

Annexure-1

DETAILED TECHNICAL SPECIFICATIONS

3 –D Digital Image Correlation system for Full Field 3 Dimensional Displacement and Strain Measurement

1. Preamble: -

BHEL R&D, HYDERABAD intends to establish a 3D Digital Image Correlation (DIC) system facility for 3-dimensional strain measurement on stationary as well as rotating test object.

The system will be used for both laboratory research work and studies in the field like thermal power plant, balancing tunnel, rotor test rig etc. Since the system is needed for field applications, the system must be portable. Given the multiple applications, extensive technical support from the vendor is required. Vendors who have sufficient experience and expertise in realistic research using 3D DIC may participate in the tender.

It is mandatory that the bidder must have supplied the 3D DIC system to research laboratory/institutes in India. Performance certificates / Technical Papers from user institute/ laboratory may be attached with the bid.

2. Parameters to be measured:

- i. Contour with coordinates.
- ii. In-plane displacements along X and Y Directions.
- iii. Out of plane displacements - Z Direction.
- iv. Strains: ϵ_{xx} , ϵ_{yy} , γ_{xy} , Engineering and Principal strains.
- v. Vector Directions
- vi. Principal Strain Directions
- vii. Full Field Accelerations (X, Y and Z Direction)
- viii. Dynamic measurement with Full Field Frequency Analysis.
- ix. Full Field FFT Analysis – Amplitude vs. Frequency
- x. Amplitude Variable: - Displacements, Strains and Accelerations

3.Details of the test object

- i. Speed/orientation of the test object: 0 to 3600RPM / Vertical
- ii. Operating Environment for the test object: Air and Nitrogen
- iii. Pressure of Environment: 50 micro bar to 5 bar
- iv. Temperature of the test object: Room temperature to 800 Deg C
- v. Diameter / length of the test object: Max 1.5 meter / length max 1.2 meter
- vi. Area of interest for measurement: 10mmx10mm to 500mmx500mm square-shape (surface could be flat or curved with maximum of 1m diameter)
- vii. Min / Max Strain (Range / Resolution): Range: +/- 5000 micro strain; Resolution: 50 micro strain or better
- viii. Temperature near the camera: Camera shall be operated safely up to 50 Deg C.
- ix. Speckle pattern paint life on test object: up to 2000 Hrs (paint used for speckle pattern on the test object will get exposed to the temperature of 800 Deg. C for this duration).

4. System Configuration

4.1 Software.

4.1.1 Image Acquisition Software

Images should be captured in the following formats:

4.1.1.1 Low Speed: -

- i. Manual: Press of keyboard or mouse click.
- ii. Time Capture: User can define the time interval for a limited or unlimited period of time. The user should have the option to stop and subsequently restart the image acquisition from the point it had stopped and without any loss of stored data.
- iii. Flexible Capture for Fatigue Measurements: Capture first set of images in a certain time period and subsequent set of images in different time periods.
- iv. Hardware trigger: Using TTL (Transistor logic) or input signal from an external sensor or manual or time.
- v. Analog Trigger: Based on the analog signal input
- vi. The software should be able to handle over exposed images and show clear images. and/or software should provide tools to avoid over exposure (automatic exposure adjustment)
- vii. The software should clearly show if the calibration carried out is correct and should indicate if the sources of errors for calibration, if any.
- viii. System should be capable of acquiring load cell, displacement sensor etc. at least 8 data channels and display-selected channels without disturbing the acquired data.

4.1.1.2 High Speed: -

- i. The software should be integrated with the High Speed Cameras.
- ii. Image capture via TTL.
- iii. Features of vi, vii and viii as mentioned above.

