

**Scope of work for
Additive manufacturing of Advance Turbo Gas Generator (ATGG) components
using Inconel 718**

1. **Objective:** Vendor shall carryout the additive manufacturing of Advance Turbo Gas Generator components (ATGG) using Additive Manufacturing technology for aero engine development activities using Inconel 718.
2. **Pre-qualification criteria:**
 - 2.1 Vendor should have executed similar components using additive manufacturing technology such as Laser Powder Bed Fusion (LPBF) and Electron Beam Powder Bed Fusion (EB-PBF). Vendor shall have required infrastructure such as additive manufacturing equipment's, materials, software and skilled manpower for execution of the intended activities. Proof of the above details regarding the facilities and relevant shall be provided along with tender documents.
 - 2.2 Vendor shall attend the Prebid meeting as per the date specified by GTRE for understanding the technical requirements. Proof for Prebid meeting shall be attached by vendor along with tender document for bid participation. Vendors who shall not attend the Prebid shall not be considered for the final bid.
3. **Specifications and Quantity:** Vendor shall manufacture Advance Turbo Gas Generator components using additive manufacturing as per the specifications mentioned below.

Sl. No	Item Description	Drawing number	Quantity	Material	AM technologies	Remarks
01	Combustor casing - Non-recurring service	AE 10110	01	Inco-718	LPBF / EB-PBF	Specimen details regarding type of test and quantity are as per Annexure "A & B "
02	Combustor casing - Recurring item		02			
03	Compressor Stator Stage 4 - Non-recurring service	AE10004	01			
03	Compressor Stator Stage 4 - Recurring item		01			
05	Exhaust Cone – Non-recurring service	AH10100	01			
06	Exhaust Cone – Recurring item		01			

Table 01: Details and specification of the proposed components for additive manufacturing

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4. Scope of work of vendor:

- 4.1.1 Vendor shall carryout the additive manufacturing of Advance Turbo Gas Generator components as per the specification mentioned Para 3.0 and deliver the fully machined and finished component as per drawings given in Annexure 'C'
- 4.1.2 Vendor shall carry out pre-processing of the component's feasibility studies using CAD data provided by the GTRE. Any discrepancy in the data shall be brought to the notice of GTRE. Report on feasibility studies on the various components shall be provided to GTRE along with input data as per Para 8.3.3.
- 4.1.3 Vendor shall perform feasibility study of various component provided as per Para 3.0 to avoid any dimensional deviation and part defects. Suitable process such as parameter optimization and process simulation shall be carried out by the vendor for Inconel 718 and equipment proposed for fabrication. Report on parameter optimization and process simulation shall be provided to GTRE as per Para 8.3.2.
- 4.1.4 Vendor responsibility to carry out CAD model modification for ease of manufacturing using additive manufacturing technique. The modification of design shall be discussed with GTRE before modification & implementation without affecting the functionality or the base design. Vendor shall consider the required machining, finishing and inspection requirements during CAD model modification as per 2D drawing of the part.
- 4.1.5 Optimized part orientation for minimum support and part deviation shall be carried out by the vendor. Support details on the components and removal method and tool details shall be discussed with GTRE to avoid any impact on functionality of the components.
- 4.1.6 Realization of the components using Inconel 718 as per the Para 3.0 and material shall be sourced from OEM / authorized sources as per the recommendations of additive manufacturing equipment manufacturer for obtaining the required mechanical and metallurgical properties. Details regarding the powder source and powder properties such as size, shape, chemical composition and flowability shall be provided to GTRE. Only VIRGIN powder shall be used for manufacturing of specified components. Powder samples (50 gram) of each specified material shall be provided to GTRE for reference along with OEM or authorized vendor material test data.
- 4.1.7 Vendor shall provide the details on the various process parameters / certificate stating the usage of optimized parameter for realization of proposed components.
- 4.1.8 Vendor shall carryout the realization of the components as per para 3.0 using the finalized CAD model and process parameters after confirmation from GTRE
- 4.1.9 Minor design modification such as change in thickness, radius, addition of fillet to be considered for realization of the components by vendor without any additional cost.

