Proposed Torsional Spring Calibration in Torque Measurement Method Described in ASTM F2213-17

Xiao Fan Ding [1], W. B. Handler [1], D. Gignac [1], and B. A. Chronik [1]

[1] The xMR Labs, Department of Physics and Astronomy, Western University, London ON, Canada

Contact: xding57@uwo.ca

INTRODUCTION

The internationally recognized standard, *ASTM F2213-17*, assesses for $\mathbf{B_0}$ induced torque (τ) on medical devices [1,2]. The *Torsional Spring Method* described in this standard uses a platform suspended by torsional springs, to which, a device is fixed. Torque induced on the device results in a measurable angular deflection ($\Delta\theta$) and is calculated by equation (1).

$$\tau = k\Delta\theta \qquad (1)$$

However, left out of the standard is information on the material and construction of the spring and a method for calibrating and quantifying the spring constant (k). Furthermore, due to a maximum allowed $\Delta\theta$ of $25°$, the springs need to adjusted for appropriate k.

The objectives are:

1. Propose a detailed methodology for calibrating the torsional spring constant
2. Calculate the calibration and accuracy of four example spring constants of 0.3, 0.9, 1.5, and 2.1 mNm
3. Plot the relative and absolute uncertainties for a full range of allowed torque measurements based on the four example spring constants

PROPOSED METHOD

Using the published schematic diagram (**Fig.1a**), the torsional springs are calibrated using standard masses and a constructed apparatus **(Fig.1b,c)**. The springs were interpreted to be nylon threads under tension and adjustable by a knob was added to the bottom.

Around the holding platform, there needs to be a groove so that a thread can be wound. With one end wound around the platform, the free end of the thread is attached to a well-measured standard mass. The use of standard masses eliminates the need for another measurement in addition to measuring. The thread is placed over a low-friction pulley. The torque applied from the weight of the standard mass creates a $\Delta\theta$ in the platform. The applied torque from the standard mass is the product of its weight (mg) and the radius of the platform (r), $\tau = mgr$, which in turn can be used to quantify k from equation (1).

$$k\Delta\theta = mgr \qquad (2)$$

From equation (2), the expected $\Delta\theta$ can be calculated for a desired k. The platform-spring system is adjusted until the approximate angular position is achieved. In the constructed apparatus, the tension adjustment knob (**Fig.1c**) was added to accomplish this. Once the desired k has been calibrated, the ASTM published procedure can be performed for static field induced torque measurements.

