ROTOR FORGINGS- GENERAL

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ROTOR FORGINGS-GENERAL

1. SCOPE

1.1 This Process Specification provides the Engineering Requirements that are common to all Gas Turbine rotor forgings. It must be used with the appropriate part process specification. These two documents complement the applicable forging drawing and the material specification.

1.1.1 This general process specification is applicable to, but not limited to, the following gas turbine rotor forging part process specification.

GT10117	Acceptance Requirements - Compressor Wheels
GT10262	Acceptance Requirements - Turbine Wheels
GT10263	Acceptance Requirements - Turbine Wheel Spacer
GT10649	Acceptance Requirements - Low alloy steel gas Turbine 16th Stage Compressor Wheel and 17th Stage Aft Compressor Shaft Forging
GT10108	Acceptance Requirements - Shafts and Couplings
GT10127	Acceptance Requirements - MS-500 ½ Compressor Wheels and MS7F/MS9F Compressor Wheels

1.1.2 This specification is applicable, but not limited to the following type materials, identified by Material specifications.

HY19368

HY19460

HY19462

HY19467

HY19482

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1.1.3 This specification is applicable, but not limited to, the following typical applications:

Turbine wheels- Magnetic & Non-Magnetic alloys
Compressor Wheels
Compressor Wheel Stub Shafts
Turbine Wheel Shafts
Coupling Shafts
Distance Pieces
Load Couplings
Turbine Wheel Spacers
Spacer Bushings

1.2 Suppliers are responsible for meeting the requirements of this specification and the other requirements set forth in the applicable Forging Drawing, Materials Specification and/or Process Specification. This responsibility also applies to the prime suppliers for any or all operations performed by sub-suppliers.

1.3 Communication

1.3.1 External Supplier (See Definition)

BHEL GT sourcing team is the authorized interface for all communication between BHEL and the External Supplier. All questions or requests for additional information shall be submitted to BHEL GT sourcing team for clarification. Conflicts between applicable Specifications or drawings shall be submitted to BHEL GT sourcing team for resolution by GT Engineering.

1.3.2 Internal Supplier (See Definition)

All communication, including questions or requests for additional information, shall be submitted to BHEL sourcing team.

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1.4 Requests for Deviations - Requests for deviations to the requirements of this specification shall be submitted as follows:

1.4.1 External Supplier - To BHEL by SDR.

1.4.2 Internal Supplier - To the appropriate Engineering personnel by NCR.

2. APPLICABLE DOCUMENTS

2.1 The following documents shall form an integral part of this specification to the extent herein specified. Unless otherwise specified, the latest issue shall apply.

2.1.1 Bharat Heavy Electricals Limited

D6C6B1	Thin-Film Corrosion Preventive Compounds
GT10146	Magnetic Particle Testing, General
GT10160	Visible Dye Penetrant Testing
GT10157	Fluorescent Penetrant Testing
GT10186	Spin Testing- Non-Composite Solid Turbine Wheels
GT10184	Ultrasonic Testing - General
GT10222	Heat Treat, Process Control
GT10117	Acceptance Requirements – Compressor Wheels
GT10262	Acceptance Requirements – Turbine Wheels
GT10263	Acceptance Requirements – Turbine Wheel Spacer
GT10649	Acceptance Requirements - Low alloy steel gas Turbine 16th Stage Compressor Wheel and 17th Stage Aft Compressor Shaft Forging
GT10108	Acceptance Requirements - Shafts and Couplings
GT10127	Acceptance Requirements - MS-500 ½ Compressor Wheels and MS7F/MS9F Compressor Wheels
GT11162	Forging Sonic and machining requirements for 100% Ultrasonic Inspection Coverage

2.1.2 American Society for Non-Destructive Testing

SNT-TC-1A	Personnel Qualification and Certification in Non-Destructive Testing.

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2.1.3 American Society for Testing and Materials

ASTM A370	Standard Methods and Definitions for Mechanical Testing of Steel Products
ASTM E21	Standard Practice for Elevated Temperature Tension Tests of Metallic Materials
ASTM E29	Standard Recommended Practice for Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values
ASTM E45	Standard Practice for Determining the Inclusion Content of Steel
ASTM E112	Standard Methods for Determining the Average Grain Size
ASTM E139	Standard Practice for Conducting Creep, Creep Rupture, and Stress Rupture Tests of Metallic Materials
ASTM E165	Standard Practice for Liquid Penetrant Inspection Method
ASTM E292	Standard practice for conducting Time-For-Rupture Notch tension Test of Materials
ASTM E350	Standard Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron
ASTM E352	Standard Method for Chemical Analysis of Tool Steels and other similar Medium and High-Alloy Steels
ASTM E380	Standard for Metric Practice
ASTM E709	Standard Practice for Magnetic particle Examination

3. DEFINITIONS

3.1 Personnel

3.1.1 Purchaser - BHEL or its Business Associate.

3.1.2 External Supplier (Including Sub-Tier) - The corporation, company, partnership, sole proprietorship or individual engaged to perform the process covered by this specification.

