Fe-Ni-Cr-Co-Mo-W ALLOY BARS & FORGINGS

1.0 GENERAL:

This specification governs the quality requirements of Fe-Ni-Cr-Co-Mo-W Alloy Bars & Forgings.

2.0 APPLICATION:

For gas turbines components such as shroud segments etc.

3.0 CONDITION OF DELIVERY:

Hot rolled/forged and solution treated and rough machined/turned condition.

4.0 COMPLIANCE WITH NATIONAL STANDARDS:

There is no National Standard to cover this grade of material.

5.0 DIMENSIONS AND TOLERANCES:

5.1 Sizes: The sizes shall be as specified in the order. Unless otherwise specified, the rolled bars shall be supplied in random lengths of 3-6 meters. Forgings shall be supplied in lengths of 1.5 to 3 meters while for forged rings, supply shall be as per ordering requirement of BHEL.

5.2 Tolerances on hot rolled bars: The tolerances on cross sectional dimensions shall be as follows:

Diameter or Width across flats, mm		Tolerance (mm)
Over	Upto & including	
--	25	+ 1.0 0
25	50	+ 1.5 0
50	80	+ 2.0 0
80	100	+ 2.5 0
100	125	+ 3.0 0
125	--	+ 2.5% of dia/width across flats

5.3 Tolerances on forged bar / flat shall be + 8 mm on the nominal diameter / side.
- 0 mm

5.4 For forged rings the tolerance shall be as per the ordering drawing.

6.0 MANUFACTURE:

6.1 The alloy shall be produced by basic electric process and Argon oxygen decarburisation process. The alloy shall be further refined by using Electro – Slag Remelting (ESR) process.

Any other process of manufacture is subjected to mutual agreement between BHEL & manufacturer.

6.2 Ingots shall be worked with a press for sufficient power to completely work the cross-section and the total work must be adequate to assure that the heat treatment will develop a refined structure with good ultrasonic penetrability & quality and uniformity of mechanical properties.

7.0 HEAT TREATMENT:

The recommended heat treatment is as follows:

7.1 **Solution treatment:** Heating to 1120° C with soaking period of 30 minutes per inch, followed by quenching in oil, water or forced air.

7.2 Whenever more than 3.5 mm of stock is machined off from the surface after solution treatment, the forgings shall be stress relieved at a suitable temperature followed by still air cooling to room temperature. Cooling rate may be increased using forced air after the temperature has reached at 250°C.
Actual heat treatment cycles followed shall be reported in test certificate.

8.0 FREEDOM FROM DEFECTS:

The bars and forged rings shall be free from injurious external and internal defects of a nature which will interfere with the purpose for which they are intended.

9.0 TEST SAMPLE:

9.1 **Chemical Analysis:** One test sample for chemical analysis shall be taken from each melt.

9.2 **Mechanical Tests:**

9.2.1 **For forged rings:** Four tangential test pieces 90° apart and two radial test pieces 180° apart, midway between ID and OD as close as possible to what will be finished machined surface of the forging pertaining to each ring/drawing number/heat treat lot shall be taken for mechanical testing.

9.2.2 **For Rolled or Forged bars:** One tensile test sample from both top and bottom ends of bar or forging per lot, comprising of bars or forgings of same size, melt and heat treatment batch shall be taken for mechanical testing.

10.0 CHEMICAL COMPOSITION:

The analysis of steel shall conform to the following:

Melt analysis	Min.	Max.
Carbon	0.02	0.10
Manganese	-	1.50
Phosphorus	-	0.040
Sulfur	-	0.030
Silicon	-	1.00
Nickel	35.0	39.0
Chromium	23.0	27.0
Molybdenum	-	2.50
Tungsten	-	2.50
Iron	31.0	-
Copper	-	0.50
Aluminium	-	0.40
Titanium	-	0.20
Columbium + Tantalum	0.40	0.90
Cobalt	-	3.0
Nitrogen	0.15	0.30
Boron	-	0.010

Note: Variation in product analysis are permitted as per ASTM A788.

