IMEKO 20th TC3, 3rd TC16 and 1st TC22 International Conference
Cultivating metrological knowledge
27th to 30th November, 2007. Merida, Mexico.

Hybrid torque standard machine for 1 kN·m developed in CENAM

D. Ramirez-Ahedo, J. C. Torres-Guzman, F. Martinez-Juarez

Centro Nacional de Metrología (CENAM, Mexico). E-mail: dramirez@cenam.mx

Abstract

The torque laboratory at the Centro Nacional de Metrología in Mexico (CENAM) started operations in 1997 with the design, built up and set up of a torque transfer standard machine for 2 kN·m (TTSM-2kN·m). Since that time, a total of five torque standards have been developed at CENAM. Two of them realize the quantity via the primary method (dead weights applied in a lever arm of a well known length) in the measuring ranges of 2 kN·m and 1 kN·m. The other three transfer standard machines are in the ranges from 20 N·m and 2 kN·m, and the last one is a TTS machine which is in the set up stage, with a range up to 20 kN·m.

This paper gives general information about the design, build up and set up of the torque standard machine up to 1 kN·m which has a dual function, this is, realizing the quantity with a primary torque standard method (PTSMe) and/or disseminating it with a torque transfer standard method (TTSMe); depending on the type of calibration one wishes to perform.

Keywords: Torque, hybrid torque standard, torque primary standard, torque transfer standard, torque calibration systems.

1. Introduction

As it is well known, the primary torque standard machines (PTS) have been constructed in several countries. There are several papers presenting the principle and description of PTS machines, including design and operation for the realization of the quantity [1], [2], [3], [4], [5]. Also, we can find information for the torque transfer standard (TTS) machines [6]. From these documents it is possible to observe some advantages and disadvantages of both types of machines, such as:

a) Differences in accuracy;
b) Time-consuming for calibrations;
c) Differences in the best measurement capabilities.

Taking into account these differences, CENAM started the construction of a hybrid torque standard machine (which could be used with the primary method and the transfer method). The primary method mode (PTSMe-1kN·m) consists basically of a set of masses - which can be used independently - in order to generate force that is applied at the end of a lever arm via thin metal belts to obtain several torque values combinations.

The machine in the torque transfer standard method (TTSMe-1kN·m) mode includes, for the dissemination of the quantity, a set of three torque standard transducers with ranges of 10 N·m, 100 N·m and 1 kN·m calibrated in the PTSMe-1kN·m mode. With any of these torque transducer standards, it is possible to perform a calibration by direct comparison of transducers, torque wrenches or other torque instruments.

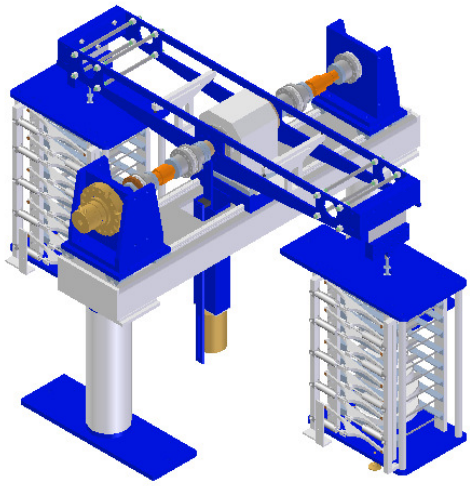


Figure 1. Hybrid Torque Standard Machine up to 1 kN·m.

The machine can be used in manual or automatic modes by means of a program developed in our torque laboratory using Lab VIEW as the programming software. General information is included in the paper "Automation of the 1 kN·m torque hybrid system standard" [7].

2. Description of the Hybrid Torque Standard Machine

2.1 Primary Method

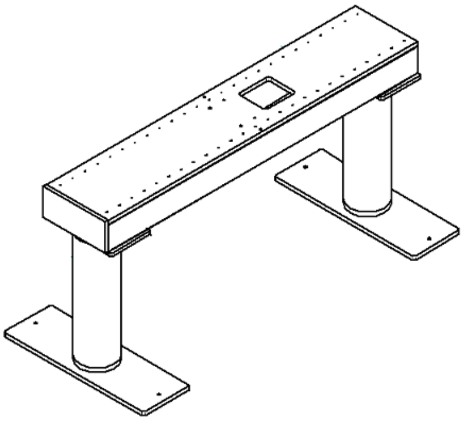
The primary method is generated by the definition of the torque quantity and consists basically of a set of weights suspended on a lever arm.

