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Torque transfer calibration system for 200 N·m and 2 kN·m, its control and characterization

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ABSTRACT
For the dissemination of torque, medium accuracy transfer calibration systems are normally operated manually, originating high consumption of man-hours in the development of a calibration. This work presents the control system designed and implemented in a 200 N·m and 2 kN·m torque transfer calibration system and its characterization to evaluate the error and uncertainty of the system. The benefits of operating a medium accuracy system with an automatic control are also highlighted.

Section: RESEARCH PAPER

Keywords: Torque; metrology; control system; characterization; torque transfer calibration system.

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1. INTRODUCTION

Normally, in a torque transfer calibration system the torque application is performed by manual operation. In this type of systems the torque load required is achieved using motor start and stop control buttons, which also applies for motor speed, applied torque load and motor spinning direction. This manual process required many man-hours for a calibration. CENAM designed, built and put into operation an automated torque transfer calibration system for 200 N·m and 2 kN·m ranges for the collective transport system Metro (Mexico City). This paper presents the control system and the characterization of the torque transfer calibration system.

2. OPERATION OF THE TORQUE TRANSFER CALIBRATION SYSTEM

The operation is based on the direct coupling of the calibration instrument to the standard transducer. For this purpose, flexible and rigid couplings are used and the whole system is supported by a ball bearing (Figure 1) [1].

The manual operation is performed using buttons for start and stop of the motor, a 3 positions interrupter for spinning direction selection and 2 potentiometers, one to change the motor speed and the other to set the load. The whole process requires manual data acquisition.

2.1. Calibration procedure

Firstly, the standard transducer and the calibration instrument are coupled and mounted on the system using all required accessories. Using the manual control system, the measuring points are set. Eight points are selected on the calibration instrument's range (from 10% to 100%), all measurements are written down in a logbook. Preloads, at 100% load, are applied (Figure 2).

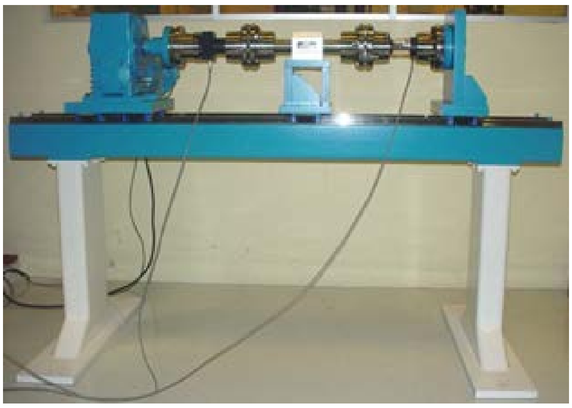

Figure 1. Torque transfer calibration system as built.

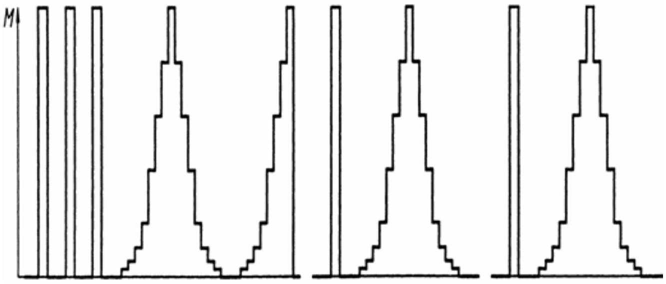

Figure 2. Example of the calibration procedure at 0°, 120° and 240° mounting positions for classes 0.05 and 0.1 (DIN 51309:2005).

This procedure is applied with increasing and then decreasing load, for three different mounting positions of the calibrating instrument and in clockwise and anticlockwise directions. A total of 112 measurements are made for one calibration. Since the process is manual the calibration is long and requires a large number of man-hours. This procedure is based in the DIN 51309:2005 Materials testing machines – Calibration of static torque measuring standard.