4.1.2 3D Digital Image Correlation Software

Software with the following features are needed:

- i. Resolution of displacement measurement.
For a Field of View of 100mm; In Plane Displacement = 1 microns; Out of Plane displacement = 2 Microns. Resolution of strain measurement: 50 micro strain or better.
- ii. Measurement range: Strain range: Max mean static value +/- 5000 micro strain and pk-pk dynamic 1000 micro strain
- iii. Expected strain computation algorithms: Lagrange, Engineering and Principal strains
- iv. Smoothing of data.
- v. User selection of the subset size, step size and strain filter size.
- vi. Indication of the appropriate subset size to be selected.
- vii. Indication, if the correlation carried out is correct and if not, indicate sources of errors.
- viii. Correlation: Software should generate automatic start point and sequence analysis.
- ix. 3D Displacement and Strain measurements.
- x. 2D and 3D Plots of the images
- xi. Co-ordinate transformation
- xii. Export of data/plots in ASCII, TIF, JPEG, AVI, clipboard, etc.
- xiii. Profile over a line, point or area measurement.
- xiv. Animation of the result

- xv. Color coded display of Displacements, Tangential Strains, Principal Strains (combined with direction)
- xvi. Computation of Principal Strains, Engineering strains and Lagrange strains
- xvii. Velocities in X, Y and Z Direction.
- xviii. Full Field FFT analysis of Displacements, Velocity, Acceleration (X, Y and Z Direction) and strains
- xix. Import of 3D DIC Data into a project from other project files.

4.1.3 Software Licenses:

- i. License 1: One Main license with portable controller system.
- ii. License 2: One Post Processing License with workstation.
- iii. Licenses must be on a USB Dongle.
- iv. Update of the software should be free during warranty period.

4.1.4 Speckle Generator Software:

Suitable speckle generator software for generating speckles.

4.1.5 Grid Generator software:

Suitable grid generator software for generating custom built grids.

4.1.6 Any other software which are required for normal operation and post processing of data.

4.2 Optics and Hardware:

A complete 3D DIC system must be quoted and vendors must include all accessories with the system. The application / requirement is clearly mentioned in the specs and it's the responsibility of the vendor to ensure that the system configured includes all necessary optics, hardware and accessories. These may not have been explicitly mentioned in the tender specification, but it's the vendor's responsibility to configure (including all accessories for smooth operation) the software and hardware accordingly.

- i. Camera: 5 MP, 40 fps or better Gigabit Ethernet Cameras – 2 Nos.

Only CMOS Cameras will be accepted technically. The camera must be directly interfaced to the PC without any external interface cards.

- ii. High Speed Cameras with accessories and interface cables: - 2 Nos.
 - Resolution 1 MP at 2000 fps.
 - 12 Bit Monochrome CMOS Cameras.
 - Global Shutter:- Less than 1.5 μ s.
 - Interface: - Gigabit Ethernet.
 - Synchronization of the 2 cameras with data acquisition system
- iii. Giga Bit Ethernet Hub – 1 No.
- iv. Trigger Switch for the camera – 1 No.

- v. Lenses:- C Mount Lens – with focal length:- 16mm , 28mm and 50mm – 2 Nos each

Lenses for High Speed cameras: - F-Mount with focal lengths – 35 mm, 50 mm and 100 mm.

Lenses should be from reputed brands like Schneider, Nikon, Nikor, Tokina, Tamron, Roadgon, Carl Zeiss, Edmond etc.

The vendor should clearly mention the make of the lenses offered.

Vendor must explicitly mention that the cameras and lenses will work in the field conditions.

- vi. IR filters for all the lenses.
- vii. Data Acquisition Module:- 1 No.

- USB Daq.

- Integrated with the Camera Capture.

- 16 Bit ADC.; +/-10 VDC.

- 8 Channels.

