

ANAMET Report 018

September 1998

ANAMET REPORT

An investigation into the variation
of torque values obtained using
coaxial connector torque spanners

N M Ridler and C Graham

ANAMET reports are produced by, and for, the members of ANAMET. They are intended for fast dissemination of technical information for discussion purposes and do not necessarily represent an official viewpoint. No responsibility is accepted by the author(s) or ANAMET for any use made of the information contained in this report.

For further information about ANAMET and its activities contact:

internet: <http://www.npl.co.uk/npl/collaboration/clubs/anamet/index.html>

e-mail: **anamet@npl.co.uk**

Comments on this report should be sent to:

mail: **ANAMET
Building 72
National Physical Laboratory
Queens Road
Teddington
Middlesex
TW11 0LW**

fax: **0181 943 6037 (UK)
+44 181 943 6037 (elsewhere)**

Extracts from this report may be reproduced
provided that the source is acknowledged.

This report has been approved by the ANAMET Steering Committee.

AN INVESTIGATION INTO THE VARIATION OF TORQUE VALUES OBTAINED USING COAXIAL CONNECTOR TORQUE SPANNERS

N M Ridler and C Graham
Centre for Electromagnetic Metrology
National Physical Laboratory

Abstract

This report presents results from an investigation into the variation in torque values obtained using coaxial connector torque spanners. The investigation was undertaken within the RF and Microwave Guided-Wave Group, Centre for Electromagnetic Metrology, at NPL. The investigation involved measuring the torque achieved by a series of different operators using the same spanner. This was complemented by an assessment made by one operator using a series of different spanners. The results are analysed statistically to determine the relative sizes of some contributions to the variability of coaxial connector torque values.

Introduction

Torque spanners (or torque wrenches) are used extensively in precision microwave metrology to achieve both reliable and repeatable connections. This might be, for example, when tightening the mechanisms involved in mating a pair of coaxial connectors. The reasons for using a torque spanner include preventing loose connections, which result in poor electrical interfaces, and preventing over-tightening, which may cause damage to either, or both, connectors. However, despite their extensive use, there is very little information available in the literature concerning the degree of variability in torque values produced using these torque spanners.

This Report presents results obtained from two simple experiments investigating the variability of torque values produced when using commercially available torque spanners found in ANA calibration kits. The two experiments include different aspects of variability when using such spanners, including operator repeatability, between-operator reproducibility and between-spanner reproducibility. The concepts of repeatability and reproducibility are similar to those given in a recent international standard [1].

Experimental details

Both experiments used an Acratork torque meter as the measuring instrument. This meter is fitted with a "maximum indication bar" which registers the maximum torque achieved during the operation of the torque spanner. The meter is calibrated periodically by an external, NAMAS-accredited, laboratory.

All torque spanners used in this investigation were made by the same manufacturer and were of the same type, *i.e.*, Hewlett Packard type 8710-1766. These spanners are routinely checked by members of the Guided-Wave Group, using the Acratork meter, to ensure that suitable torque values are being achieved. All the spanners are used on a regular basis in the Guided-Wave Group laboratories to connect coaxial devices fitted with 7 mm connectors (both GPC-7 and Type-N). The handles of all the spanners are marked with the torque value 12 lb-in (this is equivalent to 1.36 N·m in SI units.) For information on torque settings for these, and other, coaxial connectors, see an earlier ANAMET Report [2].

The individuals performing the measurements were all members of the RF and Microwave Guided-Wave Group in the Centre for Electromagnetic Metrology, NPL, and included the authors of this Report.

Experiment 1 - one spanner, multiple operators

For the first experiment, one spanner was selected at random from the range of spanners (of type HP 8710-1766) found in the laboratory. The spanners were presented in turn to six volunteer participants, who were each asked to produce six repeat measurements of the torque produced when using the spanner in conjunction with the Acratork torque meter. All six participants are considered by NPL to be suitably competent to perform these measurements.

The results of this experiment will give an indication of operator repeatability, *i.e.* how well each operator is able to repeat his/her own measurements; and, between-operator reproducibility, *i.e.*, how much variation is produced when different operators use the same torque spanner.