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- 4.1.10 Vendor shall carryout the appropriate heat treatment (stress relieving, Solution Treatment and ageing as applicable based on the material) Details regarding the heat treatment cycles shall be discussed with GTRE. Relevant information in the form of report shall be provided to GTRE after completion of the activities.
- 4.1.11 Vendor shall carryout the realization, heat treatment and machining of the required test specimens and conduct the test as per the standard provided in Annexure "A". The quantity of specimens specified in Annexure 'A' to be delivered to GTRE.
- 4.1.12 Vendor shall carryout the post processing activities such as support removal, machining and surface finishing as per the attached details Annexure 'C'. Required special tools and fixture shall be designed and fabricated as per the requirements. Details regarding the post processing plan shall be provided by the Vendor to GTRE before initiating any post processing activities. Vendor shall provide all the relevant data regarding post processing activities in the form of report to GTRE as per Para 8.3.7.

Milestone	Progress	Time specified by vendor	Remarks
T0	3D CAD models,2D drawings and other relevant details shared by GTRE		Milestone 1 – Non-recurring service
T0 + 30 days	CAD model modification, pre-processing and simulation		
T0 + 60 days	Realization of specimen and mechanical and metallurgical testing		
T0 + 75 days	Clearance by GTRE for realization of components		
T0 + 180 days	Delivery of fully finished components as per Table 1 of Para 3.0		Milestone 2 – Recurring items

Table 02: Execution plan for AM part realization

- 4.1.13 Vendor shall carryout the quality assurance of additive manufactured components such as dimensional inspection, non-destructive test such as florescent penetrant test, radiography and Computed tomography test as per the standards. Quality acceptance details for the realized components are provided as per the Annexure 'B'. Traceability of the equipment's used for NDT along with calibration shall be provided by the vendor.

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4.2 Inspection and testing:

Vendor has to carry out the dimensional inspection and non-destructive test as per the annexure 'A' & 'B'. Quality assurance report of additive manufactured components shall be provided to GTRE.

4.3 Installation and commissioning: Nil

4.4 Training: Nil

5. Scope of work of GTRE:

5.1 GTRE will provide the required 3D CAD models and 2D drawings for realization of ATGG components along with material details, quality assurance data, test specimens and test details during pre-bid meeting after signing of NDA.

5.2 GTRE will provide all the necessary approval as and when required.

6. **Acceptance criteria:** The additive manufactured test specimens and components will be accepted only after they meet the following criteria:

Specimen test results as per Annexure 'A'.

6.1 Reports on non-destructive tests such as Flurocent penetrant test, radiography, Computed tomography test results as per the acceptance details provided in Annexure 'B'

6.2 Dimensional inspection reports for all the components shall be submitted by the firm and the components are required to meet the dimensions specified as per the CAD models and drawing details as per Annexure 'C'.

7. Warranty: Nil

8. Deliverables by the vendor:

8.1 Hardware/Software deliverables:

8.1.1 Fully machined and finished Additive manufactured ATGG components as per the specification and quantity provided in Para 3.0.

8.1.2 Test specimen as per the details provided in Annexure 'A'.

8.1.3 The vendor shall deliver the tested specimens back to GTRE along with traceability.

8.2 Service deliverables:

8.2.1 Vendor shall carryout the all the relevant activities as per the Para 4.0

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8.3 Documents:

8.3.1 ALL the material test and non-destructive test documents as mentioned in Annexure 'A' & 'B' of additive manufactured specimen and components after completion of all the required activities.

8.3.2 Report on parameter optimization and process simulation shall be provided to GTRE.

8.3.3 Report on feasibility studies and CAD modification based on the data provided by GTRE.

8.3.4 3D CAD model Data used for realization of components.

8.3.5 Test specimen realization plan.

8.3.6 All quality assurance reports as per Para 4.0.

8.3.7 All other relevant documents as specified in Para 4.0.

8.3.8 One-set hard copy and softcopy on components full 3D inspection

8.3.9 The vendor shall provide the raw data from testing such as Tensile test: stress strain data for all the tests, LCF: Stress response from 0-failure cycle, stress strain plot for 1st cycle, 10th cycle, 100th cycle, 500th cycle, 1000th cycle, 1500th cycle and 2000th cycle to GTRE.

