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Enlargement of the force capability at CEM: development of a 10 MN hydraulic force standard machine

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Abstract

This paper describes the constructive characteristics of 10 MN tension–compression hydraulic force standard machine installed at CEM during the period 2006-2007 and its traceability to national standard.

Key words: Force standard machine, hydraulic force standard machine, build-up force measuring system, traceability

1. Introduction

Since 1996, the realization of force unit at CEM is made through three deadweight force standard machines of 500 kN, 20 kN and 1 kN capacity [1], that allow to generate reference force values, both in tension and compression from 10 N up to 500 kN. These machines were declared as Force National Standards by the Order of 28th December 1999 (Official Bulletin of 13th January 2000). The force generation capability of the laboratory is complemented by an hydraulic force comparator machine of 2 MN in compression with an estimate relative uncertainty of $1 \cdot 10^{-4}$ F (k=1) [2]. In order to cover the national needs, a new hydraulic force standard machine has been installed at CEM that allows extending the force range in compression and tension up to 10 MN with an estimate relative uncertainty of $1 \cdot 10^{-4}$ F (k=1) (Fig 1). The machine has been designed and manufactured by Microtest S.A. according to the technical specification outlined by CEM.

Fig 1 Set of deadweight force standards machines and 10 MN hydraulic force machine in the centre

The main criteria taken into account for designing the hydraulic force standard machines have been the following:

- The supporting structures and the loading frames should have the highest stiffness and at the same time their geometry have to help to obtain a symmetric deformation that allow to maintain the axial axis of the machines in their reference positions under load,
- Introduction or replacement of the load to the force transducer under test has to be gradual, without intermediate unloading to cero and to reach the fix point value with a tolerance of 0,1%. The force generated must be pure without hydraulic interaction,
- The machine control shall be autonomous and by force signal. The accuracy and stability of the force control shall be such that the repeatability and stability of the signal output during the period 60 s to 180 s shall be equal or less than 0,01 % of the preset force value,
- The generation and control of the oil pressure shall be obtained by a servo-electric spindle pump that allows having a variable load rate and very high load stability over time and to reach a high accuracy in the stop points. It not allow to use servo valve system,
- Easy maintenance of the machine to be made by CEM´s personnel and the cost should be minimum,
- Easy accessibility to all components and main parts of the machine,
- Easy placing of the force transducers to be calibrated.

2. Setting Up of the Machine

The 10 MN hydraulic machine has been installed in the force laboratory using the same isolated concrete foundation 12 m x 7,5 m x 2 m with and

inertial mass of 400 t specially designed to support the rest of force standards machines. [1]

Some studies were performed in the laboratory when the deadweight force standard machines were installed in order to evaluate possible influence factor in the laboratory [3]

A metallic platform resting on the isolated foundation, provides easy access to the working areas of the 1 kN, 20 kN, 500 kN and 10 MN machines. (Fig 1)

The room laboratory is equipped with an air condition system that maintains the temperature in 20 °C ± 0,5 °C .

3. Description

The machine consists of a fixed robust base frame in 3 column design with fixed crosshead, a three column movable loading frame, a hydraulic working cylinder and a reference transducer system. (Fig 2)

