**Test Schedule for Metallic Materials**

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| **Title:** | **Project/System :** |
| **Test Schedule for Metallic Materials for** **<LRU/SYSTEM Name>for <Platform name>** | < Project/System Name> |
| **LRU/System Part No.**  |
| <No.> |
| **Critical Level** |
| <A/B/C/D/E> |
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|  |  |
| --- | --- |
| **Manufacturing Plant** |  |
| **Company Name** |  |
| **Material Specification** |  |
| **Alloy Grade** |  |
| **Alloy Type** |  |
| **Supply condition** |  |
| **Heat treatment condition** |  |
| **Size range** |  |
| **Application** | Military Aircraft and Aero Engine Applications |

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**1.0 SCOPE**

1.1 This Test schedule establishes the airworthiness qualification testing requirements for \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Table 1: Size Ranges**

|  |  |
| --- | --- |
| **Size (Dia/Section Size mm)** | **Operation** |
|  |  |
|  |  |
|  |  |

1.2 Equivalent International Material Specification/Grades:

**Table 2: List of Equivalent Grades**

|  |  |
| --- | --- |
| **Material Specification** | **Grade** |
|  |  |
|  |  |
|  |  |

1.3 All reference documents are in their latest revision unless noted otherwise in another Table.

**2.0 APPLICATION**

2.1 These products have been used typically in the aerospace sector due to the cost-effective nature and versatility of the alloy------------------------------------------------------------------------------------------------------

**3.0 SUPPLY CONDITION**

**4.0 CHEMICAL ANALYSIS**

4.1 For chemical analysis three samples shall be taken from each melt.

4.2 The sample shall be tested for the chemical composition by Spectro/Leco Analyser as per ASTM E 1251 / as applicable.

**Table 3: Chemical Composition (wt. %)**

|  |  |  |
| --- | --- | --- |
| **Elements (wt %)** | **MIN** | **MAX** |
|  |  |  |
|  |  |  |
|  |  |  |

**5.0 MANUFACTURE**

 5.1 Ingots:

 5.1.1 Raw Materials:

 5.1.2 Ingot Moulds:

 5.1.3 Identification:

 5.2 Forged/ Rolled Bars/ Flats/ Sheets/ Rods/Wires:

**6.0 HEAT TREATMENT**

 6.1 Annealing:

 6.2 Hardening & Tempering:

**7.0 COUPON LEVEL TESTING**

**Table 4: Testing required for Forgings stocks/Additive manufacturing/Castings/Forgings**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Test** | **Testing Method** | **Direction of Samples (X - Horizontal, Y – Inclined at 45o and Z - Vertical)** | **Acceptance****Criteria as per relevant material standard** | **No of samples to be tested** | **Compliance (Test pass/fail) with remarks, if any** |
| Tensile test at room temperature | ASTM E8 | Decided in LTCC | As per Material Specification | Decided in LTCC |  |
| Brinell Hardness | ASTM E10 | Decided in LTCC | As per Material Specification | Decided in LTCC |  |
| Microstructure | ASTM E3&E407 | Decided in LTCC | As per Material Specification | Decided in LTCC |  |
| Chemical composition  | Relevant ASTM standard | Decided in LTCC | As per Material Specification | Decided in LTCC |  |
| Residual stress  | XRD technique (ASTM E 2860) | Decided in LTCC | Decided in LTCC | Decided in LTCC |  |
| FPT | Relevant ASTM standard | 100% surface coverage of the part | Mil S 1907 Gr B for critical partGr C for non-critical part | All parts to be tested 100% |  |
| MPI (Applicable for steel except austenitic stainless steel or nonmagnetic steel) | Relevant ASTM standard | 100% surface coverage of the part | Mil S 1907 Gr B for critical partGr C for non-critical part | All parts to be tested 100% |  |
| X ray CT Scan | BS EN 16016 | 100% coverage of the part | AMS 2175 Gr A or Gr B for critical partGr C for non-critical part | All parts to be tested 100% |  |
| Tensile test at elevated temperature | ASTM E 21 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Low cycle fatigue | ASTM E 606 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| High cycle fatigue | BS 3518 Part 2 or relevant ASTM Specification | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Stress rupture test | ASTM E 139 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Creep | ASTM E139 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Thermal fatigue | ASTM STP 465 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Stress corrosion cracking | ASTM G 47  | All 3 directions required | As per Material Specification or Test generation Purpose | 3 per each direction |  |
| Salt spray test | ASTM G 44 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Electrical conductivity test | ASTM E 1004 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| K1c Fracture toughness test | ASTM E 399 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Combined smooth and notch tensile test | ASTM E 292 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Notch tensile test | ASTM  | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Shear test | DIN 50141  | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Impact test at room or subzero temperature | ASTM E 23  | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Intergranlar corrosion | ASTM A 262 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Pin on Disc wear test | ASTM G 99 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Pitting corrosion | ASTM G 46/ G48 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Exfoliation corrosion | ASTM G34  | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Inclusion rating | ASTM E 45 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Grain morphology and size | EBSD -ASTM E 2627 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Texture study  | EBSD - ASTM E 2627 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Depth of decarburization | ASTM E 1077 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Flexural test | ASTM D 790 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Compression test  | ASTM E 9 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Hot salt corrosion | ASTM G 41 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Crevice corrosion | ASTM G 78 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Fretting wear | ASTM G 133 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Poisson ratio | ASTM E 132 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |
| Retained austenite | ASTM E 975 | Decided in LTCC | As per Material Specification or Test generation Purpose | Decided in LTCC |  |