9. Delivery period:

Milestone	Deliverables	Delivery Period	Remarks
Milestone – 1 All Non-recurring service	1. Hardware deliverables as per 8.1.2 and 8.1.3 2. Document deliverables as per 8.3.1, 8.3.2, 8.3.3, 8.3.4, 8.3.5 and 8.3.9.	60 days (To + 2 months)	
Milestone – 2 Recurring items	1. Hardware deliverables as per 8.1 2. Quality assurance report as per 8.3.6. and all other relevant documents as per 8.3.7 and 8.3.8.	180 days (To + 6 months)	✓
To: - placement of order			

Table 03: Delivery milestone

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10. Payment terms:

10.1 1ST payment against the successful delivery and acceptance as per **Milestone-1.**

10.2 2nd payment against the successful delivery and acceptance as per **Milestone-2.**

10.3 All other terms are as per GTRE payment terms and conditions.

11. General terms and conditions: As per GTRE terms and conditions.

11.1 Provision for GTRE representative to visit vendor premises to witness the additive manufacturing various stages, quality inspection and mechanical testing.

11.2 Proper packing and transportation of manufactured test specimens and components for damage free delivery to GTRE.

11.3 Vendor shall provide Non-Disclosure Agreement (NDA) document provided by GTRE to obtain the relevant technical document from GTRE for proposed activity.

11.4 Vendor should participate in pre-bid meeting before submission of quotation.

11.5 Vendor shall provide the price bid as per Non recurring cost which includes CAD model modification, pre-processing, simulation and specimen realization & testing and recurring cost which includes cost of additive manufactured components machining, part quality assurance and freight charges. Recurring cost shall not exceed 80% of the total cost.

11.6 In case of repeat order, the vendor is entitled to claim only the recurring costs for each proposed additional component.

12. Documents to be submitted along with quotation:

12.1 Vendor shall submit Specification / scope of work along sealed, signed and accepted in all pages along with quotation.

12.2 Vendor shall submit the Pre bid attendance certificate with tender document.

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Annexure "A"

SL NO	Types of tests	Orientation	Standard	No of specimens	
				Tests by vendor	For GTRE
01	Room temperature Tensile test	Vertical	ASTM E 8	06	06
02	High temperature Tensile test	Vertical	ASTM E 21	06	06
03	Stress rupture test	Vertical	ASTM E 139	06	06
04	LCF	Vertical	ASTM E 606	06	06
05	HCF	Vertical	ASTM E 466	06	06
06	Microstructure test	NA	ASTM E 112	05	05

Table 05: Details of test specimens to be manufactured by the vendor.