APPARATUS

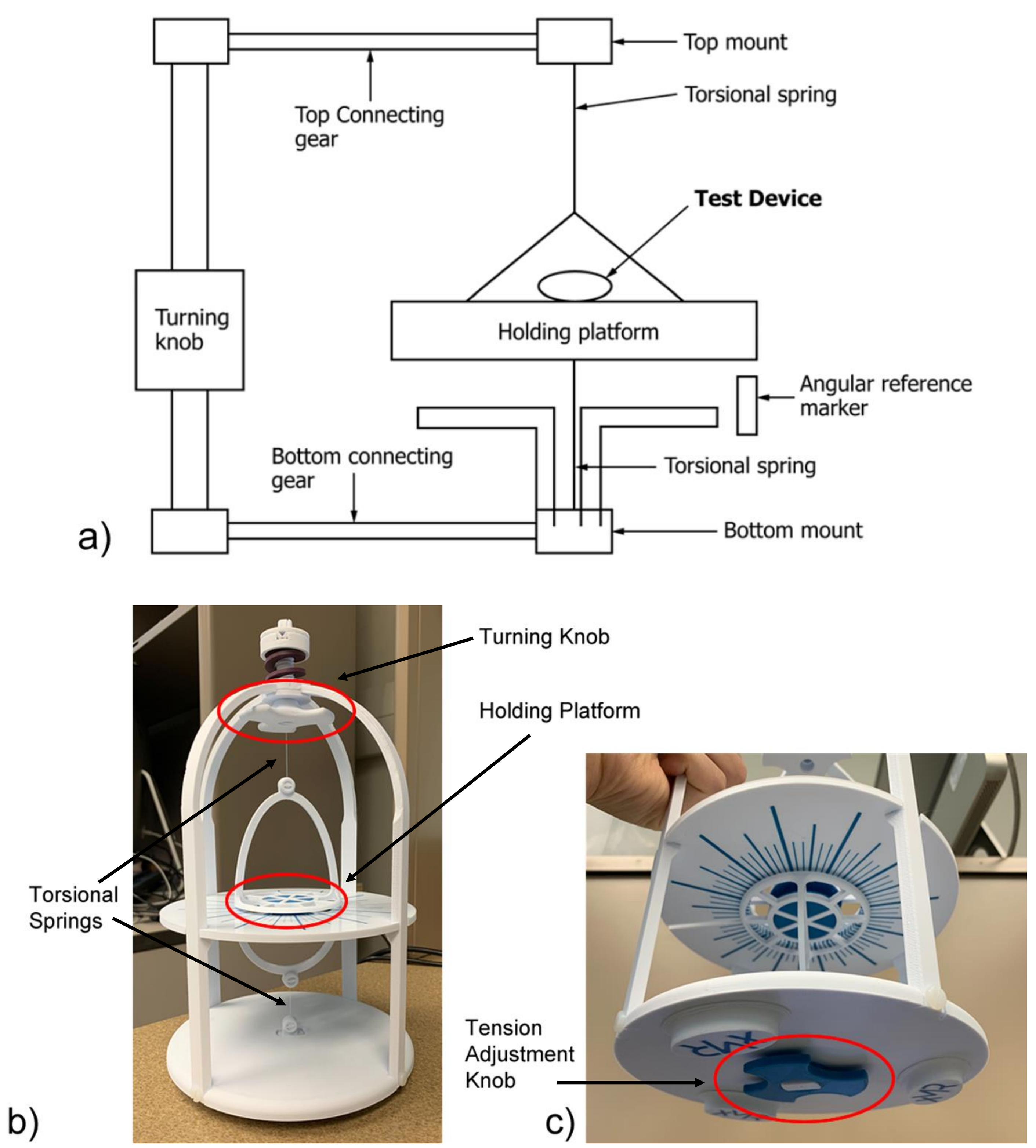

Fig.1: a) Schematic diagram of the apparatus as shown in the standard [2]. b) Front view and c) bottom view of a constructed apparatus based on ASTM specifications. The torsional springs are nylon threads under tension. The turning knob no longer rely on connecting gears. An additional knob for adjusting the tension in the nylon thread was added for the purpose of calibrating the spring constant.

RESULTS

Tab.1: For four desired spring constants, the uncertainty for the calibrated values were calculated considering the available laboratory instruments. The masses were chosen such that the expected deflection angle, through equation (2), was the same for each calibration. The radius of the holding platform was designed to be 40.00 ± 0.001 mm and the gravitational acceleration in London, Ontario is $9.8055 \pm 0.0001\ \mathrm{ms^{-2}}$ [3].

Desired Spring Constant, k (mNm)	Chosen Standard Mass, m (g)	Expected Deflection Angle, $\Delta\theta$	Uncertainty in Calibration, δ_k (mNm)
0.30	10	$13.1 \pm 0.5°$	0.02
0.90	30	$13.1 \pm 0.5°$	0.05
1.50	50	$13.1 \pm 0.5°$	0.08
2.10	70	$13.1 \pm 0.5°$	0.11

