XXI IMEKO World Congress "Measurement in Research and Industry"
August 30 − September 4, 2015, Prague, Czech Republic

THE NEW GTM 10 MN HYDRAULIC FORCE STANDARD MACHINE

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Abstract: Calibration with high forces is needed more and more. Deadweight force machines are the first choice for the lowest measurement uncertainty in force realization but their capacity cannot be extended to extrem high forces, as these becomes too expensive and too large in size. The hydraulic force standard machine is a perfect economic solution for highest values in force realization with suitable measurement uncertainty. This paper describes the new GTM 10 MN hydraulic force standard machine.

Keywords: High Forces, Hydraulic, Calibration

1. INTRODUCTION

In many fields of modern mechanical engineering forces of up to 10 MN are measured. Due to this, calibration capabilities with suitable measurement uncertainties for this high loads have to be provided. As deadweight machines are not economic for highest loads GTM developed and starts operating a Force Standard Machine (FSM) for tensile and compressive forces up to 10 MN.

Fig. 1. 10 MN FSM during installation

2. DESCRIPTION

The 10 MN machine consists of a base frame in 4-column-design with fixed crosshead, an adjustable loading frame with 2 columns and 2 transoms, a working cylinder with hydraulic system and a special reference transducer system (see Figure 1).

The machine is operated from a PC and offers the possibility of step by step - and continuous calibrations.

It is designed for force transducer calibrations both in tension and compression.

A single-acting hydraulic actuator of 10 MN nominal capacity is mounted on the top of the four-column base frame and allows a load up to 11 MN. It carries on its piston a special reference force transducer system. Freely suspended from this reference transducer is the two-column loading frame.

The test space height can be adjusted to suit the individual transducer height by means of raising and lowering the bottom transom of the loading frame.

The machine generates forces by raising the hydraulic pressure in the working cylinder, and the applied force is measured by the reference transducer system arranged on the piston. A digital closed loop feedback controller [1] adjusts the pressure so that the selected force is reached precisely and kept constant for the pre-set measuring time.

A servo-electric spindle pump, generates and adjusts the pressure as governed by the closed loop controller. This enables wide ranges both of load and of load change rate, together with superior load stability over time.

The process variable of the force control loop is measured with a reference force transducer system of the type KTN-D.

The FSM has a total weight of approximately 45 tonnes and a construction height of 6.5 metres. There are special lifting and transportation facilities to aid the placement of calibration objects. Compressive force transducers may have a diameter of up to 500 mm and a construction height of 700 mm. The tensile force range allows tensile bars up to 1800 mm in length with a connecting thread up to M200 in accordance with ISO 376. To achieve stable air conditions, the machine has a complete enclosure of aluminium profile with impact-resistant polycarbonat panes, see Figure 2.

Fig. 2. 10 MN FSM with enclosure

3. REFERENCE TRANSDUCER SYSTEM

The special double reference transducer system is designed similar to a build-up system [2]. It consists of a large reference system and a small reference force transducer. The large reference system uses three force reference transducers. The benefit of using multiple reference force transducers for the large reference system is the use of reference transducers with smaller nominal loads which simplifies the handling compared to one big force reference transducer and the traceability and calibration at the NMI is easier. However multiple reference force transducers require an exact geometrical alignment so that the nominal loads sum up correctly to one nominal load for the large reference system. In case of the GTM 10 MN force standard machine three large reference force transducers with a nominal load of 4 MN are used resulting in an high overall nominal load and allowing an overload of transducers up to 11 MN.

The small reference force transducer is mounted on top of the large reference system in a stack and both remain permanently in the force path (see Figures 3 and 4). A special design of coupling flange protects the smaller transducer from overloading when forces higher than its capacity are selected. This means that the whole force range of the machine can be utilised without changes of the reference system and without a gap in the load range and losing performance.

To avoid modifications of the double reference system when using loads above the nominal load of the small reference force transducer, the small reference force transducer is protected by an overload protection. The overload protection is realized with a special designed coupling flange. The coupling flange is a kind of preloaded spring. With increasing force and after reaching the preload of the spring the small reference transducer moves downwards until it is completely blocked. So the small reference force transducer is protected from loads above its nominal load. The operation of the machine is performed using the small reference force transducer and switches over to the large reference system automatically shortly before the small transducer is blocked. The controller adapts any offset to achieve a smooth transition from the small to the large reference system.

