GUIDANCE NOTES ON THE NEW EUROPEAN STANDARD (pr)EN 14532-2 ON CONFORMITY ASSESSMENT OF HIGH TEMPERATURE WELDING CONSUMABLES

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Author Profile

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Abstract

This paper provides a simple "road map" for user guidance on the new European Standard (pr)EN 14532-2 for conformity assessment of high temperature welding consumables [1]. It should be used only in conjunction with the Standard, which specifies the precise requirements. A companion paper from the European Creep Collaborative Committee [2], published in OMMI (www.ommi.co.uk) Volume 2 Issue 3 (December 2003), provides a reference source of stress rupture data on parent materials, as required for comparison with test data to be obtained on weld metals.

Overview

The (pr)EN 14532 European Standards for conformity assessment of welding consumables have recently been finalised by CEN and are likely to be issued in late 2004. The Standards cover primary test requirements [3] for steels and nickel-base materials, Part 1; supplementary test requirements [1] for high temperature consumables and other special cases, Part 2; and aluminium [4], Part 3. The philosophical basis of a conformity assessment standard for high temperature welding consumables [5] and a detailed analysis of the specifications [6] are discussed elsewhere. This paper provides a user's guide to the tests.

Conformity assessment of welding consumables is an option for the manufacturer and / or supplier. The Standard states that the extent of qualification should be determined on the basis of the manufacturer's assessment of market requirements. The qualification can be, but does not have to be, overseen by a third party.

In principle, the basic Part 1 qualification tests should first be completed. The more specialised Part 2 qualification tests that apply may then be carried out separately where required. Whilst this is the expected route, it is possible that some manufacturers, for example those outside Europe, may consider using the Part 2 standard on its own, in order to demonstrate special properties which are not considered in other national standards.

The Part 2 Standard covers weld metals which will be subjected to post weld heat treatment (PWHT), and / or are designed to operate at moderate or high temperatures. These are separate provisions. A weld metal that is heat treated but then operates at low temperature may be qualified without high temperature testing. Conversely, a weld metal which is used in an as-welded condition may – if the manufacturer considers it appropriate – be qualified for service at elevated temperatures.

The manufacturer has the freedom to choose whether to apply a PWHT, but must report what was applied. The Standard includes provisions for both specialised and more conventional heat treatments [7]. A specialised heat treatment, for example normalising and tempering, should only be carried out for the minority of special cases where the weld metal is actually to be used in the normalised and tempered condition. By contrast, conventional PWHT (described in the Standard as "stress relief" heat treatment) should generally be specified for weld metals which are used in the post weld heat treated condition.

Weld metals for operation at moderate temperatures may be qualified by means of hot tensile testing [8], while weld metals for operation at higher temperatures may be qualified by short term creep rupture testing [9]. The requirements depend on the maximum application temperature specified by the manufacturer. If this temperature falls below a lower limit, no special qualification is required. If the maximum application temperature lies between lower and higher limits, hot tensile testing is required. If the maximum application temperature is above the higher limit, creep rupture testing is required. For example, ferritic steel consumables operating up to 350-500°C require hot tensile testing, while those operating up to higher temperatures require creep testing [8].

The specifications for hot tensile testing are straightforward. The more detailed specifications for creep rupture testing are described below.

Creep rupture testing

To qualify a consumable for application within the creep range as specified in (pr)EN 14532-2, the manufacturer should carry out a short series of creep rupture tests on all-weld metal specimens as described below:

1. Manufacture suitable test pieces as described in the Standard, and carry out any PWHT required.

   An all-weld metal test piece is required, except where the welding process can only be used to make a welded joint (e.g. electroslag welding). Any stress relief PWHT must conform to specific provisions designed to avoid undertempering, for example a minimum holding time of 3 hours.

