ALLOY STEEL FORGINGS FOR STEAM TURBINE ROTORS
GR: 30 Cr Mo Ni V 511
(Material No.1.6946)

1.0 GENERAL:

This specification governs the technical requirements of steam turbine rotors forged out of steel grade 30 Cr Mo Ni V 511.

2.0 APPLICATION:

Steam turbine rotors having diameters up to 1500 mm

3.0 CONDITION OF DELIVERY:

The rotor forgings shall be supplied in vertically heat treated and rough machined condition.

4.0 DIMENSIONS AND TOLERANCES:

The rotor forgings shall be supplied to the dimensions shown on the ordering drawing. The tolerance shall be as follows unless otherwise specified in the drawing/order.

Upto 500 mm : + 1 mm
Over 500 mm : + 2 mm

5.0 MANUFACTURE :

5.1 The steel shall be made from basic electric furnace and shall be subsequently refined by Vacuum Carbon Deoxidation (VCD) or Electro Slag refining (ESR) process.

5.2 Sufficient discard from Top and Bottom shall be made from the ingot to ensure freedom from piping, segregation and other injurious defects.

5.3 The forging process adopted shall ensure homogenity of material throughout the section.

5.4 It is important to maintain the actual centre of the forging, as far as possible identical with the center of the ingot.

5.5 Press straightening, if necessary, may be performed before heat-treatment.

5.6 The material as per this specification shall be supplied by the manufacturers who are having complete in-house steel melting, refining, hot rolling/forging/blooming/etc., heat treatment and testing facilities.

5.7 CLOCKING SYMBOL :

Before heat-treatment, clocking symbols 3-6-9-12 shall be stamped on the rotor. If the symbols are transferred during manufacture, they shall be re-stamped in the same clock wise position. The clocking symbols shall be used for reference purposes in recording the position of defects, etc. The clocking symbols shall be encircled with oil paint for easy identification.

5.8 After heat-treatment, the forging shall be rough machined to the dimensions and surface finish shown on the ordering drawing.

5.9 If the manufacturer has not supplied the forgings as per the ordering drawing in the past, a new Manufacturing and Inspection Sequencing plan (MIP) in accordance to the specification HY 0652099 of BHEL Hyderabad shall be submitted for review & approved by BHEL. Same can be used till there are no changes in the manufacturing process and the facilities used for the manufacture of the forging.

6.0 CHEMICAL COMPOSITION:

The chemical composition of the material shall be as follows:

Element		C	Si	Mn	Cr*	Mo	Ni	V	P	S	Al (Total)
VCD Process	Min.	0.27	-	0.30	1.10	1.00	0.50	0.25	-	-	-
	Max.	0.31	0.10	0.80	1.40	1.20	0.75	0.35	0.007	0.007	0.008
ESR process	Min	0.27	-	0.30	1.10	1.00	0.50	0.25	-	-	-
	Max	0.31	0.20	0.80	1.40	1.20	0.75	0.35	0.007	0.005	0.010

*** Note:** For rotor forgings from 1400-1500 mm diameter, Cr content upto 2.00 % maximum is permitted.

Tramp Elements: The tramp elements shall be within following limits.
Cu = 0.12 max. ; As = 0.02 max.; Sb = 0.02 max. ; Sn = 0.015 max.

Small deviations in chemical composition are permissible only after approval from BHEL, provided that the specified properties are not impaired.

7.0 HEAT TREATMENT:

7.1 The rotor forging shall be heat treated vertically followed by oil or mist quenching. The heat treatment shall be done to obtain tempered upper bainitic structure uniformly through-out the cross section free of ferrite in the centre. The hardening temperature shall be between 940°C and 960°C but 950°C shall be the target. The tempering cycle shall be selected suitable to achieve the 0.2 % yield strength with the possible toughness and minimum residual stresses in the forging. It shall between 690 °C and 710°C.

At the option of the manufacturer, the rotor forgings may be suitably stress relieved (in vertical condition only) so as to achieve the residual stresses within the limits specified in Cl. 8.0.

Actual heat treatment cycles followed shall be reported in test certificate.

7.2 In case the required properties have not been obtained, reheat-treatment of the forging is to be carried out. The maximum number of reheat-treatment permitted is two. However, re-tempering is not considered as reheat treatment.

8.0 RESIDUAL STRESS MEASUREMENT:

8.1 The residual stress measurement shall be carried out as per BHEL Corporate Standard AA0850150. In lieu of BHEL standard AA0850150, residual stress measurement may be carried out by 'Blind hole method' as per ASTM E 837. However, all the other conditions of AA0850150 such as location of tests, acceptance criteria etc. remain same.

8.2 Additionally, for the rotors having barrel diameter up to 500 mm & length up to 1700 mm, Residual stress measurement by Ring cutting method is also acceptable. However, the rings shall be cut from T1 & T2 locations specified on the ordering drawing. The residual stresses shall not be more than 45 N/mm^2. The procedure for carrying out RSM by ring cutting method shall be submitted by the vendor for approval by BHEL Hyderabad.