The full system includes:

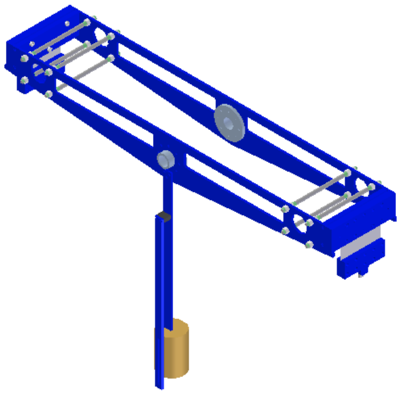
a) A main structure;
b) A lever arm system;
c) A set of weights;
d) An air bearing used as fulcrum or support for the lever arm, and
e) A servomotor used as counter reaction.

a) <u>Main structure</u>

The main structure is basically a high stiffness frame where the lever arm and counter reaction systems are mounted on a machined plate size 0.4 m x 2.5 m of length and it is supported in two fulcrums.



b) Lever arm system

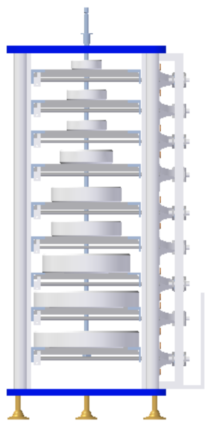


The lever arm system, consist of two parallel machined flat plates of 2 m of length made from stainless steel. The weights are suspended and its force introduced into the lever arm through a metal band of 25 μm thickness. The horizontal position of the lever arm is controlled by an inclinometer. The traceability for the length in the lever arms was obtained with the aid of the dimensional laboratory personnel by way of a laser tracker instrument.

A radial air bearing is used to support the weight of the lever arm and accessories; is mounted on the main frame and has a lever arm each side.

Calculations via the finite element method (FEM) show a maximum deflection at the lever arm tip of 91 μm for 1 kN·m (which produces a relative reduction in the lever arm of the order of 5×10^{-9} which is considered negligible for this value of torque applied).

c) Set of weights



The weights contained in the structure are traceable to the national mass standard (prototype 21 in Mexico). The set of weights for each side are:

1 x 1 N	1 x 50 N
2 x 2 N	2 x 100 N
1 x 5 N	1 x 200 N
1 x 10 N	2 x 250 N
2 x 20 N	

All weights contained in the structure were made of non magnetic stainless steel designation ASTM-304 with a value corrected for the local gravity acceleration value, and air buoyancy effect. The superficial finish of the mass was $R_Z \leq 10$ μm.

In order to apply the force, two structures or weight towers are used. Each structure has an equal set of weights and depending on the torque to be applied; the mass pieces are suspended from a lever on to a metal band, to generate the selected torsion moment on the instrument. Depending on where the load is applied both, right-hand torques or left-hand torques are generated and applied in the instrument under calibration.

The structure was designed to make direct application of the weights without having any mechanical interference or load losses. There is a central tie bar with the same weight on both sides of each structure connected to the lever arm, via the metal band foils. The central tie bar, hangs directly of the metal band where the force due to the action of the local gravity on the selected weights is applied. The weights are applied and removed in any sequence, independently of each other, using pistons connected to levers located on the structure.

d) Air bearing used as fulcrum or support for the lever arm

The air bearing is of the cylindrical type and incorporates a stator and a rotor. The rotor serves as a stiff spring. If the air pressure is maintained between 400 kPa and up to 600 kPa there will be no mechanical contact between the rotor and the stator, and the radial load remains within its capacity limits. The manufacturer specifies a residual friction lower than 20 μN·m; although the residual friction of the air bearing was estimated by the pendulum test obtaining a value of 25 μN·m.

e) Counter reaction

The counter reaction in this mode is a harmonic drive servomotor with two functions: i) used as a counter reaction and ii) to obtain the horizontal reference position of the lever arm after each applied load.

In the next figure, there is an expanded drawing for this system including other additional accessories. The parts are:

1. Transducer under calibration;
2. Hydraulic couplings (ETP type);
3. Flexible couplings;
4. Accessories for connection between hydraulic and flexible couplings;
5. Lever arm.

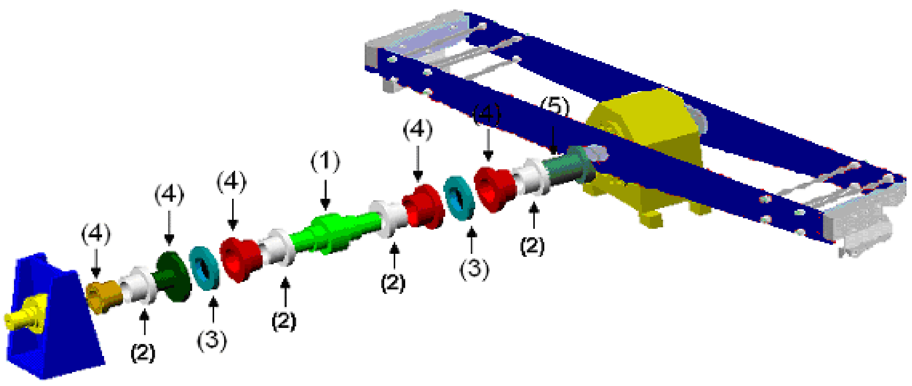


Figure 2. Primary method for torque measurement in the 1 kN·m hybrid torque standard machine.

