

STABILITY OF THE 32 MN FORCE CALIBRATION MACHINE AND INDUSTRIAL APPLICATIONS

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Abstract: In 1997 the High Force Calibration Laboratory from ICMET Craiova was accredited by DKD. The laboratory has a metrological test and calibration machine for the range 0.5 MN to 32 MN and the traceability to the German standard is ensured by means of periodic checks with 2 MN, 5 MN and 16 MN transfer standards of PTB and 2 MN and 10 MN transfer standards of ICMET. The paper contains a short presentation of the 32 MN machine, the results of its periodical checks performed within 1995-2002. A special attention is paid to the tests performed in 2001 with 2 MN and 16 MN PTB transfer standards according to EN 10000/3-94 and DKD procedure, as well as the tests of measuring equipment used in industrial applications. The aim of these tests was to check the long-term stability of the metrological performances of the machine reference measuring system.
 Key words: measurement uncertainty, force calibration machine, transfer standards

Introduction

Following a Romanian - German co-operation a 32 MN Force Calibration Machine (FCM) was commissioned at ICMET Craiova in 1995 and in 1997 the Force Calibration Laboratory was accredited by DKD.

Since 1995 the machine has been subjected to a wide testing program together with PTB Force Laboratory by means of the 2 MN, 5 MN and 16 MN transfer standards belonging to PTB.

The paper contains a short presentation of the operating and measuring principle of the machine, the results of its metrological investigations performed within 1995-2002, as well as some tests of special measuring equipment used in industrial applications.

The checks consisted in some periodical inter-comparison tests and measurements performed by means of PTB and ICMET transfer standards aiming to check the long-term reference measuring system stability of the 32 MN machine.

Construction and operation

The 32 MN FCM from ICMET Craiova works with a build-up system consisting of 3 parallel mounted reference force transducers.

The machine is located in closed, windowless and air-conditioned room where the temperature variation does not exceed $\pm 1K$ during calibration.

FCM is a hydraulic machine having three vertical columns allowing a simple access of the transducers to be tested, especially of those of large area, widely used in industrial applications.

Fig.1 shows a view of the machine and Table 1 contains its main characteristics.

Maximum operation force	32 MN
Operation range as metrological calibration equipment	0,5 – 32 – 0,5 MN
Relative overall uncertainty...(k=2).....	0,1% in the range 1 to16 MN 0,2% in the range 0,5 to 32 MN
Plane dimensions of the working table (lower part)	1200 x 1200 mm
Spherical platen diameter (upper part)	1200 mm
Max/Min height of the fixture (working space)	1700 / 500 mm
Ram stroke	160 mm
Force variation speed:	
- fast	20 to 100 kN/s
- slow.....	1 to 5 kN/s

Table 1 Main Technical Characteristics

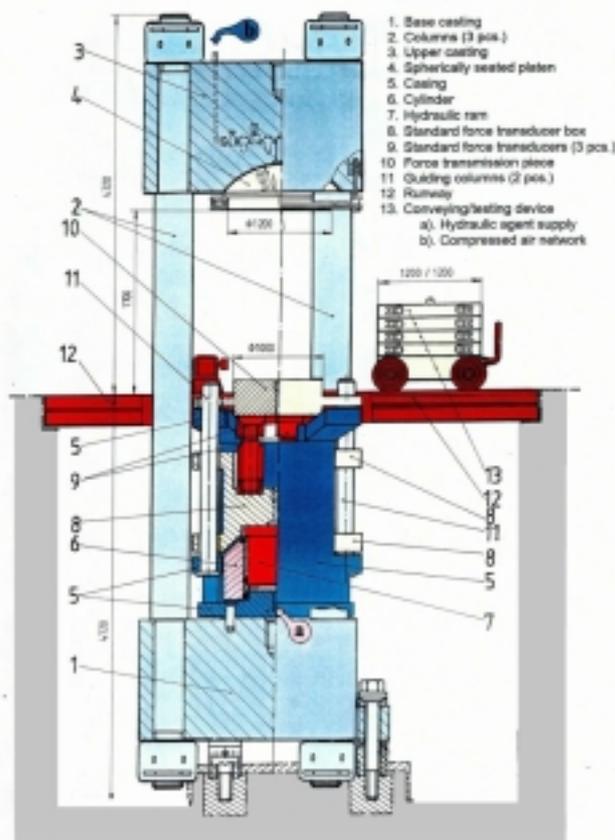


Fig.1 32 MN Force Calibration Machine

From the constructive point of view the rigid metallic structure of the 32MN FCM, consisting of two horizontal beams and three vertical columns, represents a solution having a better stability than the structures with two and four columns. This fact has been proven both experimentally and by computer simulation of 32 MN FCM structure using Finite Element Method (FEM) [3], [4].

