Contents

1. Scope

This section covers all weldable X2CrNiMo17-12-2 controlled nitrogen content austenitic stainless steel forging and drop forging with a unit weight of no more than 10 tonnes as-delivered condition.

2. Reference

RCC-MR 2007; Section-2; RM 3321 Product procurement specification: class 1, 2 and 3 X2CrNiMo17-12-2controlled nitrogen content austenitic stainless steel forgings and drop forgings for use at high temperature.

Chemical composition and impurity requirements for materials (REYV5V_v2_3)

3. Melting process

The steel shall be made using an electric furnace or by any other technically equivalent process. Melting of the steel should be completed by a suitable secondary refining processes like Argon oxygen decarburization (AOD) or Vacuum oxygen decarbonized (VOD).

4. Chemical requirements

Chemical composition, as determined by product analyses, shall comply with the following requirements (Table 1). The Steelmaker shall also supply a ladle analysis certified by the Mill Manager or his duly accredited representative.

Table 1: Chemical composition requirement

Chemical composition, X2CrNiMo17-12-2 controlled nitrogen	**Content in Wt. %**
Elements	*Range or Max*
Fe	balance
C	0.030
Mn	1.60 - 2.00
Si	0.50
P	0.030
S	0.015
Cr	17.00 - 18.00
Ni	12.00 – 12.50

Mo	2.30 – 2.70
N	0.060-0.080
Cu	1.00
B	0.0020
Additional ITER specific requirements:	
Co	0.05
Nb	0.01
Ta	0.01
Ti	0.10

Control of Co, Nb and Ta is identified as Protection Important Activity (PIA). Therefore, the compliance with above requirements have to be closely monitored.

5. Ferrite Content

The ferrite content evaluated using schaeffler diagram modified by Pryce and Andrews and measured on a solution heat treated product, must be less than 1% (Fig. RMC 1341.2; provided at the end of this spec.).

The ferrite content shall be measured in the mechanical test specimen per lot.

6. Structure

61 A micrographic examination, with photographs, shall be performed parallel to the main direction of extension.

6.2 The structure must be homogeneous.

6.3 The grain size number as determined in accordance with EN ISO 643: Steels-Micrographic determination of the apparent grain size, shall be greater than 2. The grain size homogeneity shall be ±1 around the true average value.

6.4 This grain size is determined on a test sample taken close to the mechanical test specimens.

6.5 Non-metallic inclusions amount and definition shall meet standard ASTM E45-05.

6.6 Micro inclusions (indigenous inclusions detectable by Micro Examination methods): Method D is applicable. Severity level number shall be at most 2 for types A, B, C and D. The tolerance for acceptance may be a half-class above the set limit to the extent of 2% of the fields counted.

6.7 Macro inclusions (exogenous inclusions from entrapped slag or refractories): they are strictly forbidden and are cause of rejection.

7. Manufacturing programme

Prior to commencement of manufacturing operations, the Foundry shall draw up a manufacturing programme. This shall include the following:

a) Identification of melting process
b) Ingot welding and type
c) Top and bottom end discard percentages
d) Position of the part in the ingot or product relationship,
e) A dimensional summary sketch of the part subsequent to each forging operation giving the partial and overall ratios of reduction determined in accordance with RM 0380,
f) Drawings of part as-forged or drop-forged, profiles for heat treatment, non-destructive examination and delivery,
g) Conditions for intermediate heat treatments and for final heat treatment for mechanical properties.
h) Position of acceptance test samples on the part,
i) Dimensional drawing with position of test specimens on samples.

The various heat treatment, sampling and non-destructive examination operations shall be presented in chronological order.

8. Delivery condition

Forged parts shall be delivered in the solution heat treated condition and machined to the as-delivered profile.

9. Solution heat treatment

Solution heat treatment shall consist of holding at a temperature between 1050°C and 1150°C followed by water cooling. The thermal cycles involved in the heat treatment shall be recorded and the records kept at the disposal of the Surveillance Agents.

10. Machining - Surface condition

10.1 The part shall be machined to its as-delivered profile. The surface condition evaluated shall be in accordance with RMC 7200. Further, the requirements of the various non-destructive examinations shall be fulfilled.

10.2 Unless specified otherwise, maximum average surface roughness (defined in accordance with ISO 4278:2000) shall be 6.3 µm Ra for all metallic components. The measurement shall be performed by a stylus probe type instrument.

11. Mechanical properties

11.1 Sampling:

11.1.1 Test samples shall be cut either from the part itself or from a prolongation or excess material integrally attached to the part, after the part has undergone solution heat treatment. They shall be appropriately marked.

11.1.2 The size of the test samples shall be such that they can provide enough test specimens for all tests and retests.

11.1.3 Insofar as the shape of the parts so allows, test specimens shall be cut out in such a way that their axis is oriented perpendicular to the main forging direction (transverse direction) and that the distance between the axis and the nearest treated surface (skin) is:

- 20 mm if the thickness is > 40 mm,
- mid-thickness if the thickness is <= 40 mm.