3.1.3 Internal Supplier - Any BHEL Manufacturing Department.

3.1.4 Supplier - As used herein, unless specifically designated, refers to either an External or an Internal Supplier.

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3.2 Specification Deviation Documents

3.2.1 Applicable to External Supplier

3.2.1.1 Supplier Deviation Request (SDR) - A method for the documentation, approval and control of a waiver for materials, processes or dimensions which deviate from the Purchase Order documents (drawings, specifications, Engineering instructions, etc.).

3.2.2 Applicable to Internal Supplier

3.2.2.1 Quality Control Report (QCR) - BHEL Manufacturing Department non-conformance report initiated during processing through the factory. Used by Manufacturing to document non-conformance governing documents and request corrective action.

3.3 Documentation

3.3.1 Manufacturing Process Plan (MPP) - A BHEL-approved, detailed, step-by-step list of operations by which the parts are planned to be processed, tested and inspected.

3.3.2 Qualification Package - First Piece Qualification documentation containing the results of the tests and inspections performed on the First Piece as required for qualification.

3.4 Technical Terms

3.4.1 Manufacturing Process Plan (MPP) – A detailed step-by-step list of operations by which the applicable parts are planned to be manufactured, inspected and tested. The process plan is also referred to as MPP (Manufacturing Process Plan), and was formerly referred to as MPI (Manufacturing Process Instruction).

3.4.2 Frozen Process Plan- A BHEL approved forging supplier processing/ manufacturing plan which has been successfully used to demonstrate the capability to consistently produce the specified part with all of the application required mechanical properties and material qualities/ characteristics. Once approved, the Frozen Process MPP shall not be changed without consultation with BHEL plus the submittal and approval of a new supplier (MPP).

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3.4.3 Heat Treat Envelope – The configuration of the forging, with dimensions, when it was heat-treated.

3.4.4 As-Received Forging – The condition of the forging as shipped by the Forging Supplier and as received by BHEL. Depending on the purchase order, the as-received forging can be either a forging drawing configuration or to a rough machined drawing configuration.

3.4.5 Finish Machined Forging – The configuration of the forging after all of the Forging Supplier and BHEL machining operations have been completed.

3.4.6 Ultrasonic Examination Scan Plans – Detailed identification of the ultrasonic scans that are required for a given forging per BHEL ultrasonic inspection specification. Included in the plan must be the search unit type, scan type, test surface code, scan distance, reference distance, if applicable, and sensitivity.

3.4.7 Transition Temperature – That temperature at which the cleavage or granular fracture is equal to fifty (50) percent of the original cross sectional area. The transition temperature is also referred as the FATT (Fracture Appearance Transition temperature).

3.4.8 Part Specification – A process specification, using the GTXXXXX format which set forth production and trial/ qualification requirements for specific forgings.

3.4.9 Significant Change – Any change outside the limits established by an approved Manufacturing Process Plan or the reference documents contained in the foresaid MPP.

3.4.10 Qualification Program – A detailed test plan issued by BHEL- QA, which summarizes all of the mechanical property, examination and testing required. It contains the requirements found in the applicable specification(s) as well as any additional requirement. In addition, the qualification program document defines all special acceptance criteria and schedule needs. A Qualification Program might encompass both First Piece Qualification and Pilot Lot forgings.

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3.5 Quality Terminology:

3.5.1 Characteristic: The dimensional, visual, functional, mechanical and material features or properties, which describe and constitute the design of an item and can be measured, observed, or identified to determine conformance to the design requirements.

3.5.2 Critical To Quality Characteristic (CTQ)- [Formerly known as Key Quality Characteristic (KQC)] – Those characteristics of an item which, if nonconforming, may prevent or seriously affect the unit performance, reliability, producibility, or customer satisfaction of a component.