2. Manufacture longitudinal all-weld metal uniaxial creep rupture test specimens of at least 8mm gauge diameter.

   Larger specimens (10mm diameter or greater) may be preferred to reduce the risk of data scatter. Weld metal is a mixture of columnar and refined microstructures with differing creep properties. Larger specimens which include several weld beads thus generally provide more appropriate data on averaged properties.

3. Specify the maximum application temperature T for which qualification is required. If that temperature is within the creep range as defined in Table 1 of the Standard, carry out stress rupture testing, or else put forward "legacy data" in the public domain on a "matching" consumable.

   The Standard provides criteria to determine whether the consumable to be qualified can be described as "matching" a legacy consumable, while the manufacturer takes responsibility for declaring that the criteria are met. The manufacturer can choose whether or not to take advantage of this option when it is available. Broadly, legacy creep data that are put forward must conform to the same requirements as those which apply to new test data. Alternatively, the manufacturer can submit documented evidence of the satisfactory long term service performance of the legacy consumable, in lieu of legacy creep test data.

   There is, therefore, a route to allow the manufacturer to opt out of actual testing, in cases where the consumable type is well established and there is no market demand for additional assurance. However, when the manufacturer does test the consumable which is to be qualified, the test data are analysed and recorded, and the results therefore provide clearer assurance for the prospective user.

4. Select a reference parent material, being that which the consumable most closely matches in chemical composition, and/or that which the consumable is principally designed to weld.

   The companion ECCC document [2] provides a compilation of suitable short term rupture strength data on reference materials, based on ECCC [10] and BS PD 6525 [11] data assessments. The Standard itself [12] also includes a summary of mean material rupture strength information, which (to meet requests for a simple single data table that had previously been published) was taken directly from PD 6525. Where no suitable reference material is included in these documents, public domain reference data from an alternative source can be used. If no suitable parent material data exist, e.g. for experimental alloys and consumables, then conformity assessment of the consumable is not a requirement of the Standard.

   Where there is more than one available source of reference strength values on a given parent material, the Standard allows the manufacturer to choose which source to use, provided that the choice is declared. This might be thought an undesirable ambiguity, but it is necessary to allow the use of new data sources on newly developed materials of interest. As will be seen, what is needed is a data source that provides assessed mean 1,000 hour and 10,000 hour parent material rupture strength values at the test temperature. Publications which merely report raw creep data are therefore not sufficient, and the assessment of the data should preferably be authenticated by a recognised authority such as ECCC. However, the use of parent material data from e.g. the steelmaker is not excluded, provided that all the information is properly assessed and is in the public domain. Given that the aim is to qualify the welding consumable, it is not crucial that it should be assessed against a single "right" source of parent material data, provided that the process is transparent and the source of the parent data is stated.

The ECCC document [2] offers several advantages as a source of reference parent material data. The information from PD 6525 quoted in the Standard itself [11, 12] is in parametric form and the short term strength values must be calculated by the user. However, the ECCC document provides the actual strength values which are required, for a range of suitable test conditions, on each material. The strength values recommended in the ECCC document [2] have in most cases been taken from the results of recent ECCC assessments when these are available [10], although the older PD 6525 values [11] have been quoted where necessary.

A consistent approach in selection of reference parent material data is highly desirable. It is therefore suggested that consumable manufacturers would be best advised to use the ECCC document values wherever available, unless it becomes apparent that an alternative source of parent material reference data is preferable in specific cases.

5. Determine the required limits on the range of test stresses.

   At least one specimen must be tested to failure at an applied stress which is lower than the 10,000 hour mean data creep rupture strength of the reference parent material at the specified maximum application temperature. In the companion paper [2], this is therefore given by the intersection of the row labelled "10kh" and the column corresponding to the maximum application temperature T in the following Tables. If, for example, the maximum application temperature for 11CrMo9-10 NT1 (2¼CrMo normalised and tempered < 720°C) were to be specified as 570°C, then Table 2c of paper [2] indicates that at least one test to failure should be carried out at a stress level below 92 MPa. (Steps (6) and (7) then describe how to select the test temperature and the full range of test stresses respectively).

