BHARAT HEAVY ELECTRICALS LIMITED
HEEP: HARDWAR-249403 (UK)
Fax: 01334-226462, Phone: 01334-284144
E-mail: ajayk@bhelhwr.co.in

Tender no: PPX-F&HE/EOI/SL/17-18/01 **Due Date: 28/06/2017**

Notice for Expression of Interest for empanelment of New Vendors

The Heavy Electrical Equipment Plant (HEEP) located in Haridwar, is one of the major manufacturing plants of BHEL. The core business of HEEP includes design and manufacture of large steam and turbo generators, condenser and so on.

We are looking for reputed vendors having capability to supply Turbine Blade Flats Grade X20Cr13 (HW10786 Rev: 07), X22CrMoV121 (HW10687 Rev: 07), X19CrMoNbVN11-1 (HW10670 Rev: 07), X12CrMoWVNbN10-1-1 (HW10663 Rev: 06) & NICr20TiAl (HW12784 Rev: 01)
Approx. annual requirement is 92 MT, 280 MT, 664 MT, 405 MT & 20 MT for Material Grade X12, X19, X20, X22 & NICR20TI AL grade respectively.

Contact persons:

Mr. Yashpal Yadav
Designation: Engr (PPX-F & HE)
Email: yash-pal@bhelhwr.co.in
Phone No: +91 1334-284144
Mobile: +91 9012227802

Mr. Ajay Kr Gupta
Designation: SDGM (PPX & AIX-F)
Email: ajayk@bhelhwr.co.in
Phone No: +91 1334-284570
Mobile: +91 9410395962

The offers received will be technically evaluated by BHEL & successful short listed parties will be asked to submit their detailed Techno-Commercial offers through formal NIT/Enquiry for our future requirements. Vendors shall confirm that there is no deviation with respect to BHEL Specifications. However deviations, if any are to be listed as a separate attachment. The offers that do not meet the substantial requirements of our specifications are liable to be ignored.

Following documents are to be necessarily filled and submitted along with the technical offer:

1. Details/ Documents in support of Specification/PQR (**Annexure-I up-loaded**)
2. Quality Requirements **(Annexure- II) &** Quality Plan format **(Annexure-III).**
3. Supplier/Vendor Registration Form- Go through online supplier registration portal https://supplier.bhel.in/. After filling the online registration form send the copy of same along with your offer within due date.
4. Details of Manufacturing Facility
5. Company Profile.
6. Financial report of the company.
7. Past experience along with documentary proof.

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Only Technical BID along with the documents mentioned above should be sent and the envelope containing the offer shall be duly sealed and super scribed as "**Technical Offer for (ITEM NAME) AGAINST Tender No. PPX-F&HE/EOI/SL/17-18/01**

Due Date-28.06.2017,
SUBMITTED BY (Name of company)"

- This notification shall be published on ***www.bhel.com***, ***www.tenders.gov.in*** and ***www.bhelhwr.co.in***
- Last date for downloading tender documents shall be 27.06.2017 till 1700 Hrs.(IST). Tenders will be received up to 13:45 Hrs. (IST) on 28.06.2017 will be considered and opened on the same day at 14:00 Hrs. (IST) in the Tender Room BHEL HEEP, Haridwar.
- Technical Offers complete in all respect must be addressed to "Shri Ajay Kr Gupta, SDGM (PPX & AIX- F)".
- EMD & Tender fee are not applicable.
- The Quotation should be from the Principal / Original Manufacturer, failing which the quotation may likely to be ignored. In Case the quotation is submitted through agent, the quotation must accompany original authorization letter.
- Late offers will not be considered in any case. BHEL will not be responsible for any type of postal delay / incomplete information from vendor.
- Amendments / Corrigendum, if any, will be hosted on our web site only.

For any further details please log on to *www.bhel.com* or ***www.tenders.gov.in*** or ***www.bhelhwr.co.in***

(Ajay Kr Gupta)
SDGM (PPX & AIX-F)

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ANNEXURE-I

Expression of Interest

BHEL Requirement: Rectangular flat bars for turbine

Sizes: Cross Section as per Annexure 1. Length of bars: 3-6meters

Material Grades: 1) X20Cr13 (HW10786, Rev07),

2) X22CrMoV121 (HW10687, Rev07)

3) X19CrMoVNbN11- 1(HW10670, Rev07)

4) X12CrMoWVNbN10-1-1 (HW10663, Rev 06),

5) NiCr20TiAl (HW12784, Rev 01)

Rectangular flat bars of above mentioned material grades are used for manufacturing of milled blades for Steam Turbines of rating 250 to 800MW.

Sl. No.	Technical Requirements	Vendor Confirmation (Yes/No)
1	Vendor to submit their manufacturing experience of rectangular flats in above listed material grades. Documentary evidence (like un-priced purchase order copy, test certificate covering chemical & mechanical properties, heat treatment details, dimensions etc.) in support of experience to be submitted.	
2	Vendor to furnish in house manufacturing and testing facilities. Following details are to be submitted: - In-house Steel melting facility (like Electric Arc/VIM etc.) with furnace capacity, - In-house Secondary refining facility (VD, VOD, AOD, ESR, VAR etc.) with furnace capacity, - Rolling / Forging facility to manufacture sharp edge rectangular bars - Heat treatment facility (like furnace details covering size and temperature range, quenching facility like oil, water, air etc.) - Straightening facility to supply rectangular bars within specified limits - In-house testing facilities	
3	Prerequisite requirement for approval of a new vendor is successful process qualification as per respective material specification. Process qualification is mandatory for supplier's each manufacturing plants.	

Note: All documents submitted must be in English language only.

Annexure 1							
Specification	**Size**	**Specification**	**Size**	**Specification**	**Size**	**Specification**	**Size**
HW10786	34X22	HW10786	106X53	HW10687	80X40	HW10670	122X65
HW10786	82X46	HW10786	100X59	HW10687	84X43	HW10670	98 X 62
HW10786	86X18	HW10786	58X36	HW10687	55X32	HW10670	55X32
HW10786	55X28	HW10786	143X83	HW10687	65X40	HW10670	88X45
HW10786	53X30	HW10786	50X26	HW10687	82X46	HW10670	123X69
HW10786	76X55	HW10786	118 X 59	HW10687	52X34	HW10670	82X42
HW10786	106X70	HW10786	58X32	HW10687	48X28	HW10670	100X60
HW10786	140X55	HW10786	108X83	HW10676	67X50	HW10670	115 X 60
HW10786	94X62	HW10786	85X50	HW10687	34X19	HW10670	74X37
HW10786	50X36	HW10687	65X38	HW10687	50X36	HW10670	97X57
HW10786	65X40	HW10687	68X36	HW10687	51X31	HW10670	125X76
HW10786	69X100	HW10687	68X42	HW10687	45X28	HW10670	120X60
HW10786	90X55	HW10687	93X48	HW10687	80X43	HW10663	87X44
HW10786	43X28	HW10687	42X24	HW10687	86X55	HW10663	93 X 48
HW10786	42X24	HW10687	106X70	HW10687	76X55	HW10663	82X42
HW10786	38X25	HW10687	54X27	HW10687	35X40	HW10663	87X44
HW10786	86X55	HW10687	53X26	HW10687	58X39	HW10663	93 X 48
HW10786	100X14	HW10687	58X32	HW10687	72X38	HW10663	82X42
HW10786	68X42	HW10687	75X40	HW10687	62X36	HW10663	90X46
HW10786	75X46	HW10687	110X70	HW10687	34X22	HW10663	65X32
HW10786	130X80	HW10687	98X51	HW10687	58X44	HW10663	78X46
HW10786	64X8	HW10687	97X55	HW10687	80X50	HW10663	112X52
HW10786	34X19	HW10687	92 X 52	HW10687	53X36	HW10663	102X50
HW10786	65X38	HW10687	115 X 62	HW10687	74X51	HW10663	118X59
HW10786	46X27	HW10687	92X50	HW10670	53X30	HW10663	97X55
HW10786	112X80	HW10687	72X42	HW10670	72X38	HW10663	96X50
HW10786	55X35	HW10687	87X48	HW10670	105X60	HW10663	68X40
HW10786	58X30	HW10687	94X58	HW10670	78X45	HW10663	58X32
HW10786	75X39	HW10687	98X60	HW10670	86X50	HW10663	76X38
HW10786	104X53	HW10687	100X51	HW10670	62X34	HW10663	96X46
HW10786	114X97	HW10687	100X60	HW10670	92X52	HW10663	65X38
HW10786	96X50	HW10687	75X46	HW10670	92 X 50	HW10663	68X36
HW10786	105X60	HW10687	107X62	HW10670	90X43	HW10663	70X44
HW10786	99X50	HW10687	123X70	HW10670	98X55	HW10663	80X45
HW10786	140X80	HW10687	84X48	HW10670	110X65	HW10663	72X38
HW10786	115X62	HW10687	90X57	HW10670	90X55	HW10663	79X39
HW10786	120X92	HW10687	96X48	HW10670	92X58	HW10663	75X46
HW10786	109X65	HW10687	78 X 45	HW10670	110X60	HW10663	62X31
HW10786	72X38	HW10687	53X30	HW10670	58X32	HW12784	64X29
HW10786	68X36	HW10687	57X34	HW10670	98 X 51	HW12784	60X26
HW10786	90X46	HW10687	46X30	HW10670	68X40	HW12784	62X28
HW10786	58X44	HW10687	42X26	HW10670	84X46		
HW10786	110X56	HW10687	62X31	HW10670	80X45		
HW10786	77X46	HW10687	50X26	HW10670	120X75		
HW10786	90X50	HW10687	46X26	HW10670	100X50		
HW10786	143X76	HW10687	72X46	HW10670	72X42		
HW10786	62 X 34	HW10687	65X42	HW10670	105X65		
HW10786	98X55	HW10687	90X43	HW10670	65X38		

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ANNEXURE-II

Quality Requirements-

- Vendor to furnish quality plan as per BHEL specification in enclosed format for BHEL review and approval. Refer annexure-III for quality plan format.

- Inspection by third party (LRS/TUV/BV) for import and BHEL nominated agency 'TUV' for indigenous as per finally BHEL approved Quality Plan.

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ANNEXURE-III

(Quality Plan Format)

MANUFACTURER'S NAME AND ADDRESS		QUALITY PLAN				TO BE FILLED BY BHEL	TO BE FILLED BY BHEL
BHEL	VENDOR'S NAME	ITEM		QP NO.			
				REV			
		DRG. NO.	AS PER PO				
		SPEC.	AS PER PO				
		REV		Page 1 of 1			

SL. NO.	COMPONENT & OPERATIONS	CHARACTERISTICS	CLASS	TYPE OF CHECK	QUANTUM OF CHECK	REFERENCE DOCUMENT	ACCEPTANCE NORMS	FORMAT OF RECORDS		AGENCY			REMARKS
										M	B	N	
1	2	3	4	5	6	7	8	9	D	10			11

		LEGEND: ! RECORDS IDENTIFIED WITH 'TICK' SHALL BE ESSENTIALLY INCLUDED BY CONTRACTOR IN QA DOCUMENTATION. M: MANUFACTURER / SUBCONTRACTOR B: BHEL / NOM. INSPECTION AGENCY N: CUSTOMER INDICATE 'P' PERFORM 'W' WITNESS AND 'V' VERIFICATION	FOR CUSTOMER USE	
MANUFACTURER/SUBCONTRACTOR		ALL 'W' INDICATED IN COLUMN 'N' SHALL BE 'CHP' OF CUSTOMER		APPROVED BY

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ANNEXURE-IV

SPECIFICATION

13% Cr Stainless Steel Bars for Turbine Blades

GRADE: X20Cr13+QT800

1.0 General:

This specification governs the quality of Steel rectangular bars in steel grade X20Cr13, material no. 1.4021, EN10088-3.

2.0 Application:

For machining of blades for Steam Turbine.

3.0 Condition of Delivery:

Rolled or Forged and Heat Treated.

4.0 Dimension and Tolerances:

Dimensional tolerance, straightness, twisting and bulging limits shall be as per HW0993Q08.

5.0 Manufacture:

Degassed steel (e.g. vacuum degassed) shall be used. Cast ingot is to be used as initial material for production of the bars.

The manufacturing process must ensure a homogenous grain structure over the entire length of the bar and the bar cross section.

6.0 General Requirements:

- Prerequisite requirement for approval of a new vendor is a successful Process qualification. Manufacturing process established during this shall be the basis for future manufacture.
- Manufacturing plan shall be prepared and submitted after successful process qualification. Manufacturing plan shall include specific information on manufacturing like rolling temperature, reduction ratio, heat treatment temperature, hardening method and soaking time, rate of heating and cooling etc. Test instructions for nondestructive and destructive testing are to be provided in the manufacturing and testing plan.
- Product and process qualification is mandatory for supplier each manufacturing plants.
- For new supplier, process qualification shall be required for three purchase orders.
- If necessary, BHEL may ask for process qualification for verification of manufacturing reliability from regular suppliers also.
- Any change in the agreed manufacturing plan shall be informed to BHEL. BHEL will review the requirement of renewed process qualification.

7.0 Heat Treatment:

Hardening has to be done in accordance with EN 10088 - 3, + QT 800 in line with Table A.2 (950 - 1050°C /air or liquid quenching). Tempering must be done at a temperature ≥ 650°C.

A fully transformed and tempered martensitic microstructure must be present over the entire cross section.

Hardening and tempering in bundles are not allowed. Suitable gaps between two bars are to be ensured during heat treatment for uniformity of properties.

If bars need to be straightened after the heat treatment, a stress relieving heat treatment shall be performed after completion of entire straightening process. Stress relieving is to be carried out at 20 - 30°C below the tempering temperature with a subsequent slow cooling.

The lowest possible residual stresses shall be targeted. Distortion of the finish machined part due to residual stresses from the manufacturing process or heat treatment process shall not occur.

8.0 Properties and their verification:

8.1 Chemical Composition:

Heat analysis in weight %

C	Si	Mn	P	S	Cr	Ni
0.17 -0.22	0.10 - 0.60	0.30 - 0.80	≤ 0.030	≤ 0.020	12.5 - 14.0	0.30 - 0.80

Cobalt content must be specified in the inspection certificate for information purposes.

8.2 Properties and Microstructure:

The specimens shall be taken in the longitudinal direction in accordance with Attachment 1. The properties described below shall be determined at room temperature in the delivery condition, i. e. after the last heat treatment including any stress relieving heat treatment.