3. TORQUE TRANSFER CALIBRATION SYSTEM AUTOMATIZATION

3.1. Control logics

The control logics frame was designed as follows:

1) Start the motor from 0% up to 100% of the calibrating instrument's range. Stop the motor. After 15 s to start the motor again in the opposite direction down to 0%. Wait 15 s and repeat the cycle to perform 3 preloads.
2) Start the motor and stop at 10% of the instrument's range. Wait 15 s and perform the measurement. Continue in this way up to 100%.
3) The previous activities are repeated in descendent mode from 100% to 0%.
4) The metrologist rotates the calibration instrument to 120° and performs the previously described activities and does the same for 240°.
5) The same procedure is executed for clockwise and for anticlockwise directions.

3.2. Equipment and material used

Software: Windows Vista, Lab VIEW version 2011, NI-DAQ version 6.1.

Hardware: PC Pentium, PC-DIO 24 PNP card, Interface card, PC – control system Power card.

3.3. Programming software

The programming software used was Lab VIEW, as it is a versatile and easy to use program. It works in Windows; uses blocks diagram notation and the graphic language "G". See Figure 3 for a view of the main screen arrangement. This type of programming software has proven to be particularly useful in similar applications, as can be seen in [2].

3.4. Control stage

To develop the PC´s interface with the system, a digital input/output interface card PCDIO24 PNP from National Instruments was used. The card works in a virtual instrumentation programming environment (Lab VIEW) and a power stage.

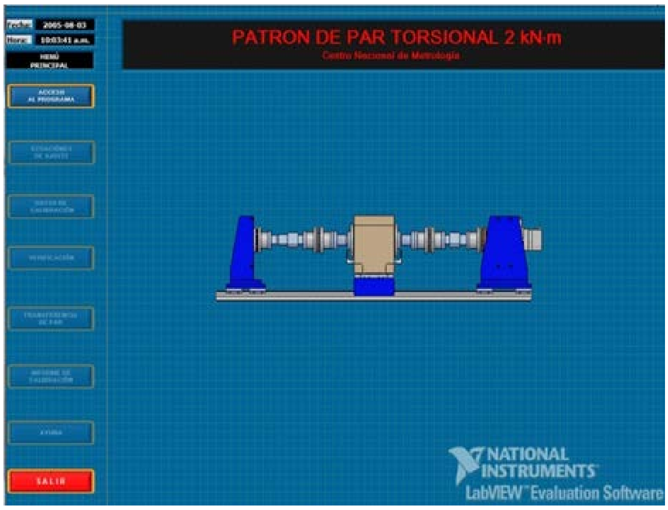

Figure 3. Main screen of the control program.

The card handles digital input and output; it has 3 ports (A, B and C) and 24 digital lines or 24 digital input and output channels. The ports can be configured as input or output, and is TTL logics compatible.

For the card operation the NI-DAQ DRIVER Software of National Instruments was used. The NI-DAQ is a function library called by the program during its interface operation. Some built-in functions are: Data acquisition, Digital, input/output, Counts/Operation time.

3.5. Control stage

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3.6. PC - control system interface card

To perform the connection between the output of the PCDIO 24 card (installed in the PC CPU) and the power stage, an interface card with an 8-pin connector was produced. Pins 1 and 2 carry the electrical power supply (5 V DC) and Ground (electrical supply for the computer), pins 3 to 8 are for the digital outputs.

3.7. Power stage

In the power stage, 2 electrical contacts 127 V/60 Hz are integrated to the existing control system and are controlled by the power card.

3.8. Control Program

The program follows the calibration procedure (2.1) and the control logics (3.1). The calibration starts with the preloads (3 preloads at maximum load). The automatic program performs the 3 first series at 0º position. The measuring range is divided