11.0 MECHANICAL PROPERTIES:

The mechanical properties of the materials shall be as follows:

Tensile Strength (N/mm^2), min.	(0.2%) Proof Strength N/mm^2, min.	Elongation %, min. L=50 mm	Reduction in Area % min.
620	275	30.00	40.00

NOTE: The tensile test shall be carried out as per ASTM A370.

12.0 NON-DESTRUCTIVE TEST:

Ultrasonic Test: All bars shall be ultrasonically tested as per BHEL standard GT10614.

13.0 FIRST PIECE QUALIFICATION REQUIREMENTS:

A comprehensive evaluation for First Piece Qualification (FPQ) shall be required of a new supplier or when there is a significant change in the approved Manufacturing Process Plan (MPP) or if a supplier has not performed this process with in two years prior to purchase order placement. FPQ is required per size. The FPQ shall be carried out in accordance with GT10604.

FPQ shall include the following in addition to the tests required as per Clause Nos. 10.0, 11.0 and 12.0.

13.1 Supplier shall submit detailed Manufacturing Process Plan (MPP) indicating the step-by-step list of operations by which the material is planned to be processed, tested and inspected for approval by BHEL prior to the commencement of production of the material.

13.2 Following tests shall be conducted.

13.2.1 Stress Rupture Tests:

Two smooth bar rupture tests per size shall be carried out as per ASTM E139. The material shall be able to meet the following requirements.

Test temperature	Stress	Minimum time to rupture
982° C	17.23 N/mm²	110 hrs.
898° C	44.81 N/mm²	120 hrs.

13.2.2 Hardness Test:

Hardness test shall be conducted as per ASTM A 370 for all bars or forgings at three locations on both top and bottom surfaces, that are 120° apart. Brinell hardness shall be reported for information.

13.2.3 Metallographic Tests:

The microstructural examination shall be conducted on fractured tensile specimens and shall be oriented tangentially. The photomicrographs at 100x magnification shall be submitted along with the test results to BHEL.

Grain size: Average grain size determined in accordance with ASTM E112 shall be predominantly ASTM No 4 or finer with occasional fields of view as large as No 2 permissible.

13.2.4 Visual Dye Penetrant Testing:

The supplier shall perform a visible dye penetrant test on each forged/rolled bar as per BHEL standard GT10160.

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14.0 RETESTS:

14.1 If any of the test specimen fails to meet the requirement specified, the sample bar from which the test specimen are, shall be rejected and two further sample bars from the same lot shall be taken for retest.

14.2 If any of the retests also fails, manufacturer is at liberty to heat treat the bars in question. However, not more than two heat treatments are allowed.

14.3 If after heat treatment, the mechanical properties are not complied with, the entire lot shall be rejected.

15.0 INSPECTION AT SUPPLIER'S WORKS:

The representative of BHEL shall have free access to the supplier's works at all times during the execution of the orders to satisfy himself that the material is produced as per quality requirement of this specification. All reasonable facilities shall be extended to him, free of charge. He may witness sampling, testing and marking called for in this specification/order.

16.0 TEST CERTIFICATE:

Five copies of the test certificates shall be supplied, furnishing the following details.

a) HY10986 Rev.03
b) BHEL Order No.
c) Size
d) Melt No./Forge No.
e) Process of manufacture
f) Heat treatment details and batch no.
g) Results of chemical analysis, mechanical properties, ultrasonic test, stress rupture test and all other tests stipulated in this specification / order..
h) FPQ test results, whenever applicable.

17.0 PACKING AND MARKING:

Marking: All bars with cross section dimension greater than 50 mm shall be stamped with the melt number, specification number and manufacturer's trade mark at one end of the bars. Bars of sectional dimension 50 mm and below shall be bundled as per each size and a metal tag bearing the following information shall be securely attached to each bundle.

a) HY10986 Rev.03
b) BHEL Order No.
c) Melt No./ Heat treatment batch no./Forge No.
d) Size/weight
e) Manufacturer's trade mark

18.0 REJECTION AND REPLACEMENT:

In the event of any material proving defective in the course of processing or testing, such material shall be rejected and the supplier shall make immediate arrangements to replace the same free of cost.