 0.430$

where η relates the mean pressure under the indenter, $\bar{p}$, to the corresponding uniaxial stress, σ, in the relationship $\sigma = \eta\bar{p}$

$\beta = 2.180$

where β relates the creep displacement, Δ^c, to the corresponding uniaxial creep strain, ε^c, in the relationship

$$\varepsilon^c = \frac{\Delta^c}{\beta d}$$

Because the relative dimensions of the two specimen indenter configurations remain unchanged, the FE derived conversion factors β and η remain unchanged. When converting indentation rate to creep rate however allowance must be made for the difference in specimen thickness, which is effectively the specimen gauge length. The conversion factor of 2.180 for a 2.5mm thickness becomes 2.180 x 0.8 = 1.744 for a 2mm thickness.

Validity Check

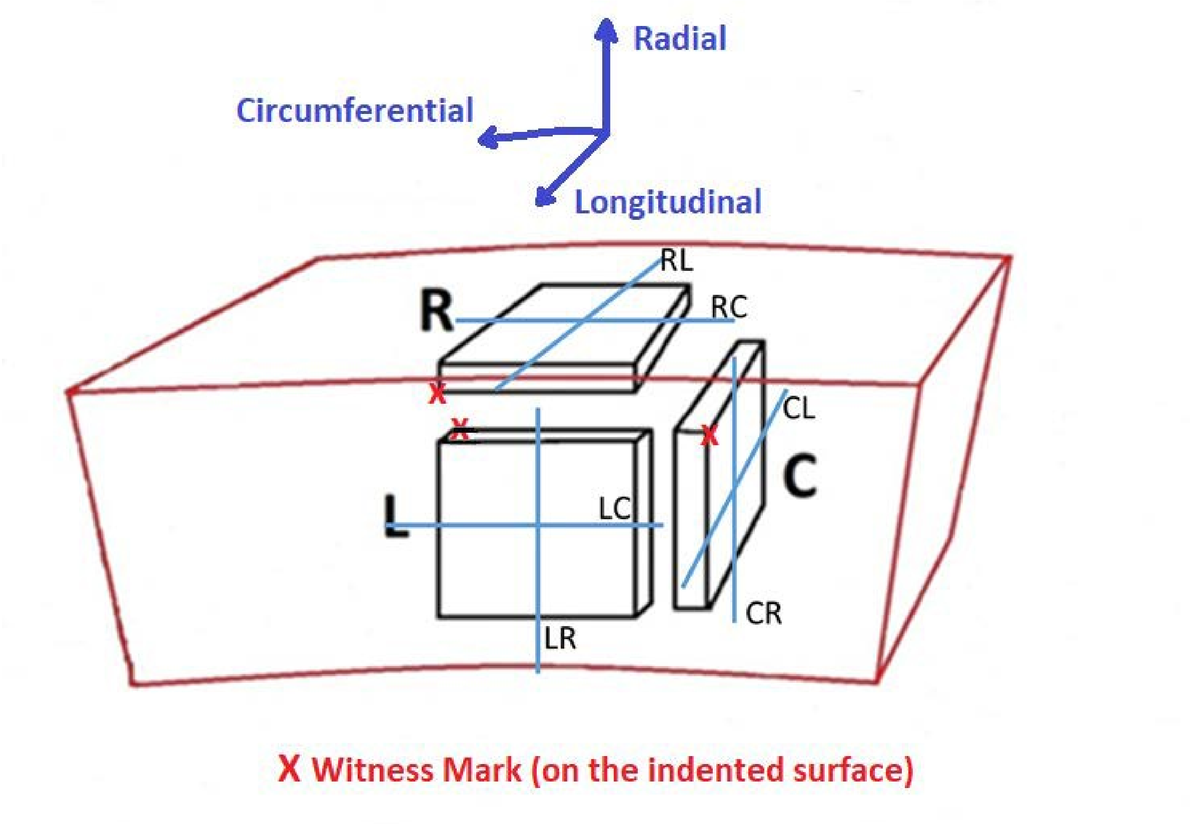
It has been agreed that a validity check should be available to apply to the data produced. Initially it is proposed initially to apply this only to the single step test or to the first step in a stepped stress test.

Three methodologies have been suggested:

1. Either the indentation rate or the converted creep strain rate over the last 100hrs of the test or step will be compared to the corresponding rates measured over the last 75hrs. The 100hrs rate will be considered valid if the rates are within 10%.
2. A more complex procedure comparing the maximum to minimum variation in rate within a range of test duration divided by the average rate within that range. The acceptance criterion would be that this value should fall within a +/-10% variation.
3. A rate measurement validity test based on the Z factor used to assess the validity of creep rupture data in the European Creep Collaborative Committee's Post AssessmentTests.

The various options will be applied to the proposed Round Robin tests before agreeing a recommended procedure.

Annex B Proposed Notation for Specimen and Indenter Orientation



1. The circumferential, longitudinal, and radial directions correspond to the original sampled component, in this case assumed to be a pipe. The circumferential direction is clockwise when looking in the longitudinal direction.

2. Specimen orientation is defined by whichever of these directions is normal to the indented surface, with the arrow representing the direction of indentation.

3. Each specimen orientation has two possible indenter orientations, defined by the direction corresponding to the line of intersection with the specimen.

4. Witness marks, in each case placed in the positive quadrant, are used to distinguish the indented surface. For R type specimens the witness mark is on the side furthest away from the component surface (consistent with the convention previously used for specimens machined from scoop samples). Please also note that for L type specimens the witness mark shown is on the side opposite to the viewer.