The metallographic investigations shall be performed on the hardest and softest bar with an area of at least 320mm^2 each. The areas to be investigated must be in the longitudinal direction. The longitudinal direction must be indicated in the documentation.

8.2.1 Mechanical Properties:

Hardness of the bars in a test unit shall be verified by Brinell hardness testing in accordance with ISO 6506 -1, HBW10/3000 or HBW 5/750 may be used.

The surface of the bar shall be prepared in the area of the hardness measurement so that the result is not affected by the surface condition.

Hardness testing shall be performed on 10% of each test unit but at least on 10 bars or on each bar if test unit is less than 10 bars. The greatest resulting difference in hardness shall not exceed 35HBW.

Mechanical properties shall be determined on the hardest and softest bar determined in a test unit.

Tensile testing shall be performed in accordance with ISO 6892 -1 or ASTM E8M (round specimen with L_0 = 50mm and d_0 = 10mm) or ASTM E8 (standard specimen in accordance with Figure 8). Standard specimens Charpy (V-notch) in accordance with ISO 148 -1 shall be used for determining the absorbed impact energy.

The following properties must be achieved at room temperature:

0.2 % Proof Stress (N/mm^2)	Tensile Strength (N/mm^2)	Elongation After Fracture (%)	Reduction in area %	Impact Energy (J)[1]	Hardness HBW
≥ 600	800 - 950	≥ 15	≥ 50	≥ 20	240 - 280

[1] Average of 3 specimens and minimum value for two specimens in accordance with EN10021, where the lowest value shall be at least 14 Joule.

8.2.2 Microstructure:

Microstructure must be uniform, without porosity, excessive segregation or other inhomogeneities.

8.2.2.1 Cleanliness:

The cleanliness shall be determined as per ASTM E45 method A. Acceptance criteria:

Inclusion: Thin Series

Type A, B, C: 2 max Type D: 2.5max

Inclusions: Heavy Series

Type A, B, C, D: 1.5max

Maximum Number and dimension of globular inclusions (type D)

IR (D) = n1 + 2.5n2, IR (D) is converted to an area of $160mm^2$

IR (D) ≤ 10

n = number of globular inclusions

n1 (25-50µm); n2(51-75µm)

Any material discontinuities present at the inclusion must also be accounted for in determining the size of globular inclusion.

Inclusions > 75 µm, including any material discontinuities, are not allowed.

8.2.2.2 Delta Ferrite content and grain size:

- **Delta ferrite content shall be < 5%.** The determination of delta ferrite content shall be performed based on analysis methods in accordance with ASTM E45 Method A, "Worst field method" with V=100:1.
- **An average grain size of 4 or finer** has to be achieved. Grain size shall be determined on the martensitic secondary grain structure in accordance with ASTM E112 or ISO643. A deviation of more than 2 grain sizes in size of individual's grains from the average grain size is not allowable.

8.3 Non-destructive Testing:

8.3.1 Test Scope:

The following Non – destructive inspections shall be performed in the as delivered condition:

- Visual inspections of all bars
- Ultrasonic examination of all bars in accordance with TWP 1204. 100% of the volume must be tested in accordance with the recording level.

8.3.2 Recording level and acceptance criteria:

- Indications of surface defects such as rolled marks shall be ground out to investigate their depth at least at both ends, in the middle of the indication and at an interval of approx. 250mm.
- Surface defects with a depth extension of ≥ 1mm are not allowable, and these areas shall be cut out of the bar.

- Ultrasonic examination shall be carried out on all bars in accordance with TWP 1204.
- Defects above the recording level are not acceptable and must be cut out.
- It shall be confirmed in writing to the BHEL that bar sections containing defects above the recording level have been cut out of the bar.
- The acceptance of material at vendor's works does not relieve the supplier of his responsibility for defects discovered at later stages.

8.3.3 Material Identity Test:

An identity test must be conducted in the as – delivered condition on all bars.

9.0 Process Qualification:

In addition to testing as per clause 8.0 of this specification, following additional testing shall be performed in process qualification (see Attachment 2). **All test results carried out during process qualification shall be submitted to BHEL for approval.**

- **Tensile tests[1]:**
  The strength values (0.2% Proof Stress and Tensile Strength) in the transverse direction (specimen orientation ZQ) shall not differ by more than 10% from the corresponding longitudinal values.
- The absorbed impact energy in the transverse direction (KQ 1 -3) should not differ by more than 25% from the values in the longitudinal direction (Kl at room temperature).
- **FATT:** Determination of FATT (fracture appearance transition temperature) in accordance with ASTM A370. The FATT should be preferably evaluated based on SEP 1670 (software). The test scope must include at least 10 specimens. FATT < 30°C is to be achieved.
  In accordance with ISO 6892 -2, a tensile test (in longitudinal direction) has to be performed at 500°C. The following properties must be achieved:

0.2 % Proof Stress (N/mm^2)	Tensile Strength (N/mm^2)	Elongation After Fracture (%)	Reduction in area (%)
≥ 380	≥ 480	≥ 20	≥ 60

[1] **For case where standard specimens in transverse direction cannot be made: -**

- For tensile test specimens, a round specimen with $L_0 = 5\ d_0$ or a flat specimen with a proportionality factor of k= 5.65. Proportional specimens in accordance with Fig 8 shall be used if ASTM E8 is applied.
- An undersized specimen in accordance with ISO 148 -1 for impact test specimen. Undersize dimension to be reported.
- If dimension do not allow testing in the transverse direction, even with special specimen, testing will be carried out in the longitudinal direction only.

Intergranular Fracture Determination Test:

The fraction of Intergranular fracture shall be determined over the entire brittle fracture portion of the fracture surface of the impact test specimens tested at room temperature. The fraction of Intergranular fracture shall not exceed 10%. This test is not required for materials which indicate ≥90% ductile fracture at room temperature.

Magnetic Particle Test:

Performance of MT testing by the magnetic flux leakage method, alternating current phase shifted and a field strength of 20 – 65A/cm.

Distribution, type and size of grain structure in-homogeneities (e.g. segregation or delta ferrite) shall not result in MT indications.

10.0 Identification Marking:

All bars are to be marked with following information:

- Purchase Order Number
- Size
- Material Grade
- Supplier Identification

The details are to be clearly stamped and encircled by oil paint. Each bar shall be painted with pink colour with white strip on both ends. All the bars shall be suitably packed to protect them against corrosion and damage during transportation.

Bars having maximum and minimum hardness (from which test samples are taken) shall be clearly marked by oil paint for easy identification. Their respective hardness values shall also be punched on these bars.

11.0 Documentation:

Prior to, but in no case later than the delivery of the material, an inspection certificate as per EN 10204 shall be provided to BHEL in duplicate; this certificate must contain the following data:

(a) Material code no and P.O. number
(b) Material designation
(c) Heat no., heat analysis and melting methods
(d) Complete information on all heat treatments performed
(d) Mechanical test results including hardness range and the metallurgical examination.
(e) Results of non-destructive tests, UT inspection report
(f) Confirmation of the material identity check
(g) Dimensions and visual inspection reports

12.0 Cross Referred Standard:

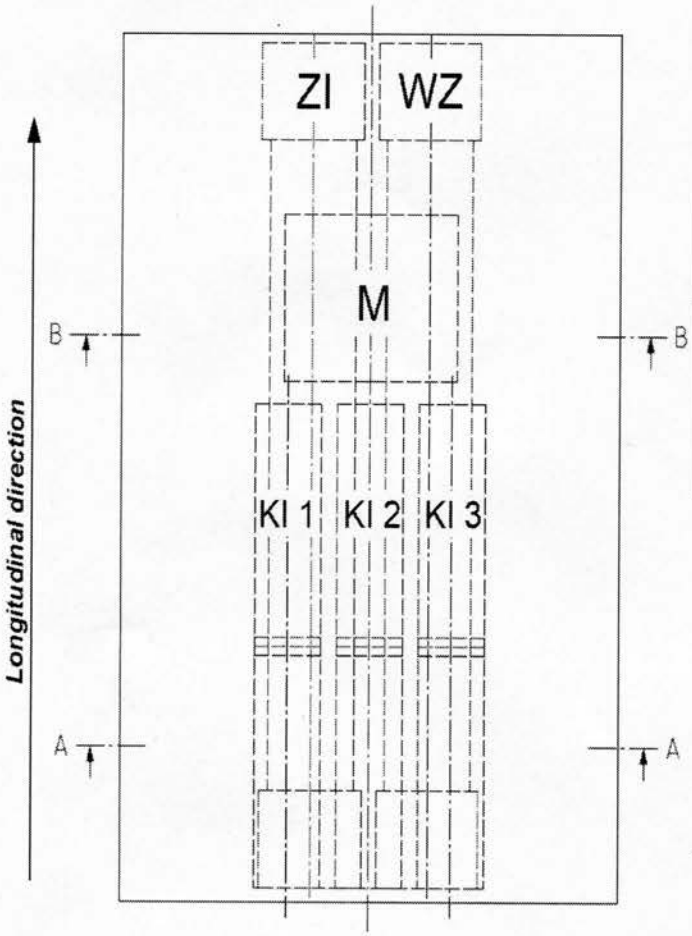
EN10088-3, HW0993008, ISO 6506-1, ISO 6892, ASTM E8, ISO 148-1, EN10021, ASTM E45, TWP1204, ASTM E112, ISO 643, ASTM A370, EN10204

13.0 Modification with respect to last revision:

- Clause 4.0 modified.
- Clause 4.0 modified.
- Clause 12.0 modified.

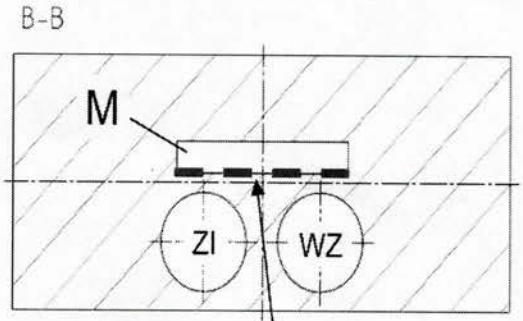
Attachment 1

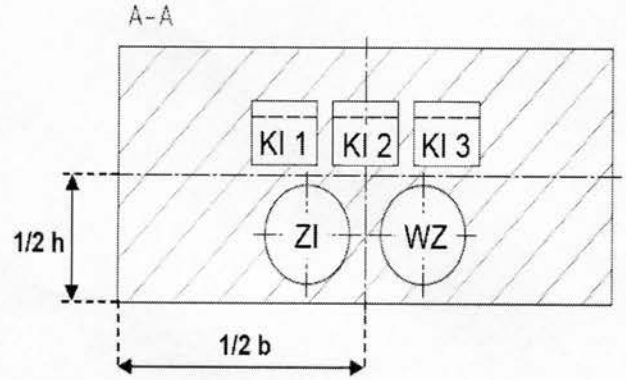
Standard Testing



Label	Specimen
ZI	*Tensile Specimen Centre*
WZ*	*Hot Tensile Specimen*
KI 1 - KI 3	*Notched Impact Specimen Centre*
M	*Metallographic Specimen*

* *if required in material* **specification**

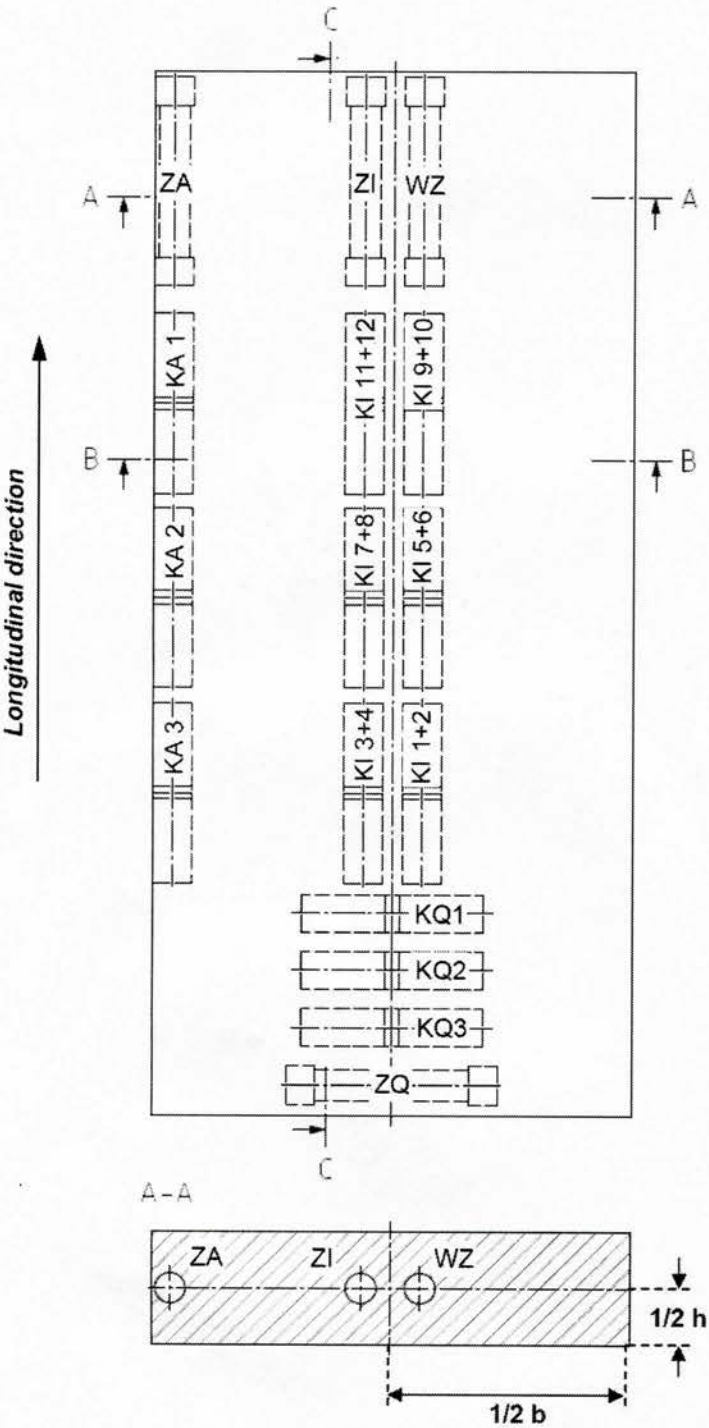




Lower Surface *of the Metallographic Specimen has to be examined. Longitudinal direction must be indicated in the documentation.* $A \geq 320\ mm^2$

Attachment 2, Page 1/2

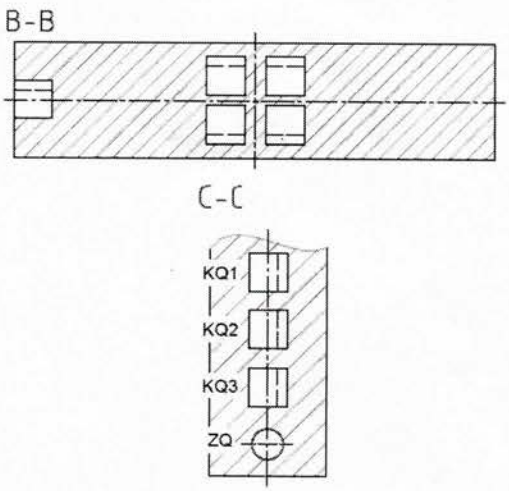
Process Qualification



Label	Specimen
ZI	*Tensile Specimen Centre*
ZA	*Tensile Specimen Rim*
ZQ	*Tensile Specimen Transverse*
WZ*	*Hot Tensile Specimen*
KI 1 - KI 12	*Notched Impact Specimen Centre (FATT)*
KA 1 - KA 3	*Notched Impact Specimen Rim*
KQ 1 - KQ 3	*Notched Impact Specimen Transverse*

* *if required in material* **specification**

Note the notch positions of the notch impact specimens (see B - B and C - C).