The transducers under test are placed on a mounting truck and then they are located and fixed under the machine pressure plate.

The height of the mounting space can be adjusted adding or removing the plates used to load the force on the transducers under test.

Near the measuring and control room there is the hydraulic equipment room which provides the hydraulic agent (special hydraulic oil for extreme pressures). The hydraulic equipment generates the force by means of a hydraulic cylinder mounted in the basement.

A special attention has been paid to the design and construction of this hydraulic

equipment allowing a fine and stable control in both force variation directions [1], [2].

In the control and measuring room there are located the FCM control panel and a force measuring/indication equipment consisting of a HBM MGC multi-channel digital device and a PC. The three reference force transducers mounted in build-up system and the transducer under test are connected to the MGC digital device [2].

A special software controls the synchronous data acquisition from the four transducers/measuring channels in the pre-selected measuring points.

The magnitude of the generated force is proportional to the effective pressure in the hydraulic equipment.

Pressure adjustment and its variation rate are monitored from the control panel by means of a hand-operated potentiometer controlling the desired operation mode of a special electro-hydraulic throttles.

Close to each step force value set by the program at the beginning of a measurement sequence the force raising/increasing rate will be decreased at the minimum machine working speed, about 5 kN/sec to 10 kN/sec.

When the generated force value is within a bandwidth of about $\pm 1\%$ of the reference force step value all MGC signals are acquired and saved. This is automatically and synchronously performed for all measuring channels. The pair of values wanted for the generated force and measuring signal are recorded and calculated immediately by interpolation.

With these raw data, namely both real and saved measuring values, it is possible to make a system check if needed.

Comparative and time-stability measurements

In order to ensure and maintain 32 MN FCM traceability to the 16,5 MN Force Standard Machine (FSM) from PTB a wide program of tests and comparison measurements was developed using 2 MN, 5 MN and 16 MN transfer standards belonging to PTB.

In June 1995 the tests and measurements for 32 MN FCM calibration using 5 MN, 16 MN and 2·16 MN transfer standards were firstly performed according to EN 10002/3-94.

The results of these comparison measurements were presented [1], [2].

In October 2001 the calibration tests and measurements for the 32 MN FCM performed according to EN 10002/3-94 and DKD measuring technologies were repeated in comparison with 2 MN and 16 MN transfer standards.

The results of these comparison measurements are presented in detail in [5].

The comparison measurements consisted in performing preliminary tests and measurements with the 16,5 MN FSM at PTB, then similar tests and measurements were performed with the 32 MN FCM at ICMET and subsequently tests and measurements were performed again at PTB.

During these comparison measurements the influence of temperature difference between PTB and ICMET measurements as well as the long term drift behavior for the transfer standard were taken into account.

The preliminary tests and measurements from PTB were performed at the beginning of September 2001, while the checking ones for the 32 MN FCM from ICMET were performed at the end of October 2001 [5]. Afterwards, in March 2002 tests and measurements were performed when the transfer standards returned at PTB.

A temperature coefficient α_θ was established using the measurements performed at PTB with the 16 MN transfer standard at different temperatures. A drift coefficient α_z describing transducer sensitivity variation in time was established using long term measurements performed at about the same temperature.

This is rendered obvious in Tables 2 and 3 for the comparison measurements performed in 2001 with the 16 MN transfer standard.

