



# DESIGN, DEVELOPMENT AND CALIBRATION OF TORQUE STANDARD MACHINE

By

Khaled Abdelaziz Mohamed Abdelrhem

A Thesis Submitted to the

Faculty of Engineering at Cairo University

As Partial Fulfillment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

in

MECHANICAL DESIGN AND PRODUCTION ENGINEERING

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**Title of Thesis:**

Design, development and calibration of torque standard machine

**Key Words:**

Torque, Calibration, Temperature, Humidity

**Summary:**

A NIS 1 kN·m secondary standard torque calibration machine designed earlier [1] is further developed to be a primary standard torque calibration machine. Design and construction of a lever-mass system with ends to be coaxial with the transducer axis are implemented. FEM analysis is used to check the mechanical stresses occurring in the critical components affecting the deflection in the designed lever arm. Procedures for accurate measurements torque arm are described. Expected relative expanded uncertainty is worked out to be  $2 \cdot 10^{-4}$ .

A study on the effect of relative humidity and temperature on the DMP40 measuring amplifier and the BN100A bridge calibration unit as one of the main sources of torque machine uncertainty is reported. Furthermore, the effect of relative humidity on the zero signal of torque transducers is investigated. Finally a study of the influence of temperature and relative humidity on the sensitivity and the characteristics of torque transducers such as residual zero torque, reversibility and creep, is presented. Equations are presented to predict the effect of temperature/relative humidity changes on the sensitivity of torque transducers.

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## Nomenclature

$A$	Torque transducer characteristic constant for zero signal, mV/V.
$A_H$	Torque transducer's humidity characteristic constant for sensitivity, mV/V.
$A_T$	Torque transducer's temperature characteristic constant for sensitivity, mV/V.
$w$	Width, m.
$b$	Inverse $\tau$ , s <sup>-1</sup> .
$b_H$	Inverse $\tau_H$ , s <sup>-1</sup> .
$b_T$	Inverse $\tau_T$ , s <sup>-1</sup> .
$C$	Viscoelastic humidity constant of torque transducer's zero signal, (%·s)mV/V).
$C_H$	Viscoelastic humidity constant of the sensitivity of torque transducer, (%·s)/(mV/V).
$C_T$	Viscoelastic temperature constant of the sensitivity of torque transducer, (°C·s)/(mV/V).
$d_c$	Core diameter of the screw, m.
$E$	Young's Modulus, Pa.
$e_{cg}$	Maximum change of torque transducer signal due to lever inclination, N·m
$e_{st}$	Relative air pressure stability error, %.
$F$	Force, N.
$\vec{F}$	Resultant force vector.
$F_1, F_2$	Two forces applied at both lever sides, N.
$\vec{F_1}$	Vector of the first force.
$\vec{F_2}$	Vector of the second force.
$f$	Factor of safety
$g_{local}$	local gravity acceleration at the place of NIS, m/s <sup>2</sup> .
$H_1$	Starting relative humidity, %.
$H_2$	Final relative humidity, %.
$h$	Height, m.
$K$	Elastic humidity constant of torque transducer's zero signal, (% % mV/V).
$K_H$	Elastic humidity constant of the sensitivity of torque transducer, %/(mV/V).
$K_{H,v}$	DMP40 humidity coefficient at input voltage ratio, mV/V/%.
$K_T$	Elastic temperature constant of the sensitivity of torque transducer, °C/(mV/V).
$K_{T,v}$	DMP40 temperature coefficient at input voltage ratio, mV/V/°C.