4. QUALIFICATION REQUIREMENTS

4.1 The First Piece Qualification (FPQ) forging shall be required of a new supplier, a new plant of a current supplier, or when there is significant change in the shape, the composition or the processing of the forging. A destructive cut-up First Piece Qualification Program is necessary for each of the gas turbine rotor forging. Materials and Process Engineering might group or classify similar forgings into families that would require only cut-up forging or might waive the cut-up forging on the basis of related experience with a given forging supplier or another forging from the same family. Users of BHEL specifications such as Licensees, Manufacturing Associates, Business Associates, etc. must employ the destructive cut-up Qualification Procedure unless they obtain a waiver in writing from the Materials & Process Engineering. Requirements of 4.1.1 through 4.1.3 are applicable to steel forgings only

4.1.1 The mechanical properties testing locations within First Piece Qualification must include, as a minimum, tests from the following four (4) regions:

- All of the production part test locations.
- The most deep-seated region or regions of the forging; i.e., furthest removed from the as-heat treated surfaces.
- The highest stressed region in the intended application or regions when the qualification is for multiple applications.
- The regions where it is believed most difficult to develop the required mechanical properties.

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4.1.2 FPQ forgings shall first be heat treated with an aim tensile strength being that of the specification maximum value. All mechanical properties will be measured in this heat-treated condition.

4.1.3 Extra material for a duplicate set of mechanical properties shall be obtained and then tempered with the FPQ forging or in a laboratory furnace to a tensile strength aim value that is in the lower one-half of the material specification's required tensile strength range. All required mechanical properties tests shall be repeated and reported in the Qualification Program Report.

4.1.4 When the forging supplier has made the similar parts for BHEL that have similar requirements, then the Material and Process Engineering will review the results and will decide whether or not a qualification forging is required and if destructive cut-up qualification is needed. This decision will be communicated to the supplier through BHEL in writing.

4.2 The first step for a Supplier to achieve the status of a Qualified Supplier for a given class/ type of gas turbine rotor forgings is the submittal of a Qualification Forging Manufacturing Process Plan. Next is the successful production and evaluation of a First Piece Qualification forging. This forging must meet all specification requirements and it also must exhibit the same properties and quality margins that other suppliers are capable of developing in the same forging. The First Piece Qualification (FPQ) forging will therefore have special requirements for testing and/or properties that are beyond the Specification(s) and Purchase order document. These special requirements will be defined in the BHEL Qualification Program document given to the supplier prior to FPQ manufacturer.

4.2.1 Qualification Program Report/ Package – The Supplier shall submit two (2) copies of the FPQ documentation to BHEL for review and approval. This program Report/Package must contain, as a minimum, the following:

4.2.1.1 The Qualification MPP approved by BHEL prior to the initiation of FPQ.

4.2.1.2 All required testing and examination results

4.2.1.3 A Certificate of Conformance

4.2.1.4 Qualification Samples – FPQ samples shall be provided as requested.

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4.3 The second step for achieving Qualified Supplier status is the successful production and evaluation of a set of “pilot lot” forgings. These pilot lot forgings might have tests and examinations that are in addition to those tests required for the production forgings manufactured by a Supplier, after qualified forgings Supplier status has been obtained. The pilot lot forging requirements might include the additional destructive evaluation of forgings, but most likely, they will specify additional tests on core sections and prolongations, plus non-destructive examinations. The exact details of pilot lot program, including the number of forgings, and the nature of the tests and examinations will be determined by BHEL after the review of the results of the First Piece Qualification forging with the forging Supplier

4.4 Upon receipt of written notification of FPQ status, the Supplier is approved for the manufacture of the qualified part. Prior to the manufacturer of production of parts, the supplier must submit a production forging MPP. This MPP must be “FROZEN”, therefore not changed without the submission and approval of another MPP.

4.5 A “verification of qualification status” forging might be required by BHEL after a Supplier has been making a particular forging for five years or longer, after a Supplier has not made a particular forging or similar forgings for two years or longer, or after the Supplier’s production forging exhibit unusual mechanical properties and/or quality trends.

5. FORGING SUPPLIER PRODUCTION PROCESS REQUIREMENTS

5.1 General – The forging shall be manufactured in accordance with a documented supplier Frozen Manufacturing Process Plan (MPP) which has been reviewed and approved by BHEL, except in areas which are considered proprietary. In such cases, the review by BHEL shall be limited to objective evidence of the existence and documentation of the instructions. The MPP shall be identified by the supplier and such identity shown on the certification, herein required. The supplier shall monitor actual processing of the forging, compare the processing to the MPP and report to BHEL (using SDR routine) any variances from the plan. In addition, BHEL reserved the right to periodically audit the supplier’s facilities and practices used for the processing and testing of the forging. Such reviews or audits shall not relieve the supplier from the responsibility of producing a suitable forging.

