DESIGN, CONSTRUCTION AND START UP OF A
200 N·m AND 2 kN·m TORQUE TRANSFER CALIBRATION SYSTEM

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Abstract: CENAM developed a torque transfer calibration system with nominal torques defined at 200 N·m and 2 kN·m in order to meet the calibration needs identified for the Metrology Laboratory of the collective transport system "Metro" in Mexico City. Its use is mainly for the calibration of torque meters and low accuracy transducers; design started from that consideration. Integrating mechanical design and control, a functional torque calibration system was built and put into operation.

Keywords: Torque, calibration, transfer standard.

1. INTRODUCTION

Initial considerations were made to determine the type of torque calibration system that should be developed. Considering that most torque instruments are calibrated through the static method, particularly the ones used in the Metro (e. g. torque meters and transducers), that type of system was decided upon.

Most torque instruments to be calibrated with the designed system do not require a standard of high accuracy [1], as most torque meters work with an approximate expanded relative uncertainty of "±1% to ±5%" and low accuracy transducers with an approximate expanded relative uncertainty of "±0.25% to ±1%" [2]. Taking into consideration these arguments, the uncertainty provided by a transfer system is adequate, generally being around 800 ppm [3].

Also, considering the indication intervals of the torque meters used by the "Metro", it was determined that a torque transfer calibration system using the static method and maximum intervals of 200 N·m and 2 kN·m would be developed.

2. DEVELOPMENT

2.1. Conceptual Design

The system developed is a transfer system, meaning it uses transducers to generate torque measurements and calibrations through a comparison of a reference transducer with a test transducer. To maintain a high level of accuracy in the system, a radial support must be used between the transducers to reduce or remove undesired loads. Additionally, flexible couplings are used to reduce the effect of radial and axial misalignments. Lastly, the system can be used in a vertical configuration [4] or a horizontal one; the latter is more user-friendly considering the transducers will be changed constantly, which is why it was selected for the system developed. Figures 1 and 2 show schematics of the design.
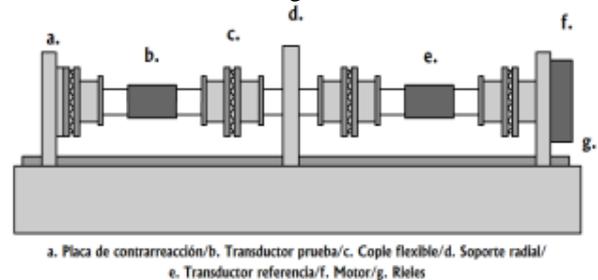

a. Placa de contrarreacción/b. Transductor prueba/c. Cople flexible/d. Soporte radial/
e. Transductor referencia/f. Motor/g. Rieles

Figure 1. General conceptual design of the system, in a transducer calibration configuration.
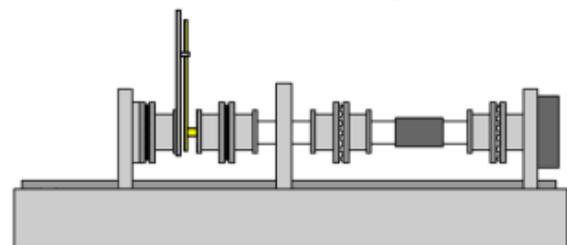

Figure 2. General conceptual design of the system for torque meter calibration.

2.2. Systemic Analysis

Considering the functional requirements of the system, it can be conceptually divided into subsystems, each with its own particular components. The following subsystems were established: *Support system or base, Load system or actuator, Low friction connection system, Coupling system, and Measurement system*.

The *Support system or base* refers to the base structure of the system, providing it with robustness, rigidity, positioning, and mobility to the other parts of the system. It consists of the *base* and the *rails and profile rail bearings*. See Figure 3.

Figure 3. Profile rail bearing.

The *Load system or actuator* generates the external load to be measured in the system, in this case being the torque to be measured through comparison. The Load system has to be capable of generating the appropriate torque constantly, for the required intervals, while also allowing the user to make adjustments to such parameters to meet his or her measurement needs. This subsystem consists of two main parts: i) the *servomotor* and ii) its *control*.

