XIX IMEKO World Congress
Fundamental and Applied Metrology
September 6-11, 2009, Lisbon, Portugal

DESING AND DEVELOPMENT OF PRECISION ARTIFACT FOR DISSEMINATION OF LOW FORCES OF 1 N AND 2 N

S.S.K.Titus [1], *Kamlesh K.Jain* [1], *S.K.Dhulkhed* [2] *and Poonam Yadav* [1]

[1]Force and Hardness Standard, National Physical Laboratory
New Delhi, India, titus@mail.nplindia.ernet.in
[2]Depart. of Mechanical Engg, SDM College of Engg. & Tech.,
Dharward, Karnataka, India.

Abstract - This paper describes the preliminary results of the design, development and characterization of precision artifacts for the measurement of low forces of 1 N and 2 N. For designing the elastic element, we carried out the finite element analysis (FE) to determine the stress and strain distribution on the elastic element for appropriately identifying the location for fixing the strain gauges. In order to obtain optimum performance and sensitivity, the strain gauges are emplaced on the identified location using a high quality curing adhesive. Characterization of these artifacts are performed on a recently developed low force dead weight machine having an estimated best measurement capability (BMC) of ± 0.0012% (k=2). The repeatability and reproducibility of the developed artifact are found to be within ± 0.003% and ± 0.006% respectively

Key words: load cell, force transducer, force metrology

1. INTRODUCTION

There has been a constant demand and requirement from the industrial sectors to improve upon the accuracy in the force measurements due to the advancement in science and technology [1,2]. Precision measurement in the low force range has recently received lot of attention particularly in emerging fields of biotechnology, micro and nanotechnology because of the miniaturization of components and gadgets [3,4]. Metrologists are constantly working on the development of various kinds of force transducers to be used as a reliable and stable artifact to achieve better characteristics and performance in different force ranges to cater to the wide range of desired applications [5,6].

Precision artifacts are extremely necessary to disseminate the realized force to the ultimate end user industries. As these transducers are not so commonly available to disseminate the force scale, a detailed work plan has been drawn to design and develope force transducers in the lower range (1 N – 10 N), which is the need of the hour to provide national traceability to the end user. The results of these studies pertaining to 1N and 2 N transducers are presented here.

2. DESIGN AND DEVELOPMENT OF FORCE TRANSDUCERS

Precision force transducers having a capacity of 1 N and 2 N are modeled and designed by using a finite element analysis (FE) technique. Single cantilever type force transducer elements were designed and fabricated using aluminum alloy. The FE model for the designed force transducer element of 1 N capacity has been generated using 10 node tetrahedron element. Standard checks like six rigid body modes, dimensions, mass and quality of elements of the FE model has been checked to qualify the model shown in the Fig.1 for stress analysis. The boundary conditions were carefully set to determine the distribution of stress and strain at various points for appropriately identifying the locations for fixing the strain gauges to make the elastic element sensitive and accurate for optimum performance and reliability. FE model of the force transducer element with boundary conditions are shown in Fig.1, where the load is applied at the central hole by using the RBE3 rigid element to distribute the load evenly and the bolt locations are constrained in all degrees of freedom to simulate the bolts.

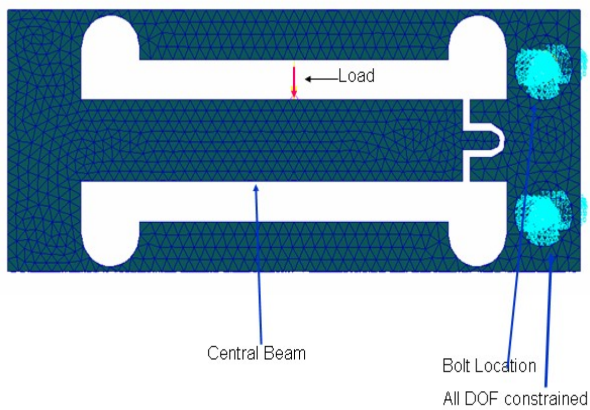


Fig.1. FE model of the force transducer element of 1 N capacity with boundary conditions.

Linear static analysis has been performed on the model at different load steps, from 10 gms to 150 gms with an incremental load step of 10 gms as depicted in Fig. 2, to understand the deformation and the stress distributions in the designed artifact element.