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5.2 Critical to Quality Characteristics (CTQ) – The following CTQ's has been identified for GT forgings and shall be monitored on a continual basis by the Supplier using Statistical Process Control (SPC).

5.2.1 Low Alloy Steel and M152 Steels

CTQ — Tensile Strength and Ductility

CTQ — Deep Seated Toughness - CVN FATT and/or charpy V-Notch Energy

CTQ — Ultrasonic Quality

5.2.2 Nickle Base Alloys

CTQ — Tensile Strength and Ductility

CTQ — Grain Size

CTQ — Ultrasonic Quality

5.2.3 The supplier shall control and monitor the above applicable CTQs. This shall be done either directly or indirectly through the control and the measurement of the applicable processing and testing parameters.

5.2.3.1 The Supplier shall identify the means by which the above CTQs shall be verified.

5.2.3.2 The Supplier may monitor these CTQ's directly or indirectly through various parameters as applicable. The supplier shall identify the means by which these CTQ's will be verified. At least three (3), but not more than ten (10), total CTQ's should be identified to satisfy this specification requirement. This information shall be submitted to BHEL by means of a MPP or an overarching document for approval. A written summary of SPC activity for each CTQ shall be submitted to BHEL for review at least once every six-month period. The Supplier's internal statistical process control system nay monitor many CTQs; however, a maximum of ten (10) shall be reported to BHEL on periodic basis.

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5.2.3.3 The Supplier's internal statistical process control system (SPC) likely monitors many more processing and testing parameters than just those for the reported CTQs. All of the parameters measured by the Supplier SPC system shall be available for BHEL review upon prior request.

5.3 Manufacturing Process Plan (MPP) - The MPP must be appropriately identified and shall include as a minimum the following items:

5.3.1 Melting Practice, including the location of the melting facility, and the identity of the melting, vacuum and teeming equipment and procedures. Additional details are the ingot sizes and weight plus the hot topping and the ingot discard practices.

5.3.1.1 DELETED.

5.3.1.2 For materials melted using a remelt process [Vacuum Arc Remelt (VAR) or Electro-Slag remelt (ESR)], the melting Supplier is required to conform to para 5.3.1 above, and to submit a detailed MPP for melting. This MPP should include the requirement of para 5.3.1 above, plus the following:

5.3.1.2.1 Ingot Made using ESR- The MPP must include as a minimum:

- Start-up procedure (hot or cold start)
- Upper and lower limits of the melt rate
- Upper and lower limits of the current and volt

5.3.1.2.2 Ingot Made Using VAR- The MPP must include as a minimum:

- Upper and lower limits of the melt rate
- Upper and lower limits of the current and voltage
- Procedure for arc gap control

5.3.2 Forging Practices shall include:

- orientation and location of qualification forgings with in the ingot
- the forging press and capacity that is used for each operation
- dimensioned changes of the forging after each working operation

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- description of the dies and any mandrels, punches or upset pots that are used
- Heating Practices- Aim and maximum range of furnace temperatures, plus aim and maximum range of furnace holding times.

5.3.3 Heat Treatment practices shall include:

- configuration and dimensions of the forging as it is hat treated
- the types of furnace that will be used for each of the operations and the shop identities
- rules of placement and orientation of forgings with in the heat treatment furnaces
- aim thermal heating and cooling temperature ramps
- general rules for holding times at heat treatment temperatures and the temperature ranges
- liquid immersion quench times and the rules/method for the calculation of the immersion time
- Positioning and orientation of the forgings in the quench tank.

5.3.4 Mechanical properties Testing shall include:

- dimensioned sketch of the test specimen within the as heat treated forging
- summary of the mechanical properties tests that will be performed.

5.3.5 The MPP shall contain or make reference to Supplier Internal Examination procedures for ultrasonic, magnetic particle and liquid penetrant inspections.

5.3.6 Any additional items required by the applicable forging drawing, part specification or material specification shall be included.

5.4 Melting Process – The melting process shall be in accordance with the requirements of the applicable Material Specification.

5.5 Discard – Sufficient discard shall be made from each ingot to assure freedom from piping and undue chemical and non-metallic segregation.

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

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5.6.1 **Low spots** on the forging surface, due to forging under the planned forging contour, can be cause for surface and/or sub-surface non- metallic and/or decarburized material, which could extend into the finished machine parts. These situations must be treated as processing variances and require a SDR (Ref. Para. 6.9) approval prior to further processing.

5.7 Rough Machining - At the option of the supplier, forgings may be rough machined prior to final heat treatment for mechanical properties to the configuration (heat treat envelope), as referred by the MPP.