Results - experiment 1

Table 1 shows the results obtained by the six participants using the same torque spanner, along with the standard deviation and range for each participant's set of readings. The standard deviation and range values give a measure of each participant's repeatability. The range expresses the maximum variation in each set of readings and is therefore a sensitive indicator of the presence of outlying, or unusual, data values. For example, for data drawn from a Gaussian distribution, the range will be approximately 2.5 times larger than the standard deviation, for samples containing six values. Ranges considerably larger than this value may be due to the presence of outlying values.

Participant No	Torque measurement results (lb-in)						Summary statistics (lb-in)	
	No 1	No 2	No 3	No 4	No 5	No 6	Standard deviation	Range
1	10	10	9.9	10	10.7	10.3	0.3	0.8
2	10.5	10.5	10.5	10.5	10.5	10.5	0.0	0.0
3	9.5	10	9.5	9.75	9.75	9.2	0.3	0.8
4	11	11	11.75	11.5	11	10.25	0.5	1.5
5	8.2	8.9	9.4	8.6	8.9	8.4	0.4	1.2
6	9.5	8.8	9.4	9.6	9.4	9.6	0.3	0.8

Table 1: Results, and summary statistics, obtained by the six participants using one spanner.

The Acratork meter's scale is graduated in divisions of $\frac{1}{4}$ lb-in. This explains why some participants values are recorded to two decimal places, *e.g.*, as .25 (for the $\frac{1}{4}$ division) and .75 (for the $\frac{3}{4}$ division). This degree of limited resolution also explains why one operator recorded the same value of torque for each measurement. A contribution due to limited resolution in the measuring instrument [3] could be included when summarising the torque values but this will have only a small effect on the values obtained here.

The results in Table 1 are further summarised in Table 2, which gives the mean value of each participant's values, along with summaries in terms of the standard deviation and range for these mean values. The summary values give a measure of the between-operator reproducibility, *i.e.* how well each participant's values are reproducible by the other participants.

	Participant number						Summary statistics	
	1	2	3	4	5	6	Standard deviation	Range
Mean torque values (lb-in)	10.2	10.5	9.6	11.1	8.7	9.4	0.9	2.4

Table 2: Mean values, and summary statistics for these mean values, for all results obtained from experiment 1.

Experiment 2 - one operator, multiple spanners

The second experiment involved selecting just one operator from the previous six volunteers and asking him to use six *different* spanners to produce a set of six repeat measurements using each spanner in turn.

The results of this experiment will produce an indication of the between-spanner reproducibility, *i.e.* how much variation is produced when one operator uses different spanners.

Results - experiment 2

Table 3 gives the mean of the six values obtained by one participant for each of six spanners, along with the standard deviation and range for these mean values. This time, the standard deviation and range provide a measure of the between-spanner reproducibility, *i.e.* how well each spanner produces torque values similar to the other spanners' values.

	Spanner number						Summary statistics	
	1	2	3	4	5	6	Standard deviation	Range
Mean torque values (lb-in)	10.5	10.8	10.5	10.8	11.1	9.4	0.6	1.7

Table 3: Mean values, and summary statistics for these mean values, for measurements made by one participant using six spanners.

Summary statistics

The standard deviations, given in Table 1, for each operator's measurements vary from 0.0 lb-in to 0.5 lb-in, with 0.3 lb-in being the most frequent value (*i.e.* the mode). This value will be used here to further summarise the operator repeatability data. (Incidentally, 0.3 lb-in is also the arithmetic mean and median of the values.)

Table 4 gives summary standard deviation values for the three types of variability considered in this investigation, obtained from the values calculated in the previous Tables.

Type of variation analysed	Standard deviation (lb·in)
Operator repeatability (from experiment 1)	0.3
Between-operator reproducibility (from experiment 1)	0.9
Between-spanner reproducibility (from experiment 2)	0.6

Table 4: Summary statistics, in terms of standard deviations, obtained from the two experiments.

Observations

The following observations are based primarily on the values for the summary statistics given in Table 4, obtained from the two experiments. It should be noted that these values are derived from only one investigation into connector torque variability and are based on a relatively small sample size (of six). Therefore, it is expected that these values, like most statistical summaries, will themselves be subject to a degree of variability. However, the values obtained from this investigation do indicate trends in the variations observed during these experiments and these trends are discussed below.