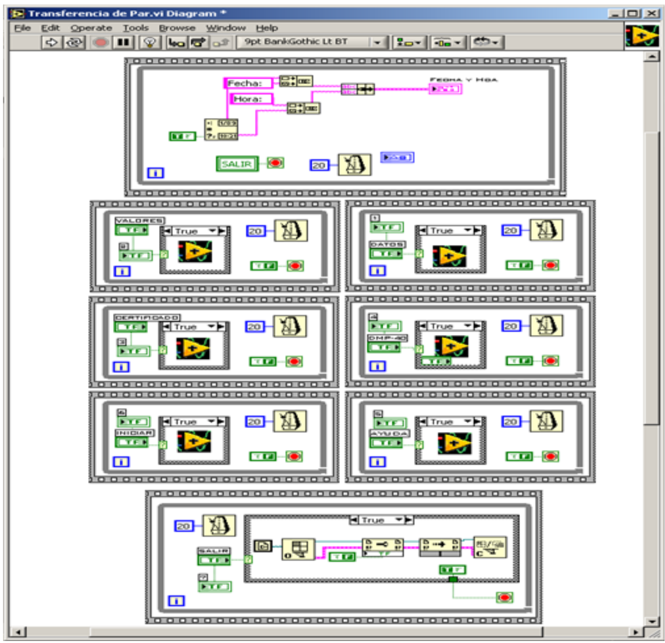

Figure 4. Control program diagram.

into 8 points proportional to the operation time and measurements are taken in each point. The first reading is taken at 10% of the maximum range and the 8 points are evenly distributed up to 100% of the defined operation time.

The program stops after the 3 first series to allow the rotation of the instrument under calibration to 120º and then continues according to the calibration procedure (2.1). The same series is repeated for 240º.

The calibration process requires an open program, capable to perform the calibration in automatic mode but able to adjust it to fit all different measurement ranges, starting from 1 N·m and up to 2 kN·m.

Figure 4 presents a diagram of the control program.

4. TORQUE TRANSFER CALIBRATION SYSTEM CHARACTERIZATION

The objective of this study is to evaluate the torque transfer calibration system for the reliable measurement of torque. The

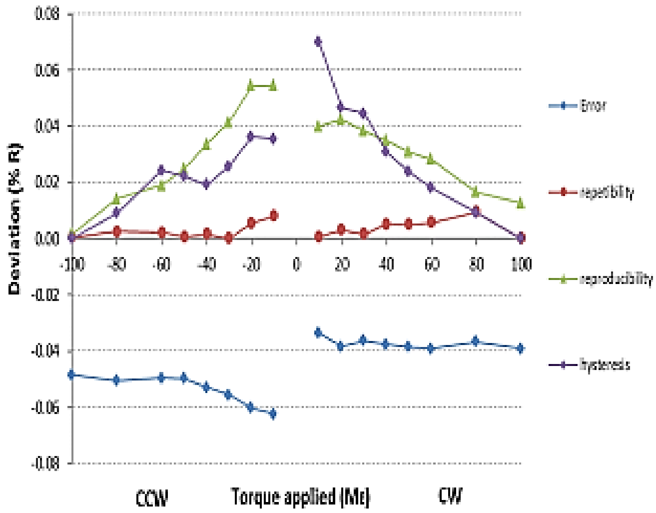

Figure 6. Factors of influence, transducer 2 kN·m.

main part consists of the calibration of the whole system in situ, at normal operation conditions.

4.1. Characterization

For the characterization, it was necessary to perform various tests by means of reference torque transducers; in each test, an influence factor or metrological characteristic was isolated to determine its influence. The most important characteristics to be measured were a) torque stability, b) elapsed time between torques applied, c) repeatability, d) hysteresis, e) reproducibility, f) resolution (stability of reading) and g) combined expanded uncertainty of the whole system.

The characterization of the torque transfer calibration system was performed by means of two torque standard transducers, one with a range of up to 200 N·m and another with a range of up to 2 kN·m.

Figures 5 and 6 show the results obtained from the analysis of the main factors of influence which contribute to the combined expanded uncertainty of the torque transfer calibration system (repeatability, reproducibility or position change, hysteresis or reversibility) and the error or deviation of the whole system.