9.0 SELECTON OF TEST SAMPLES:

9.1 The location of the test pieces shall be shown on the ordering drawing. The test samples shall not be removed before heat treatment of the rotor forging. However the method of removal of the test pieces is left to the discretion of the supplier.

9.2 The test samples shall be identified according to the locations specified in the ordering drawing. The test shall be carried out on the above identified samples and the balance test pieces (duly identified) shall be sent to BHEL for further testing.

10.0 MECHANICAL PROPERTIES:

10.1 The mechanical properties, when tested on the tangential or radial test pieces shall conform to the following at room temperature.

Tensile Strength N/mm^2 Max.	0.2% proof Stress N/mm^2	% Elongation L=5d Min.	% Reduction in area Min.	Impact Strength J Min.
850	550 - 700	15	40	24

10.2 **Axial core testing:** If specified on the ordering drawing, axial trepanned core shall be tested in accordance with the standard AA0850155 and the following properties shall be obtained on the samples taken in radial direction.

0.2% Proof Stress	:	530 N/mm^2 min.
Impact Strength (Average of 3 samples) ISO-V notch	:	55 J min. at $+80^0$ C
FATT	:	$\leq +80^0$ C,

T: Tangential Test piece, Q: Radial test piece.

The axial core shall be clearly marked, so that its original position can be easily identified with respect to the shaft. The stamp of the manufacturer's authorized inspector close to the identification number shall confirm traceability of the trepanned core to the forging.

Note: a) Tensile test shall be carried out as per IS: 1608 or any National Standard.

b) Impact test shall be carried out as per IS: 1757 ISO-V notch or any National standard. The minimum impact strength value specified above is the average of three samples at the same location. Only one value is permitted below the specified min. value, but in no case shall be lower than the 2/3 of the same. All values shall be reported in test certificate.

11.0 NON-DESTRUCTIVE TESTS:

11.1 Ultrasonic Test:

Ultrasonic test and evaluation shall be carried out as per BHEL Corporate Standard AA0850106.

11.2 Magnetic particle test:

Magnetic particle test and evaluation shall be carried out as per BHEL Corporate Standard AA0850106.

12.0 METALLOGRAPHIC TEST:

Metallographic test shall be conducted on samples taken from broken tensile test pieces. The photo micrographs at 500X shall show tempered upper bainitic structure and the photomicrograph (original) shall be submitted to BHEL along with test certificates.

13.0 THERMAL STABILITY TEST:

If specified in the ordering drawing, thermal stability shall be carried out according to BHEL Standard AA0850152.

14.0 FIRST PIECE QUALIFICATION TESTS:

Whenever the supplies are made for the first time to BHEL, the requirements of BHEL specification HY0800099 shall also be applicable in addition to this specification.

15.0 INSPECTION AT SUPPLIER'S WORKS:

BHEL representative shall have all reasonable facilities offered to him, at any time, by the supplier to satisfy himself that the material is being furnished in accordance with this specification. The representative shall have free access at all times while the work on the contract is being performed, to all parts of the manufactures works.

16.0 QUALITY PLAN:

16.1 Vendor shall follow the Quality Plan Ref. BHEL/QP/HY19473 Rev.04 attached as Annexure 'A' unless conditions stipulated in Cl.16.2 & 16.3 are applicable.

16.2 In case Customer / Project related additional requirements are applicable in the enquiry / tender, vendor may be asked to submit a separate QP including such requirements.

16.3 In case of new vendors or first time supplies according to drawings mentioned in BHEL enquiry, a separate QP shall be submitted for approval by BHEL.

17.0 TEST CERTIFICATE:

17.1 Five copies of test certificates (in English) giving the following details shall be furnished.

a) HY 19473 Rev .04
b) BHEL Order No.
c) Item Description and Drawing No. of the forging.
d) Supplier's Name.
e) Melt No. and Forge No. (Steel making & refining processes)
f) Results of chemical analysis alongwith trace elements.
g) Results of Mechanical Tests & FATT (if applicable)
h) Results of residual stresses.
i) Report of ultrasonic testing giving details of probe type and size, frequency, sensitivity, sketch showing the areas covered etc.
j) Report of Metallographic test alongwith microphotographs (original).
k) Actual Heat treatment charts
l) Results of thermal stability test, if called for in the drawing/purchase order.
m) Report magnetic particle inspection.
n) Copy of approved MIP duly attested by BHEL Hyderabad.

17.2 The certificate shall be attested by chief of inspection/chief metallurgist of the supplier and BHEL representative.

18.0 MARKING:

The following details shall be punched clearly on one end of the forging.

a) HY 19473 Rev.04
b) Forging No. and Melt No.
c) Drawing NO.
d) Manufacturer's Stamp.
e) BHEL Inspector's stamp
f) Clocking symbols.
g) Top and Bottom sides of ingot.