11.1.4 The distance between the test-pertinent area of the test specimen and the other treated surfaces shall not be less than:

- 40 mm if the thickness is > 40 mm:
- the thickness if this is <= 40 mm.

11.1.5 If the shape of the parts does not permit this, values as close as possible to those given above shall be obtained.

11.1.6 For Drop forged parts, Mechanical test samples shall be cut out from one or more parts in a lot or, when this is impossible (for instance, very small parts) and subject to the approval of the Contractor, from a test bar of the same heat of steel simultaneously treated in the same heat treatment charge. This test bar shall first have been subjected to forging operations considered to be representative of those undergone by the parts. The position / location of test specimens in the parts or the test bar shall be given in the mechanical test report in accordance with the requirements of clause 11.1.2 to 11.1.5 above.

11.2 Testing in the solution heat treated condition

Tests shall be performed on test specimens which were not subjected to heat treatment after sampling.

11.3 Definition of a lot

11.3.1 General Case:

A lot shall comprise parts of similar shape, cross-section and diameter, as defined below:

$$\frac{\varnothing_{max}}{\varnothing_{min}} \leq 1{,}1 \;;\; \frac{e_{max}}{e_{min}} \leq 1{,}1 \text{ et } \frac{S_{max}}{S_{min}} \leq 1{,}25$$

∅: Diameter; e= Thickness; S= Stress

11.3.2 Special case:

(i) The dimensions given above do not apply to hollow, circular parts 80 mm thick or less and weighing 500 kg or less.

(ii) In all cases the parts of the lot shall be from the same heat of steel. They shall have undergone the same processing cycle and shall be from the same furnace charge or shall have been subjected to the same heat treatment run. A lot shall be limited to 5000 kg. However, each part with an as-delivered unit weight of more than 1000 kg shall constitute a lot.

11.4 Number and content of tests

11.4.1 One series of tests shall be performed per lot for parts weighing 500 kg or less.

11.4.2 Two series of tests shall be performed for parts weighing more than 500 kg.

11.4.3 A tests series shall comprise:
(i) one tension testing at room temperature
(ii) one tension testing (only Yield Strength) at 200 C

11.5 Tension testing at room temperature

11.5.1 Test specimen:

Test specimens shall have a circular section. Their normal diameter shall be 10 mm and their dimensions as specified in **RMC 1211**.

11.5.2 Test method:

The tension test shall be performed in compliance with **RMC 1211**. The following values shall be recorded:

(i) Yield strength at 0.2% offset, in MPa,
(ii) Yield strength at 1% offset, in MPa,
(iii) Ultimate tensile strength, in MPa,
(iv) Percentage elongation after fracture,
(v) Percentage reduction of area after fracture.

11.5.3 Results

Results obtained shall meet the requirements given in Table-2 Below.

Table-2: Tensile properties at Room temperature

Yield strength at 0.2% offset, in MPa, $R_{p0.2}$	220
Yield strength at 1% offset, in MPa, R_{p1}	To be recorded For Information
Ultimate tensile strength, in MPa, Rm	525-700
Percentage elongation after fracture, A% (5d)	45 (Longitudinal) 40 (Transverse)
Percentage reduction of area after fracture	To be recorded For Information

11.5.4 If the requirements of clause 11.5.3 are not fulfilled, and the test specimen has a physical defect (which does not affect the usefulness of the product) or if unsatisfactory test results are due to incorrect mounting of the specimen or a testing machine malfunction, the test shall be repeated using another specimen. If the results of the second test are satisfactory, the part and/or the lot shall be accepted; if not, the following paragraph shall apply.

Where unsatisfactory results cannot be attributed to any of the above-mentioned causes, two retests may be performed for each unsatisfactory result obtained. The second set of test specimens shall be taken close to those which were defective. If the results of the retests are satisfactory, the lot shall be accepted; if not, it shall be rejected (clause 11.7).

11.6 Tension testing at high temperature (at 200 C)

11.6.1 Test specimen:

The nominal diameter shall be 10 mm and their dimensions as specified in RMC 1212.

11.6.2 Test method:

The tensile test is performed in compliance with RMC 1212.

11.6.3 Results:

Yield strength at 0.2% offset, MPa, $R^t_{p0.2}$:	144
Yield strength at 1% offset ($R_{p1\%}$)	To be recorded for information
tensile strength (R_m)	To be recorded for information

11.6.4 If the requirements of clause 11.6.3 are not fulfilled, then follow clause 11.5.4.

11.7 Retreatment

11.7.1 Lots rejected on the basis of unsatisfactory results for one or more mechanical tests may be retreated (solution heat treatment).

11.7.2 Retreatment conditions shall be described in the test report.

11.7.3 In such cases, test samples and specimens shall be taken in the same conditions as specified in clause 11.1 and clause 11.2. The tests performed shall be the same as those described in clause 11.3 to 11.6.

11.7.4 No more than one retreatment shall be allowed.

12. Surface examination - Surface defects

12.1 Surfaces shall be thoroughly examined during all phases of production and machining to check the soundness of the metal. The part shall be sound and free of scale, strings, tears, nicks or other injurious defects.

