EUROPEAN COMMISSION

ECSC Research Project RFS-PR-09032
Executive Committee TGS8

"STRUCTURAL APPLICATIONS OF FERRITIC STAINLESS STEELS"

Report
August 17, 2011

WP 1

EUROPEAN COMMISSION

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Research Location:	Outokumpu Tornio Works Tornio Research Centre 95490 Tornio, Finland
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Structural Applications of Ferritic Stainless Steels (SAFSS)
WP1 End-user Requirements and Material Performance
Task 1.3 Characterization of stress-strain behavior

Technical Specifications for Room-Temperature Tensile and Compression Testing

Abstract

This report describes the methods used for room-temperature tensile and compression testing in the project Structural Applications of Ferritic Stainless Steels (SAFSS).

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1. BASIC INFORMATION

The room temperature tensile and compression testing is performed by means of a Zwick Z250/SW5A tensile testing machine with the capacity of 250kN, Figure 1. The tensile testing machine is equipped with GTM load cell no. 30971, hydraulic specimen grips and Zwick B06650 macro extensometer, figure 2. The clamping of the sensor arms and the setting of the original gauge length L_0 is automatic with this extensometer type. The equipment is regularly calibrated according to standards SFS-EN ISO 7500-1:2004 and SFS-EN ISO 9513:2002. At the time of writing of this report, the last calibration was carried out on the 6th of November 2010.

Figure 1. Zwick / Roell Z250 tensile test machine used.

Figure 2. Hydraulic grips and Zwick Macro extensometer with motorized sensor arms.

2. SPECIMENS FOR COMPRESSION TESTING

In-plane compression testing of sheet metals is performed by employing adhesively bonded laminated specimens. The laminated test pieces are obtained in two steps. First rectangular preforms of size 25x235 mm are adhesively bonded into a laminated stack of thickness greater than or equal to 15 mm. After the adhesive has cured, the test piece is machined from the laminated stack.

The adhesive used is two-component epoxy-based adhesive Loctite Hysol 9466. The shear strength of the adhesive, measured according to ISO 4587, is 37 MPa. Due to the high strength of the adhesive, de-bonding occurs only after the buckling of the specimen. The thickness of each adhesive layer is roughly 0,2 mm. Consequently, the influence of the adhesive on the stress-strain curve is negligible. Before applying the adhesive, the bonding surfaces are lightly ground with 60 grit sandpaper and the surfaces are cleaned with acetone to dissolve oils and fats. After applying the adhesive on the surfaces, the stack is compressed with a hand press and allowed to cure for 24 hours.

The test piece geometry is shown in figures 3 and 4.The geometry is adapted from the tensile test specimen of type 1 in annex B of EN ISO 6892-1 by reducing the parallel length to 55mm. The original gauge length used in the compressive testing is $L_0 = 40mm$.

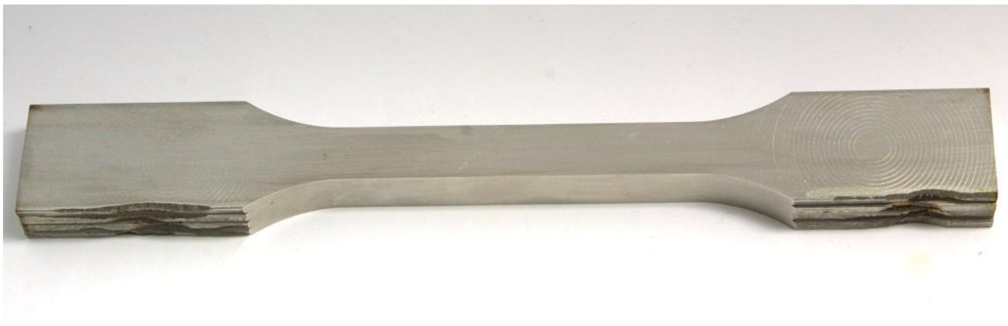

Figure 3. The laminated test piece.