- viii. Hard carry case for the Optics.
- ix. Lens Cleaning Kit.
- x. High intensity monochromatic LED illumination system with intensity control to illuminate 1m² area (surface could be flat or curved with maximum of 1m diameter)
- xi. Suitable Tripod for mounting the cameras with 3-way Tripod head in stereo vision- 1 Set
- xii. Suitable Aluminum Channel Mounting unit for the cameras -1 Set
- xiii. Suitable calibration grids for the specified measurement area and range. They should be provided with proper carrying case. Since measurements are done in the field the grids should be rugged. Should the grid drop on the floor it should withstand the impact and be undamaged.
- xiv. **Portable controller system with warranty period of 5 years:** Suitable portable controller system for the data acquisition and DIC algorithm with following or better configuration

2.9. GHz or higher, Quad i7, Minimum 15.6" with 1920x1080 resolution, DVD-RW, 32 GB DDR4 (2400 MHz) RAM, 256 GB SSD, 1TB Hard Disk(7,200RPM), 4GB NVIDIA Graphics Card or better, Windows 10 – 64 Bit , MS Office -2016, USB 3.0 Super Speed Ports Carry Case and other Standard Features.

The Same controller will be used for Low Speed and High Speed Measurements.

- xv. **Fixed controller system with post processing and storage features with warranty period of 5 years:** Suitable fixed controller system for the data acquisition and DIC algorithm with following or better configuration

Dual Intel Xeon processor with each 18 cores with base frequency of min 3GHz, minimum 256GB ECC Type - {32GB, DDR4-2666 MHz} RAM expandable to 1TB, Minimum 512GB SSD, 4TB HDD with 7200 RPM or more, Two No. 2 Gigabit Ethernet ports, LED Monitor with resolution 3840x2160@60Hz or better, Additional One No. Integrated GigaBit Ethernet ports, Genuine Window 10 – 64 Bit Professional, MS Office -2016 , Minimum 4 no's of USB 3.1G ports, Minimum 4 no's USB 2.0 ports and Graphics Card: NVIDIA Quadro P5000 with 16GB GDDR5X

- xvi. 8 Channel USB data acquisitions module to capture analog inputs along with the images.
- xvii. Speckle rollers of various dot sizes of 0.15mm to 0.5mm
- xviii. High temperature paint – For application upto 800 Deg C and long duration of at least 2000hrs
- xix. Air Brush Set – Air Brush with nozzle – 0.15mm, 0.2mm, 0.4mm, 0.6mm nozzles; Hose Pipe compressor, White Paint – 2.0 Lts; Black Paint – 2.0 Lts; Cleaning Liquid – 4.0 Lts.

5. Pre-Dispatch Inspection & training:

- i. Pre-dispatch inspection to be carried out at supplier's works. Inspection shall be carried out by BHEL. Vendor should demonstrate the working of the system as per the specifications. Vendor shall provide hands on training at their works after PDI.
- ii. The Vendor shall give minimum of 28 days' notice for inspection along with internal test certificates.
- iii. Scope, Duration and daily schedule for PDI and training for 2 BHEL officials should be indicated in the offer.
- iv. During PDI, suggested modifications/ changes, if any by BHEL official should be carried out and intimated to BHEL for dispatch clearance.
- v. PDI charges, if any, have to be quoted separately with the enquiry.
- vi. Travel and stay for personnel deputed for PDI & training will be borne by BHEL

6. Acceptance test procedure: During PDI System to be demonstrated in a strain simulator to cover entire strain range as specified and withstandability of paint upto 1000 degC for at least 1 hour.

7. Installation, Commissioning and Post Installation training:

- i. Vendor has to carry out the installation and commissioning (I&C) and Post Installation training at BHEL R&D.
- ii. Any special tools/materials for installation and commissioning shall be supplied by vendor.
- iii. Any other requirements during installation and commissioning shall be specified clearly.
- iv. Vendor shall provide training to BHEL engineers after successful installation at BHEL R&D.
- v. Training shall cover, operation and maintenance of the DIC system.
- vi. Training shall cover safety features/guidelines for the protection of men and equipment.
- vii. Scope, Duration and daily schedule for post installation training should be indicated in the offer.
- viii. I&C report should be submitted to BHEL after successful completion of the I&C and Post installation training.
- ix. I&C and Post installation training charges will be paid only after successful completion of I&C and Post installation training and submission of report.
- x. **Supplier should indicate duration (in weeks) for completion of Installation & commissioning (including Post Installation training) from the date of BHEL intimation about site readiness.**
- xi. Delay in completion of I&C (including Post Installation training) within stipulated time indicated earlier will attract penalty as per Late Delivery (LD) clause mentioned in commercial terms and conditions (CTC) as applicable.
- xii. **The estimated percentage value of these charges (I&C and Post Installation Training Charges) as per BHEL: 3% of System price (on ex works basis i.e. Sl.No.11 of Unpriced and price bid format of Annexure II&III).**
- xiii. **The Supplier should quote these charges (I&C and Post Installation Training Charges) as % of System price (on ex works basis i.e. Sl.No.11 of Unpriced and price bid format of Annexure II&III). Only in case where quoted value is less than the value (in %) specified above or separate value is not mentioned in the offer, value for I&C shall**