12.2 A visual examination shall be performed on all parts and this may be followed by a liquid penetrant examination in accordance with **RMC 4000.**

12.3 The following recordable conditions and examination criteria shall be applied for liquid penetrant examination:

12.3.1 Except in the particular case described below:

Any defect with one dimension of 1 mm or more shall be considered a recordable condition

12.3.2 The following indications shall be unacceptable:

(i) linear indications,

(ii) rounded indications with one dimension greater than 3 mm,

(iii) 3 or more indications aligned less than 3 mm apart edge to edge.

(iv) 5 or more grouped indications within a rectangular area of 100 cm2, whose greater dimension shall not exceed 20 cm, taken in the most unfavourable location relative to the indications being evaluated.

12.3.3 In the particular case of parts to be deep machined (removal of over 30 % of the wall thickness), the condition regarding grouped indications shall be applied taking into account defects with one dimension greater than 0.5 mm.

12.4 When the examinations described above indicate the presence of unacceptable defects on the part, the instructions of clause 15 shall apply.

13. Volumetric examination

13.1 An ultrasonic volumetric examination shall be performed.

13.2 Degree and time of examination:

13.2.1 This examination shall be performed when the profile of the part permits satisfactory test performance. It shall be performed in the following order of preference:

(i) after final machining,

(ii) after heat treatment for mechanical properties, whether subsequent machining is performed or not.

13.2.2 Parts or portions of parts which cannot be examined after heat treatment due to the geometry of the part shall be examined at the latest intermediate stage possible.

13.2.3 In the case of small formed parts, the examination may be performed on semi-finished products.

13.3 Procedures

13.3.1 Ultrasonic examination procedures are specified in paragraphs RMC 2310 and RMC 2320.

13.3.2 Probe characteristics shall normally be as follows:

(i) Straight beam examination: frequency 2 MHz,

(ii) Angle beam examination: frequency 1 MHz, refraction angle depends on the part geometry.

(iii) A lower frequency may be used for thick parts if the structure so requires.

13.4 Scanning plan and degree of examination

13.4.1 The entire volume of all the part shall be subject to ultrasonic examination.

13.4.2 100% scanning coverage defined in §12.4 of NF EN 10228-4 shall be performed. Part type is 1, 2, 3 or 4.

13.5 Evaluation of indications

Indications shall be evaluated in accordance with the requirements of RMC 2310 and RMC 2320.

13.6 Recordable conditions and examination criteria

13.6.1 Straight beam examination

(i) The ranges considered and the acceptance criteria which depend on the thickness of the parts examined, shall be those defined by the standard NF EN 10228-4 for normal probe. The quality class 2 shall be adopted.

(ii) For thickness above or equal to 75 mm, concerning the loss of back echo, the recordable attenuation range is R <=0.12 with no acceptability limit.

13.6.2 Angle beam examination

(i) Any indication with echo amplitude >=50% of the reference echo shall be recorded.

(ii) Any indication whose echo amplitude is greater than the reference echo amplitude shall be unacceptable.

14. Removal of unacceptable areas

14.1 The forging mill may eliminate surface defects by grinding, provided that the dimensional tolerances of the part in the as-delivered condition are respected.

14.2 After grinding, a liquid penetrant examination shall be performed in accordance with RMC 4000. Examination criteria shall be those defined in clause 12 above.

14.3 No repairs by welding by the forging mill shall be permissible.

15. Dimensional check

15.1 The dimensions shall be checked in accordance with the requirements of the procurement drawings.

15.2 The main dimensions shall be recorded.

15.3 The values obtained shall be within the tolerances given on the drawing.

15.4 In the case of drop forgings, this examination shall be performed by representative sampling.

16. Marking

16.1 The Supplier shall specify the identification and marking methods used, in compliance with RC 1300.

17. Cleanliness - Packaging – Transportation

17.1 Requirements shall be specified in the purchase order, taking particular account of the requirements of Annexure 13.

18. Test reports

18.1 In addition to the inspection certificate type 3.1 in accordance with NF EN 10204, the following reports shall be drawn up by the Supplier after each individual test and, in

any case, prior to delivery of the part:

18.1.1 Ladle and product analyses

18.1.2 Micrographic examination, grain size

18.1.3 Intergranular corrosion test

18.1.4 Ferrite Content

18.1.5 Record of all the heat treatment

18.1.6 Mechanical tests

18.1.7 Non-destructive examinations

18.1.8 Dimensional check

18.2 These reports shall also include:

18.2.1 Heat number and part reference number

18.2.2 Supplier's particulars

18.2.3 Purchase order number

18.2.4 Name of the inspection agency, where applicable

18.2.5 Test and retest results together with required values

Figure RMC 1341.2: Schaeffler diagram, modified Pryce and Andrews – determination of the δ ferrite content

Nickel equivalent: Ni éq. = Ni + 21 C + 11.5 N + 0.5 Mn
Chromium equivalent: Mo < 2 %: Cr eq. = Cr + Mo + 3 Si
Mo ≥ 2 %: Cr eq. = Cr + 2 Mo + 3 Si