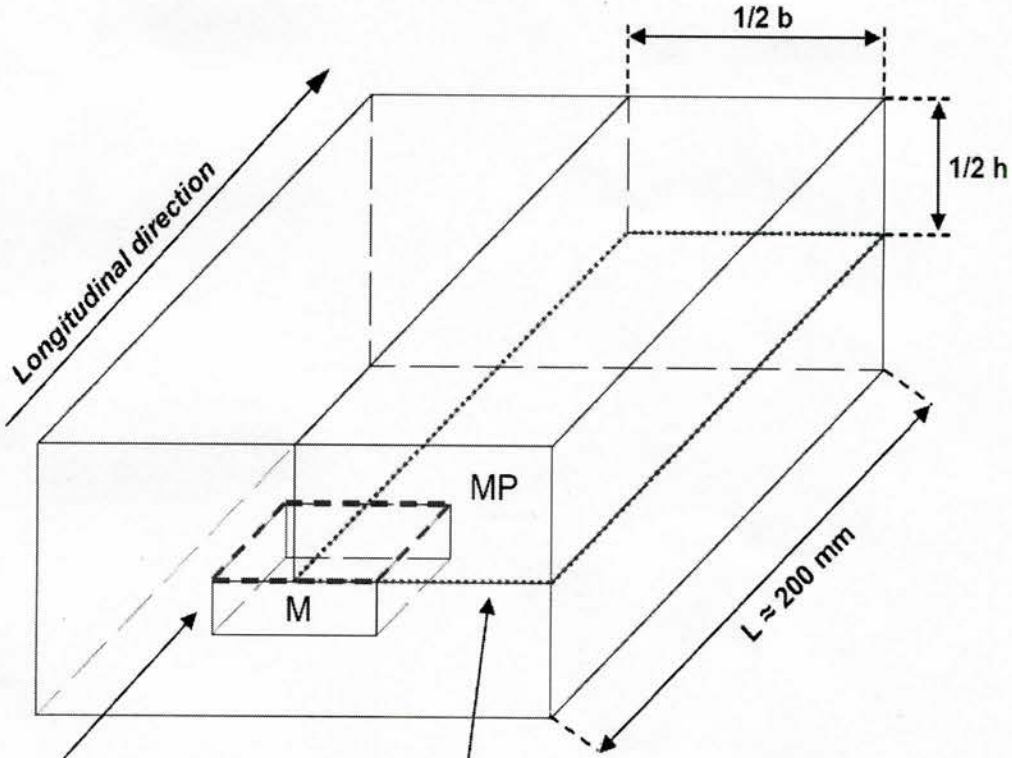


स्तांकर एवं दिनांक SIGN & DATE

सामग्री सूची संख्या को अधिक्रमित करता है SUPERSEDES INVENTORY NO.

Process Qualification

Label	Specimen
M	*Metallographic Specimen*
MP	*Specimen for Magnetic Particle Test*



***Upper Surface** of the Metallographic Specimen has to be examined. Longitudinal direction must be indicated in the documentation. A ≥ 320 mm²*

***Lower Surface** of the specimen has to be examined in Magnetic Particle Test .*

हस्ताक्षर एवं दिनांक SIGN & DATE 02/5/17

सामग्री सूची संख्या INVENTORY P-2182

REV 07

निर्माणकर्ता WORKED BY	Ashish Ranjan	Ranjan	02.05.17
जांचकर्ता CHECKED BY	Gopal Krishnan		02.05.17

HEAT RESISTANT STEEL BARS FOR TURBINE BLADES
GRADE: X22CrMoV121 +QT2

1.0 General:

This specification governs the quality of Steel rectangular bars in steel grade X22CrMoV121, material no. 1.4923 EN10269.

2.0 Application:

For machining of blades for Steam Turbine.

3.0 Condition of Delivery:

Rolled or Forged and Heat Treated.

4.0 Dimension and Tolerances:

Dimensional tolerance, straightness, twisting and bulging limits shall be as per HW0993008.

5.0 Manufacture:

Degassed steel (e.g. vacuum degassed) shall be used. Cast ingot is to be used as initial material for production of the bars.

The manufacturing process must ensure a homogenous grain structure over the entire length of the bar and the bar cross section.

6.0 General Requirements:

- Prerequisite requirement for approval of a new vendor is a successful Process qualification. Manufacturing process established during this shall be the basis for future manufacture. Manufacturing plan shall be prepared and submitted after successful process qualification. Manufacturing plan shall include specific information on manufacturing like rolling temperature, reduction ratio, heat treatment temperature, hardening method and soaking time, rate of heating and cooling etc. Test instructions for nondestructive and destructive testing are to be provided in the manufacturing and testing plan.
- Product and process qualification is mandatory for each of the supplier's manufacturing plants.
- For new supplier, process qualification shall be required for three purchase orders.
- If necessary, BHEL may ask for process qualification for verification of manufacturing reliability from regular suppliers also.
- Any change in the agreed manufacturing plan shall be informed to BHEL. BHEL will review the requirement of renewed process qualification.

7.0 Heat Treatment:

Hardening has to be done in accordance with EN 10269 + QT2 in line with Table B .1 (1020 - 1070°C /air or liquid quenching).

Tempering must be done at a temperature ≥ 650°C.

A fully transformed and tempered martensitic microstructure must be present over the entire cross section.

Hardening and tempering in bundles are not allowed. Suitable gaps between two bars are to be ensured during heat treatment for uniformity of properties.

If bars need to be straightened after the heat treatment, a stress relieving heat treatment shall be performed after completion of entire straightening process. Stress relieving is to be carried out at 20 - 30°C below the tempering temperature with a subsequent slow cooling.

The lowest possible residual stresses shall be targeted. Distortion of the finish machined part due to residual stresses from the manufacturing process or heat treatment process shall not occur.

8.0 Properties and their verification:

8.1 Chemical Composition:

Heat analysis in weight %

C	Si	Mn	P	S	Cr	Mo
0.18 - 0.24	0.10 - 0.50	0.30 - 0.80	≤ 0.020	≤ 0.020	11.0 - 12.5	0.80 - 1.20

Ni	V
0.30 - 0.80	0.25 - 0.35

8.2 Properties and Microstructure:

The specimens shall be taken in the longitudinal direction in accordance with Attachment 1. The properties described below shall be determined at room temperature in the delivery condition, i. e. after the last heat treatment including any stress relieving heat treatment.

The metallographic investigations shall be performed on the hardest and softest bar with an area of at least 320mm^2 each. The areas to be investigated must be in the longitudinal direction. The longitudinal direction must be indicated in the documentation.

8.2.1 Mechanical Properties:

Hardness of the bars in a test unit shall be verified by Brinell hardness testing in accordance with ISO 6506 -1, HBW10/3000 or HBW 5/750 may be used.

The surface of the bar shall be prepared in the area of the hardness measurement so that the result is not affected by the surface condition

Hardness testing shall be performed on 10% of each test unit but at least on 10 bars or on each bar if test unit is less than 10 bars. The greatest resulting difference in hardness shall not exceed 35HBW.

Mechanical properties shall be determined on the hardest and softest bar determined in a test unit.

Tensile testing shall be performed in accordance with ISO 6892 -1 or ASTM E8M (round specimen with L_0 = 50mm and d_0 = 10mm) or ASTM E8M (standard specimen in accordance with figure 8).

Standard specimens Charpy (V-notch) in accordance with ISO 148 -1 shall be used for determining the absorbed impact energy.

The following properties must be achieved at room temperature:

0.2 % Proof Stress (N/mm^2)	Tensile Strength (N/mm^2)	Elongation After Fracture (%)	Reduction in area %	Impact Energy (J)[1]	Hardness HBW
≥ 700	900 - 1050	≥ 11	≥ 35	≥ 20	265 - 310

[1] Average of 3 specimens and minimum value for two specimens in accordance with EN10021, where the lowest value shall be at least 14 Joule.

8.2.2 Microstructure:

Microstructure must be uniform, without porosity, excessive segregation or other inhomogeneities.

8.2.2.1 Cleanliness:

The cleanliness shall be determined as per ASTM E45 method A. Acceptance criteria:

Inclusion: Thin Series

Type A, B, C: 2 max Type D: 2.5max

Inclusions: Heavy Series

Type A, B, C, D: 1.5max

Maximum Number and dimension of globular inclusions (type D)

IR (D) = n1 + 2.5n2, IR (D) is converted to an area of $160mm^2$

IR (D) ≤ 10

n = number of globular inclusions

n1 (25-50 µm); n2 (51-75 µm)

Any material discontinuities present at the inclusion must also be accounted for in determining the size of the globular inclusion.

Inclusions > 75 µm, inclusing any material discontinuities are not allowable.

8.2.2.2 Delta Ferrite content and grain size:

- **Delta ferrite content shall be < 5%.** The determination of delta ferrite content shall be performed based on analysis methods in accordance with ASTM E45 Method A, "Worst field method" with V=100:1.
- **An average grain size of 4 or finer** has to be achieved. Grain size shall be determined on the martensitic secondary grain structure in accordance with ASTM E112 or ISO643. A deviation of more than 2 grain sizes in size of individual's grains from the average grain size is not allowable.

8.3.2 Recording level and acceptance criteria:

- Indications of surface defects such as rolled marks shall be ground out to investigate their depth at least at both ends, in the middle of the indication and at an interval of approx. 250mm.
- Surface defects with a depth extension of ≥ 1mm are not allowable, and these areas shall be cut out of the bar.
- Ultrasonic examination of all bars in accordance with TWP 1204.
- Defects above the recording level are not acceptable.
- It shall be confirmed in writing to the BHEL that bar sections containing defects above the recording level have been cut out of the bar.
- The acceptance of material at vendor's works does not relieve the supplier of his responsibility for defects discovered at later stages.

8.3.3 Material Identity Test:

An identity test must be conducted in the as – delivered condition on all bars.

9.0 Process Qualification:

In addition to testing as per clause 8.0 of this specification, following additional testing shall be performed in process qualification (see Attachment 2). **All test results carried out during process qualification shall be submitted to BHEL for approval.**

- **Tensile tests[1]:**

  The strength values (0.2% Proof Stress and Tensile Strength) in the transverse direction (specimen orientation ZQ) shall not differ by more than 10% from the corresponding longitudinal values.
- The absorbed impact energy in the transverse direction (KQ 1 -3) should not differ by more than 25% from the values in the longitudinal direction (Kl at room temperature).
- **FATT:** Determination of FATT (fracture appearance transition temperature) in accordance with ASTM A370. The FATT should be preferably evaluated based on SEP 1670 (software) method. The test scope must include at least 10 specimens. FATT < 25°C is to be achieved.

In accordance with ISO 6892 -2, a tensile test (in longitudinal direction) has to be performed at 600°C. The following properties must be achieved:

0.2 % Proof Stress (N/mm^2)	Tensile Strength (N/mm^2)	Elongation After Fracture (%)	Reduction in area (%)
≥ 285	≥ 380	≥ 18	≥ 60

[1] For case where standard specimens in transverse direction cannot be made: -

- For tensile test specimens, a round specimen with $L_0 = 5\ d_0$ or a flat specimen with a proportionality factor of k= 5.65. Proportional specimens in accordance with Fig 8 shall be used if ASTM E8 is applied.
- An undersized specimen in accordance with ISO 148 -1 for impact test specimen. Undersize dimension to be reported.
- If dimension do not allow testing in the transverse direction, even with special specimen, testing will be carried out in the longitudinal direction only.

Intergranular Fracture:

The fraction of Intergranular fracture shall be determined over the entire brittle fracture portion of the fracture surface of the impact test specimens tested at room temperature. The fraction of Intergranular fracture shall not exceed 10%. This test is not required for materials which indicate ≥90% ductile fracture at room temperature.

Magnetic Particle Test:

Performance of MT testing by the magnetic flux leakage method, alternating current phase shifted and a field strength of 20 – 65A/cm.

Distribution, type and size of grain structure in-homogeneities (e.g. segregation or delta ferrite) shall not result in MT indications.

10.0 Identification Marking:

All bars are to be marked with following information:

- Purchase Order Number
- Size
- Material Grade
- Supplier Identification

The details are to be clearly stamped and encircled by oil paint. Each bar shall be painted with gold colour on both ends. All the bars shall be suitably packed to protect them against corrosion and damage during transportation.

Bars having maximum and minimum hardness (from which test samples are taken) shall be clearly marked by oil paint for easy identification. Their respective hardness values shall also be punched on these bars.