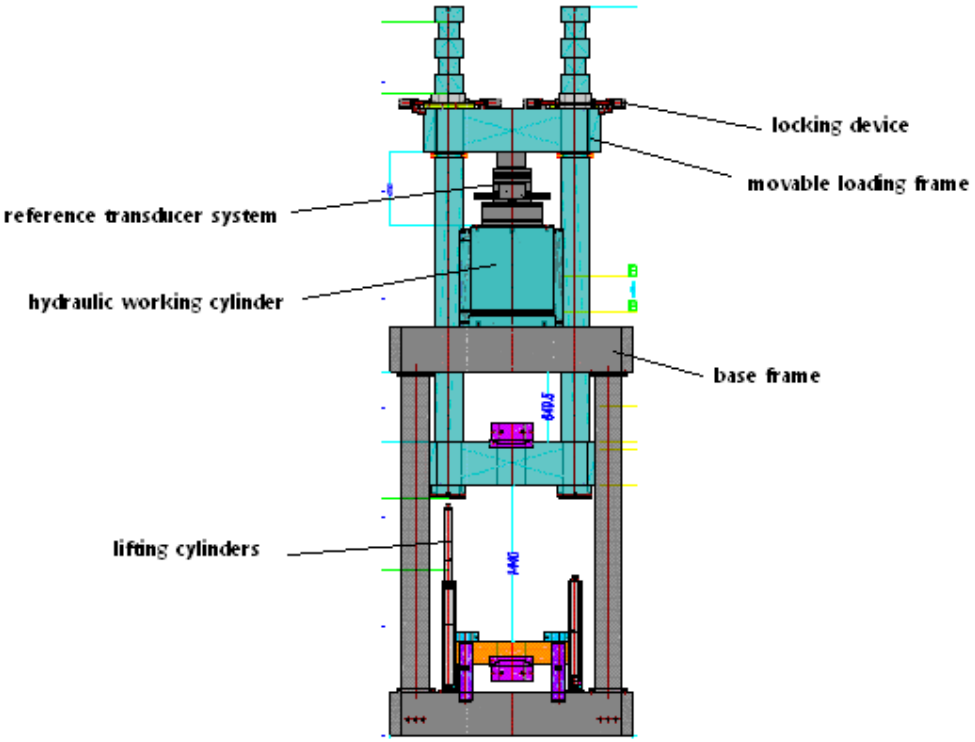

Fig 2 10 MN hydraulic force machine scheme

The hydraulic working cylinder plunger type, designed with a special seal in order to avoid leakage flow, is mounted on the top of the three-column base frame. It carries on its piston a reference force transducer system. Freely suspended from this reference transducer system is the three-column loading frame, the lower transom of which carries the force transducer to be tested: For compression the force transducer sits centrally on the compression platen, and in tension it is suspended (in mountings according to ISO 376 or similar) from the bottom transom. The reaction force, i. e. the feed-back of the test force into the frame is provided by the compression or tension cross-head, respectively.

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 in steps, using separate lifting cylinders and semi-automatic operated locking device. Fine adjustment is by means of the piston travel.

The generation and control of the oil pressure are obtained by a servo-electric spindle pump, consisting of plunger cylinder piston, ball screw spindle and motor/gearbox combination that allows having a variable load rate and very high load stability over time. (Fig 3)

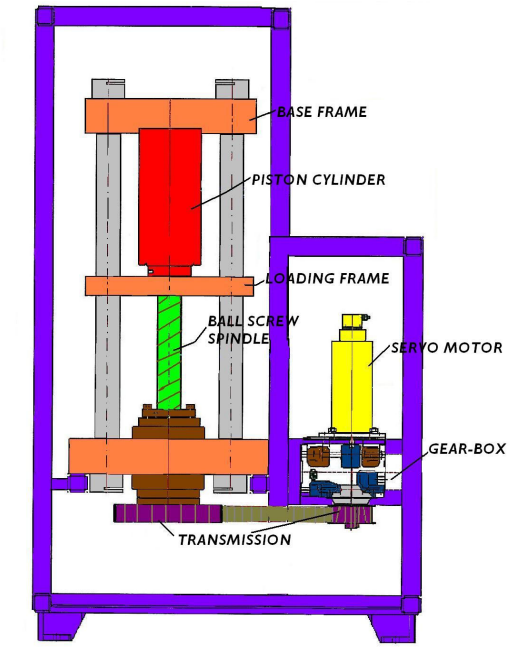

Fig 3 servo-electric spindle pump

The reference transducer system is a GTM development and consists in a 1500 kN accuracy force transducer and a build up of 10 MN (3 x 3,3 MN) mounted in a stack and remain permanently fixed on the top of the hydraulic cylinder. An elastic coupling flange protects the smaller transducer from overloading when force over its capacity is applied. This system allows to have available all the force range of the machine with the maximum accuracy possible without necessity to change the reference transducer and generate gap in the load range. (Fig 4)

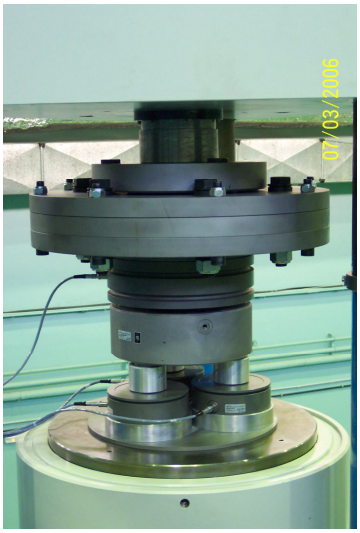

Fig 4 Reference transducer system.

The operation principle of the machine is to generate forces as pre-set by the operator, increasing them from zero or from the previous load step up to the required value at a pre-selectable rate. This is achieved 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 adjusts the pressure so that the selected load is reached accurately and kept constant for the pre-set measuring time.

The control system unit consists in a main board of 8 I/O (system SCM 3000) that includes a microprocessor which controls the functions of the machine by means of internal software and the communication with peripheral.