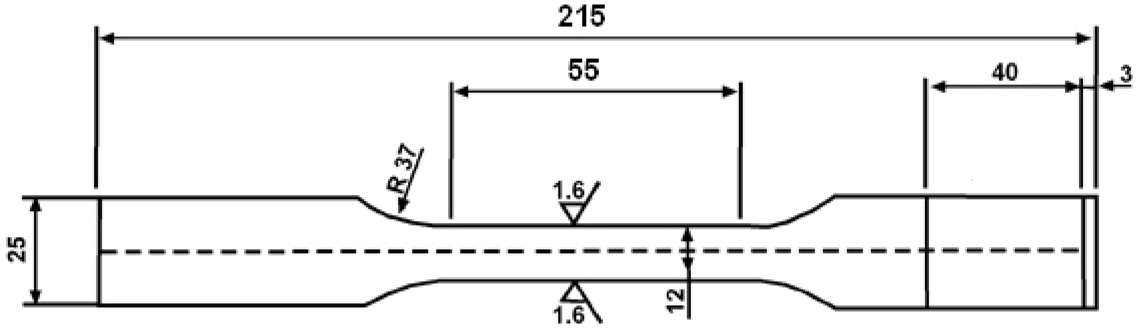

Figure 4. The geometry of the test piece for compression testing.

3. SPECIMENS FOR TENSILE TESTING

Two different test piece types are used depending on the material thickness. The test pieces are obtained by machining or by laser cutting. The results of a comprehensive testing program carried out at Outokumpu Tornio Research Centre have shown that the laser cutting does not have an influence on the test results for materials thinner than 6 mm. The test piece geometry for materials with thickness less than 3 mm is shown in figure 5. This test piece geometry corresponds to test piece type 2 in the Annex B of SFS-EN ISO 6892-1. The original gauge length used for the test piece is $L_0 = 80mm$.

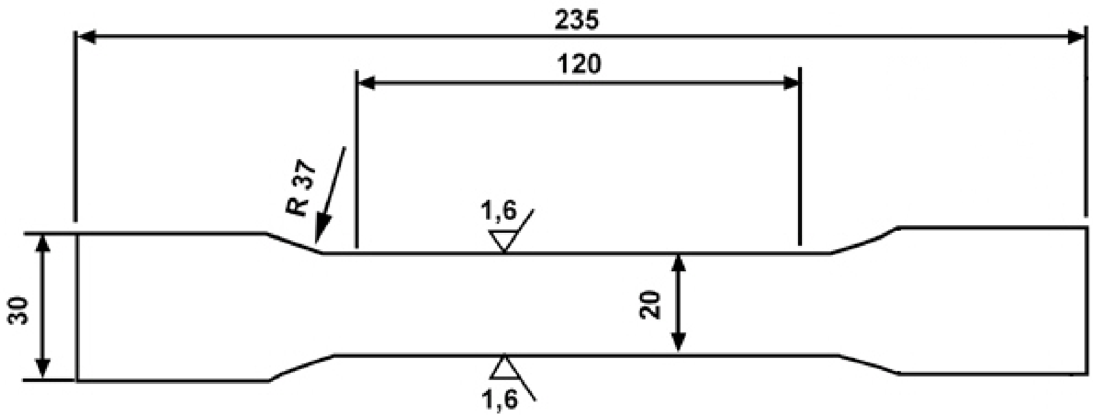

Figure 5. The tensile test piece geometry for materials with thickness less than 3mm.

The test piece geometry for sheets with thickness equal or more than 3mm is shown in figure 6. This test piece geometry corresponds to type 1 in the annex B of EN ISO 6892-1. The original gauge length used for this test piece type is $L_0 = 50mm$.

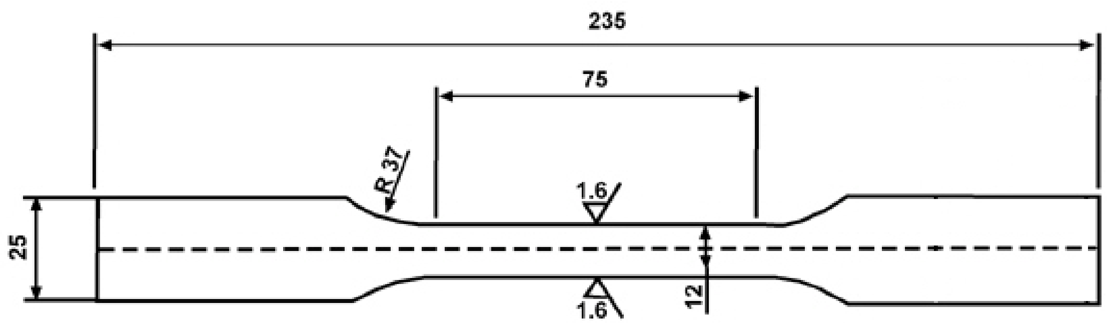

Figure 6. The tensile test piece geometry for materials with thickness ≥3mm.