11.0 Documentation:

Prior to, but in no case later than the delivery of the material, an inspection certificate as per EN 10204 shall be provided to BHEL in duplicate; this certificate must contain the following data:

(a) Material code no and P.O. number
(b) Material designation
(c) Heat no., heat analysis and melting methods
(d) Complete information on all heat treatments performed
(d) Mechanical test results including hardness range and the metallurgical examination.
(e) Results of non-destructive tests, UT inspection report
(f) Confirmation of the material identity check
(g) Confirmation of the dimensions and visual inspection

12.0 Cross Referred Standards:

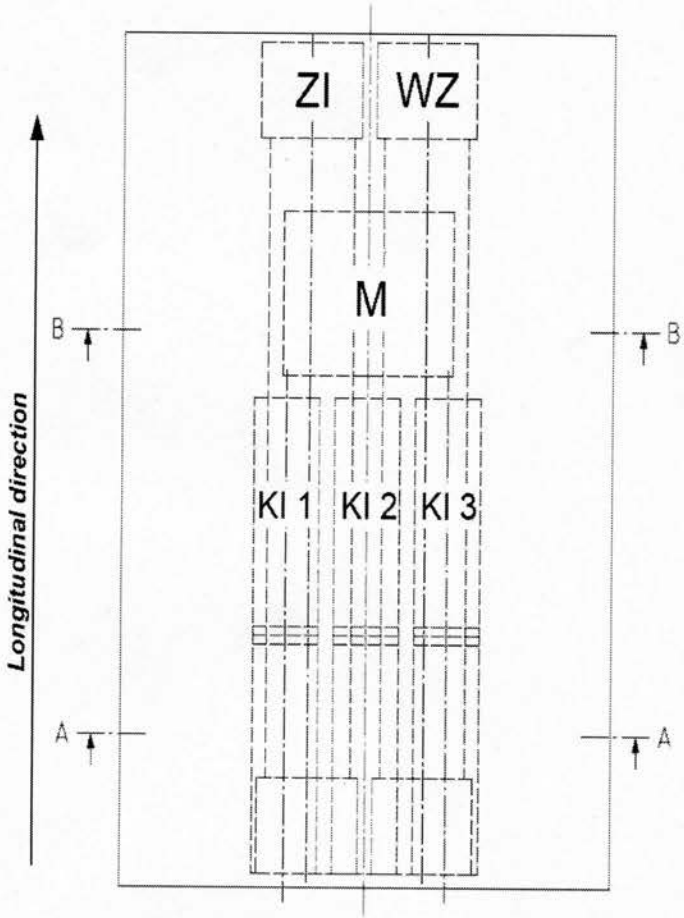
EN10269, HW0993008, ISO 6506-1, ISO 6892, ISO 148-1, ASTM E8M, EN10021, ASTM E45, ASTM E112, ISO 643, TWP1204, ASTM A370, SEP1670, EN10204

13.0 Modification with respect to last revision:

- Clause 4.0 modified.
- Clause 9.0 modified.
- Clause 12.0 modified.

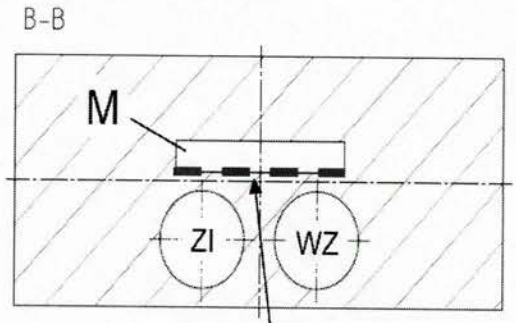
Attachment 1

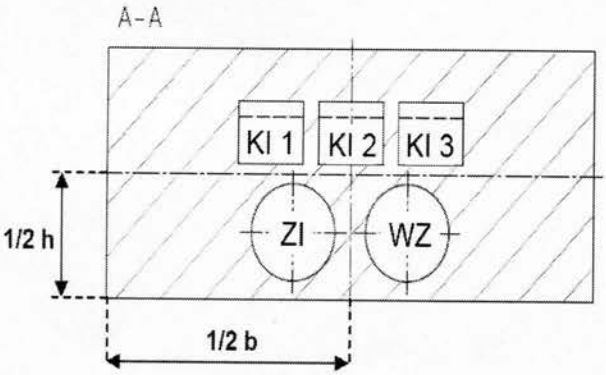
Standard Testing



Label	Specimen
ZI	*Tensile Specimen Centre*
WZ*	*Hot Tensile Specimen*
KI 1 - KI 3	*Notched Impact Specimen Centre*
M	*Metallographic Specimen*

* *if required in material* **specification**

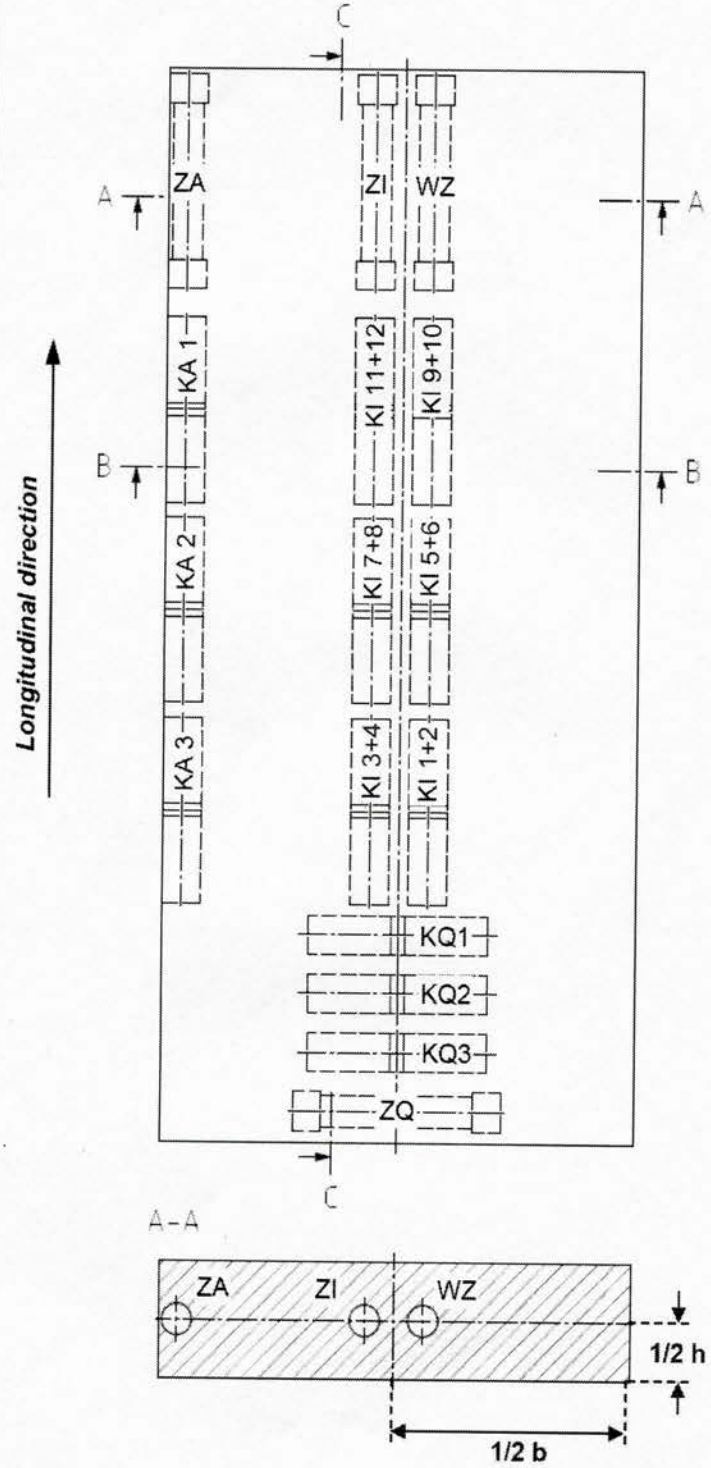




Lower Surface *of the Metallographic Specimen has to be examined. Longitudinal direction must be indicated in the documentation. A ≥ 320 mm²*

Attachment 2, Page 1/2

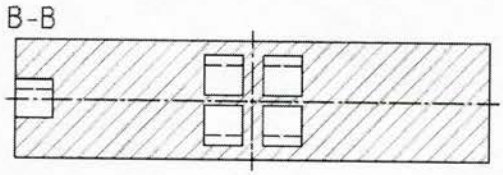
Process Qualification

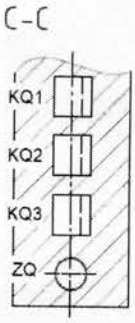


Label	Specimen
ZI	*Tensile Specimen Centre*
ZA	*Tensile Specimen Rim*
ZQ	*Tensile Specimen Transverse*
WZ*	*Hot Tensile Specimen*
KI 1 - KI 12	*Notched Impact Specimen Centre (FATT)*
KA 1 - KA 3	*Notched Impact Specimen Rim*
KQ 1 - KQ 3	*Notched Impact Specimen Transverse*

* *if required in material* **specification**

Note the notch positions of the notch impact specimens (see B - B and C - C).

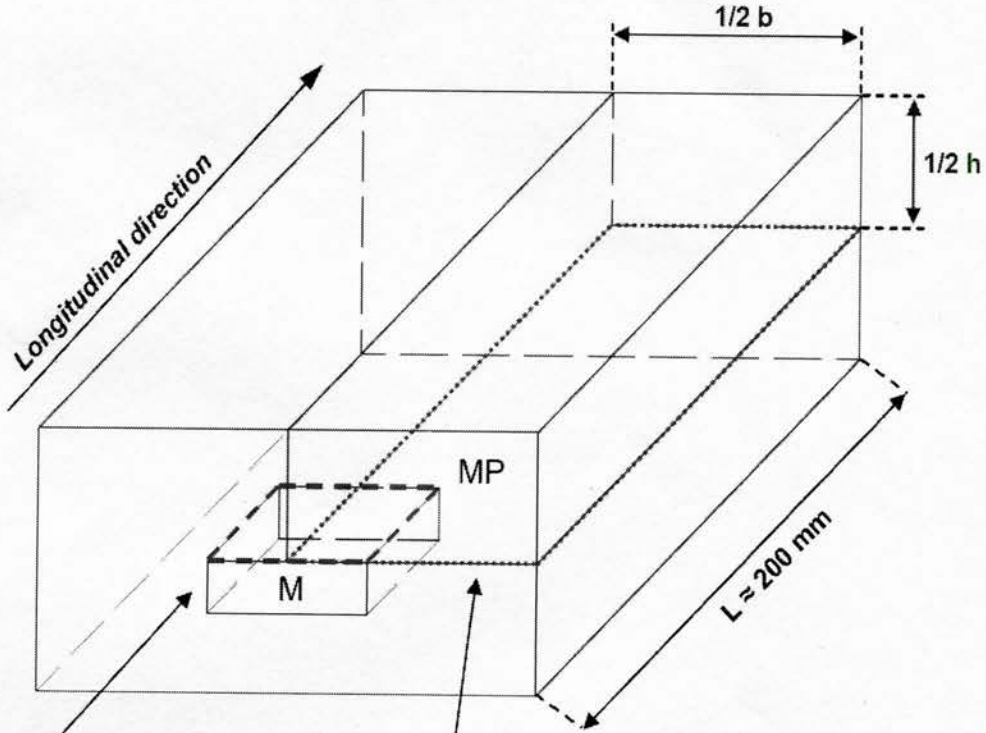




Attachment 2, Page 2/2

Process Qualification

Label	Specimen
M	*Metallographic Specimen*
MP	*Specimen for Magnetic Particle Test*



***Upper Surface** of the Metallographic Specimen has to be examined. Longitudinal direction must be indicated in the documentation. A ≥ 320 mm²*

***Lower Surface** of the specimen has to be examined in Magnetic Particle Test .*

HEAT RESISTANT STEEL BARS FOR TURBINE BLADES GRADE X19CrMoNbVN11-1 + QT FOR SERVICE TEMPERATURE ≤ 540°C

1.0 General:

This specification governs the quality of Steel rectangular bars in steel grade X19CrMoNbVN11-1 +QT, material no. 1.4913 as per EN10269.

2.0 Application:

For machining of blades for Steam Turbine.

3.0 Condition of Delivery:

Rolled or Forged and Heat Treated.

4.0 Dimension and Tolerances :

Dimensional tolerance, straightness, twisting and bulging limits shall be as per HW0993008.

5.0 Manufacture:

Degassed steel (e.g. vacuum degassed) shall be used. Cast ingot is to be used as initial material for production of bars.

The manufacturing process must ensure a homogenous grain structure over the entire length of the bar and the bar cross section.

6.0 General Requirements:

- Prerequisite requirement for approval of a new vendor is a successful Process qualification. Manufacturing process established during this shall be the basis for future manufacture.
- Manufacturing plan shall be prepared and submitted after successful process qualification. Manufacturing plan shall include specific information on manufacturing like rolling temperature, reduction ratio, heat treatment temperature, hardening method and soaking time, rate of heating and cooling etc. Test instructions for nondestructive and destructive testing are to be provided in the manufacturing and testing plan.
- Product and process qualification is mandatory for each of the supplier's manufacturing plants.
- For new supplier, process qualification shall be required for three purchase orders.
- If necessary, BHEL may ask for process qualification for verification of manufacturing reliability from regular suppliers also.
- Any change in the agreed manufacturing plan shall be informed to BHEL. BHEL will review the requirement of renewed process qualification.

7.0 Heat Treatment:

Hardening: 1100 - 1130°C / air or liquid quenching

Tempering: 670 - 750°C, with holding time minimum 2 hours.

A fully transformed and tempered martensitic microstructure must be present over the entire cross section.

Hardening and tempering in bundles are not allowed. Suitable gaps between two bars are to be ensured during heat treatment for uniformity of properties.

If bars need to be straightened after the heat treatment, a stress relieving heat treatment shall be performed after completion of entire straightening process. Stress relieving is to be carried out at 20 - 30°C below the tempering temperature with a subsequent slow cooling.

The lowest possible residual stresses shall be targeted. Distortion of the finish machined part due to residual stresses from the manufacturing process or heat treatment process shall not occur.

8.0 Properties and their verification:

8.1 Chemical Composition:

Heat analysis in weight %

C	Si	Mn	P	S	Cr	Mo
0.17 -0.23	≤ 0.50	0.40 - 0.90	≤ 0.025	≤ 0.015	10.0 - 11.5	0.50 – 0.80
Ni	**V**	**Nb**	**N**	**B**	**Al**	
0.20 – 0.60	0.10 – 0.30	0.25 – 0.55	0.05 - 0.10	≤ 0.0015	≤ 0.020 to be aimed at ≤ 0.010	

8.2 Properties and Microstructure:

The specimens shall be taken in the longitudinal direction in accordance with Attachment 1. The properties described below shall be determined at room temperature in the delivery condition, i. e. after the last heat treatment including any stress relieving heat treatment.

The metallographic investigations shall be performed on the hardest and softest bar with an area of at least 320mm^2 each. The areas to be investigated must be in the longitudinal direction. The longitudinal direction must be indicated in the documentation.

8.2.1 Mechanical Properties:

Hardness of the bars in a test unit shall be verified by Brinell hardness testing in accordance with ISO 6506 -1, HBW10/3000 or HBW 5/750 may be used.