19.0 PACKING AND TRANSPORTATION:

Rotor forgings shall be properly protected from corrosion and damage during transit, journal portions shall be protected with anti-corrosive compound.

20.0 REJECTION AND REPLACEMENT:

In the event of any forging proving defective in machining, testing erection and operation such forging shall be rejected notwithstanding any previous acceptance. The supplier shall replace the rejected forging at his own cost.

ANNEXURE A (as per clause 16.0)									**HY19473REV.04 PAGE 6 OF 7**			
Vendor's Name & Address				Customer:			BHEL ENQ. NO.		QP No. BHEL/HY19473 Rev.04			
				Project:			Date:		Page: 1 of 2			
				Product:			BHEL Spec. HY19473 Rev.04					
Sl. No.	Component Operation	Characteristics	Class	Type of Check	Quantum	Reference Document	Acceptance Norms	Format of records	AGENCY			Remarks
									P	W	V	
1.	Melting	Chemical composition	Critical	Chemical	100%	Vendors standard	HY19473Rev.04	TC	2	-	1	Steel melting & refining process shall be specified in TC
2.	Forging	Forging Steps	Major	Visual	100%	-do-	BHEL approved MIP	TC	2	-	1	Overall reduction ratio shall be mentioned in TC
3.	Preliminary Heat Treatment	Time Temp. Control	Major	Measure	100%	-do-	-do-	Internal Record	2	-	1	
4.	Marking of Clocking Symbols		Major		100%	BHEL Drawing & Spec.	BHEL Drawing & Spec.		2	1	-	
5.	Quality Heat Treatment (in vertical condition)	Time Temp. Control	Major	Measure	100%	BHEL Drawing & Spec.	BHEL Drawing & Spec.	TC	2	-	1	
6.	Ultrasonic test & Magnetic particle test	Ultrasonic test & Magnetic particle test	Major	Internal Defects	Whole volume/ surface of the forging	BHEL Drawing & Spec.	BHEL Drawing & Spec.	TC	2	1	-	
7.	Residual Stress Measurement	Residual Stress Testing	Major	Internal stresses	Each rotor	BHEL Drawing & Spec.	BHEL Drawing & Spec.	TC	2	1	-	
8.	Sampling for Mechanical Testing		Major		As per drg.	BHEL Drawing & Spec.	BHEL Drawing & Spec.		2	1	-	
9.	Mechanical Testing & Metallography	Tensile test Impact test Microstructure	Major	Mechanical & Metallo-graphy	Each rotor	BHEL Drawing & Spec.	BHEL Drawing & Spec.	TC	2	1	-	
10.	Trepanning of Axial core		Major			BHEL Drawing & Spec.	BHEL Drawing & Spec.		2	-	-	If specified on the ordering drg.
11.	Axial Mechanical Test	Tensile test Impact test , FATT & Microstructure	Major	Core properties	As per drg. & BHEL Spec	BHEL Drawing & Spec.	BHEL Drawing & Spec.	TC	2	1	-	If specified on the ordering drg.

ANNEXURE A (as per clause 16.0)												**HY19473 REV.04 PAGE 7 OF 7**
Vendor's Name & Address				Customer:			BHEL ENQ. NO.					QP No. BHEL/HY19473 Rev.04
				Project:			Date:					Page: 2 of 2
				Product:			BHEL Spec. HY19473 Rev.04					
Sl. No.	Component Operation	Characteristics	Class	Type of Check	Quantum	Reference Document	Acceptance Norms	Format of Records	AGENCY			Remarks
									P	W	V	
12.	Thermal stability test	Dimensions	Major	Heat stability of rotor	Each rotor as per drg.	BHEL Drawing & Spec.	BHEL Drawing & Spec.	TC	2	-	1	If specified on the ordering drg.
13.	Boroscopic & MPI of Axial Bore	Boroscopic & Magnetic particle test	Major	Boroscopic & MPI	100%	BHEL Drawing & Spec.	BHEL Drawing & Spec.	TC	2	1	-	If axial bore test specified on the drg.
14.	Plugging of Axial Bore			Visual check	Each rotor	BHEL Drawing & spec.	BHEL Drawing & Spec.		2	-	-	If axial bore test specified on the drg.
15.	Finish Machining	Dimensions	Major	Measure	100%	Drawing	Drawing	TC	2	1	-	
16.	Completeness of documents, test certificates, HT charts etc.		Major	Verification	Each rotor	BHEL Drawing & spec.	BHEL Drawing & Spec.	Endorseme-nt by TPIA on all documents	2	-	1	
17.	Marking preservation & Packing	Marking Preservation & packing	Major	Visual check	100%	BHEL drawing & spec.	BHEL drawing & spec.		2	-	1	

Legend: P Perform ;W Witness ;V Verification ; Indicate 1 for BHEL or BHEL nominated inspection agency & 2 for vendor / sub vendor as appropriate against each component / characteristic under P, W & V columns.

Signature of the supplier with Company Stamp
(To be submitted along with the technical offer)