2.2 Torque Transfer Method

The transfer method is shown in figure 3 as an expanded drawing and in conjunction with other parts as described below.

1. Standard torque transducer;
2. Torque under calibration;
3. Hydraulic Couplings (ETP type);
4. Flexible Couplings (torsion-proof resilient couplings);
5. Accessories for connection between hydraulic and flexible couplings (also part 7);
6. Accessory to connect the hydraulic coupling ETP type with the servomotor.

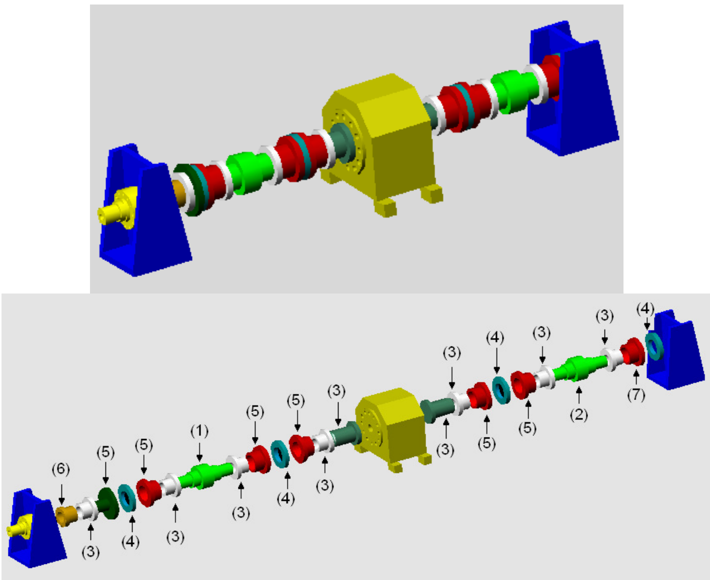


Figure 3. Torque transfer arrangement in the 1 kN·m hybrid torque standard machine.

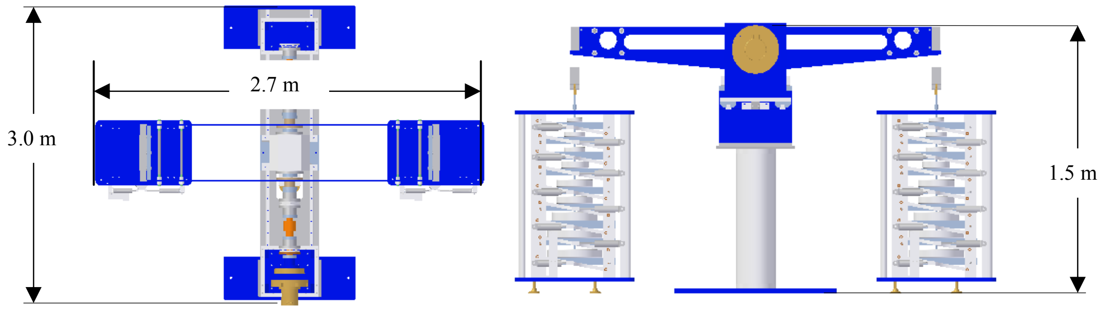
The torque transfer principle has been well described in several papers as the principle of component system [6].

The counter reaction used in the primary torque mode is now a torque generator in the transfer mode. A torque transducer calibrated in the primary method, serves now as reference standard and is connected in the horizontal position through hydraulic and flexible couplings. The air bearing, serves to take up all side forces and bending moments when a torque transducer or a torque wrenches is under calibration. Note that, it is necessary to unplugged previously (to be able to shift from primary mode to transfer mode) two hydraulic couplings - one for each side of the air bearing; which connect the lever arm through a uniform diameter shaft of 50 mm – in order to install the transducer under calibration, as shown in figure 3.

An additional counter torque reaction plate is mounted on a set of four carriages and is located at the other end of the arrangement, on the main structure. Two parallel linear guides are mounted in the main structure and are used to adjust for the length of the torque transducers in operation (the reference transducer and the transducer under calibration) in between the torque generator - air bearing and air bearing - counter reaction plate.

3. Specification of the Hybrid Torque Standard Machine

The hybrid torque standard has a size of 3.0 m (length) x 2.7 m (length of the lever arm and mass structures) x 1.5 m of overall height, with an approximate weight of 8 kN (≈ 800 kg). The relative uncertainty for the PTSM-1kN·m is within the order of 10 x 10^{-5} (k = 2) and for the TTSM-1kN·m is around 5 x 10^{-4}.



a) Aerial view b) Frontal view.