5.8 Heat Treatment - The heat treatment shall be in accordance with the requirements of the applicable Material Specification. Allowable variations include re-temper treatments to adjust the tensile strength and also one complete re-heat treatment cycle. If more than one complete re-heat treatment is planned by the manufacturer for a given forging then it must be referred to BHEL by SDR (Ref. Para. 6.9) for approval.

5.8.1 Heat Treatment Records - The heat treat furnace and thermocouple records, properly identified relative to purchase order and forging serial numbers, shall be retained by the Supplier for a period of at least one (1) year from the forging ship date.

5.9 Finish Machining (To forging Drawing Dimensions) -

5.9.1 Surface finish requirements, reference to Para. 6.3.3 for ultrasonic surface finish requirements and 6.8 for all other surface finish requirements.

5.10 Marking and Shipping -

5.10.1 Required Marking - Each forging must be steel stamped (low stress type) as follows:

5.10.1.1 An “O’’ (12:00 o’clock) location which will be used as the circumferential reference point for all non-destructive and mechanical tests. The “O’’ location must be established at the time of manufacture when the forging is first examined non-destructively per Para. 6.3.4 and 6.3.5 or when the first test material is removed. The ‘’O’’ location must be maintained during manufacture and remain legible and available on the as-shipped forging

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5.10.1.2 In the general area of the ''O'' location, the following information shall also be stamped:

- Forging Drawing and Part Number
- BHEL Serial Number
- Supplier Code
- Heat Number or Supplier Tracking Number
- SDR Number (if applicable)

5.10.2 Preservation - All machined surfaces of alloy steel forging shall be painted with a protective coating, Tectyl 506, or BHEL approved alternative prior to shipping. The coating shall be applied by spray, dip or brush with a continuous film (0.002 to 0.004 inches thickness) with a minimum of sags or runs in the coating.

NOTE: The coating material should be applied "as received", thinning is not required.

5.11 Deviations - Any deviation from the requirements of this Specification shall be submitted by SDR/NCR for BHEL GT Engineering disposition before the item is shipped.

6. INSPECTION/TEST PROCEDURES AND REQUIREMENTS

6.1 Chemical Composition

6.1.1 Heat (Ladle) Analysis - An analysis of each heat shall be made by the manufacturer to determine the percentage of the elements specified under Chemical Composition as set forth in the applicable Material Specification. The analysis shall be made on a suitable sample obtained just prior to pouring of the heat and shall conform to the requirements of the applicable Material Specification.

6.1.2 Re-Melt Heat Analysis - When consumable re-melting processes (Electro-slag Re-Melting or Vacuum Arc Re-Melting) are used for final melting, an analysis shall be made on samples taken from the top and bottom of the ingot, billet or forging, at the option of the manufacturer. The analysis shall conform to the requirements of the applicable Materials Specification.

6.1.2.1 When electrodes form different master heats are re-melted sequentially, an analysis shall be made on each zone of the re-melted ingot corresponding to proportions of each a respective heat. The chemical analysis of each zone shall conform to the requirements of the applicable Material Specification.

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6.1.3 Deviations from the Chemical Composition set forth in the applicable Materials Specification, as determined from the process or the forged [product, may be allowed if an evaluation by BHEL of the mechanical properties and the qualities of the forging indicates that the forging is suitable for the intended application.

6.1.4 The Chemical Composition as determined by the Heat Analysis or Re-Melt Heat Analysis (as applicable) shall be reported in the Certification, herein required.

NOTE: For purposes of determining conformance to the Chemical Composition, as set forth in each applicable Material Specification, all specified limits are absolute limits as defined in ASTM E29.

6.2 Hardness Tests - When required by the applicable Material Specification. Forging Drawing and/or Part Specification, forgings shall be hardness tested using Brinell Hardness Testing Methods, or other methods, which have been approved by BHEL.

6.3 Ultrasonic Test - Ultrasonic testing (UT) shall be performed after machining to the sonic shape. Testing shall be performed in accordance with the applicable UT specification as required on the BHEL drawing.

6.3.1 Forging sonic shape shall meet GT11162 requirements unless otherwise approved by BHEL, and documented in the qualification record. Forging qualified prior to release of GT10047 Rev-03 shall be reviewed with BHEL to determine compliance and acceptance of sonic shapes.