The surface of the bar shall be prepared in the area of the hardness measurement so that the result is not affected by the surface condition Hardness testing shall be performed on 10% of each test unit but at least on 10 bars or on each bar if test unit is less than 10 bars. The greatest resulting difference in hardness shall not exceed 35HBW.

Mechanical properties shall be determined on the hardest and softest bar determined in a test unit.

Tensile testing shall be performed in accordance with ISO 6892 -1 or ASTM E8M (round specimen with L_0 = 50mm and d_0 = 10mm) or ASTM E8M (standard specimen in accordance with figure 8).

Standard specimens Charpy (V-notch) in accordance with ISO 148 -1 shall be used for determining the absorbed impact energy.

The following properties must be achieved at room temperature:

0.2 % Proof Stress (N/mm^2)	Tensile Strength (N/mm^2)	Elongation After Fracture (%)	Reduction in area %	Impact Energy (J)[1]	Hardness HBW
≥ 780	900 - 1050	≥ 12	≥ 40	≥ 20	265 - 310

[1] Average of 3 specimens and minimum value for two specimens in accordance with EN10021, where the lowest value shall be at least 14 Joule.

8.2.2 Microstructure:

Microstructure must be uniform, without porosity, excessive segregation or other inhomogeneities.

8.2.2.1 Cleanliness:

The cleanliness shall be determined as per ASTM E45 method A. Acceptance criteria:

Inclusion: Thin Series

Type A, B, C: 2 max Type D: 2.5max

Inclusions: Heavy Series

Type A, B, C, D: 1.5max

Maximum Number and dimension of globular inclusions (type D)

IR (D) = n1 + 2.5n2, IR (D) is converted to an area of $160mm^2$

IR (D) ≤ 10

n = number of globular inclusions

n1 (25 – 50 µm); n2 (51- 75 µm)

Any material discontinuity present at the inclusion must also be accounted for in determining the size of globular inclusion.

Inclusion > 75 µm, including any material discontinuities, are not allowed.

8.2.2.2 Delta Ferrite content and grain size:

- **Delta ferrite content shall be < 5%.** The determination of delta ferrite content shall be performed based on analysis methods in accordance with ASTM E45 Method A, "Worst field method" with V=100:1.
- **An average grain size of 4 or finer** has to be achieved. Grain size shall be determined on the martensitic secondary grain structure in accordance with ASTM E112 or ISO643. A deviation of more than 2 grain sizes in size of individual's grains from the average grain size is not allowable.

8.3 Non-destructive Testing:

8.3.1 Test Scope:

The following Non – destructive inspections shall be performed in the as delivered condition:

- Visual inspections of all bars
- Ultrasonic examination of all bars in accordance with TWP 1204. 100% of the volume must be tested in accordance with the recording level.

8.3.2 Recording level and acceptance criteria:

- Indications of surface defects such as rolled marks shall be ground out to investigate their depth at least at both ends, in the middle of the indication and at an interval of approx. 250mm.
- Surface defects with a depth extension of ≥ 1mm are not allowable, and these areas shall be cut out of the bar.
- Ultrasonic examination of all bars in accordance with TWP 1204.
- Defects above the recording level are not acceptable.
- It shall be confirmed in writing to the BHEL that bar sections containing defects above the recording level have been cut out of the bar.
- The acceptance of material at vendor's works does not relieve the supplier of his responsibility for defects discovered at later stages.

8.3.3 Material Identity Test:

An identity test must be conducted in the as – delivered condition. The inspection scope is:

Bars: 100%

Fixed lengths: 10%

In case that cut pieces are made from the bars then the marking must be performed directly after cutting to prevent any mix-up from occurring during the subsequent processes.

9.0 Process Qualification:

The following additional investigations shall be performed in process qualification (see Attachment 2):

- **Tensile tests:**

  The strength values (0.2% Proof Stress and Tensile Strength) in the transverse direction (specimen orientation ZQ) shall not differ by more than 10% from the corresponding longitudinal values.
  Following properties must be achieved in transverse direction:
  Elongation after fracture: ≥ 10%; Reduction of area: ≥ 25%
  Absorbed impact energy ≥ 12J, where the lowest value shall be at least 10 Joule.
  Additionally, 3 impact tests in transverse direction have to be performed at 100°C. For all value > 20J have to be achieved.

  For case where standard specimens in transverse direction cannot be made: -

  - For tensile test specimens, a round specimen with $L_0 = 5\ d_0$ or a flat specimen with a proportionality factor of k= 5.65. Proportional specimens in accordance with Fig 8 shall be used if ASTM E8 is applied.
  - An undersized specimen in accordance with ISO 148 -1 for impact test specimen. Undersize dimension to be reported.
  - If dimension do not allow testing in the transverse direction, even with special specimen, testing will be carried out in the longitudinal direction only.

- **Tensile tests at 550°C:**

  A tensile test in longitudinal direction in accordance to ISO 6892 -2 has to be performed at 550°C and following properties must be achieved:

0.2 % Proof Strength (N/mm^2)	Tensile Strength (N/mm^2)	Elongation After Fracture (%)	Reduction in area %
≥ 475	≥ 520	≥ 16	≥ 55

- **FATT:** Determination of FATT (fracture appearance transition temperature) in accordance with ASTM A370. The test scope must include at least 10 specimens. FATT < 50°C is to be aimed.
- The fraction of Intergranular fracture shall be determined over the entire brittle fracture portion of the fracture surface of the impact test specimens tested at room temperature. The fraction of Intergranular fracture shall not exceed 10%. This test is not required for materials which indicate ≥90% ductile fracture at room temperature.
- Performance of MT testing by the magnetic flux leakage method, alternating current phase shifted and a field strength of 20 – 65A/cm.
  Distribution, type and size of grain structure in-homogeneities (e.g. segregation or delta ferrite) shall not result in MT indications.
- **All test results shall be submitted to BHEL for approval.**

10.0 Identification Marking:

All bars are to be marked with following information:

- Purchase Order Number
- Size
- Material Grade
- Supplier Identification

The details are to be clearly stamped and encircled by oil paint. Each bar shall be painted with gold colour on both ends. All the bars shall be suitably packed to protect them against corrosion and damage during transportation.

Bars having maximum and minimum hardness (from which test samples are taken) shall be clearly marked by oil paint for easy identification. Their respective hardness values shall also be punched on these bars.

11.0 Documentation:

Prior to, but in no case later than the delivery of the material, an inspection certificate as per EN 10204 shall be provided to BHEL in duplicate; this certificate must contain the following data:

(a) Material code no and P.O. number
(b) Material designation
(c) Heat no., heat analysis and melting methods
(d) Complete information on all heat treatments performed
(d) Mechanical test results including hardness range and the metallurgical examination.
(e) Results of non-destructive tests, UT inspection report
(f) Confirmation of the material identity check
(g) Confirmation of the dimensions and visual inspection

12.0 Cross Referred Standard:

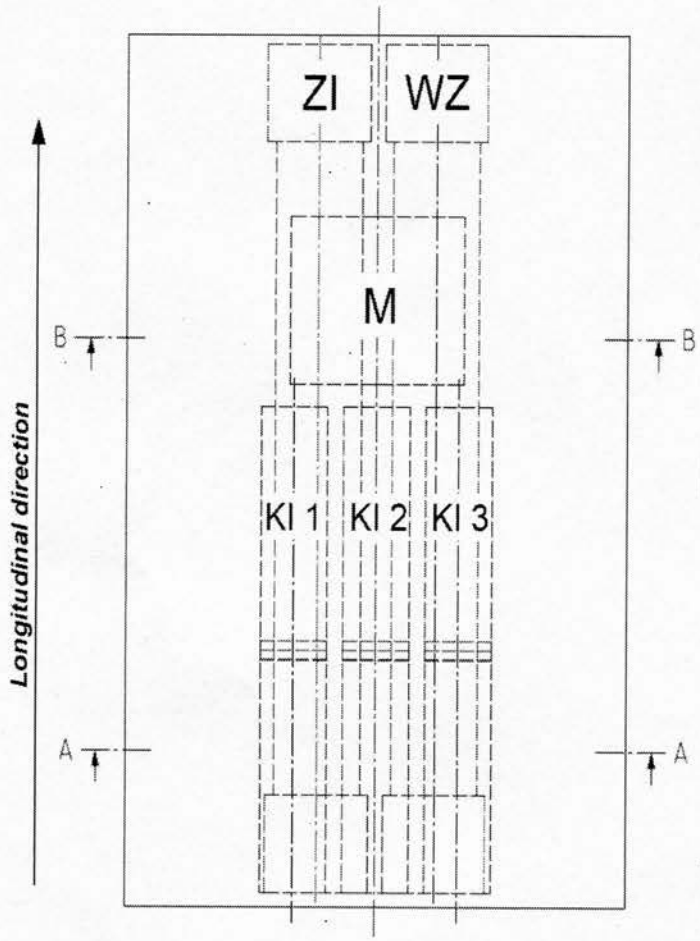
EN10269, HW0993008, ISO 6506-1, ISO 6892, ASTM E8, ISO 148-1, EN10021, ASTM E45, TWP1204, ASTM E112, ISO 643, ASTM A370, EN10204

13.0 Modification with respect to last revision:

- Clause 4.0 modified.
- Clause 7.0 modified.
- Clause 12.0 modified.

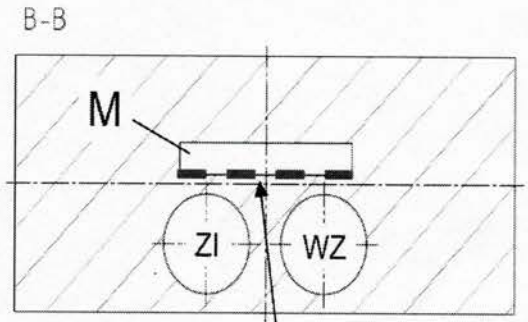
Attachment 1

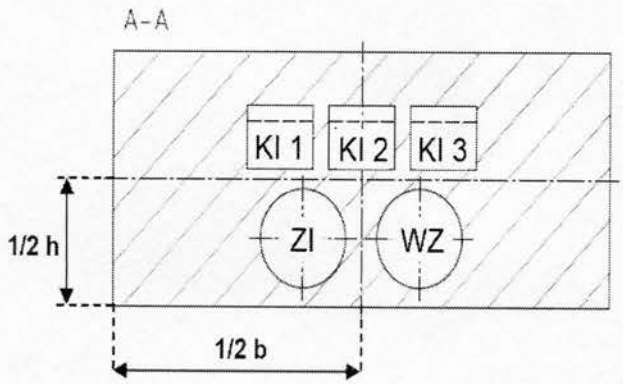
Standard Testing



Label	Specimen
ZI	*Tensile Specimen Centre*
WZ*	*Hot Tensile Specimen*
KI 1 - KI 3	*Notched Impact Specimen Centre*
M	*Metallographic Specimen*

** if required in material* **specification**

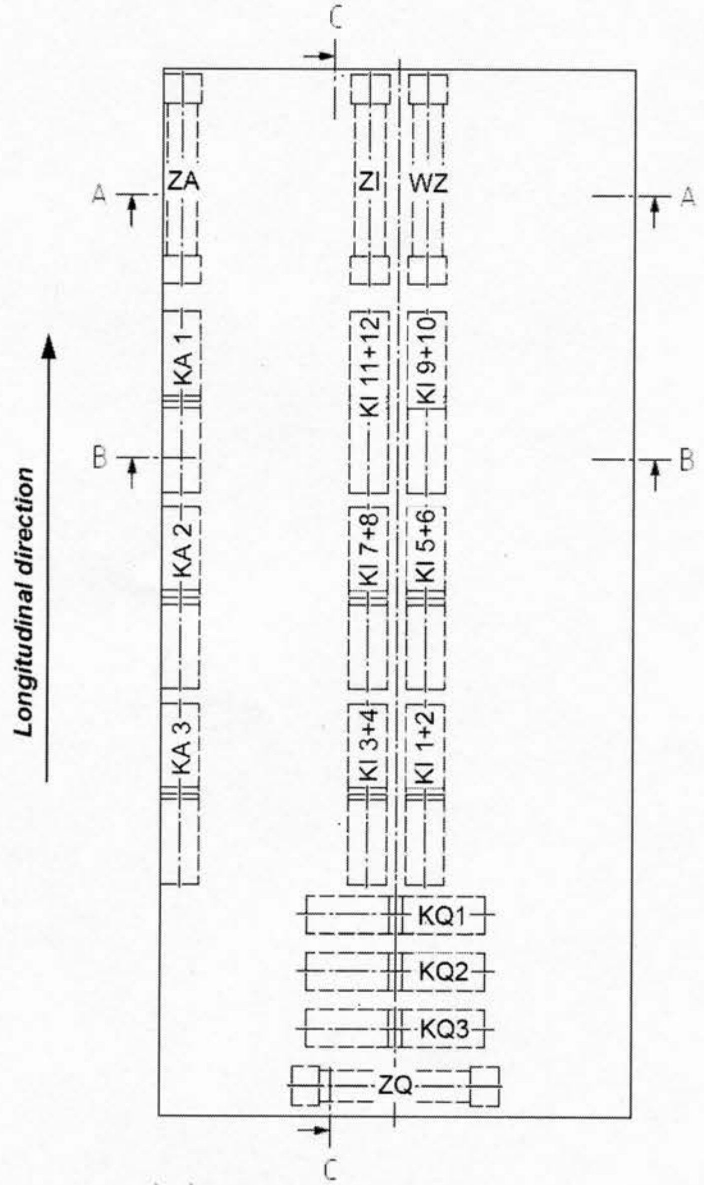


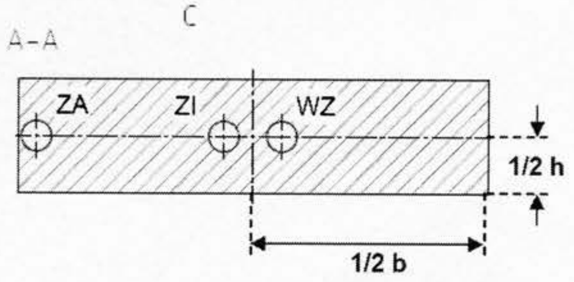


Lower Surface *of the Metallographic Specimen has to be examined. Longitudinal direction must be indicated in the documentation. A ≥ 320 mm²*

Attachment 2, Page 1/2

Process Qualification

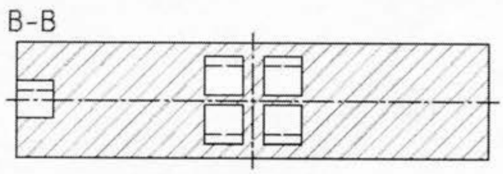


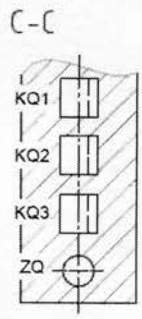


Label	Specimen
ZI	Tensile Specimen Centre
ZA	Tensile Specimen Rim
ZQ	Tensile Specimen Transverse
WZ*	Hot Tensile Specimen
KI 1 - KI 12	Notched Impact Specimen Centre (FATT)
KA 1 - KA 3	Notched Impact Specimen Rim
KQ 1 - KQ 3	Notched Impact Specimen Transverse

* *if required in material* **specification**

Note the notch positions of the notch impact specimens (see B - B and C - C).