The output signals from different channels are digitalized by a A/D converter of 16 bits, obtaining a high resolution in the measurements and consequently in the control of the machine

For operation, the machine uses a PC as human-machine interface with a measurement and control software development in Visual Basic.

The software allows to programming test sequences, setting speed of load application, load direction, load steps and stabilization time. All commands, the programming and loading routines are activated by easy intuitive graphic mode via keyboard or mouse-click (Fig 5). The system has available drivers for direct read-out of measuring values from laboratory and customer amplifiers. This software allows operating in fully automatic or manual way.

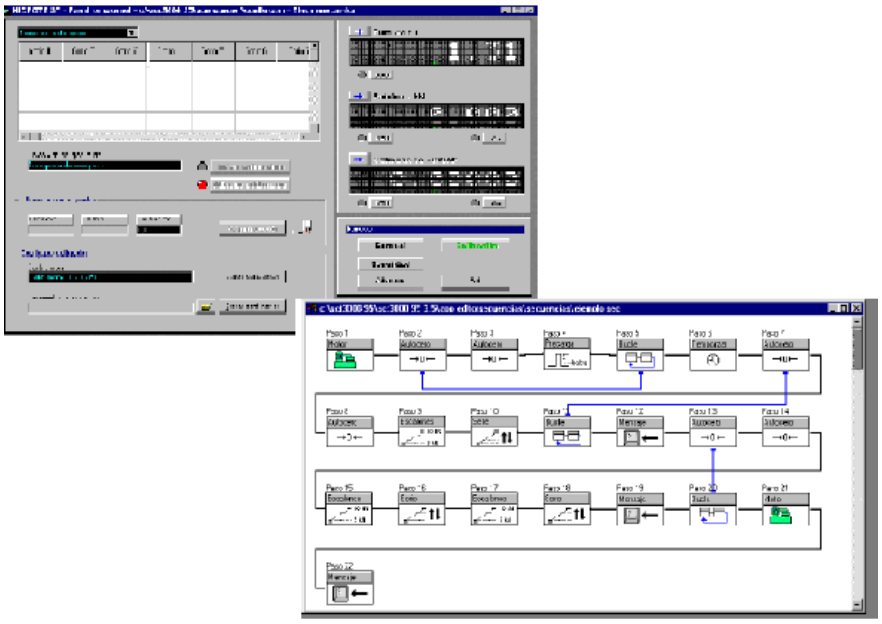

Fig 5 Measurement and control software screen view

4. Specific characteristics:

Force range ……...	100 kN – 10 MN
Reproducibility ……	$2x10^{-4}$ (to be checked)
Uncertainty of the force ……	$2x10^{-4}$ (to be checked)
Testing space :	
Maximum vertical space allowable	
Compression ……	100 mm/ 1000 mm
Tension ……...	800 mm/1800 mm
Horizontal span between columns ……	760 mm
Number of the columns of the loading frame work ...	3
Approx. overall height of the machine …….	6700 mm
Base area, W x D ……...	1900 mm x 1900 mm
Approx. weight of the machine ……	25 000 kg

5. Traceability

The traceability and periodical control of the machine will be achieved using an external GTM 10 MN build up system [4] (9 x 1 MN) that will be traceable to national force standards. (Fig 6). The design allows to use 3 build- up of 3 MN by individual way.

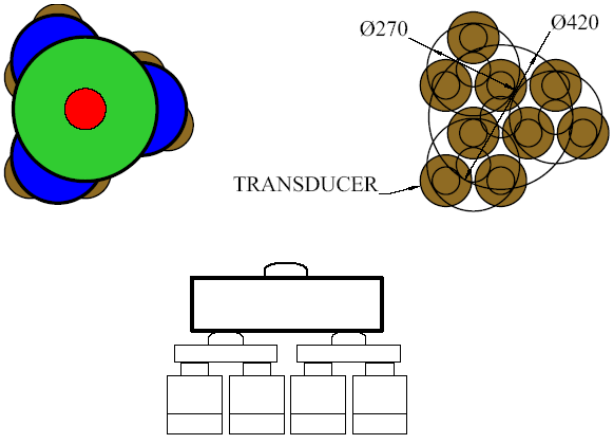

Fig 6 10 MN build up system scheme

6. Conclusions

A new hydraulic force standard machine has been installed at CEM that allows extending the force range in compression and tension up to 10 MN.

This paper describes the construction salient features and metrological performance of 10 MN hydraulic force machine that will serve as the primary standard of force in the range above 500 kN up to 10 MN in Spain. Characterization studies will be carried out during 2007 - 2008.

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