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Instrumentation improvements in the MMS-150 kN force standard machine, CENAM Mexico

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Abstract

The Mexican National Metrology Center (CENAM) has installed a Dead Weights Force Standard Machine as national standard with a measuring range up to 153.6 kN (MMS-150 kN), which allows to carry out calibrations of force transducers in traction or compression mode. This machine has an automatic system which permits, by a series of comparisons with well known masses, to perform a calibration procedure in three different modes (high accuracy, low accuracy and special procedures).

This force standard facility gives traceability to measurements (and calibrations) made by the net of secondary calibration laboratories in Mexico by means of their secondary force standards calibration. The instruments that can be calibrated in the MMS-150kN are high accuracy load cells, force transducers and proving rings.

This paper describes the improvements in the data acquisition, signal processing and automatic control implementation to obtain the readings of the calibration process.

Key words: control, force standard, calibration, traceability.

1. Introduction

The MMS-150 kN force standard machine is a primary force standard and can be used to calibrate load cells, proving rings, force gauges, and other types of force measuring instruments in accordance with ISO 376 and other international written standards. The MMS-150 kN can be used to calibrate in both modes, compression and traction forces. This machine is a national force standard and consists, basically, of a loading frame where a set of masses (of a well-known value) are suspended. With the action of the local gravity attraction on the masses, the force quantity is applied.

This calibration machine is designed to make full use of the accuracy of the suspended masses without any mechanical interferences or machine losses [1]. A yoke -loading frame with a well known mass value- where the weights are suspended, is applied directly on the instrument being calibrated. There are no intervening levers or flexures between the force applied and the instrument under calibration.

The automatic control was designed by the Centro Nacional de Metrologia (CENAM, Mexico) with the main objective to automate the calibration process (to avoid man mistakes) and to reduce the time spent (man hours) in calibrations. Other such projects have been developed by this group before [2, 3, 4].

2.   Test Instrument Interface

2.1 Adjustable Loading Frame

A motorized yoke adjustment allows adjusting easily the loading frame when making the calibration setups.

2.2 Loading Adaptors

The yoke and loading frame were designed to apply axial forces, various adaptors and accessories can be also used, depending on the different types of force measuring instruments, to ensure vertical load application. These, includes accessories and adaptors such as tension rods, load balls, and load buttons, normally used to perform force calibrations.

3.   Weight Loads

The loads that the MMS-150 kN is able to apply are in a binary combination thanks to the following weights:

2 weights of 100 N	1 weight of 200 N	1 weight of 400 N
1 weight of 800 N	1 weight of 1 600 N	1 weight of 3 200 N
1 weight of 6 400 N	1 weight of 12 800 N	5 weights of 25 600 N

Figure 1. Mexican national force standard MMS-150 kN.

Since there are no machine losses or mechanical interference, the machine is able to apply forces with an expanded relative uncertainty of 2×10^{-5} of the applied load.

4. Calibration Process

The calibration process is as follows:
a) To select 10 force application points evenly distributed along the measurement range of the instrument to be calibrated. Select 10% and 100% of the measurement range as force application points;
b) To take measurements on the instrument to be calibrated in three different positions, relative to the MMS-150 kN axis, i. e. 0°, 120°, 240°;
c) To preload the instrument three times to 100% of its measurement range in the 0° position, during 30 s. Make a pause of 30 s between preloads;
d) To take two series of measurements in increasing load direction, 30 s after the last preload and in the same mounting position (0°);
e) To rotate the instrument 120°, after these 2 series, and preload only once to 100% of the measurement range. Three minutes after unloading the cell, two series of measurements are taken in load increasing direction;
f) To use the same procedure of measurements for the position of 240°.

5. Computer Controlled Weight Selection

In accordance with the previous calibration process, it was considered to develop an automatic system with control actuators to obtain an automatic calibration process, in two stages.
i) The virtual load application control, is a control algorithm designed to send the electrical signals and to perform data processing by means of a virtual software, according to the data input given by the technical personnel responsible of force calibrations. Here, the selection of load application points, measurement cycles, and periods of load application as well as pause between loads is made. The programming software used was Lab VIEW, for its versatility and ease of use. It works in Windows; uses blocks diagram notation and graphic language "G".
ii) The actuators control, is used to receive the data process, as electrical signals through a parallel port via a PC. An electronic system was implemented to multiplex these electrical signals by means of an internal program, which activates electronic contacts to enable automatically a series of pneumatic valves, which let the selected masses move into a damped free fall, and hence generate the selected force for the calibration point.

