Refurbishing the NIST 4.45 MN deadweight force standard machine

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Abstract: Refurbishment of the 4.45 MN (1,000,000 lbf) deadweight machine was undertaken and completed. The newly restored machine has been tested and found to be in excellent operating condition. Numerous procedural steps were followed to assure that repair, recalibration and reassembly were performed correctly and that restart of the machine was performed methodically and with measured patience. Most importantly, the forces realized by all the deadweights in the machine before and after restoration have remained in agreement as shown by repeated measurements performed with a precision referee force transducer over the past 15 years. The consistency of these measurements verifies the absolute value of each realized force data point and substantiates the uncertainties associated with the values. The project will be discussed and validation of machine operation which permits reopening the 4.45 MN force calibration service to customers will be highlighted.

1. INTRODUCTION

The 4.45 MN (1000000 lbf) deadweight machine (DWM) has been in use in the NIST Force Laboratory since 1965 and has performed thousands of measurements during the lifespan of the machine. The machine participated in two multi-year, multi-NMI international key comparisons that assured comparability of measurements throughout the world; participated in several bi-lateral comparisons and has disseminated force units to a worldwide customer base.

2. RATIONALE FOR REFURBISHMENT

The largest NIST Deadweight Force Standard Machine had developed a material anomaly or a form of galling of key structural components inside the weight stack as evidenced by observations documented by staff members of the force laboratory. During machine operation, galling-induced binding of parts that should remain free occurs, and, shock or impact forces were imparted to the entire machine as the bound components are freed during weight unloading. Repair of the components required shutdown of the machine, disassembly of at least part of the weight stack, remachining of affected components, recalibration of all removed weights and reassembly and testing of the rebuilt machine. The machine was out of commission for more than 18 months.

3. RESULTS

Discussion and photographs documenting the material anomalies found after disassembly will be shown. Design drawings will be displayed.

3.1. Results A

The first material damage appeared on the bottom center hub seat of weight no. 5-3 which mated to center stud no. 5-4, also damaged. As suspected, weight nos. 5-3, 5-4 and 5-5 sustained some sort of galling/material damage at the seat/stud interfaces.

3.2. Results B

Concurrently to the ongoing machine work, structural analysis of the conical seated joints in the 4.45 MN machine was performed by members of the Mass and Force Group using finite element modelling. The parametric studies were performed by varying geometry, material constitutive relations and frictional forces at the interface of the convex and concave cones. The results provided insights into the generation of stress at the conical seats and the mechanism by which damage occurred in the high-stress joints. These results also contributed to the selection of tribological and mechanical solutions that were employed to minimize future damage to the interface joints. A full report of this study is published separately.

4. DISCUSSION

All of the weights were calibrated by the large mass staff of the Mass and Force Group. Several weights required the anticipated adjustment of mass values in order to match the nominal values of the weights that were not removed from the machine. The reasons for adjustment were either to compensate for the material removed during machining or to compensate for an original bolt replacement with a new-old-stock bolt. Following adjustment, the adjustment cavities were sealed with stainless steel caps using new-old-stock caps and a 50-year old custom device designed to properly seat the caps into a recessed counter bore at the tops of the cavities.

5. CONCLUSION

Results of the mass calibrations of the 22696 kg masses will be presented and discussed. Results of the startup and force realization and testing procedures will be presented and discussed.

ACKNOWLEDGEMENTS

Relevant personnel and documentation essential to success of the project will be listed.

REFERENCES

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