4. CONDITIONS OF TESTING FOR COMPRESSION TESTING

The testing is performed, as much as possible, by following the tensile test standard SFS-EN 10002-1. The crosshead speed of 0,8 mm/min is used throughout the test. This crosshead speed results in the straining rate value of 0,00025 s^{-1}. The same straining rate is used in initial parts of tensile testing as described in the next chapter. The test is continued until the specimen fails by buckling or deponding or until the maximum compressive strain of 5% is reached. An example of a measured stress-strain curve is given in the appendix 1.

5. CONDITIONS OF TESTING FOR TENSILE TESTING

The testing is performed according to the tensile test standard SFS-EN ISO 6892-1. The tensile testing standard specifies two different methods of controlling the machine rate in different parts of the tensile testing. The method A for strain rate based machine control is used in the present testing program. The strain rate values used are given in table 1. An example of a measured stress-strain curve is to be found in the appendix 2.

Table 1. The loading rate limits in ISO EN 6892-1 method A.

Range	Straining rate (s^{-1})
Elastic range	0,00025 ± 20%
Proof strength	0,00025 ± 20%
Tensile strength	0,0067 ± 20%

6. TEST REPORT FOR COMPRESSIVE TESTING

The test report given for the compressive testing contains the following information:

- Sample material identification
- Measured sample thickness and width
- The following measured values:
  - Proof stress values $R_{p0,01}$, $R_{p0,1}$, $R_{p0,2}$ and $R_{p1,0}$.
  - Maximum stress value R_m and the corresponding plastic strain value A_g obtained during the test.
  - The slope of the stress-strain curve in the elastic range m_E.
  - The Ramberg-Osgood parameter *n* calculated by means of the three first proof stress values above.
- The measured nominal stress – total nominal strain curve.

7. TEST REPORT FOR TENSILE TESTING

The test report given for the tensile testing contains the following information:

- Sample material identification
- Measured sample thickness and width
- The following measured values:
    - Proof stress values $R_{p0,01}$, $R_{p0,1}$, $R_{p0,2}$ and $R_{p1,0}$.
    - The upper and lower yield point values R_{eH} and R_{eL} and the percentage yield point elongation A_e when applicable.
    - Maximum stress value R_m and the corresponding plastic strain value A_g.
    - The slope of the stress-strain curve in the elastic range m_E.
    - The Ramberg-Osgood parameter *n*
- The measured nominal stress – total nominal strain curve.

8. ACCURACY OF THE RESULTS

According to SFS-EN ISO 7500-1:2004, the tensile testing machine used belongs to accuracy class 1. It follows that

- The relative error of the original gauge length is less than 1,0%.
- The error on the extension, defined as the increase of the extensometer gauge length, is 3μm or 1% - whichever is larger.
- The error on the force value is less than 1,0%.

REFERENCES

SFS-EN ISO 12002-1:2002. Metallic Materials. Tensile testing. Part 1: Method of test at ambient temperature. Helsinki, Finland: Finnish Standards Association, 2002.

SFS-EN ISO 6892-1:2009. Metallic materials -- Tensile testing -- Part 1: Method of test at room temperature. Helsinki, Finland: Finnish Standards Association, 2009.

SFS-EN ISO 7500-1:2004. Metallic materials. Verification of static uniaxial testing machines. Part 1: Tension/compression testing machines. Verification and calibration of the force-measuring system. Helsinki, Finland: Finnish Standards Association, 2004.

SFS-EN ISO 9513: 2002. Metallic materials. Calibration of extensometers used in uniaxial testing. Helsinki, Finland: Finnish Standards Association, 2004.

SFS-EN ISO 377:1997. Steel and steel products. Location and preparation of samples and test pieces for mechanical testing. Helsinki, Finland: Finnish Standards Association, 1997.

EXAMPLE COMPRESSION TEST STRESS-STRAIN CURVE

Trials were performed on cold-rolled Outokumpu 1.4301 of thickness 1,5 mm to validate the compression test setup. The stress-strain curve measured in the test is given for in the figure A1. The failure of the specimen occurred after 9% of compressive strain in the test. The specimen buckled in the sideward direction before bonding failure.