Figure 2. Photograph of the PC control and the force machine.

The two stages of the automatic control are finished. The automatic control has been successfully tested and it is now in operation. A loading control system to allow automated computer control as well as manual selection of the masses to be applied and removed is included. This control permits selection, application, and removal of any weight, independently of any other, except for the yoke assembly which always must be included in the first load to be selected and the last load to be removed. Masses can be applied incrementally in any order. This allows calibrations to be performed in accordance with any particular specification or international written standard. The control system permits to use automated computer control as well as manual selection of the masses to be applied and removed.

The electronic system is located on a cabinet together with the system that generates electrical energy to the control system. The operation principle is by the activation of solenoids, which allow that a mass, with a known value of weight, be deposited to the calibration system. The main objective of the control program is to activate each weight depending on the range of the instrument under calibration. This process is done in real time for loading and unloading of the masses selected. In this way, the calibration process is reduced in time, and supports the accuracy of the measurement process.

6. Automatic control of the calibration process

The function of the control card implemented in the automatic system is to condition the electrical signals for the control provided by the computer program; as well as, to send the electrical signals coming from the PC to active the process of the program in the electronic system.

The actuators have electro-pneumatic sensors, air valves maintain the masses in unload position and when activated, in milliseconds, the masses are loaded to the calibration system; the signal indication is performed with the feedback control system in the calibration panel.
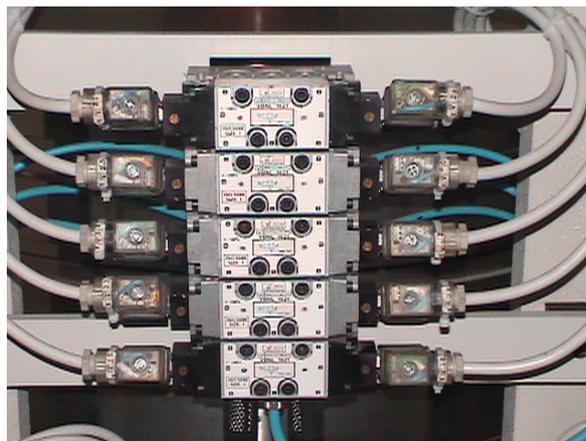

Figure 3. Actuators.

In the automatic program, the value of the maximum load measurement and the time delay in each calibration point are defined by the technician. From there, the program calculates the percentage between each calibration point and the weights required in each calibration target force.

These signals are sent through a parallel port to the electronic system, in order to apply the adequate force according to the calculations.

6.1 Configuration System

The configuration of the serial and parallel port as communication channel in the personal computer is described in the graphical program Lab VIEW. The automatic program manipulates the outputs of data by these ports.

The program designed for this aim is a tool of graphical programming that has the capacity to interact between the command signals, but also to make the processing of the same signals.

The next figure shows the frontal panel of the software for the process of calibration in automatic mode in the MMS-150 kN.

Figure 4. Panel of the calibration process computer program.

As it can be seen, the panel includes a series of icons to access the program that the technical wants to use. Here, it is describe the most important modules:

a) NIVEL SUPERIOR-INFERIOR. Shows the masses selected in the calibration process;
b) CALIBRACION. Select the "inicio" and it begin the force application points evenly distributed along the measurement range of the instrument to be calibrated in initial position. Selects 10% and 100% as force application points;

c) CONFIGURACION. In this panel the metrologist can select the number of preloads and delay of the load as well as the range of the calibration process.

Others parameters shown in this panel are: the real time reading of the amplifier used by the instrument to be calibrated and different alarms.

At the end of the calibration, the control program sends the readings of the transducer to be calibrated in order to be stored. Hence, a calibration report is stored in an Excel file.

7. Conclusions

The automatic control has been successfully tested and it is now in operation. The involuntary errors due to the metrologist, when selecting in the dash board the mass to be applied (for each load to be applied in each cycle), are now avoided since the calibration process to be used can be selected in the virtual program and the masses are applied automatically. Also, the period of load application and the resting time is better controlled since, instead of having the metrologist keeping track of the time in a watch, the program uses the PC time (having repeatability and constant periods in every point). On the other hand, man hours used in the calibration process have been reduced, as the calibration is performed continuously, while the metrologist is working in other activities.

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