हस्ताक्षर एवं दिनांक SIGN & DATE

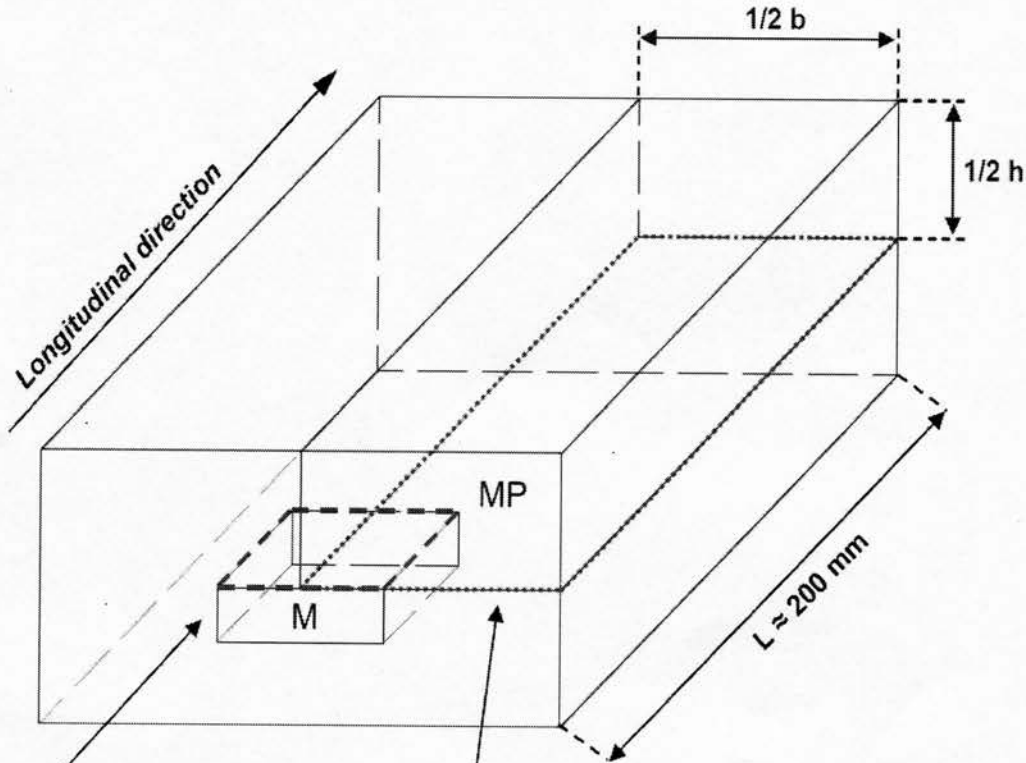
सामग्री सूची संख्या को अधिक्रमित करता है SUPERSEDES INVENTORY NO.

सामग्री सूची संख्या INVENTORY P7208

Attachment 2, Page 2/2

Process Qualification

Label	*Specimen*
M	*Metallographic Specimen*
MP	*Specimen for Magnetic Particle Test*



***Upper Surface** of the Metallographic Specimen has to be examined. Longitudinal direction must be indicated in the documentation. A ≥ 320 mm²*

***Lower Surface** of the specimen has to be examined in Magnetic Particle Test .*

HEAT RESISTANT STEEL BARS FOR TURBINE BLADES, GRADE: X12CrMoWVNbN10-1-1

1.0 General:

This specification governs the quality of Steel rectangular bars in steel grade X12CrMoWVNbN10-1-1, material no. 1.4906.

2.0 Application:

For machined/milled blades for Steam Turbine.

3.0 Condition of Delivery:

Rolled or Forged and Heat Treated.

4.0 Dimension and Tolerances:

Dimensional tolerance, straightness, twisting and bulging limits shall be as per HW0993008.

5.0 Manufacture:

Electro slag re-melted steel (ESR) shall be used.

The manufacturing process must ensure a homogenous grain structure over the entire length of the bar and the bar cross section.

6.0 General Requirements:

- Prerequisite requirement for approval of a new vendor is a successful Process qualification. Manufacturing process established during this shall be the basis for future manufacture.
- Manufacturing plan shall be prepared and submitted after successful process qualification. Manufacturing plan shall include specific information on manufacturing like rolling temperature, reduction ratio, heat treatment temperature, hardening method and soaking time, rate of heating and cooling etc. Test instructions for nondestructive and destructive testing are to be provided in the manufacturing and testing plan.
- Product and process qualification is mandatory for each of the suppliers manufacturing plants.
- For new supplier, process qualification shall be required for three purchase orders.
- If necessary, BHEL may ask for process qualification for verification of manufacturing reliability from regular suppliers also.
- Any change in the agreed manufacturing plan shall be informed to BHEL. BHEL will review the requirement of renewed process qualification.

7.0 Heat Treatment:

Hardening:

1070 - 1100°C / air or liquid quenching, cooled down to a temperature <100°C in the center of the bar.

Tempering:

A two-step tempering treatment must be performed as follows:

- The first tempering must be carried out at a temperature of 570°C and holding time of ≥ 4h. Air has to be used for cooling.
- Temperature of second tempering step has to be ≥ 700°C.

A fully transformed and tempered martensitic microstructure must be present over the entire cross section.

Hardening and tempering in bundles are not allowed. Suitable gaps between two bars are to be ensured during heat treatment for uniformity of properties.

If bars need to be straightened after the heat treatment, a stress relieving heat treatment shall be performed after completion of entire straightening process. Stress relieving is to be carried out at 20 - 30°C below the tempering temperature with a subsequent slow cooling rate.

The lowest possible residual stresses shall be targeted. Distortion of the finish machined part due to residual stresses from the manufacturing process or heat treatment process shall not occur.

8.0 Properties and their verification:

8.1 Chemical Composition:

Heat analysis in weight %

C	Si	Mn	P	S	Cr	Mo
0.11 -0.13	≤ 0.12	0.40 - 0.50	≤ 0.010	≤ 0.005	10.2 - 10.6	1.00 – 1.10
Ni	**V**	**Nb**	**N**	**Al**	**W**	
0.70 – 0.80	0.15 – 0.25	0.040 – 0.060	0.045 - 0.060	≤ 0.010	0.95 - 1.05	

Trace element content for Ti, Cu, As, Sb and Sn must be specified in the inspection certificate for information purposes.

8.2 Properties and Microstructure:

The specimens shall be taken in the longitudinal direction in accordance with Attachment 1. The properties described below shall be determined at room temperature in the delivery condition, i. e. after the last heat treatment including any stress relieving heat treatment.

The metallographic investigations shall be performed on the hardest and softest bar with an area of at least 320mm^2 each. The areas to be investigated must be in the longitudinal direction. The longitudinal direction must be indicated in the documentation.

8.2.1 Mechanical Properties:

Hardness of the bars in a test unit shall be verified by Brinell hardness testing in accordance with ISO 6506 -1, HBW10/3000 or HBW 5/750 may be used.

The surface of the bar shall be prepared in the area of the hardness measurement so that the result is not affected by the surface condition.

Hardness testing shall be performed on 10% of each test unit but at least on 10 bars or on each bar if test unit is less than 10 bars. The greatest resulting difference in hardness shall not exceed 35HBW.
Mechanical properties shall be determined on the hardest and softest bar determined in a test unit.
Tensile testing shall be performed in accordance with ISO 6892 -1 or ASTM E8M (round specimen with L_0 = 50mm and d_0 = 10mm) or ASTM E8M (standard specimen in accordance with Figure 8).
Standard specimens Charpy (V-notch) in accordance with ISO 148 -1 shall be used for determining the absorbed impact energy.
The following properties must be achieved at room temperature:

0.2 % Proof Stress (N/mm^2)	Tensile Strength (N/mm^2)	Elongation After Fracture (%)	Reduction in area %	Impact Energy (J)[1]	Hardness HBW
750 - 830	870 - 970	≥ 14	≥ 55	≥ 50	270 - 310

[1] Average of 3 specimens and minimum value for two specimens in accordance with EN10021, where the lowest value shall be at least 35 Joule.

Additionally, on the softest bar a tensile test in accordance with ISO 6892 - 2 has to be performed (in longitudinal direction) at 600°C. The following properties must be achieved:

0.2 % Proof Stress (N/mm^2)	Tensile Strength (N/mm^2)	Elongation After Fracture (%)	Reduction in area (%)
≥ 405	≥ 420	≥ 18	≥ 65

8.2.2 Microstructure:

Microstructure must be uniform, without porosity, excessive segregation or other inhomogeneities.

8.2.2.1 Cleanliness:

The cleanliness shall be determined as per DIN 50602 - K1. A minimum of 4 specimens per heat shall be used for determination of cleanliness.

Acceptance criteria:

Summary value K1: ≤ 2.0 (relating to 1000mm²)

8.2.2.2 Delta Ferrite content and grain size:

- **Delta ferrite content shall be < 5%.** The determination of delta ferrite content shall be performed based on analysis methods in accordance with ASTM E45 Method A, "Worst field method" with V=100:1.
- **An average grain size of 3 or finer** has to be achieved. Grain size shall be determined on the martensitic secondary grain structure in accordance with ASTM E112 or ISO643. A deviation of more than 2 grain sizes in size of individual's grains from the average grain size is not allowable.

8.3 Non-destructive Testing:

8.3.1 Test Scope:

The following Non – destructive inspections shall be performed in the as delivered condition:

- Visual inspections of all bars
- Ultrasonic examination of all bars in accordance with TWP 1204. 100% of the volume must be tested in accordance with the recording level.

8.3.2 Recording level and acceptance criteria:

- Indications of surface defects such as rolled marks shall be ground out to investigate their depth at least at both ends, in the middle of the indication and at an interval of approx. 250mm.
- Surface defects with a depth extension of ≥ 1mm are not allowable, and these areas shall be cut out of the bar.
- Ultrasonic examination and acceptance of all bars in accordance with TWP 1204.
- Defects above the recording level are not acceptable.
- It shall be confirmed in writing to the BHEL that bar sections containing defects above the recording level have been cut out of the bar.
- The acceptance of material at vendor's works does not relieve the supplier of his responsibility for defects discovered at later stages.

8.3.3 Material Identity Test:

An identity test must be conducted on 100% of bars in the as – delivered condition.

9.0 Process Qualification:

The following additional investigations shall be performed in process qualification (see Attachment 2):

- **Tensile tests:**

  The strength values (0.2% Proof Stress and Tensile Strength) in the transverse direction (specimen orientation ZQ) shall not differ by more than 10% from the corresponding longitudinal values.

  The smallest individual value for absorbed impact energy in transverse direction shall not be below 30J.

  For case where standard specimens in transverse direction cannot be made: -

  - For tensile test specimens, a round specimen with $L_0 = 5\ d_0$ or a flat specimen with a proportionality factor of k= 5.65. Proportional specimens in accordance with Fig 8 shall be used if ASTM E8 is applied.
  - An undersized specimen in accordance with ISO 148 -1 for impact test specimen. Undersize dimension to be reported.
  - If dimension do not allow testing in the transverse direction, even with special specimen, testing will be carried out in the longitudinal direction only.

- **FATT:** Determination of FATT (fracture appearance transition temperature) in accordance with ASTM A370. The FATT should be preferably evaluated based on SEP 1670 (software). The test scope must include at least 10 specimens. FATT < 25°C is to be achieved.
- The fraction of Intergranular fracture shall be determined over the entire brittle fracture portion of the fracture surface of the impact test specimens tested at room temperature. The fraction of Intergranular fracture shall not exceed 10%. This test is not required for materials which indicate ≥ 90% ductile fracture at room temperature.
- Performance of MT testing by the magnetic flux leakage method, alternating current phase shifted and a field strength of 20 – 65A/cm.

  Distribution, type and size of grain structure in-homogeneities (e.g. segregation or delta ferrite) shall not result in MT indications.
- **All test results shall be submitted to BHEL for approval.**

10.0 Identification Marking:

All bars are to be marked with following information:

- Purchase Order Number
- Size
- Material Grade
- Supplier Identification

The details are to be clearly stamped and encircled by oil paint. Each bar shall be painted with a band of colour **orange - blue - orange** on both ends. All the bars shall be suitably packed to protect them against corrosion and damage during transportation.

Bars having maximum and minimum hardness (from which test samples are taken) shall be clearly marked by oil paint for easy identification. Their respective hardness values shall also be punched on these bars.