Figure 4. Overall size of the HTSM-1 kN·m.

4. Hybrid Torque Standard Machine Tests Program

Several tests were made in the machine in order to ensure the quality of its measurements. The deformation on the main frame, for different levels of torque, was measured. Negligible deformations were found in the machine. Many other tests were performed in the machine; however, and due to the high level of accuracy required, the machine was found no to be adequate to act as a national primary standard. The main reason was the recurrent difficulty to control small interactions of the accessories to switch from transfer to primary method which causes friction with consequent parasitic components increase and deviation of the torque generation (within several parts per million).

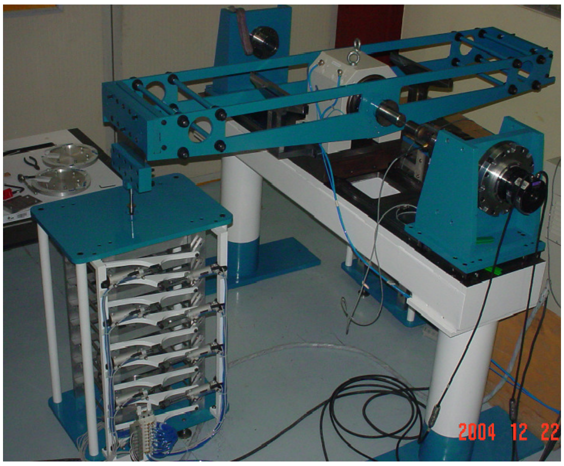


Figure 5. Hybrid torque standard machine for 1 kN·m.

5. Conclusions and Comments

The hybrid torque standard machine has been developed at CENAM in Mexico. The design, mechanical production, assembly, control system and characterization of the machine were performed by the Force and Torque Group at CENAM.

The relative uncertainty budget for the PTSMe-1kN·m is 10 x 10^{-5} while for TTSMe-1kN·m the uncertainty is in the order of 5 x 10^{-4}. Better uncertainties for Primary Torque Standard machines are possible; however, for this type of design, shifting from primary to transfer method and vice versa, presents some difficulties which have a direct impact in the uncertainty of the measurement.

For the purposes of the high accuracy primary laboratory level required in Mexico, the use of a machine with only a primary method is preferred and a separate transfer standard machine could be used to disseminate the quantity.

For this reason, the operation of this machine is ideal in a laboratory where the levels of uncertainty within 10 x 10^{-5} and 20 x 10^{-5} are adequate. The machine is now owned by Volkswagen de Mexico (VW-M) and it is installed in their plant located in the city of Puebla (from September 2007); new tests are carried out in order to have the machine in optimal conditions for its new application.

A thorough training program to transmit all necessary knowledge to operate and to maintain the HTSM-1kN·m was given to VW-M, including training courses, laboratory assessment, calibrations practice, evaluation of the machine, and proficiency testing.

References

[1] Ramirez-Ahedo D., Torres-Guzmán J., “Diseño y Construcción del Patrón Primario Nacional de Par Torsional en México” (“Design and Construction of a Primary Torque National Standard in Mexico”). Simposio de Metrología 2001. Queretaro, Mexico, May 2001.

[2] Peschel, D.: “Mechanical Parasitic Components and Their Influence on the Calibration of Torque Transducers”. 13th International Conference on Force and Mass Measurement, Helsinki (Finland), 10.-14. May 1993.

[3] Röske D., Adolf K., “On the Problem of Lever Arm Lengths in the Realization of the Torque – Finite Element Calculations on Lever Models”, Proc. of the 14th IMEKO TC3 Conference (Warsaw, 5.-8. September 1995), Warsaw, Poland, 1995, pp. 178-182.

[4] Adolf K., Mauersberger D., Peschel D., “Specification and uncertainty of the 1 kNm torque standard machine by PTB/Germany”. 14th IMEKO TC3 Conference, Warsaw (Poland), 5.-8. September 1995.

[5] K. Ohgushi, T. Tojo and A. Furuta, “Development of the 1 kN m Torque Standard Machine”, 16th IMEKO World Congress, Vienna, Austria 2000.

[6] Peschel D., “Proposal for the design of torque calibration machines using the principle of a component system” Proceedings of the 15th International Conference, IMEKO TC3. October 07 – 11, 1996. Madrid, Spain.

[7] Morales C., Ramirez-Ahedo D., Torres-Guzman J., Jimenez R., Banda E. “Automation of the 1 kN·m torque hybrid system standard”. The 2006 International Conference on Dynamics, Instrumentation and Control, CDIC-06. August 13-16, 2006, Queretaro, Mexico.