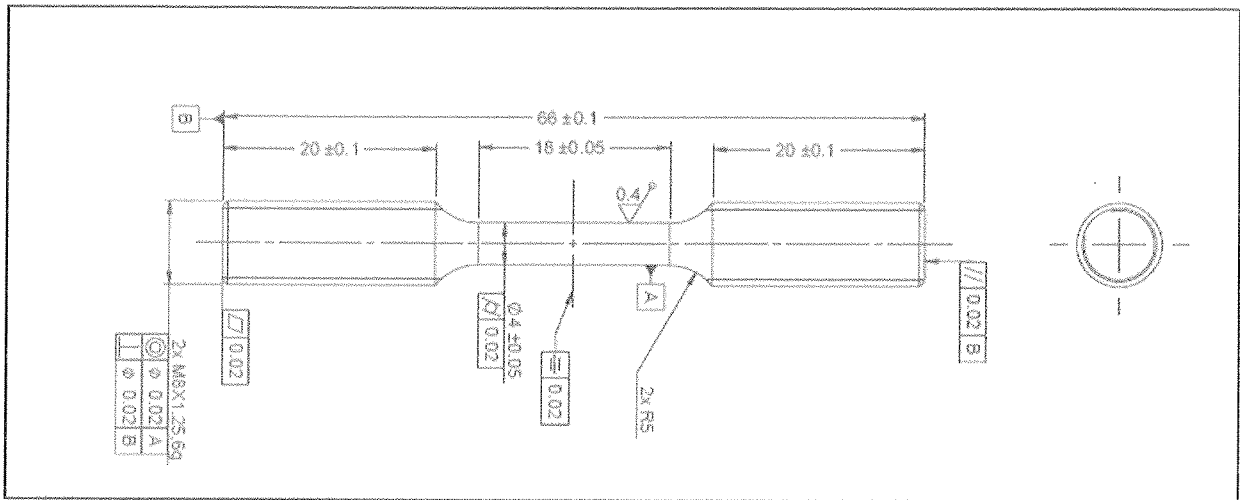
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SI No.	Types of tests and standard	Specimen details	Required minimum test results				
			0.2% YS (MPa)	UTS (MPa)	El. (%)	RA (%)	
01	Room temperature Tensile test	Sketch 1	1035	1275	10-12	20	
02	High temperature Tensile test @650°C		860	1000	10-12	20	
03	Stress rupture test@ 650°C	Sketch 2	Stress (MPa)	Life (Hours)	-----		
			690	23			
04	LCF @ 590°C	Sketch 3	Maximum Stress (MPa)	Minimum Stress (MPa)	Life (Cycles)	El. (%)	RA (%)
			896	0-33	To be recorded	--	
05	HCF @ 650°C	Sketch 4	500	--	To be recorded	--	
06	Microstructure test	Sketch 5	Micro Porosity	Inclusion Content	Inter Granular		
			The micro porosity in the air foil region shall not be more than 1 % for any given frame (dimensions of each frame being 1 mm x 1 mm). In other areas the micro porosity levels shall not be more than 2% in any given frame	The average inclusion content, if present, shall not exceed 0.1%	The maximum depth of inter-granular attack, alloy depletion and carbide oxidation allowable after any processing is 0.025 mm		

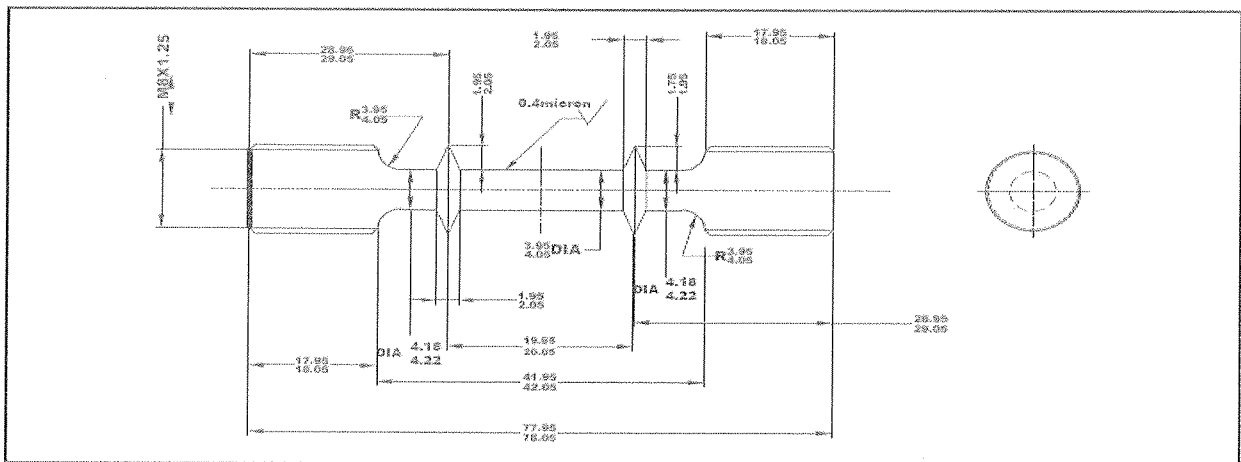
Table 06: Details of Test Conditions and Mechanical Properties