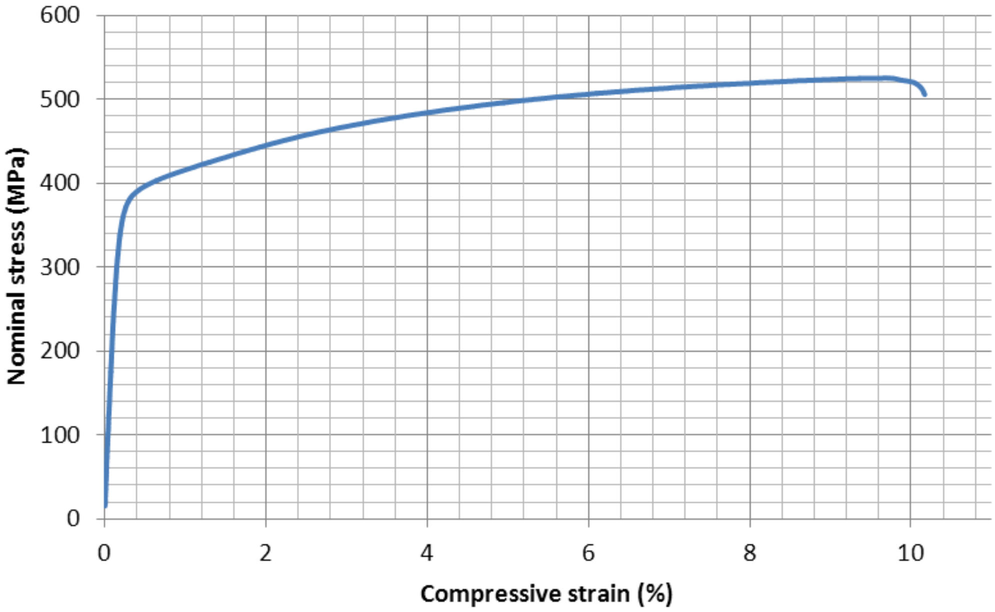

Figure A1. Measured compressive stress-strain curve.

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EXAMPLE TENSILE TEST STRESS-STRAIN CURVE

Trials were performed on Outokumpu 1.4003 with thickness 2mm to validate the machine setting given above. The stress-strain curve measured in the test is shown in the figure A2. The straining rate calculated from the measured data is shown in figure A3. The tensile testing machine keeps the straining rate at the specified constant values.

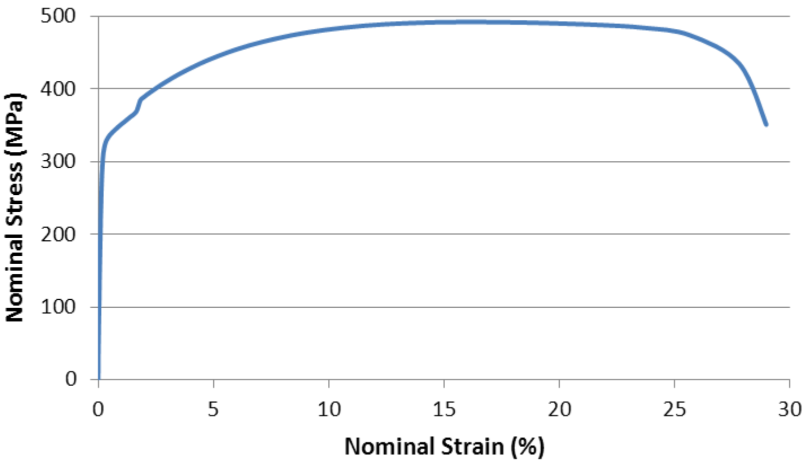

Figure A2. The measured stress-strain curve.

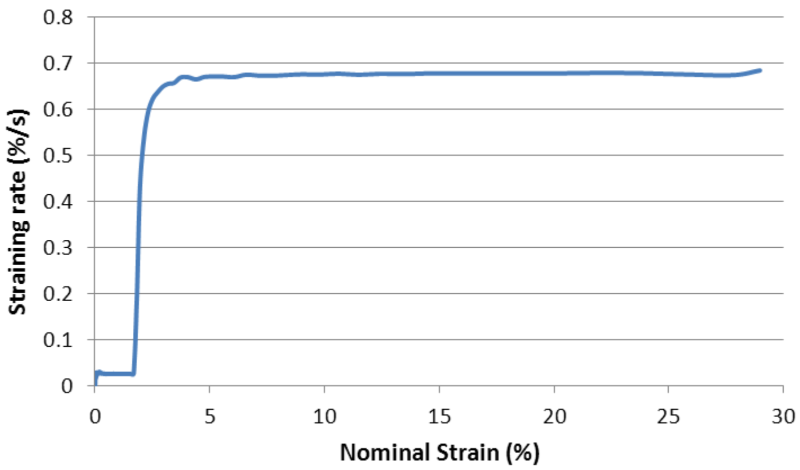

Figure A3. The straining rate during the test.

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