6.3.2 In lieu automated UT, two manual UT inspections are permissible for low alloy steel forgings. The manual UT inspections shall be performed independently by different qualified inspection sources, i.e., the same agency or company shall not perform both tests. The sonic shape may be the same for both manual UT inspections, unless otherwise approved by BHEL. The second sonic shape, if applicable, shall be approved by BHEL. The redundant manual UT shall be performed on the forging in the BHEL approved, sonic shape configuration prior to machining to the BHEL approved ship shape unless otherwise approved by BHEL. The second sonic shape may be the same as the ship shape. Forging and sonic shapes qualified prior to release of GT10047 Rev-03 shall be reviewed with BHEL to determine compliance and acceptance of sonic shapes and the redundant UT inspection shape.

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6.3.3 Prior to UT, the surface finish shall not exceed the following RMS values. Also surfaces shall have no steps greater than 0.002 inches (0.05 mm) due to interruptions in machining

UT Specification	Acceptance Standard	Surface Finish
GT10184	Quality Level B	250 µinches (6.4 µm)
GT10184	Quality Level A	125 µinches (3.2 µm)
DELETED		
DELETED		
DELETED		
DELETED		
All Other	All	250 µinches (6.4 µm)

6.3.4 An SDR shall be submitted to BHEL for Forgings with indications determined to exceed the Acceptance Standards of the applicable Drawing. Part Specification and/or Ultrasonic inspection Specification Per section 6.9 below. The SDR must be approved by BHEL before the forging is marked with “UT”. The SDR number shall be marked on the forging and the final machined part.

6.3.5 The forging shall be stamped as specified on the BHEL drawing. The location of the stamping shall be on the outside circumferential surface for disk type forgings and on the outside axial surface for shaft type forgings

6.4 Magnetic Particle/ Penetrant Inspection - For ferrous alloy steel forgings all accessible surfaces of the forging shall be magnetic particle inspected in the finished machined state. If the part is spin tested, the applicable magnetic particle or penetrant inspection shall be after the spin test. The magnetic particle inspection shall be per specification GT10146. The penetrant inspection shall be per specification GT10157. All indications that exceed the Drawing or Specification requirements shall be documented and referred using the appropriate non-conformance process for disposition by Design Engineering and M&PE Engineering.

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6.5 Mechanical Tests

6.5.1 General - Forgings with mechanical properties below the minimums of the applicable Material Specification shall be referred to BHEL, by SDR (Ref Para. 6.9), for review and disposition relative to the suitability of the forging for the intended application. If the balance of mechanical properties make the forging suitable for its intended application, it shall be accepted. If any of the properties are outside the specified property limits and the overall mechanical property balance is unsatisfactory, then the forging will be rejected on the manufacturer and BHEL is not liable.

6.5.1.1 All final mechanical tests shall be performed by an approved testing source using test procedures in accordance with ASTM A370 on test specimens removed from the respective forging after the final heat treatment. If a subsequent stress relief anneal is performed at a temperature less than 50F below the final tempering cycle, the final mechanical tests shall be performed for this heat treat condition. The requirements for mechanical tests including type, location, quantity and limits shall be set forth in the applicable Material Specification and/or Part Specification.

6.5.2 Mechanical Tests - Mechanical test specimen, such as, tensile, creep, stress rupture, fracture toughness, impact, fatigue, crack growth, etc., shall be taken in accordance with the applicable Part Specification.

6.5.3 Charpy V-Notch Impact Tests - Test specimens shall have 45-degree V-notch in accordance with ASTM A370. The root of the notch shall be parallel to the primary axis of the forging with the notch opening directed at the forging bore or axial centerline.

6.5.4 FATT - When required, FATT shall be estimated from the curve obtained from at least four specimens, tested at different temperatures. About half of the specimens should have percentages of cleavage or granular fracture above the 50 percent level and about half below.

6.5.5 Re-Tests

6.5.5.1 If a tensile specimen exhibits tensile or yield strengths that are below the specified values due to an error in testing procedure, one adjacent re-test may be performed.

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6.5.5.2 If the lower than specified tensile test result was not caused by an error in testing procedure and was not caused by any unusual condition, such as rupture, flakes. Or cracks in the steel, two adjacent specimens must be tested without a re-heat treatment

6.5.5.3 If a Charpy V-notch specimen exhibits a value below the minimum specified energy and this value is not less than two-thirds of the minimum specified, re-testing is permitted. Re-testing will be three additional Harpy V-notch tests from a location adjacent to an on either side of the specimen that failed. Each of these test results must meet the minimum specified energy value. Re-testing is not permitted when the measured energy value is below two-thirds of the minimum specified value unless variances in the specimen preparation of the test procedure cause the test to be invalidated

6.5.5.4 Retest procedures for other mechanical property failures such as stress rupture, creep, fatigue, crack growth, fracture toughness, FATT, etc., shall be referred to BHEL for approval. All re-tests results must meet the requirements of the applicable Material Specification.