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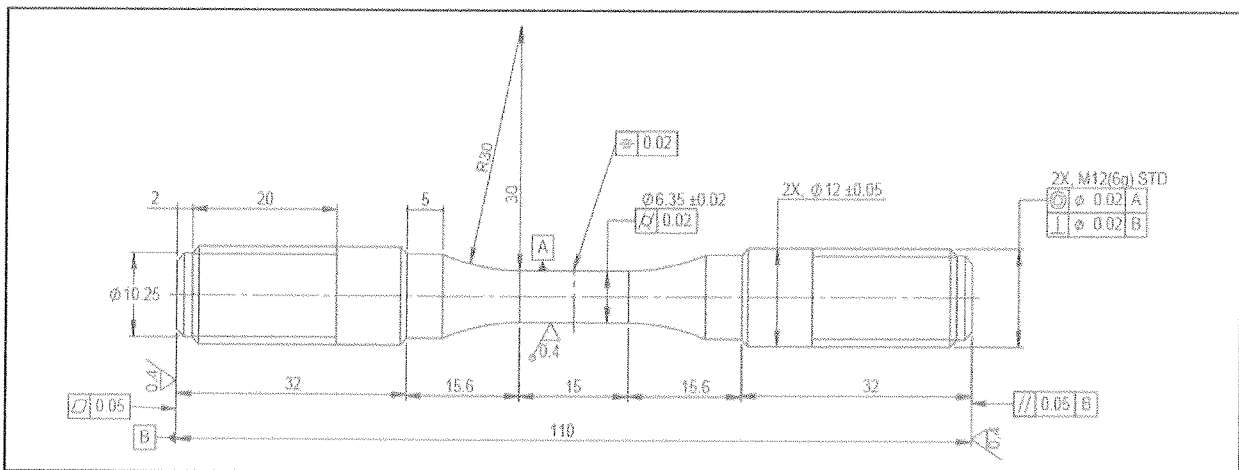
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Sketch 1: Specimen for RT tensile testing (Round) (as per ASTM E8/E21). The same specimen will be used for HT tensile.

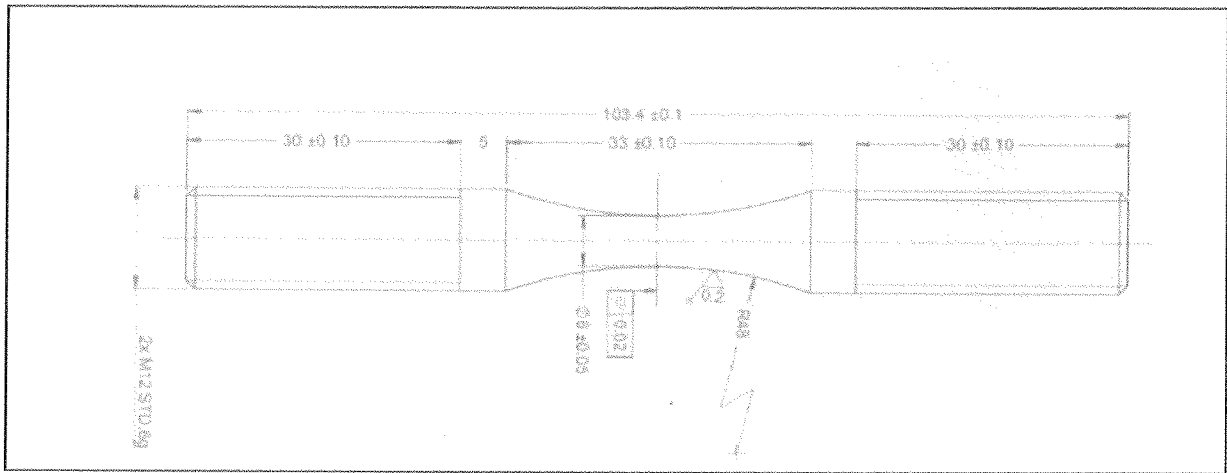


Sketch 2: Specimen for Stress rupture test (Round) (as per ASTM E139).