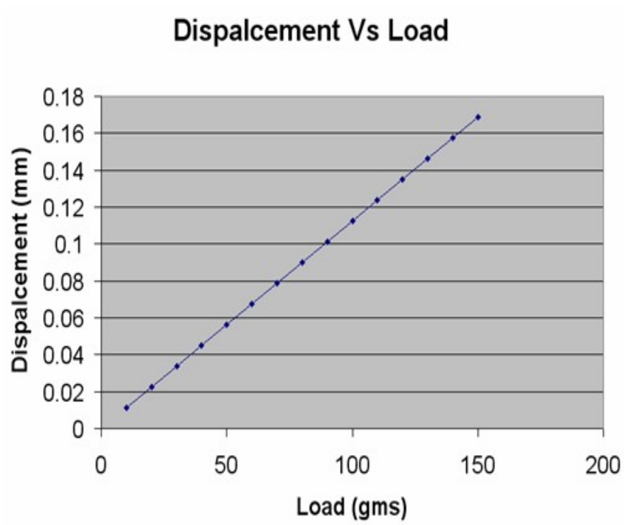
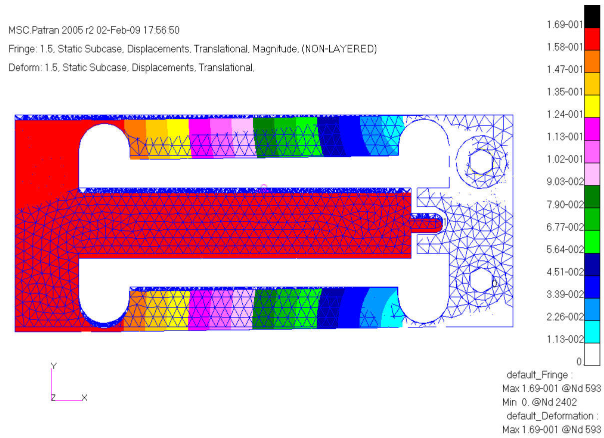
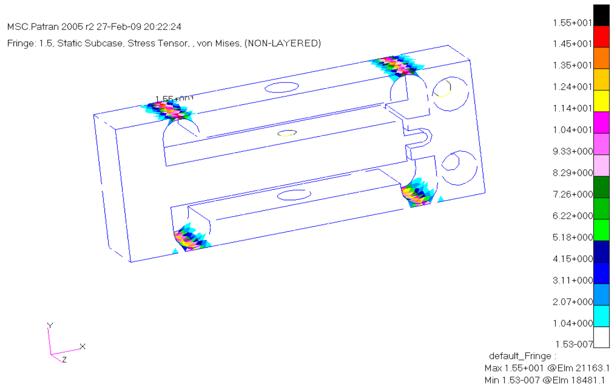


Fig. 2. The plot for displacement with load for 1 N transducer element.

It can be seen from the Fig. 2 that the deflection is linear up to the tested loading range of 150 gms and the maximum deflection and stress observed in the element are 0.169 mm and 15.5 MPa respectively. As the design of the load is governed by stiffness and the allowable stress limit for aluminum alloy Al2014-T6 is 480 MPa, the stress induced in the load cell will be very less and well within the limits of the scope for which it is designed. In order to understand the FE analysis better, the observed deformation and stress distribution of the force transducer element at its maximum load step (150 gms) is included in Fig. 3. Similar FE analysis was carried out on the designed and fabricated 2 N force transducer element and is not detailed here.



Deformation 0.169 mm



von-Mises stress 15.5 MPa

Fig. 3. Deformation and stress in the load cell at 150 gms.

After having identified the locations for the emplacement of strain gauges on the transducer elements, foil type strain gauges were carefully pasted on the thoroughly polished and cleaned surfaces at the identified locations on the elastic elements. These foil type strain gauges were procured from HBM, Germany having a resistance of 300 Ω and gauge factor of 2.04 compatible to the elastic element material. The strain gauges were properly bonded using a high quality hot curing adhesive, supplied by HBM, Germany, compatible to the grid backing material. For maintaining uniform thickness of adhesive and to make the strain gauges free from any air trap, pressure regulated clamps were employed. After the curing and post curing of the strain gauges, electrical connections were made in the wheatstone bridge configuration to obtain a full scale output of 2 mV/V. Finally, the strain gauges were properly sealed with a coating material and the elastic element was then housed in a metallic shell to protect it from the external environmental disturbances.

3. CHARACTERIZATION OF THE FORCE TRANSDUCERS

The metrological characterization of the 1 N and 2 N force transducers (artifacts) were performed on the fully automated low force dead weight machine [2,7] using a calibration procedure NPL -02C broadly based on ISO 376: 2004 [8]. The force transducers were carefully placed on an adjustable cross head of the dead weight force machine and connected to a high resolution indicator (model DK-38, HBM, Germany) interfaced with a computer through GPIB cord for automatically measuring its output signal. Calibration of these 1 N and 2 N force transducers were carried out by applying series of calibration forces through a self-aligning compression pads. At 0° position, the force transducer was preloaded three times to its maximum capacity and two series of forces with increasing values were applied without disturbing the load cells. Further, at 120° and 240° positions, the transducers were preloaded once and one series of forces with increasing and decreasing values were applied. Measurements are made at

0.5, 0.7, 0.9 &1.1 N force steps for the I N force transducer and at 1, 1.2, 1.4, 1.6, 1.8 & 2 N force steps for the 2 N force transducer. The preliminary results obtained on these load cells are depicted in Fig. 4 and Fig. 5 showing that the repeatability and reproducibility are better than ±0.003% and ± 0.006% respectively in the optimum working range. Further work is in progress to develop and fabricate such precision artifact in the entire range of scope of our interest.