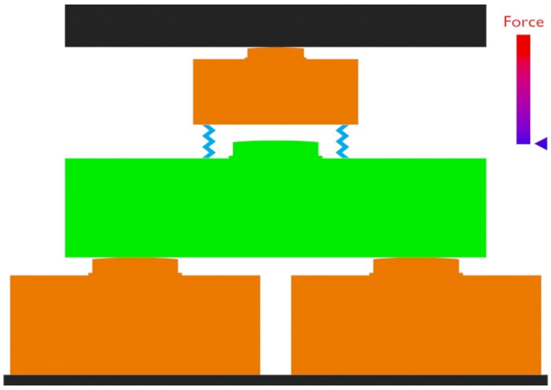

Fig. 3. Unloaded Reference Transducer System

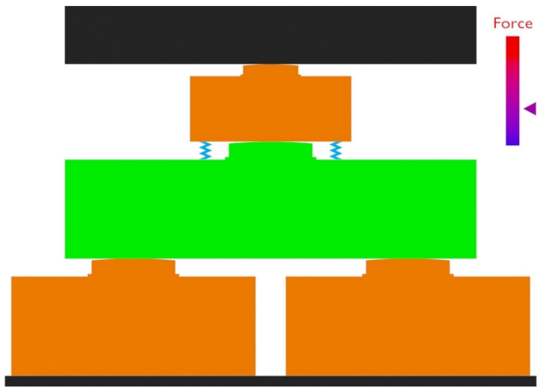

Fig. 4. Loaded Reference Transducer System at nominal load of the small reference transducer

Each reference force transducer is connected to separate amplifier and all amplifiers are connected to the machine controller. In the controller a multi-level linearization and correction is performed. For example the reference force transducers are scaled to Newton and linearized using the calibration certificates of the calibration at the NMI, or the hysteresis of the machine is corrected in various measuring ranges by performing comparison measurements with force transfer standards calibrated at a NMI and in the machine.

Figure 5 shows the real design of the double reference transducer system.

Fig. 5. Double Reference Transducer System

4. MEASUREMENT CAPABILTY

An uncertainty budget associated with the construction of the machine, the calibration of reference transducers at PTB and the comparison procedure with laboratory owned transfer standards has been developed and confirmed by comparison measurements by use of transfer standards of PTB. Five transfer standards of 500 kN, 1 MN, 2 MN, 5 MN and 10 MN nominal load has been used for the comparison procedure. Figure 6 shows the achieved deviations of the comparison measurements and the calibration and measurement capabilities based on the uncertainty results.

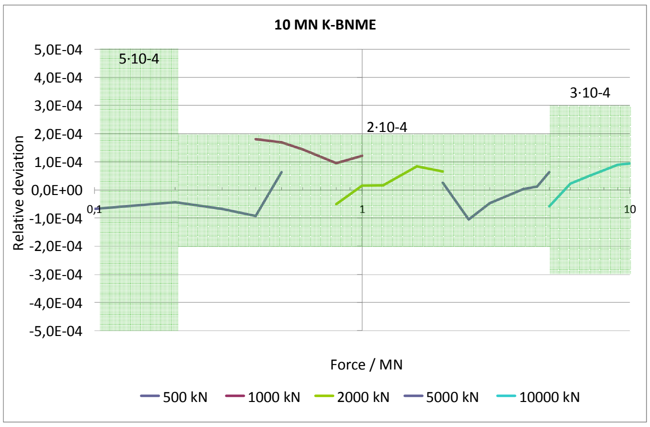

Fig. 6. Relative deviation and calibration and measurement capabilities (CMC)

An audit of the 10 MN FSM by the Deutsche Akkreditierungsstelle (DAkkS) (Germany's accreditation body) has been successfully passed and the accreditation certificate was issued. The 10 MN FSM is now listed as secondary force standard machine (K-BNME) (respectively reference measurement standard according VIM) among the services offered by the GTM calibration laboratory. Calibrations up to 10 MN are offered for force transducers and tensile bars. The maximum possible measuring range of the 10 MN FSM crosses three orders of magnitude between 50 kN and 11 MN.

Up to 10 MN, the accredited uncertainty of measurement is 0.03% and between 200 kN and 5 MN it is only 0.02%.

For this reason the 10 MN FSM is the largest Force Standard Machine for tensile and compressive forces in a private sector calibration laboratory worldwide.

Fig. 7. 10 MN FSM tensile force calibration

5. CONCLUSIONS

A 10 MN hydraulic Force Standard Machine is installed in the GTM calibration laboratory. The 10 MN FSM has a measuring range between 50 kN and 11 MN and is accredited by DAkkS in the range of 200 kN up to 5 MN with a CMC of 0,02% and up to 10 MN with a CMC of 0,03%.

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