6.5.6 Test results - The results of all properly tested mechanical property test specimens performed after the final heat treatment shall be reported in the Certification required by this specification. All re-tests must be suitably identified.

NOTE: For purposes of determination of conformance to the Mechanical Requirements, as set forth by the applicable Material Specification, an observed or calculated value shall be rounded off to the nearest five-hundred (500) psi for tensile and yield strengths and to the nearest one (1) percent for the elongation and reduction of area, in accordance with the round-off method of ASTM E29.

6.6 Stress Rupture

6.6.1 When required by the applicable Part Specification, the Supplier shall perform stress rupture tests using the procedures set forth in ASTM E292 to the requirements set forth in the applicable Material Specification.

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6.6.2 Test Specimen - Stress rupture testing may use either separate or combination (smooth-notch) type bars. The type specimens actually used and its dimensions must be reported in the Certification required by this specification. The stress rupture test specimen shall meet the following dimensional requirements:

Percent Notch, Percent Area	50
Included Angle, deg.	60 ± .05
Major Diameter, in.	0.251 ± 0.001
Minor Diameter, in.	0.178 ± 0.001
Notch radius, in.	0.005 ± 0.0005

6.6.2.1 The forging supplier has the option of testing another size bar as long as the geometric proportionality is the same and the notch stress concentration (K) is 3.9 or larger. All such variations must be reported in the Certification required by this specification.

6.6.3 The stress rupture test may be completed at an increased test temperature. The procedure of accelerating the test is to conduct it for 100 hours per the parameters set forth in the application Material Specification and then increase the test temperature by 50°F. Any such accelerated test condition must be reported in the Certification required by this specification.

6.7 Photomicrograph - When required by the applicable Material or Process Specification, the supplier shall submit to BHEL, in the Certification, photomicrographs (100X magnification) of the microstructure, cleanliness ratings and/or grain size ratings. The procedures to be used are as follows in Paras. 6.7.1 - 6.7.4.

6.7.1 Microstructure - As etched in accordance with the requirements of the applicable Material Specification.

6.7.2 Cleanliness - As etched in accordance with the requirements of the applicable Material Specification.

6.7.3 Grain Size - In accordance with the procedures set forth in ASTM E112 to the requirements set forth in the applicable Part Specification or Material Specification.

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6.7.4 Photomicrograph Locations - The photomicrographs shall be taken from the grip portion of a broken test specimen from each test location(s) set forth in the applicable Part specification when unusual microstructural features are observed.

6.7.4.1 Unless otherwise stated in the applicable Part Specification, all test locations in FPQ's shall have photomicrographs taken at 100X or higher magnification as required. Photomicrographs taken from test samples of qualification forgings shall be included in the Qualification Program Report.

6.8 Dimensions and Tolerances - Forgings shall be furnished in accordance with the drawing accompanying the purchase order, with a surface finish satisfactory for ultrasonic examination per paragraph 6.3.3. The finish shall be tear free and shall have no surface waviness in excess of 0.005" in any 2" area for phonograph type finishes and 0.001" for broad nose finishes.

6.9 Deviation Requests - The supplier may request deviations to forging drawing, Material Specification and/or Part Specification requirement(s) by means of a Supplier Deviation Request (SDR).

6.9.1 SDR's must include all of the applicable information available (i.e. test properties, dimensions, heat treatment history, complete forging identification, etc.) which would be required by BHEL for prompt disposition. Additionally, all SDRs must contain information relative to the supplier corrective action to be taken to prevent future deviation conditions from occurring.

6.9.2 SDR's, which have been promptly approved, must become a permanent part of the records for all parts involved. A copy of the approved SDR must be attached to each copy of the Certification required by this specification.

6.9.2.1 SDRs, which have been approved by BHEL for deviations to the dimensions required by the forging drawing, shall be permanently marked on the forging with steel stamps. The SDR number must be marked on the applicable part.

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6.10 BHEL Testing - BHEL reserves the right to perform tests and examinations, similar to those performed by the supplier to facilitate the evaluation of the acceptability of the forging. The results of all such tests must meet the requirements of the applicable specifications.

6.10.1 Non-destructive testing techniques such as ultrasonic inspection, magnetic particle, liquid penetrant, etching and others shall be used to determine the forging soundness.

6.10.1.1 All magnetic forgings will be magnetic particle inspected, in the finish machined condition.

6.10.1.2 All non-magnetic forgings will be fluorescent penetrant inspected, in the finish machined condition.

6.10.1.3 When the bore length of forgings exceeds 18”, a borescope will be used to facilitate MP or LP examination of bore.