**8.0 RAW MATERIAL POWDER TESTING (For Additive Manufacturing)**

**Table 5: Powder Testing**

|  |  |  |
| --- | --- | --- |
| **Test** | **Testing standard or Method** | **Acceptance Criteria as per Powder Specification or finalized after 3 batches testing** |
| Powder Source |  |  |
| Powder type (Virgin /Reuse) | **-** |  |
| Particle size | SEM  |  |
| Particle size distribution | Laser particle size analyzer or Sieve analysis |  |
| Apparent density (Hall flow meter) | ASTM B 212 |  |
| Tap density | ASTM B 527 |  |
| Flow rate (Hall flow meter) | ASTM B 214 |  |
| O2 | ASTM E1409 |  |
| N2 | ASTM E1409 |  |
| H2 | ASTM E1447 |  |
| Powder chemical composition | ASTM E2371 / ASTM E539 |  |
| Powder porosity (optional) | Gas Pycnometry or CT X Ray Scan  |  |
| Particle shape | SEM |  |

 **9.0 MACROSTRUCTURE INSPECTION**

9.1 Macro etch test shall be carried out on two samples as per ASTM A 604 / as applicable.

 **10.0 ULTRASONIC INSPECTION for Forging/Mill Forms**

**Table 6: Details on acceptance standard as per AMS 2630/2631/2154**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Quality class** | **Single discontinuity FBH size (max)** | **Multiple discontinuities FBH size (max)** | **Linear Discontinuity FBH size (max)** | **Loss of back wall reflection % (max)** |
| As per Customer requirement |  |  |  |  |

 **11.0 VISUAL INSPECTION**

11.1 The surface of the bars shall be inspected visually for deep scratches, cracks, seams, burnt spot, excessive scale and rust. It should be free from porosities, laps or any other foreign material.

**12.0 RADIOGRAPHIC INSPECTION for Casting /Mill Forms**

12.1 Radiographic inspection shall be conducted in accordance with ASTM E 1742

12.2 Acceptance of Radiography test as per AMS 2175 Quality Class/ as per Customer requirements

**13.0 DIMENSIONAL INSPECTION**

13.1 As per Drawing requirements

**14.0 APPROVAL**

14.1 Developing agency shall establish the control factors of processing, which would yield products meeting the respective requirements of this schedule consistently for bars. These shall constitute the approved manufacturing procedures for each product and shall be used for subsequent production of products. If necessary to make any change in factors of processing which could affect quality or consistency in properties of the product, vendor shall submit a detailed statement of the revised operations for re-approval.

14.2 Control factors for producing the product include, but not limited to the following:

-Melting procedure

-Ingot reduction ratio

-Forging/Rolling procedure

-Working temperature range

-Intermediate size, discard, dressing

-Heat treatment

-Inspection procedure

**15.0 RECORDS**

**15.1 Maintenance of facilities**

15.1.1 Developing agency shall keep record demonstrating the facilities used to produce, control and measure and the tests of the respective product during approval. It should be properly maintained and also checked at stage intervals against acceptable standards of accuracy.

15.1.2 The facilities such as heat treatment, melting furnace and measuring/testing equipment must be calibrated and the calibration record should be produced on demand by Airworthiness agency.

15.1.3 In case of heat treatment / preheating furnaces, a uniform temperatures zone should be specified with temperature variation therein the process.