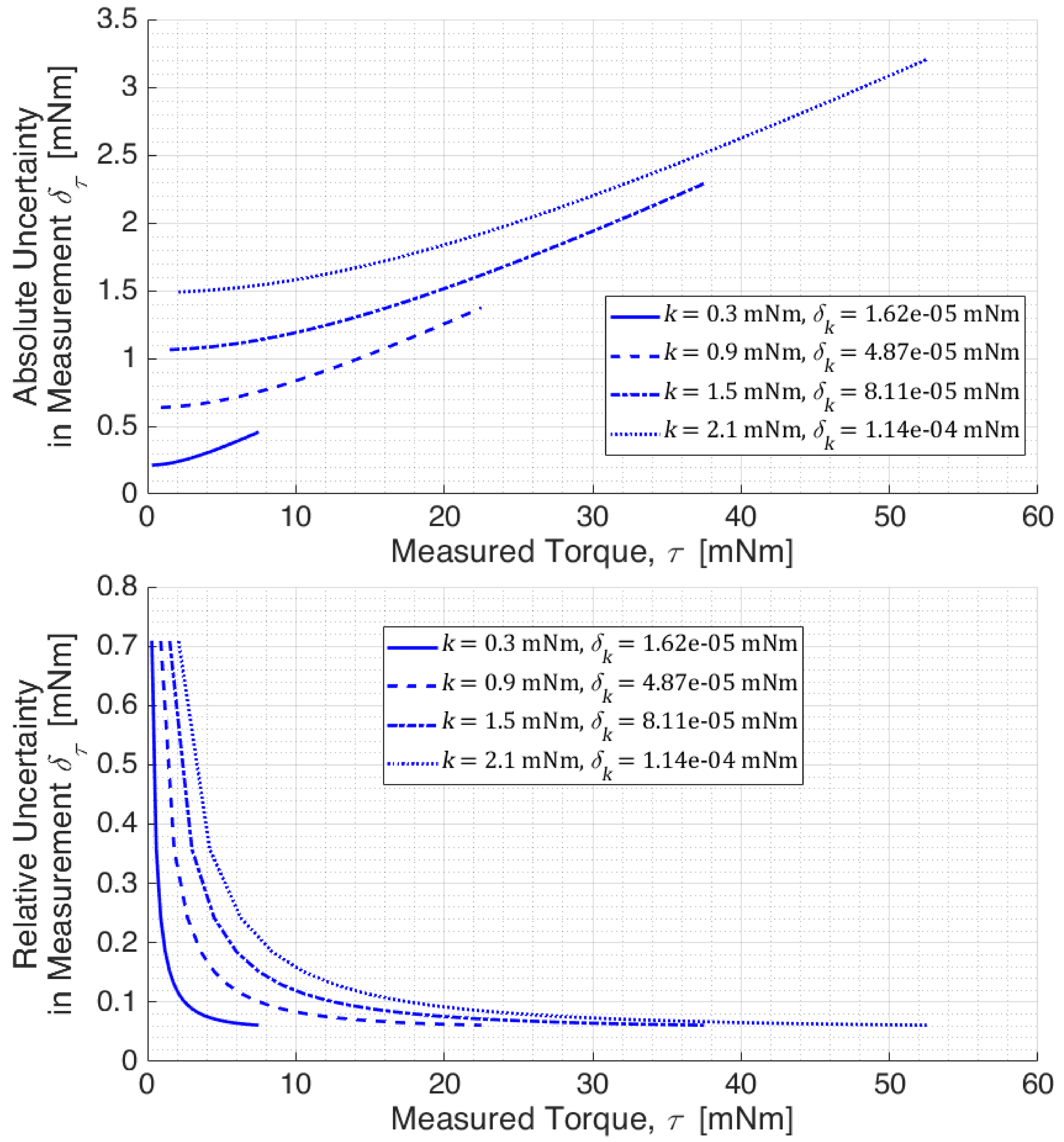

Fig.2: Using information from Tab.1, the absolute (top) and relative (bottom) uncertainties for $k = 0.3$, 0.9, 1.5, and 2.1 mNm, were propagated for the full range of measurable torques from $1°$ to $25°$.

DISCUSSION and CONCLUSION

The current Torsional Spring Method is restricted to a small range of measurable torques due to the $25°$ deflection limit as shown in **Fig.2**. It can also be cumbersome to use without information on the construction of springs and how k should be quantified. This is exacerbated whenever a measurement falls outside of the allowed range and a new apparatus needs to be altered.

The proposed schema allows for torsional spring calibration built into the apparatus. Choosing the right k depends on the measured torque. Shown in **Fig.2**, a large k results in a large absolute uncertainty. For small torque measurements, k would need to be reduced. With a way to dynamically calibrate the spring built into the apparatus, the Torsional Spring Method has the capacity to be used for a variety of devices. The method proposed in this work is to enhance the utility of an internationally recognized test standard.

REFERENCES

1. Woods, T. O. (2007) *J Magn Reson Imaging*, 26, 1186–1189
2. ASTM F2213-17 (2017)
3. Pavlis, N. K. et al. (2008) *J. Geophys. Res. Solid Earth*, 118, 2633

ACKNOLEDGEMENTS

The authors would like to acknowledge the following sources of funding.

Ontario Research Fund

NSERC CRSNG

INNOVATION.CA
CANADA FOUNDATION FOR INNOVATION | FONDATION CANADIENNE POUR L'INNOVATION