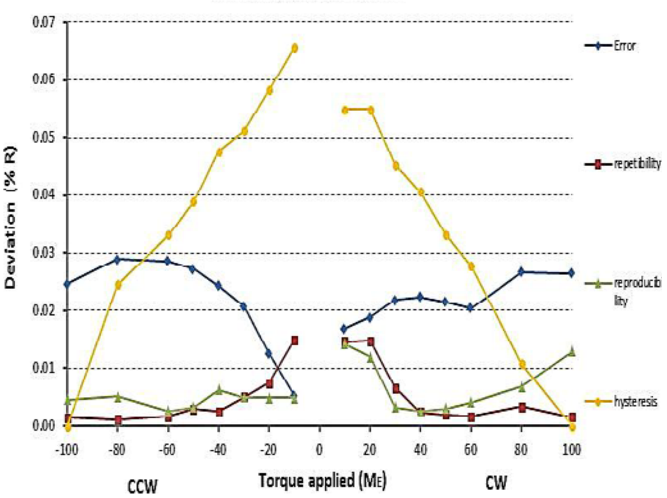

Figure 5. Factors of influence, transducer 200 N·m.

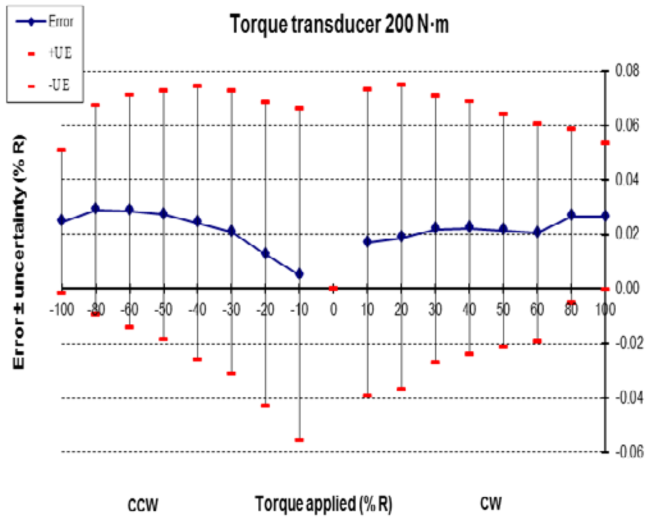

Figure 7. Error and uncertainty of the 200 N·m torque transducer.

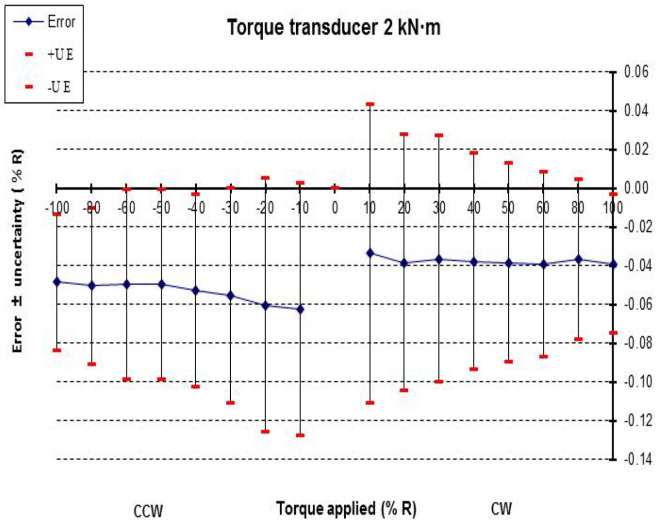

Figure 8. Error and uncertainty of the 2 kN·m torque transducer.

Figure 5 presents the results of the measurements made for the case with the low range torque transducer (range up to 200 N·m). Figure 6 presents the results of the measurements made for the case with the high range torque transducer (range up to 2 kN·m).

In figures 7 and 8, the errors and uncertainties found in the torque transfer calibration system for each applied torque are shown: figure 7 for the 200 N·m torque transducer and figure 8 for the 2 kN·m torque transducer.

5. CONCLUSIONS

The control system and the results of the characterization brought a number of benefits to the operation and use of the torque transfer calibration system. Some of the most important benefits of the work presented in this paper are:

I. Instrument's calibration time considerable reduction.
II. Minimum metrologist intervention during a calibration.
III. Better control over the process influence variables.
IV. Better control on the data acquisition, ensuring better measurement quality.

The characterization proved that the torque transfer calibration system is adequate for torque meters and medium accuracy torque transducers calibrations.

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