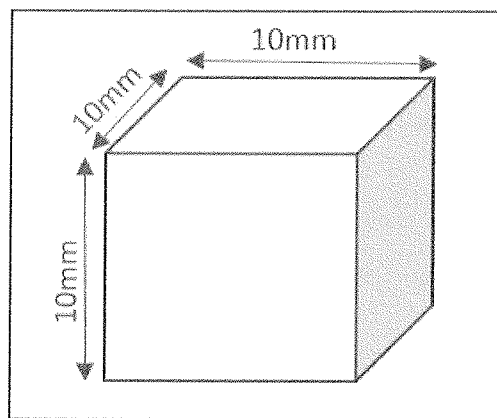


Sketch 3: Specimen for Low Cycle Fatigue (Round) (as per ASTM E606).

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Sketch 4: Specimen for High Cycle Fatigue (Round) (as per ASTM E466)



Sketch 5: Micro structure test specimen detail

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Annexure "B"

Sl No	Quality acceptance details	Standard	Acceptance value
01	Dimensional inspection	----	<ul style="list-style-type: none">As per the details provide in Annexure 'C' on finished surface
02	Fluorescent Penetrant test	ASTM E-1417	<ul style="list-style-type: none">No Porosity and No Cracks on finished surface
03	Radiography test	ASTM E-1742	<ul style="list-style-type: none">Radiography shall be performed for both process and product development in accordance with ASTM-E-1742, to accept/reject criteria as indicated in the component / specimen drawing. (Ref Annexure 'C')Technique Sheets to be prepared to ensure 100% Coverage any put up to GTRE to approval.
04	Computed tomography test (only on Aerofoils)	ASTM-E-1570	<ul style="list-style-type: none">Cracks, through defects are not acceptableThe max number of permissible defects in each zone should be within the following limits as per Annexure 'C'.<ul style="list-style-type: none">No more than 2 defects per face in zone 1. aero foil trailing edge (5 band)No more than 2 defects per face in zone 1, aero foil fillet radius (6 band)<ul style="list-style-type: none">No more than 2 defects per face in zone 2.Indications less than 0.25 are acceptable provided they are clearly separated by a space equal to 5 times the largest adjacent indication.<ul style="list-style-type: none">Salvage by welding is not allowed.Defects which will be removed by subsequent machining are allowedTechnique Sheets to be prepared to ensure 100% Coverage any put up to GTRE to approval.Details regarding Scan speed and resolution shall be provided.

Table:7 Input data, Dimensional and NDT details of additive manufactured components

Provision for GTRE personnel to witness NDT inspection process

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Annexure "C"

1. CMM dimensional inspection of aerofoil and 3D formed features on fully machined, surface finished and ready to use component to be carried out and results to be submitted in form of dimensional inspection report. (As per component drawings)
2. References for inspection of additive manufactured parts to be noted and if any additional requirement shall be decided by the vendor.
3. Tolerances on machined faces are ± 0.25 mm unless otherwise stated.
4. Tolerances on drilled holes are 0.25 mm positive and 0.05 mm negative unless otherwise stated.
5. Surface roughness to be 3 Ra unless otherwise mentioned.
6. Sharp corners to be removed with a minimum tolerance of 0.25mm and maximum tolerance of 0.50 mm.
7. Chamfer value to be taken as $1 \times 45^\circ$ unless otherwise stated.
8. Radii to be taken as 1mm unless otherwise stated.
9. Non dimensional and non-displayed geometry to be taken from 3D model.
10. All residual machining marks must fall within surface finish requirements
11. Angular tolerance is $\pm 0^\circ 15'$ unless otherwise stated.
12. Surface texture limits given below aerofoil apply to gas stream direction.

Sl. No	Item Description	Drawing number	Remarks
01	Combustor casing	AE 10110	Drawings shall be provided by GTRE during pre-bid meeting after obtaining the signed NDA
02	Compressor Stator Stage 4	AE10004	
03	Exhaust Cone	AH10100	

Table number 08: Drawing details of proposed components

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