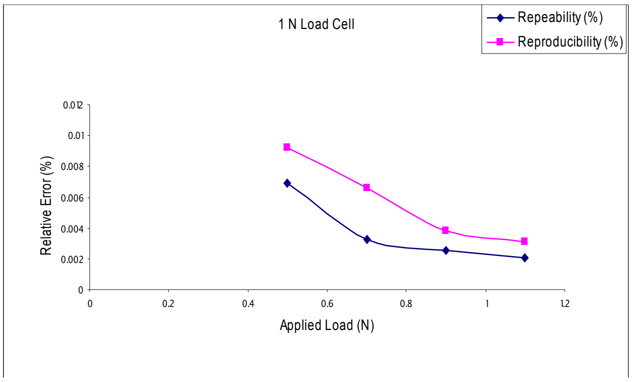


Fig. 4. Repeatability and Reproducibility of 1N load cell.

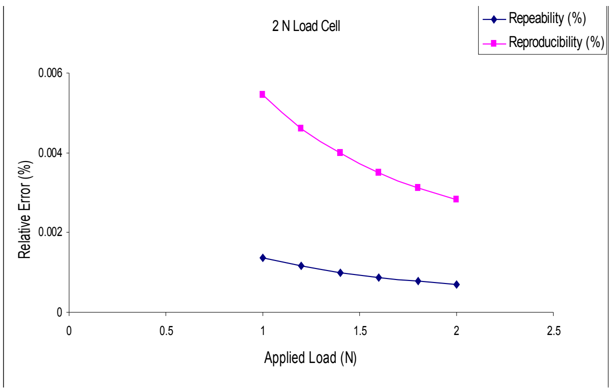


Fig. 5. Repeatability and Reproducibility of 2N load cell.

4. CONCLUSION

The designed single cantilever type force transducer of 1 N and 2 N capacities based on the FE analysis using aluminum alloy are found to exhibit good repeatability and reproducibility. These force transducer may be used as transfer standards (artifacts) for the dissemination of low forces of 1 N and 2 N to the user industries with better accuracy to maintain the national traceability.

ACKNOWLEDGEMENTS

The authors are grateful to Prof. Vikram Kumar, Director, National Physical Laboratory for permission to publish the work. The authors are also thankful to Dr.S.K.Jain, Mr. Harish Kumar Force and Hardness standard, NPL and Mr. Prashant A Mahindrakar, Dept. of Mechanical Engg, SDM College of Engg. & Tech., Dharward, Karnataka, for their valuable suggestions and timely help.

REFERENCES

[1] Sinan Fank, Amritlal Sawla and Hakan O. Ozbay, “Long term observation of newly developed 110 kN /1.1 MN lever amplification dead weight force standard machine at UME”,IMEKO XIV World Congress Proceedings, Finland, vol 3, pp 7-12, 1997.

[2] Kamlesh K Jain, S S K Titus, Harish Kumar and H N P Poddar, “An Automated Dead Weight System for Realizing Force in 1 N-10 N Range” NCSL International conference, Orlando,USA, 3rd –7th August 2008.

[3] S.Niehe, “New Experience with a force Measuring facility from the range from 1mN to 5N” IMEKO 19th TC3, Proceeding “force, mass, and torque” Cairo, 2005.

[4] Jens Illemann, “The achievable uncertainty for balance-based force standard machines in the range from micro Newton to newton” IMEKO 20th TC3, 3rd TC16 and 1st TC22 Merida, Mexico, 27th -30th November 2007.

[5] Vladimir Nesterov, “Facility and methods for the measurement of micro and nano forces in the range below 10^{-5} N with a resolution of 10^{-12} N (development concept)” Meas Sci.Tech, Vol. 18, pp. 360-366, 2007.

[6] Toshiyuki Hayashi, Yoshihisa Katase, Kazunaga Ueda,Tsuyoshi Hoshino, Hiroshi Suzawa, Masaaki Kobayashi, “Evaluation of tuning-fork type force transducer for use as a transfer standard”, Measurement, vol. 41, pp. 941-949, 2008.

[7] S S K Titus, *S.K.Dhulkhed, Poonam Yadav, and Kamlesh K Jain, “Development and Performance Evaluation of a Dead Weight Force Machine in 2-50N Range”, Mapan, (in press).

[8] “Calibration of Force – proving instruments used for the verification of uniaxial testing machines”, ISO 376 – 2004.