- be deemed to be considered as the value indicated above (3%) and accordingly supply value will be adjusted from that quoted value and balance will be released as I&C payment as per Payment terms- under Commercial terms and conditions of enquiry.
- xiv. All travel, boarding, lodging and other charges (if any) for authorized personnel deputed for E&C/Installation and demonstration should be borne by the vendor

8. Warranty:

- i. Warranty for the system except controllers (portable and fixed) shall be 12 months from the date of installation and acceptance at R&D or 18 months from the date of supply, whichever is earlier.
- ii. Vendors shall quote and supply the spares (including low-shelf life spares) required for this warranty period.
- iii. Warranty for the controllers (portable and fixed) shall be 60 months from the date of installation and acceptance at R&D or 66 months from the date of supply, whichever is earlier.
- iv. During warranty period, the repairs and maintenance of the system and sub-systems shall be carried out by the vendor free of cost at BHEL R&D, Hyderabad.
- v. During warranty period, all upgrades to the operation related to data acquisition, processing and data-logging software must be provided free of cost.
- vi. Contact information of service engineers MUST be provided at the time of installation & commissioning.
- vii. Availability of trained service engineers in India for attending the problem in at most 7 days has to be ensured and complied to.

9. Delivery period: For Supply portion, duration shall be counted from the date of Purchase Order. Vendors are required to indicate the best delivery period (i.e., Order acceptance, submission of drawings etc., should not be linked to the delivery period) for the followings:

- i. Delivery period (in weeks) for scope of supplies from the date of PO.
- ii. Delivery period (in weeks) for completion of Installation & commissioning (including Post Installation training) from the date of BHEL intimation about site readiness.

10. Documents:

The following documents should be provided by the vendor: -

- i. Data sheets of the DIC System and all the optics and hardware quoted.
- ii. User manual, schematic of the system.
- iii. For bought out items, details of the vendor shall be provided.
- iv. For consumables, Grade and Make details shall be provided

11. After sales support and non-comprehensive Annual Maintenance Contract (AMC) for the system excluding controllers (portable and fixed):

- i. Non-comprehensive AMC charges shall be quoted for 4 years beyond the stipulated warranty period quoted on per year basis as % of basic system cost (which is Sl. No. 7 of Unpriced and price bid format of Annexure II&III).
- ii. BHEL will add the quoted AMC charges of 4 years for cost evaluation while deciding the tender priorities.
- iii. BHEL reserves the right to place a separate order/ orders for AMC contract for 4 years and/ or part thereof, at the rates quoted after warranty period.
- iv. All software upgrades have to be provided free of cost during service AMC period.
- v. AMC charges will be paid on half yearly basis after completion of services including mandatory visit to BHEL R&D, failure of which shall entail forfeiture of the half yearly

payment and extension of warranty at the discretion of BHEL. Consequential impact on any failure due to the above shall be to the account of the vendor.

12. Spares:

- i. Vendors shall quote and supply the spares (including low-shelf life spares) required for the stipulated warranty period.
- ii. Spares shall be quoted for 4 years beyond the stipulated warranty period on per year basis.
- iii. BHEL will add the quoted spares of 4 years for cost evaluation while deciding the tender priorities.
- iv. BHEL reserves the right to place a separate order/ orders for spares for 4 years and/ or part thereof, at the rates quoted after stipulated warranty period.