6.10.1.4 When required by the applicable Part Specifications, the part will be spin tested in accordance with GT10186.

6.10.1.4.1 All forgings, which have been spin tested, will be ultrasonic tested after spin testing.

6.10.1.4.2 All magnetic forgings, which have been spin tested, will be magnetic particle tested after spin testing and any subsequent finish machining operations.

6.10.1.4.3 All non-magnetic forgings, which have been spin tested, will be fluorescent penetrant tested after spin testing and any subsequent finish machining operations.

6.10.1.5 Interpretative techniques, such as fracture mechanics, may be used to evaluate the non-destructive test data.

6.10.2 BHEL Test Samples - The Supplier shall save, when the remaining test material permits, sufficient material for BHEL to duplicate all of the Supplier’s Certification mechanical properties tests. These test materials shall be saved by the supplier for a period of one year after the forging is shipped to BHEL unless instructions to do otherwise are received from BHEL.

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6.10.2.1 All such sored test material shall be properly identified by low stress metal stamping, ¼" minimum sized. The stored test material shall not be used without approval from BHEL

6.10.3 BHEL product Check Analysis - A chemical analysis may be made by BHEL on specimens machined from the surface of any forging. The forging will be acceptable if the chemical composition, thus determined, is within the Product Analysis check limits set forth in applicable Material Specification.

6.10.4 Referee Methods - Unless otherwise set forth in the Forging Drawing, Material Specification, this Specification or Part Specification, the following will be applicable as Referee methods. Unless otherwise specified, the latest issue shall apply.

Chemical composition	ASTM E350 or ASTM E352
Grain size	ASTM E112
Hardness test	ASTM A370
Impact test	ASTM A370
Inclusion content	ASTM E45
Liquid penetrant test	ASTM E165
Magnetic particle test	ASTM E709
Metric conversions	ASTM E 380
Stress rupture test	ASTM E139 and ASTM E292
Tensile test	ASTM A370

6.11 Certificate of Conformance

6.11.1 Internal Supplier – Shall promptly submit the Certificate of Conformance to Manufacturing Quality Assurance.

6.11.2 External Supplier - Shall promptly submit the Certificate of Conformance to BHEL address shown on the Purchase order at the request of BHEL.

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6.11.3 A Certificate of Conformance for each rotor forging shall state that the rotor forging was processed in accordance with the requirements of this Specification and other applicable documents. The Certificate shall be signed and dated by an authorized Supplier Representative and shall, as minimum, include the following information:

- Supplier's name/identity
- Heat Number(s)
- BHEL Purchase Order Number
- BHEL Forging Drawing Number and Revision letter or Number (as applicable)
- BHEL Serial Number
- BHEL Material Specification, Grade and Revision(s) Number
- Supplier Process manufacturing Plan (MPP)/ Identification Revision Level and Revision date
- All Test Data
- Heat treating times, temperature, cooling media

Attachments
- Ultrasonic Test Report 9When required)
- Applicable SDR(s) (As applicable)
- Photomicrograph(s) (When required)

6.11.4 The supplier shall submit as specified in Paras. 6.11.4.1 and 6.11.4.2 copies of the certification, including all necessary attachments, to BHEL sourcing team.

6.11.4.1 DELETED.

6.11.4.2 The Certification for all forgings, including those in para. 6.11.4.1 shall be retained by the Supplier for at least seven (7) years. They shall be available for review by BHEL upon request.

6.11.5 The Supplier shall electronically self release forgings prior to shipment through the BHEL sourcing team concerned personnel.

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6.12 Audit

6.12.1 BHEL reserves the right to periodically audit the supplier's facilities and practices. Such audits shall not relieve the Supplier from the responsibility of producing the material in a suitable condition.

7. NOTES

7.1 The application of this specification shall make null and void any prior agreement, understanding or documentation, which violates the requirements set forth in this specification.

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RECORD OF REVISIONS

Rev. No.	Date	Revision Details	Revised By	Approved By
00	22.07.1989	FIRST MADE	S K SRIVATSA	E V ADITYA
01	26.12.1994	COMPLETELY REVISED AND RETYPED IN LINE WITH P3B-AG10, REV'E'.	VAR	E V ADITYA
02	18.01.2021	SPEC GENERALLY REVISED	Shridhar	Kamaldeep
03	17.06.2021	REVISED AND RETYPED INLINE WITH P3B-AG10, REV 'K'	Shridhar	Kamaldeep

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