11.0 Documentation:

Prior to, but in no case later than the delivery of the material, an inspection certificate as per EN 10204 shall be provided to BHEL in duplicate; this certificate must contain the following data:

(a) Material code no and P.O. number
(b) Material designation
(c) Heat no., heat analysis and melting methods
(d) Complete information on all heat treatments performed
(d) Mechanical test results including hardness range and the metallurgical examination.
(e) Results of non-destructive tests, UT inspection report
(f) Confirmation of the material identity check
(g) Confirmation of the dimensions and visual inspection

12.0 Cross Referred Standard:

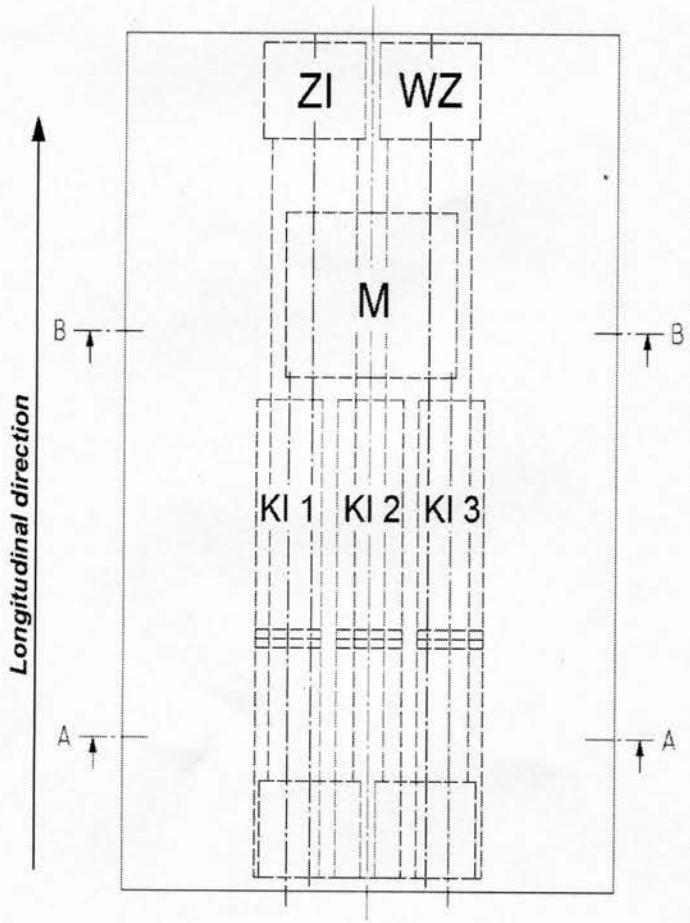
HW0993008, ISO 6506 -1, ISO 6892 – 1, ISO 6892 – 2, ASTM E8M, ISO 148 – 1, EN10021, ASTM E45, ASTM E112, ISO 643, DIN50602, TWP 1204, ASTM A370, EN10204

13.0 Modification with respect to last revision:

- Clause 4.0 modified.
- Clause 9.0 modified.
- Clause 12.0 modified.

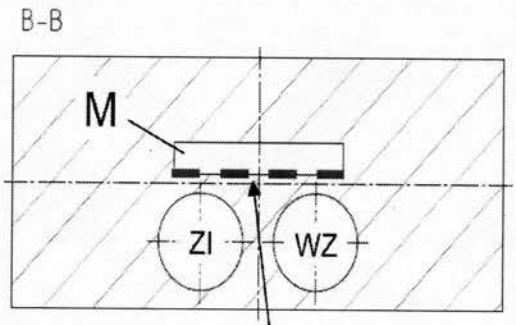
Attachment 1

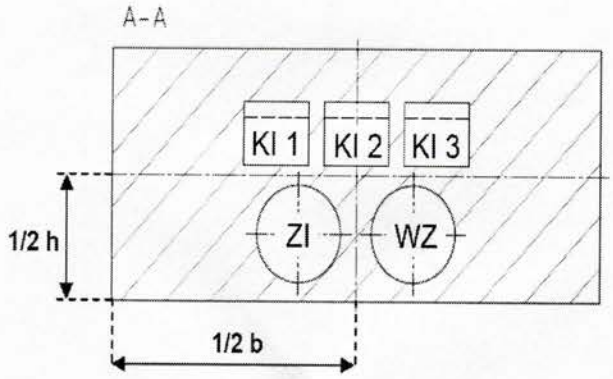
Standard Testing



Label	Specimen
ZI	*Tensile Specimen Centre*
WZ*	*Hot Tensile Specimen*
KI 1 - KI 3	*Notched Impact Specimen Centre*
M	*Metallographic Specimen*

* *if required in material* **specification**

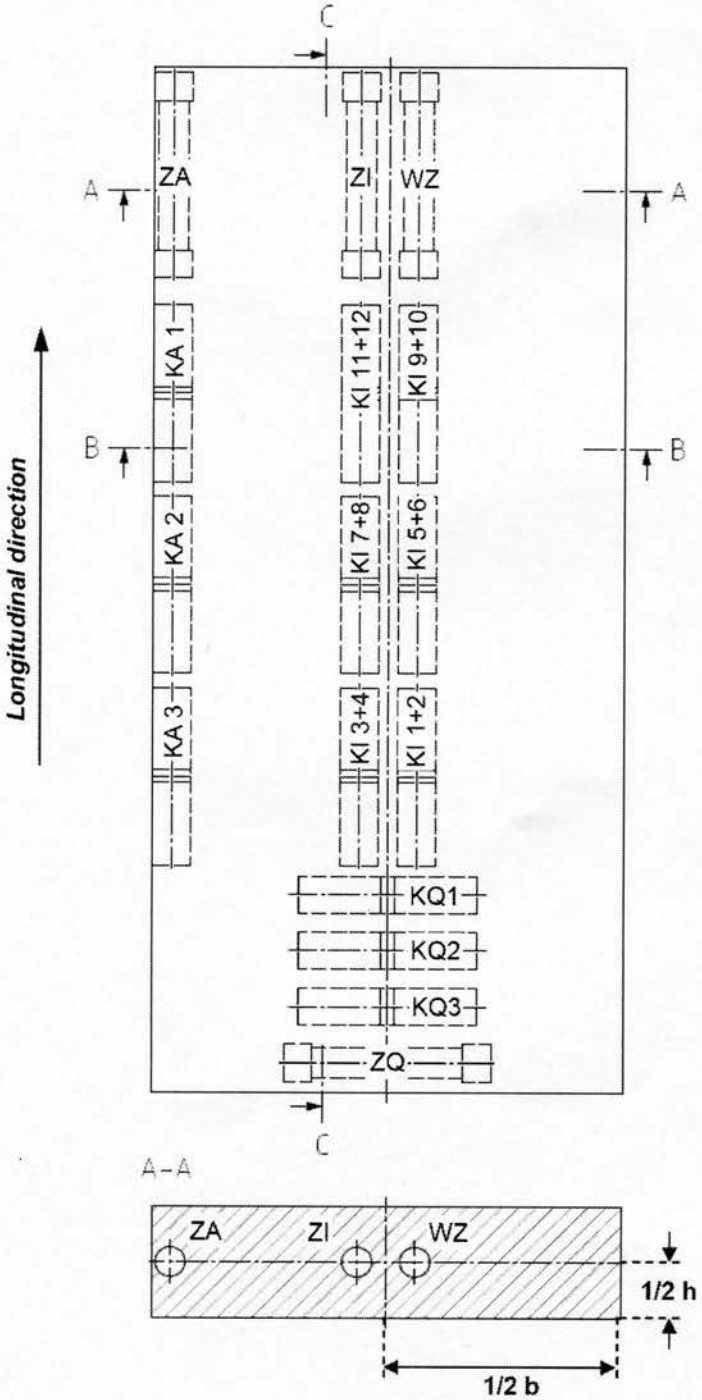




Lower Surface *of the Metallographic Specimen has to be examined. Longitudinal direction must be indicated in the documentation.* $A \geq 320\ mm^2$

Attachment 2, Page 1/2

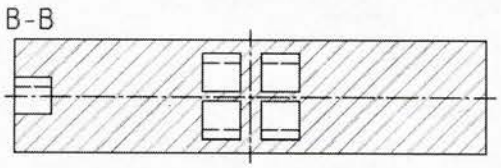
Process Qualification

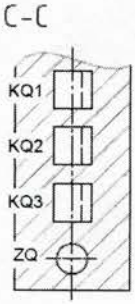


Label	Specimen
ZI	*Tensile Specimen Centre*
ZA	*Tensile Specimen Rim*
ZQ	*Tensile Specimen Transverse*
WZ*	*Hot Tensile Specimen*
KI 1 - KI 12	*Notched Impact Specimen Centre (FATT)*
KA 1 - KA 3	*Notched Impact Specimen Rim*
KQ 1 - KQ 3	*Notched Impact Specimen Transverse*

* *if required in material* **specification**

Note the notch positions of the notch impact specimens (see B - B and C - C).

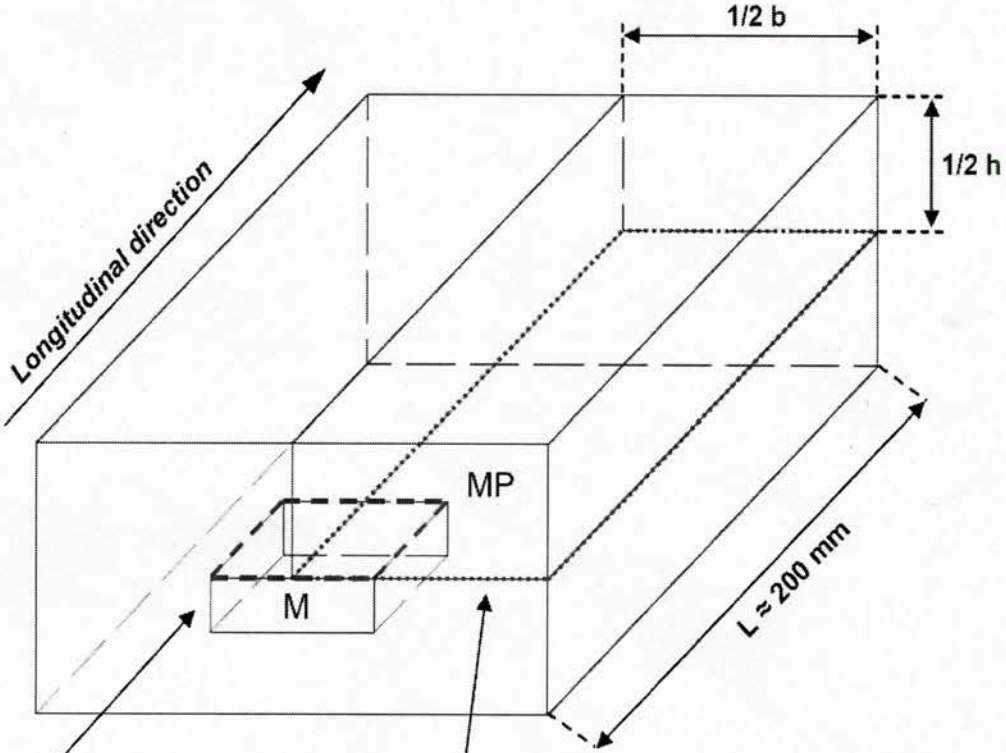




Attachment 2, Page 2/2

Process Qualification

Label	Specimen
M	*Metallographic Specimen*
MP	*Specimen for Magnetic Particle Test*



Upper Surface *of the Metallographic Specimen has to be examined. Longitudinal direction must be indicated in the documentation. A ≥ 320 mm²*

Lower Surface *of the specimen has to be examined in Magnetic Particle Test .*

BAR MATERIAL FOR TURBINE BLADES
NiCr20TiAl

1.0 GENERAL:

The specification governs the quality of bars, rolled or forged for milled turbine blades in grade NiCr20TiAl (Material no. 2.4952).

2.0 APPLICATION:

Bars are required for blades used for turbine and compressor.

3.0 CONDITION OF DELIVERY:

Bars shall be supplied in hot rolled or forged and milled, heat treated condition. The bars should be straight and free from waviness.

4.0 DIMENSION AND TOLERANCES:

The dimension shall be as per order and tolerance shall be as per EN 10269.

5.0 GENERAL REQUIREMENTS:

The manufacturer must demonstrate that he has implemented a quality system that meets the requirements stipulated in EN ISO 9000. The stipulations of the present purchasing specification apply for all the manufacturers' production shops, as well as their sub-suppliers. If the material is delivered for the first time, a process qualification according to clause 12.0 "Process qualification" must be performed. Separate process qualification is required for each facility of the manufacturer.

Before starting the production, the manufacturer shall provide BHEL a manufacturing and inspection sequence plan (MIP) for information after the successful process qualification. The MIP establishes the quality assured sequence of operations. Information on internal and external specifications is also given in the MIP. BHEL may view the manufacturer's internal MIP if he wishes to do so. The manufacturer has to inform BHEL about every change in the manufacturing or subcontractor process or inspection process. BHEL decides if a new qualification process is necessary. Subcontracting of any manufacturing steps is permissible only with BHEL written approval.

Also manufacturer shall submit test instructions for non-destructive and destructive testing which are performed as part of his own quality assurance measures. The test instructions shall include precise information on the tests, illustrated by sketches if necessary. General hints on other specification are not sufficient.

6.0 MANUFACTURING:

6.1 Melting:

The alloy shall be made by vacuum induction melting / electro-slag re-melting (VIM / ESR) or by vacuum induction melting / vacuum arc re-melting (VIM / VAR) process.

6.2 Ingot Discard:

Sufficient discard shall be made from each ingot to ensure freedom from piping, injurious segregation and other imperfections.

6.3 Forging:

The ingot conversion shall be conducted in such a manner as to produce substantially uniform structure throughout the forged bar. The manufacturing process of the bars can be rolling or forging.

6.4 Heat Treatment:

The forging shall be heat treated to get desired mechanical properties as per clause 7.2.1.

Solution treatment : 8 h at 1050 - 1080°C, Air cooling
Stabilizing: 24 h at 845°C (± 10°C), Air cooling
Precipitation hardening: 16 h at 700°C (± 10°C), Air cooling

The forming process and the solution treatment shall be chosen in such a way that over the whole cross section a homogeneous microstructure with a grain size of 3 to 6 according to ASTM E 122 will be reached. (See also 7.2.2)

7.0 PROPERTIES AND TESTS:

7.1 Chemical Composition:

Heat analysis in weight % (according to EN 10269 table 1) shall be as follows:

C	0.04 – 0.10	**Si**	≤ 0.30	**Mn**	≤ 1.00
P	≤ 0.010	**S**	≤ 0.010	**Cr**	18.0 – 21.0
Ti	1.80 – 2.70	**Ni**	Rest	**Co**	≤ 1.00
Fe	≤ 1.50	**Al**	1.0 – 1.8	**B**	≤ 0.008
Cu	≤ 0.20	**Ti + Al**	≥ 3.50		

7.2 Position of test pieces:

Specimen extraction is performed as per attachment 1.The specimens are to be taken in longitudinal direction. The positions of the specimens given in the attachment are meant to serve only as an example. Details concerning the locations of specimens, both at bar material and at bar material made of semi finished parts, are to be agreed upon by BHEL and must be given in the MIP, including a sketch of the specimen location.

7.2.1 Mechanical Properties:

It shall be ensured that the required mechanical properties are achieved throughout the entire bar cross section. The uniformity of the strength of the bars of a given delivery (per melt and heat treatment batch = **test unit**) shall be verified by a hardness test per EN ISO 6506-1. HBW 10/3000 or HBW 5/750 shall be used. Any other hardness test method shall be subject to prior agreement with BHEL. The hardness test shall be performed on 10% of each test unit, however on at least 10 bars, or if the test unit comprises less than 10 bars on every bar.