Force [MN]	PTB	PTB	ICMET	PTB	ICMET	Relative deviation
	03.09.01 T=22°C	10.03.02 T=21,85°C	25.10.01 T=18,5°C	03.09.01 correction with α_z	25.10.01 correction with α_θ	
1	0.171171	0.171210	0.171092	0.171180	0.171112	-3.9E-04
2	0.342077	0.342257	0.341959	0.342094	0.341999	-2.8E-04
4	0.638485	0.683803	0.683230	0.683518	0.683309	-3.1E-04
6	1.024415	1.024974	1.024089	1.024465	1.024207	-2.5E-04
8	1.365129	1.365688	1.364563	1.365194	1.364719	-3.5E-04
10	1.705318	1.705939	1.704548	1.705400	1.704744	-3.8E-04
12	2.044957	2.045571	2.044208	2.045056	2.044442	-3.0E-04
14	2.384061	2.384796	2.383032	2.384175	2.383305	-3.6E-04
15	2.553365	2.554141	2.552421	2.553488	2.552714	-3.0E-04
16	2.722656	2.723363	2.721396	2.722787	2.721708	-4.0E-04

Table 2 Comparison of uncorrected results

Table 3 Comparison of mean corrected values

Fig.2 presents the results of the comparison measurements between 32 MN FCM from ICMET and 16,5 MN FSM from PTB performed in 1995 and 2001 with PTB transfer standards for the range 0,5 MN to 16 MN [1], [5].

Analyzing the results of the above measurements it is found out that mean value deviation does not exceed $4 \cdot 10^{-4}$ for the operating/measuring range 0,5 MN to 16 MN of FCM.

Following the comparison measurements of 32 MN FCM performed with PTB transfer standards it was found out that the said machine and its reference measuring system have a very good long-term stability and FCM measurement uncertainty ($k=2$) of $1 \cdot 10^{-3}$ in the range 1 MN to 16 MN is preserved.

Taking into account that ICMET has a 10 MN transfer standard (KAS) that was periodically checked at PTB it was possible to develop a periodical check program for 32 MN FCM within the range 1 MN to 10 MN. This 10 MN transfer standard of ICMET was checked at PTB in January 1997 and November 2000.

Fig.3 presents the results of the comparison measurements between 32 MN FCM of ICMET and 16,5 MN FSM of PTB performed by means of the 10 MN transfer standard of ICMET within 1997-2002. Analyzing these comparison measurements it is found out that mean value deviation does not exceed $6,5 \cdot 10^{-4}$. The deviations measured with KAS lie in a gap having a width of $1 \cdot 10^{-3}$.

At the same time 32 MN FCM was periodically subjected to a metrological check up to 30 MN by means of three 10 MN C6 Hottinger force, previously calibrated in FCM. Their mean reference value for the range 1 MN to 10 MN was obtained and used as reference value for the comparison with the build-up system (3·10 MN) for FCM operating/ measuring range 3 MN to 30 MN.

Fig.4 presents the measurements performed within 1997-2001 with 32 MN FCM in comparison with the system of three 10 MN transducers in build-up connection.

Analyzing these measurements a maximum deviation of $1,4 \cdot 10^{-3}$ for the operating/measuring range 18 MN to 30 MN was found out; this deviation is within the