**15.2 Process Sheets**

15.2.1 Developing agency shall prepare and maintain documented instruction defining the processing methods and routing in the manufacturing cycle for producing the respective products.

15.2.2 Process sheet should capture info on the melt calculation, master alloy used, furnace, raw material and its sources, any recycled material used, ingot preparation, ingot casting, homogenization treatment (if required), mill form fabrication (rolling/forging), complete details of forging/rolling process.

**15.3 Traceability**

15.3.1 Each vendor shall maintain records to produce traceability of the forged/rolled bars back to particular melt. Disposition of all stock shall be maintained by the vendor (e.g., scrapped for cause, supplied to etc.). Record shall be maintained at least ten years.

**15.4 Report**

15.4.1 Vendor shall furnish reports giving complete processing details of final supply to determine conformance to the technical requirement of the schedule. The schedules shall be included as enclosure to the type test record along with copy of application of approval.

1. Chemical analysis – Ladle – Mill TC
2. Heat No. details
3. Heat treatment batch No. and cycle graphs
4. Mechanical test reports
5. Metallography (Macro etch, Inclusion rating, Grain size)
6. Ultrasonic test report / MPI / Cleanliness Test
7. Dimensional & visual inspection report
8. Certificates and report review
9. Any other customer requirement

**16.0 RE-SAMPLING AND RE-TESTING**

 If any of the test specimen first selected FAIL to pass the mechanical tests, two further specimens from the same batch shall be selected for re-testing.

16.1 If the test specimens from both these additional specimens pass, the batch represented by the specimens shall be considered as PASS. If the test specimen from either of these additional specimens FAIL, the failure of any shall be the cause of rejection of the batch. Re-testing shall be done with the knowledge of the Airworthiness agency/QA agency.

16.2 During ultrasonic inspection of stocks at suitable stage of manufacture if unacceptable defects found, the area containing each indication shall be removed and re-examined if adequate analysis can be made from observation of ultrasonic indications to identify cause of indication, no further investigation would be necessary. If the nature of extent of the indication cannot be adequate analyzed by examination, the removed portion shall be further sectioned to complete the analysis.

16.3 The product faces adjacent to indication shall be etched and examined. If ultrasonic indications are determined to be isolated and caused by or associated with segregation, voids or inclusion the remainder of the affected slab may be used. However, if etched of the adjacent cut faces of the stock reveals additional evidence of segregation, voids or inclusions, further cutting, etching and examination shall be conducted until it is assured that the defective area has been removed.

**17.0 IDENTIFICATION (AS PER AMS 2806)**

1. P.O No.

2. Material specification No. including Revision Letter

3. Heat No.

 4. Bar No.

5. Nominal Size

 6. Heat treatment Batch No. and Date

 7. HT condition

 8. Vendors name and insignia/symbol

**18.0 PACKING**

20.1 The product shall be prepared for shipment in accordance with commercial practice to avoid any physical damage during shipment and storage as per ASTM A700 / as applicable.

**19.0 REJECTIONS**

21.1 Material not conforming to this test schedule or to the unauthorized modifications will be subject to rejection.

**20.0 Notes**

20.1. All data logs for 3 development batches to be kept till approval stage and further as per IMTAR21 SubpartC3.

20.2. All Process & Testing documents to be submitted thereafter.

20.3. Process control document has to be finalized tentatively before the first development batch and send it to RCMA / CEMILAC for coordination. It should be finalized and control copied after development of 3 batches.

20.4. Process and Testing have to be informed to RCMA / CEMILAC and DGAQA in advance to plan the coordination for all three development batches. Physical or online witness will be intimated by TAA based on their resources and work load.

20.5. After production of the first batch is completed, process compliance test and test reports are duly signed by DGAQA which are then forwarded to RCMA/ CEMILAC for clearance and after clearance the material is then dispatched to customer.

20.6. A subsequent batch of two or more must be produced, tested in accordance with the test schedule, and all the results duly signed by DGAQA, along with performance feedback, must be submitted to RCMA / CEMILAC to obtain LoA.

20.7 It does not cover any long cycle testing such as notch tensile, fatigue, creep, stress rupture, corrosion, wear, erosion and any physical/thermal/electrical properties. When the OEM/designer/customer selects this material bar for any aircraft/aero engine applications, it is the OEM/designer/customer responsibility to ensure the part specific properties (any additional coupon level and part level) requirements in the machined part. Failing which, OEM/designer/customer is only accountable for the airworthiness lapse.

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