IMEKO 23rd TC3, 13th TC5 and 4th TC22 International Conference
30 May to 1 June, 2017, Helsinki, Finland

PTB'S NEW 200 KN DEADWEIGHT FORCE STANDARD MACHINE

R. Kumme, H. Kahmann, F. Tegtmeier, N. Tetzlaff and D. Röske

Physikalisch-Technische Bundesanstalt, Department 1.2 Solid Mechanics, Germany, rolf.kumme@ptb.de

Abstract: This paper describes PTB's new 200 kN deadweight force standard machine with a large force range from 50 N up to 200 kN with lowest relative uncertainties of 0.001% in the range from 5 kN up to 200 kN which was possible by using deadweights of stainless steel in the quality of mass standards of class F1. The deadweights are adjusted according the gravity value and the masses are then determined with a relative expanded uncertainty of 3E-6. This maschine allows the investigation and calibrate force transducers in tension and compression without changing the installation position so that it is possible to determine the hysteresis effect (remanance) if the force changes from tension to compression.

Keywords: deadweight force standard machine

1. INTRODUCTION

In Germany many force calibration laboratories are accreditated in the kN force range up to a few hundred kN because in this range is the largest number of industrial applications. Force calibration machines in industry need traceablity to national standards with lowest uncertainty. To improve the traceability in this range PTB decided to realize a new force standard machine with lowest uncertainties of 0.001% in the range from 5 kN up to 200 kN. But the machine should also cover the lower range down to 50 N so that force transducers and load cells can be investigated in a large range, especially in respect to the remanance effect and to the temperature and humidity effect.

2. MACHINE PRINCIPLE

To cover the large force range the machine principle is based on two independent deadweigh stacks with one larger mass stack with deadweights generating forces from 5 kN up to 200 kN and one smaller stack generating forces from 50 N up to 5 kN (Fig. 1). In the force range up to 5 kN a tara balance is necessary for the compensation of the load frame which increases the uncertainy.

In the case that the force is generated by the deadweights the force $\vec{F}$ can be calculated by the following equation

$$\vec{F} = \sum_{i=1}^{n} m_i \cdot g_i \cdot \left(1 - \frac{\rho_{mi}}{\rho_a}\right) \cdot \vec{e}_i \qquad (1)$$

where
m_i is the mass of the deadweight number i
g_i is the local gravity at the center of the mass number i
ρ_{mi} is the density of the mass number i and
$\vec{e}_i$ is the unit vector considering the direction of the force generated by the deadweight number i.

Both the smaller and the larger deadweight stack consists of a binary mass stack combination so that it is possible to compare also within the machine different mass combinations. The mass stack configuration of the machines is as follows:

Mass number	Force in N
M1	50
M2	50
M3	100
M4	200
M5	200
M6	500
M7	1000
M8	2000
M9	2000

Mass number	Force in N
M10	5 000
M11	10 000
M12	20 000
M13	20 000
M14	40 000
M15	50 000
M16	50 000

Table 1: Mass stack configuration of 200 kN fsm smaller stack (left side) and larger stack (right side)

Up to three load frames are necessary to apply the forces generated by both mass stacks. The first load frame generates a force of 5 kN and can be coupled with a couple frame of 1 kN used to couple the masses from the smaller mass stack and with a second couple frame of 4 kN to couple the masses from the larger mass stack.

Before the deadweights are adjusted to the Newton values depending on the different hights in the machine the local gravity g_i was determinend by the Institute of Geodesy of the University of Hannover. After the installation of the machine also the change of gravity was investigated like described in an other paper of this conference [1].

The deadweights are calibrated by the mass department of PTB with an expanded relative uncertainty of 3E-6 [2]. Before the mass calibration the density of the deadweights was determined by the density group of PTB.

A uncertainty model for 200 kN new force standard machine is described which considers the different influences and which results in an relative expanded uncertainty of 0.001% for the range from 5 kN to 200 kN.