Along with the servomotor, a gearbox reducer is used, helping both to reduce the speed of the output shaft and increase its torque. The planetary gearbox is often used for its high conversion ratio and for allowing axial alignment between the input and output components (Figure 4). The following equation represents its conversion ratio:

$$n = \frac{1}{1+\frac{Na}{Ns}} \tag{1}$$

Where, n is the transmission ratio, Na is the number of teeth of the outer gear and Ns is the number of teeth of the sun gear.
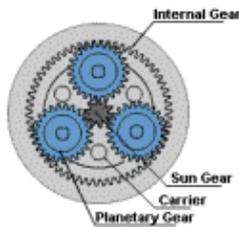

Figure 4. Planetary gearbox used in the system.

The *Low friction connection system* refers to a bearing upon which a solid cylindrical bar should be able to rotate in an almost frictionless manner. This cylindrical bar works as a connection between the components mounted on both of its ends. On one side, the servomotor is coupled with a transducer and, on the other, a torque meter with the counter-reaction plaque. The main function of this subsystem is to remove or reduce parasitic loads generated by deflection of the components caused by their own weight.

The *Coupling system* provides the connection and joints between the measurement instruments and the Low friction connection system, as well as with the actuator. Additionally, it fixes the coupled components to a plaque, providing stability and allowing for tests involving elastic deformations, thus complying with the requirements for a static torque calibration system.

The components that integrate this system are: *rigid couplings*, *flexible couplings* (Figure 5), the *counter-reaction plaque*, and the *counter-reaction bar for torque meters*.
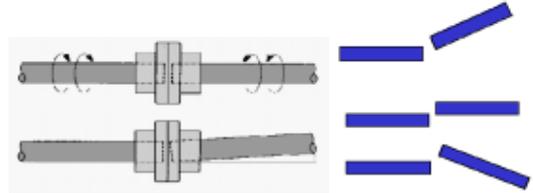

Figure 5. Capabilities of a flexible coupling (left) and kinds of misalignment they can correct (right).

The *Measurement system* consists of transducers and a signal amplifier; this subsystem produces the numeric results from the work of all the other components, the information obtained being the point of interest for the user. The parts of this subsystem are *torque transducers* and *digital signal amplifiers*.

Torque transducers (Figure 6) transform that magnitude into low-power electric signals that can be quantified.

Figure 6. Bar-type torque transducer.

A digital signal amplifier is a data acquisition system that facilitates the capture, interpretation and measurement of low-power electric signals, in this case, those produced by the transducer.

2.3. Mechanical Design

For the components of the base, the mechanical design was approached by first considering the instruments to be used and the loads that should be withstood. Considering the weight of the measurement components as well as a maximum torque of 2 kN·m applied through the servo output shaft, materials and specific geometries were used to make the system robust and secure.

Steel was used in the whole base structure, as well as for the plaques and beams used, chosen in specific nominal sizes and configurations so that their resistance would suffice for the inclusion of a safety factor (Figure 7). This would eliminate the possibility of a safety risk during a test. Once the CAD model was finalized and its stability and functionality analyzed, the technical drawings were made to start the manufacture of all the pieces in the system.
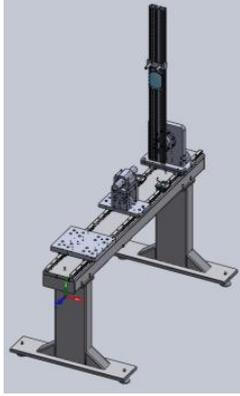
Figure 7. Assembly of the torque meter calibration configuration of the system, with the exception of the servo and the coupling system.

2.4. Control Design and Construction

Once the servomotor to be used was acquired, the design of the control system was based on the electric signals handled by it, regarding voltage and current specifications.

Upon understanding the input and output signals of the servo, a circuit was built with potentiometers and switches that allowed the variation of the input signals to obtain the desired torque or speed of the shaft as an output. The control system is to be fully detailed in a separate publication. See [5].

3. FINAL COMMENTS AND CONCLUSIONS

Proper care and investigation is required in the process of designing and constructing a calibration system, simply because accuracy is its most valuable asset. In the design stage, the constitutive elements of the definition of the quantity to be analyzed have to be taken into account, so that they can be translated properly into the elements of the calibration system. The system has been put in operation and the maximum relative expanded uncertainty ($k = 2$) for the two ranges was less than 0.07 % of the reading, better than the 0.08% required. Figure 8 shows the system as build.

Figure 8. 200 N•m and 2 kN•m torque transfer calibration system as put in operation. Set up for transducers.

4. REFERENCES

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