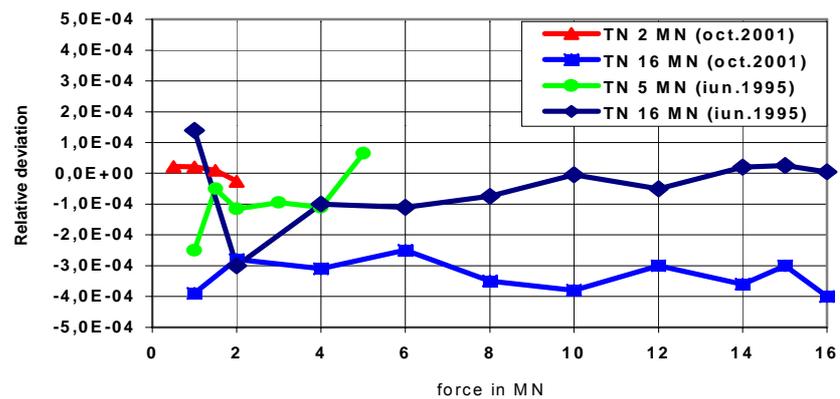


Fig. 2 Relative deviation between ICMET and PTB

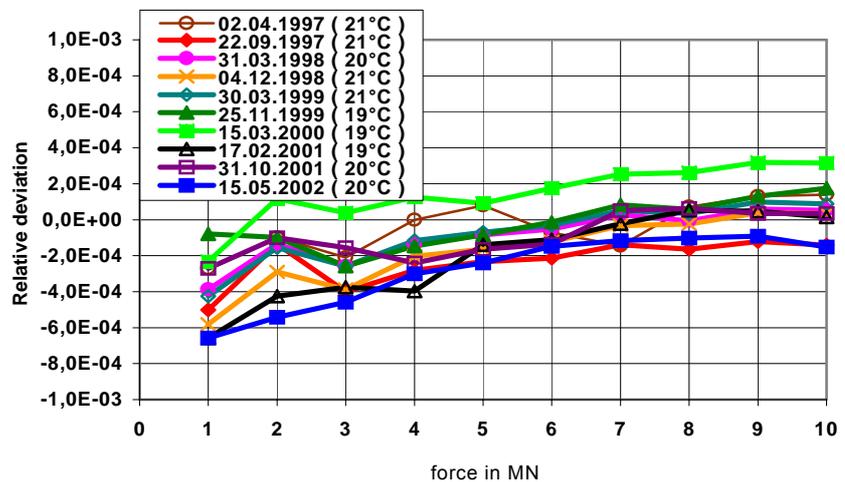


Fig.3 Mean value deviation between ICMET and PTB for KAS 10 MN

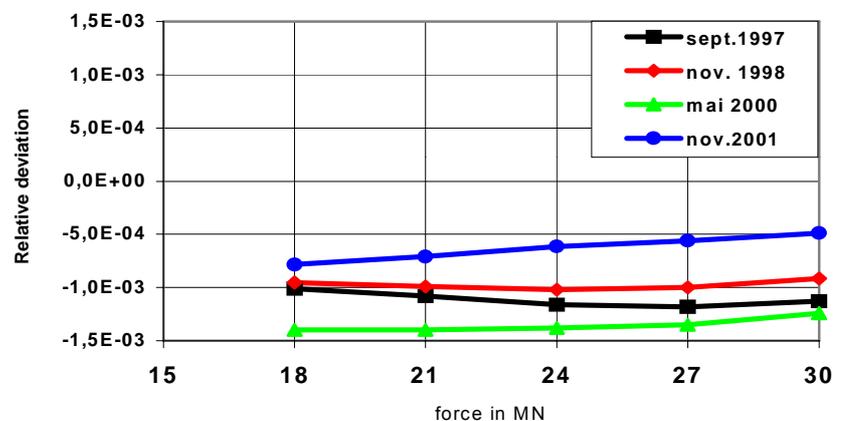


Fig.4 FCM check with build-up system 3·10 MN

limits of the measurement uncertainty for which FCM was qualified/ accredited.

Concerning the measurements performed in both force variation directions, the reference measuring system of 32 MN FCM was characterized establishing inverse function coefficients only for increasing forces, that is the hysteresis of the three reference force transducers was not taken into account.

Since the transducer to be calibrated is series connected to FCM reference measuring system the measured hysteresis includes the sum of both hysteresis components (belonging to the transducer to be calibrated and to the FCM reference measuring system).

Comparing the results obtained with the 16 MN transfer standard [5] it is obvious that its hysteresis has the same order of magnitude as the one of the FCM reference measuring system and they compensate partially each other.

At high hysteresis force transducers, like magnetoelastic transducers, this effect may be neglected.

Additional checks of FCM at eccentric loading

In order to investigate 32 MN FCM behavior at eccentric load, namely positioning of the force transducer to be calibrated outside the machine central axis, additional tests and measurements were performed with the 16 MN transfer transducer [5] in October 2001. Related to the three columns, the transfer transducer was moved at ± 20 mm towards the machine central position in the direction of each column and then it was loaded up to 16 MN. This procedure was repeated in the direction of all three columns.