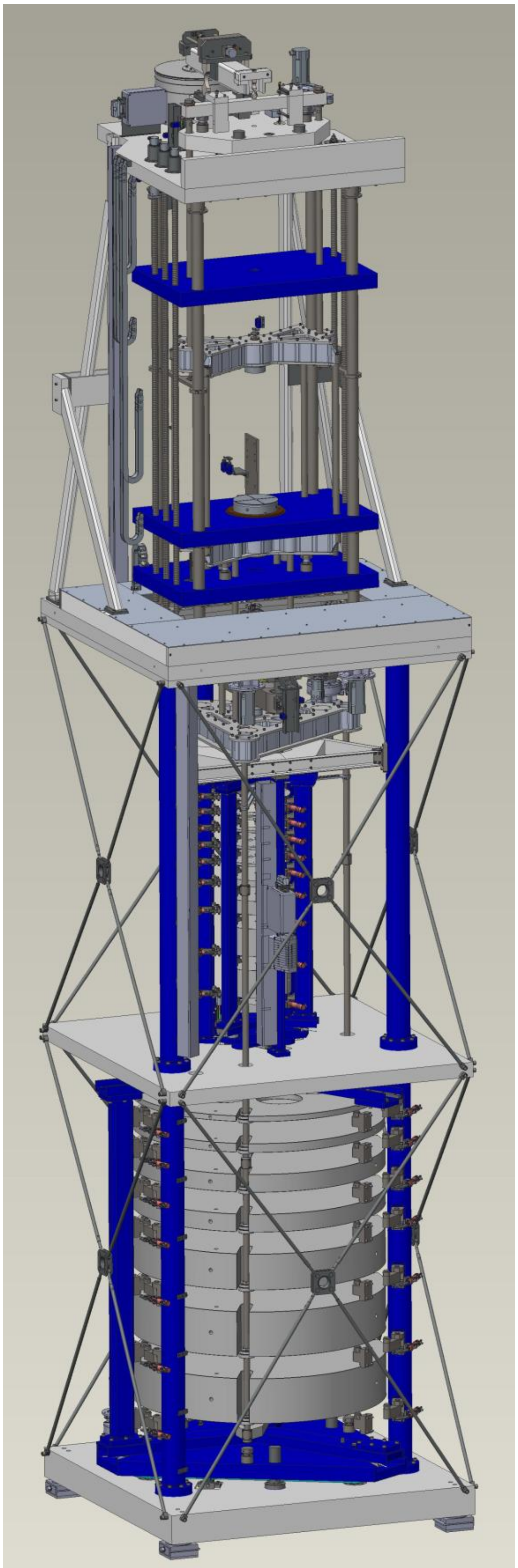

Figure 1: 200 kN deadweight force standard machine

3. RESULTS OF COMPARISON WITH PTB´S 20 KN AND 100 KN FORCE STANDARD MACHINES

Before the machine can be used for calibrations the uncertainty has to be validated by comparisons. Therefore in the machine was compared with the 2 kN, 20 kN, 100 kN and 2 MN deadweight machines of PTB. PTB has participated in the 5 kN, 10 kN, 50 kN and 100 kN force key comparisons so that a link to these comparisons is available [3, 4]. The results of the comparison of the 200 kN machine with the other machines show a good agreement and consistency with the declared uncertainties. The measurement results obtained with a set of different force transducers will be summarized in this paper.

4. SPECIAL INFESTINGTIONS TO INESTIGATE THE REMANANCE OF FORCE TRANSDUCERS

The new force standard machines enables investigation of the hysteresis of force transdcuers when going through zero from tension to compression. This was possible by implementing a special operation principle using the movement of independent cross heads of the machine according the PTB patent [5]. The operation principle and first results will be presented in this paper in more detail.

4. ACKNOLEDGEMENT

The authors would like to thank the companies GTM and Häfner for the manufacturing of the machine and the high quality of the deadweights.

5. REFERENCES

References:

[1] M. Schilling, L. Timmen, R. Kumme, “The gravity field in force standard machines”, to be published in Proc. of IMEKO 23rd TC3, 13th TC5 and 4th TC22 International Conference, Helsinki, 2017.

[2] M. Mecke, Th. Tippelt, “Calibration Certificate of the deadweights of the 200 kN deadweight force standard machine”, PTB, Braunschweig, 30.01.2016.

[3] CCM.F-K1.a, http://kcdb.bipm.org

[4] CCM.F-K2.a, http://kcdb.bipm.org

[5] H. Kahmann, R. Kumme, F.L. Tegtmeier, “Zug-Druck-Belastungsmaschine”, German Patent Nr. 10 2013 003 691