Mechanical properties shall be determined on the hardest and softest bar indentified by this test. Tensile testing shall be conducted according to EN 10002 resp. ASTM E8M (preferred round tension test specimen with L_0 = 50 mm and d_0 = 10 mm) or ASTM E8 (Standard specimen per fig. 8). Impact testing shall be performed with standard-test pieces with V-notch according to EN 10045. The following properties must be demonstrated at room temperature by the following tests:

0.2% proof Strength N/mm²	Tensile Strength N/mm²	Elongation (Lo=5d) (%)	Reduction in area (%)	Impact Energy (J)	Hardness HBW
≥ 600	1000 - 1300	≥ 17	≥ 17	≥ 20 [1)]	≥ 260

[1)] Average of 3 Charpy V-notch specimens.

In addition a short time creep rupture test according to DIN EN 10291 or other agreed standard has to be carried out, using the following parameters:

Test temperature: $T = 750°C$

Proof stress $\sigma_o = 310$ MPa

The following values have to be reached:

Creep rupture time $t_m \geq 100$ h

Elongation $A_u \geq 4$ %

Reduction of area $Z_u \geq 4$ %

If no creep rupture is occurred after 100 h, the proof stress can be increased for further 30 MPa after every 24 h, until the creep rupture occurred.

7.2.2 Grain Size Check:

The metallographic examination has to be carried out at the beginning and at the end of the hardest and softest bar and in each case in the corner and in the center of the cross section. A substantially homogeneous microstructure with a grain size 3 -6 according to ASTM E 112 has to be achieved in the cross section. A grain size DUPLEX ALA 3 according to ASTM E 930 is acceptable provided, that a grain size of 1 is not exceeded. A deviating microstructure has to be documented according to ASTM E 1181 and to be approved by the BHEL. Reduction of amount of testing can be agreed with the BHEL. For this purpose the manufacturer has to provide adequate results.

7.2.3 Outer and Inner Quality / NDE:

7.2.3.1 Scope of Inspection:

Following NDE shall be performed in delivery condition:

- Visual inspection of all bars
- verification test of all bars
- Complete ultrasonic inspection (UT) of all bars according to EN 10308 type 1a (table 1) or other agreed standard (e.g. AMS STD 2154) has to be carried out. The calibration block and the reference block have to be manufactured out of materials with similar acoustic properties and similar surface conditions. The test has to be performed only by employees with level 2 certified according to EN 473 or SNT-TC-1A.
- 100% PT of all bars without the face areas according to EN 571-1. It is permitted to carry out a UT with a double transducer probe in the near surface area instead of PT.

7.2.3.2 Criteria for registration and decision:

a) Regarding UT inspection quality class 3 according to EN10308 (table 3) shall be applied.

The decision limit for loss of back wall echo is 3 dB for all bar dimensions. The recording level is defined with > 1mm d_{eq}. All indication $d_{eq} \leq$ 1mm are acceptable.

b) PT: Indications ≥ 5 mm are unacceptable. Indications-free grinding excavations with depths ≤ 1mm are acceptable.

8.0 MARKING:

Blades are to be marked as per attachment 2 and specification AA0400310.

9.0 DOCUMENTATION:

The supplier shall supply four copies of the test certificate 3.1 as per EN10204 unless and otherwise stated on the order. The test certificate shall bear the following information:

- Order no.
- Specification no. / Material Designation
- Heat Number, heat analysis and melting method
- Complete information of all heat treatments performed
- Results of mechanical testing, including a list with all measured hardness
- Photos of microstructure with results of the grain size determination & creep test report
- Results of non destructive testing
- Confirmation of the material identification check
- Confirmation of the dimensional and visual check

10.0 CLEARANCE FOR DELIVERY:

The total results of the tests / checks carried out are the deciding factor for clearance for delivery, and hence shall be intimated to BHEL in advance. In case of nonconformance, BHEL evaluates the total results taking into consideration intended use of the material and examines accordingly the acceptability of deviation (if any). No material shall be delivered, if deviated, without acceptance by BHEL. The clearance, however, does not relieve the supplier of his responsibility for the hidden / unreported non-permissible defects which are found later.

11.0 DEVIATIONS:

Deviations from this Purchase Specification, which arise during manufacturing, may be submitted to BHEL in writing, giving full details of the deviation. Acceptance of concession request will be at the sole discretion of BHEL.

12.0 PROCESS QUALIFICATION:

A qualification review, performed jointly by the BHEL and supplier, is required before starting production for the first order.

This initial process qualification is required for each fabrication facility of the manufacturer. The fabrication and inspection parameters stipulated during this phase form the basis of the manufacturing and inspection sequence plan (MIP) which the supplier prepares at his own responsibility. Manufacturing is commenced after the check of conformity by the purchaser and depends on the results of the qualification review, If necessary; the manufacturing parameters are to be further optimized.

Unless otherwise stipulated by the purchaser, the process qualification shall also be required for the first three orders in addition. If desired, a process qualification can also be called for as verification of the reliability of fabrication.

In addition to the scope of testing and examination given in section 7.0 the following tests shall performed (also on the hardest and softest bar):

- Mechanical tests also in the edge position of the cross section
- Photos of the microstructure with results of the grain size determination in longitudinal direction

All results shall be given in a detailed report to BHEL.

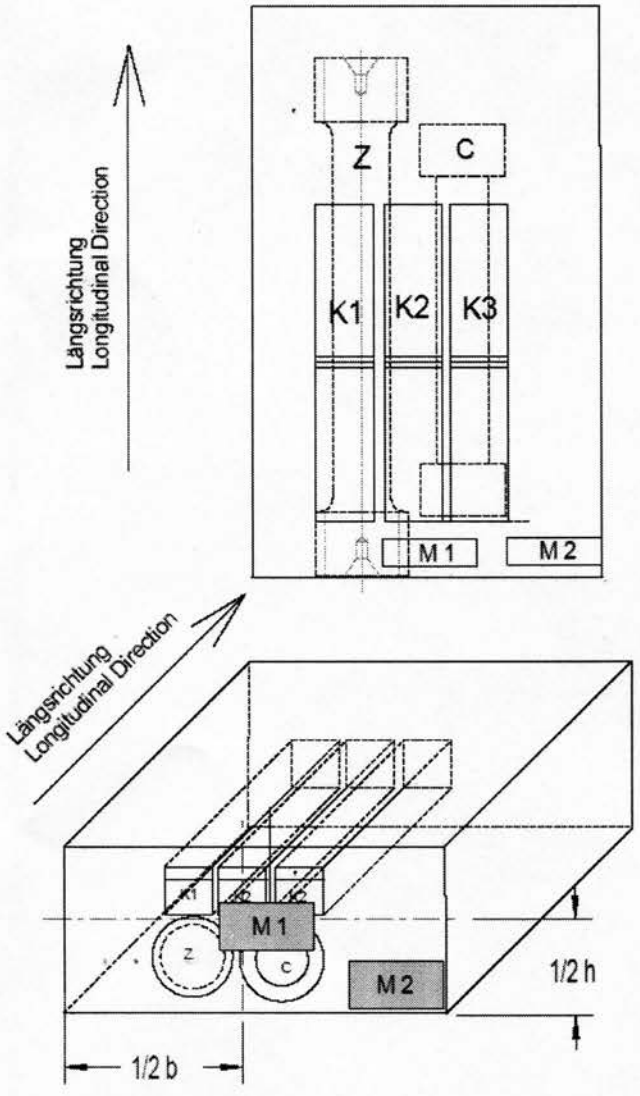
13.0 CROSS REFERRED STANDARDS:

EN ISO 9000, ASTM E122, EN 10269, EN ISO 6506-1, EN 10002, ASTM E8M, EN 10045, DIN EN 10291, ASTM E930, ASTM E1181, EN 10308, EN 473, EN 571-1, EN10204

Attachment 1

STANDARD TESTING

Make sure that all specimens are located in the middle of material.



Z: Tensile Specimen

C: Creep test specimen

K1- K3: Charpy impact specimen

M1: Micro specimen (Cross Section)

M2: Micro specimen (Cross Section)

Attachment 2

Marking for Steel for Steam Turbine Blades

Following details are to be marked on the blades:

Heat No.

Manufacturer Name / Reference

Purchase order No.

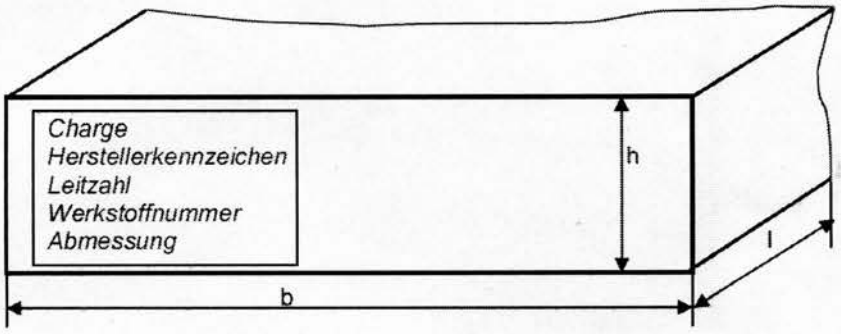
Material No.

Dimensions

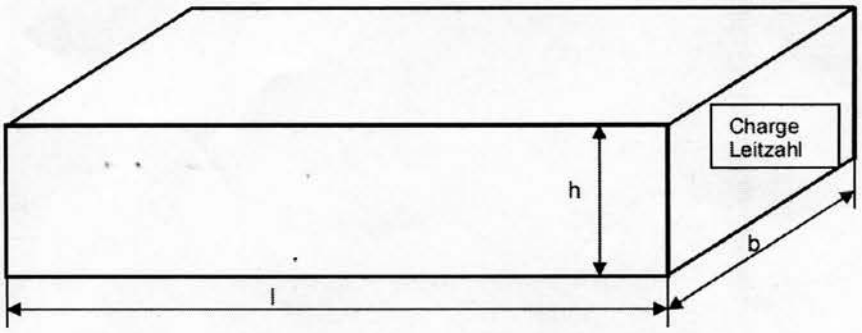
The identification marking shall be applied as follows:

In Case of bars:

Marking of each individual bar at the front with details mentioned above.



In case of cut pieces (cut bars, rhomboids): with stamped figures, ink stamp or stickers/labels



h = Dicke, thickness
l = Länge, length
b = Breite, width

Own Experience

DIMENSION AND TOLERANCES OF BAR MATERIAL OF BLADES FOR SPEC NO HW10663, HW10670, HW10786, HW10687

1. Dimension & Tolerances:

The dimension shall be as per purchase order. Unless otherwise stated in the purchase order, length or bars shall be 2.5- 5 meters with maximum 10% short down to 1 meter.

Tolerance on thickness and width are as follows:

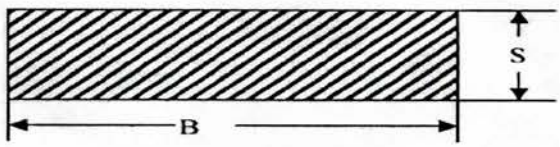
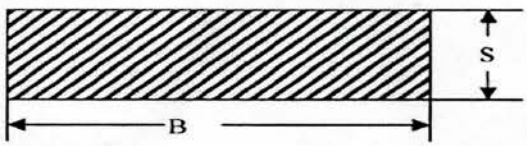


Table: 1

B, width across flats (mm)	Max Allowable deviation on B, mm	S, Thickness (mm)	Max Allowable deviation on S, mm
$B \leq 35$	+1.5	$S \leq 20$	+1
$35 < B \leq 75$	+2	$20 < B \leq 40$	+2
$B > 75$	+3	$S > 40$	+3

Twisting and bending will be allowed as per following table: 2



				नाम NAME	दिनांक एवं हस्ताक्षर SIGNATURE & DATE
MTE	A. RANJAN				
TSX	Lalit Kumar	Lalit Kumar 8/5/17	निर्माणकर्ता WORKED BY	ANIL KUMAR	02/5/17
STE-TB	Ramesh	6/5/17	जांचकर्ता CHECKED BY	RAJIV KUMAR RAJAK	2/5/17
QAX	U.K. Panda	06.05.17	स्वीकृतकर्ता APPROVED BY	NEETU KUMAR SINGLA	03/5/17
सहमत विभाग AGREED DEPTT.	नाम NAME	दिनांक एवं हस्ताक्षर DATE & SIGNATURE	पर्यवेक्षणकर्ता SUPERVISED BY	VIJAY KUMAR CHUGH	03/5/17

दिनांक एवं हस्ताक्षर SIGN & DATE

सामग्री सूची संख्या INVENTORY NO. P-4123

स्वीकृति संस्थान मानकीकरण समिति
APPROVED : PLANT STANDARDIZATION COMMITTEE

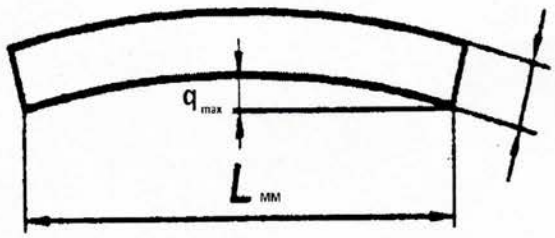
Gr. NO. 6.40

REV.NO.	00	निर्माण PREPARED : TBM	ज़ारी ISSUED : TSX	दिनांक DATE : 02.05.2017
Dt.	02.05.17			
CHANGE ADVICE NO.				

Table:2

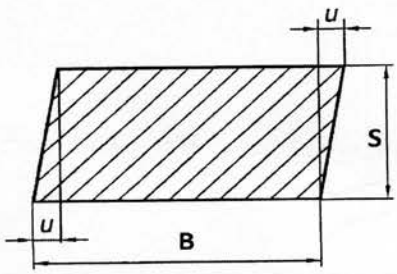
Condition	Bending	Twisting
B & S both ≤ 110	1.5 mm/meter	1.5 mm/meter
B or S > 110	2 mm/meter	2 mm/meter

Table 3: Straightness tolerances (q_{max}) for rectangular section bar

Straightness	Value of q_{max} (mm)	Condition
	(L x 1.5)/2000	B & S both ≤ 110
	(L x 2)/2000	B or S > 110

Bulging on the sides shall not be more than 0.01 X B & 0.02 X S respectively

Table 4: Out of section tolerance for rectangular section bar:

Out of section	Nominal Thickness (mm)	Tolerance(mm)
	10 < S ≤ 25	u≤ 0.5
	25 <S≤40	u≤ 1.0
	40 <S≤80	u≤ 1.5
	S > 80	u≤ 3.0

2. Cross referred documents: HW10663, HW10670, HW10786 & HW10687.