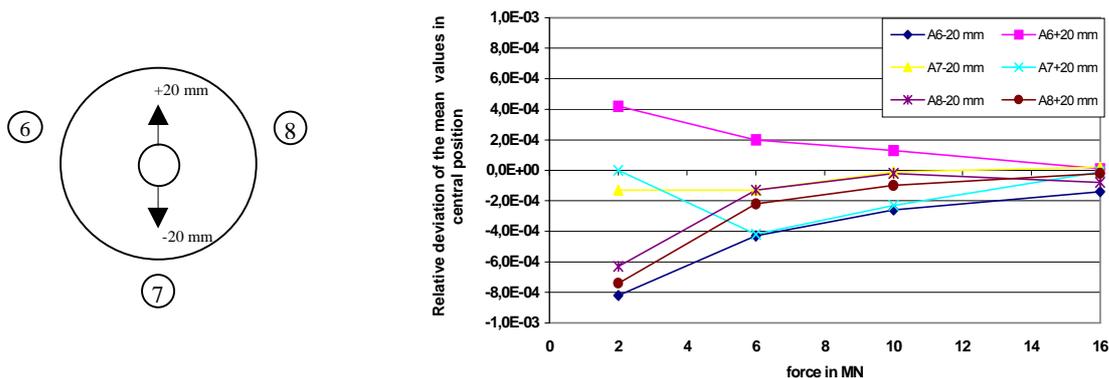


Fig.5 Eccentric positioning of the transducer in FCM

From Fig. 5, presenting the measured relative deviations, it results that these deviations are within the limits $\pm 1 \cdot 10^{-3}$ even at an extreme eccentricity of 20 mm outside central force action line.

These measurements prove that small positioning errors do not influence transducer calibration result in a significant way.

32 MN FCM use to test and calibrate force transducers for industrial applications

The construction of 32 MN FCM allows test and calibration for high force and large area transducers used for various industrial applications. Until now about 50 pieces 8 MN to 16 MN rolling mills magnetoelastic force transducers were tested and calibrated.

Fig.6 presents the "sandwich test arrangement", in which several 16 MN large area magnetoelastic transducers are connected in series, separated by metallic plates in order to reduce the calibration time.

Other tests have been performed on special transducers used in shipyard companies. An example is a 2,5 MN dynamometer (test performed in an force inverter device designed at

ICMET Craiova) and another is a 10 MN disk shape transducer for testing ship anchor chains (Fig.7). All these calibrations are periodically requested and monitored by the Romanian Naval Authority.

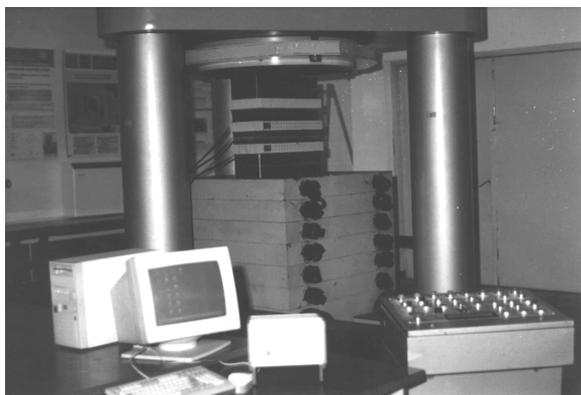


Fig.6 Sandwich test arrangement for 16 MN magnetoelastic transducers



Fig.7 Test arrangement for 10 MN

Conclusions

The traceability of the 32 MN FCM of ICMET to the German metrology standard (16,5 MN FSM) is achieved by inter-comparison periodical tests and measurements performed using transfer standards belonging to PTB and ICMET.

The long-term calibration stability is ensured: the comparison measurements performed in 2001 confirmed the measurement uncertainty evaluation established at 32 MN FCM commissioning.

It has been proven that for the range 1 MN to 16 MN the relative uncertainty value is less than $1 \cdot 10^{-3}$ and FCM works within these limits even under 1 MN.

FCM works safely even for eccentric loads (small positioning errors of the force transducers under test).

It was shown that for extreme conditions, like environment temperature $<18^{\circ}\text{C}$, FCM works within the limits.

FCM construction allows to test all type of force transducers (large area or concentrated load).

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