6. Select a single test temperature within the range T to (T+100) °C.

   Note that the maximum duration of testing to failure is required only to exceed 1,000 hours. If, for example, the test temperature were selected as temperature T, and the weld metal rupture strength proved to be 100% of the mean parent rupture strength, then the duration of a test at a stress below 92 MPa would be in excess of 10,000 hours. This is permissible, but the manufacturer may prefer to minimise test time by selecting a higher test temperature. The parent material data tables provide approximate guidance on this. For the example given above, the parent material 1,000 hour rupture strength falls below 92 MPa at a temperature between 600°C and 610°C, see Table 2c of reference [2]. Therefore, a temperature of 610°C might be selected for the creep rupture tests. Note that if the consumable proves to be much stronger than the parent material, the test carried out at below 92MPa might still last well beyond

1,000 hours. To minimize the risk of any such delay in completing the tests, a higher test temperature could be selected.

7. Carry out a series of constant load creep rupture tests at the chosen temperature and determine the weld metal 1,000 hour rupture strength.

   The constant load creep rupture tests shall be carried out at the selected temperature (as chosen in step (6)). At least four tests to rupture shall be obtained. At least one of these shall record a rupture life in excess of 1,000 hours. At least one shall record a rupture life of between 50 and 250 hours. Any data points which record a rupture life below 50 hours shall be discarded. At least one of the tests to failure shall be carried out at an applied stress lower than the 10,000 hour mean data creep strength of the reference parent material at the specified maximum application temperature. In practice, it may be sensible to run five or six parallel tests covering a range of stresses to ensure the requirements are met. Multi-string test equipment, which can test several specimens together at the same temperature and different stresses, may be cost effective.

8. Analyse the test data using a best-fit linear regression between the logarithm of the test life and the logarithm of the applied stress. Hence calculate the 1,000 hour creep rupture strength of the all-weld metal at the test temperature, expressed as a percentage of the mean data 1,000 hour creep rupture strength of the reference parent material.

   For example, suppose that the 1,000 hour creep rupture strength of the all-weld metal at 610°C is found to be 93 MPa. Then from Table 2c of reference [2] for the example above, this is (93/89 x 100) = 104% of the mean parent material strength at 610°C. This is the main result of the test programme. The value quoted in this example is within the target range of 80% to 120% specified in the Standard. When the result falls outside the target range, a cautionary note is to be added to the test certificate.

9. Additionally, use the best-fit linear regression to evaluate the extrapolated 10,000 hour creep rupture strength of the weld metal as a percentage of that of the reference parent material at the same test temperature, as required by the Standard.

   For example, suppose that the extrapolated 10,000 hour creep rupture strength of the all-weld metal at 610°C is determined as (approximately) 46 MPa. Then from Table 2c of reference [2] for the example above, this is (46/54 x 100) = 85% of the mean parent material strength value at 610°C.

   The figures given in this example might suggest a possible adverse trend in the longer term creep rupture properties of the weld metal. Since limited data have been subjected to severe extrapolation, however, no definite conclusion can be drawn. The result of this adverse trend check calculation is therefore obtained for information only. Should the result fall below 80%, it should again be recorded by means of a cautionary note on the test certificate, as specified in the Standard.

There are, therefore, no rigid "pass / fail" criteria in the creep rupture testing section of the Standard. It is for the manufacturer and user to evaluate the significance of the results.

Acknowledgement

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REFERENCES

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4 European Standard prEN 14532-3 "Welding consumables - Test methods and quality requirements – Part 3: Conformity assessment of wire electrodes, wires and rods for welding of aluminium alloys".

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6 D. J. Allen, "New European Standards for High Temperature Welding Consumables", Conference on "High Temperature Plant Integrity & Life Extension", Cambridge, April 2004, to be published.

7 Reference 1, section 4.2.1.

8 Reference 1, section 4.2.2.

9 Reference 1, section 4.2.3.

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12 Reference 1, Annex E.