1 The measured values.

All the measured values recorded during the investigation were less than the value indicated on the handle of the spanners (and usually recommended by manufacturers [2]). Although, in principle, the spanners could be adjusted to provide torque values closer to 12 lb·in, this is not advisable in practice since values obtained by different operators may well then include values greater than 12 lb·in (as demonstrated by the between-operator reproducibility statistics). This may then result in damage to connectors tightened using the spanners. In general, spanners providing torque values moderately less than the recommended values will be safer to use by a range of (competent) individuals.

2 Statistical techniques.

For all the data sets, the range values are not more than three times the standard deviation values. This is similar to the factor of 2.5, mentioned earlier, which is characteristic of data drawn from a Gaussian distribution. This indicates that there is no outlier contamination in the data sets of this investigation and it is therefore appropriate to use Gaussian statistical methods (e.g. mean and standard deviation) to provide summaries for the data sets.

3 Operator repeatability.

The operator repeatability assessment represents the minimum degree of variability we can expect for this type of measurement and, as such, can be used as a baseline figure to compare with the other values of variability.

4 Between-operator reproducibility.

Comparing the two values of variability obtained from experiment 1, we see that the between-operator reproducibility value is three times larger than the operator repeatability summary value. This indicates that the torque produced by a given spanner is significantly operator-dependent. This is illustrated in Figure 1, which shows plots of the mean and standard deviation for each participant's series of measurements.

If torque variability relates in some way to variability in the electrical performance for a given connection, then this indicates that a given operator could induce a systematic error (as well as random errors due to connector repeatability) to a given RF and microwave measurement. Such an operator-dependent systematic error could be very difficult to detect, and quantify (for example, for the purposes of uncertainty budgetting, etc).

5 Between-spanner reproducibility.

Comparing the values of variability due to operator repeatability and between-spanner reproducibility, we see there is a significant difference (by a factor of two) although, not as large as that between the operator repeatability and between-operator reproducibility. This can be seen in Figure 2, which shows plots of the mean value of each spanner's torque values - the error bars in this Figure represent the summary value of operator repeatability derived from experiment 1 (*i.e.* 0.3 lb-in).

The between-spanner reproducibility could potentially be reduced by calibrating and adjusting each spanner to the same value. The choice of spanner may then provide an insignificant contribution to the variability of the torque applied to a given connection (*i.e.* of a similar order to the operator repeatability values for variability, found here to be between 0.0 lb-in and 0.5 lb-in).

Conclusions

An investigation has been carried out into the variability of torque values obtained from operators using torque spanners in the Guided-Wave measurement laboratories at NPL. If this laboratory represents a typical measurements laboratory, then the values obtained from this investigation may be representative of variations occurring in other similar laboratories.

The investigation has shown that there is indeed considerable variation in torque values obtained using commercially available torque spanners. Factors which significantly affect the variation in torque achieved have been shown to include the operator repeatability (of the order of 0.3 lb-in), the between-spanner reproducibility (typically 0.6 lb-in), and between-operator reproducibility (typically 0.9 lb-in).

This shows that, for the operator/spanner combinations considered on this occasion, using different operators produced significantly more variation in the torque obtained compared with using different spanners. This may impact on any reliance in using torque spanners to provide a repeatable value of torque independent of the operator using the spanner.

Acknowledgement

The work described in this Report was supported by the UK's Department of Trade and Industry's National Measurement System Policy Unit.

References

- [1] ISO 5725-1, "Accuracy (trueness and precision) of measurement methods and results - Part 1: General principles and definitions", First edition, 1994.
- [2] A D Skinner, "Guidance on using coaxial connectors in measurement - Draft for comment", Appendix D, ANAMET Report 015, February 1998.
- [3] I H Lira and W Wöger, "The evaluation of standard uncertainty in the presence of limited resolution of indicating devices", *Meas. Sci. Technol.*, **8** (1997) pp 441-443.

Figure 1: Graph showing the results from experiment 1, involving one spanner and multiple operators

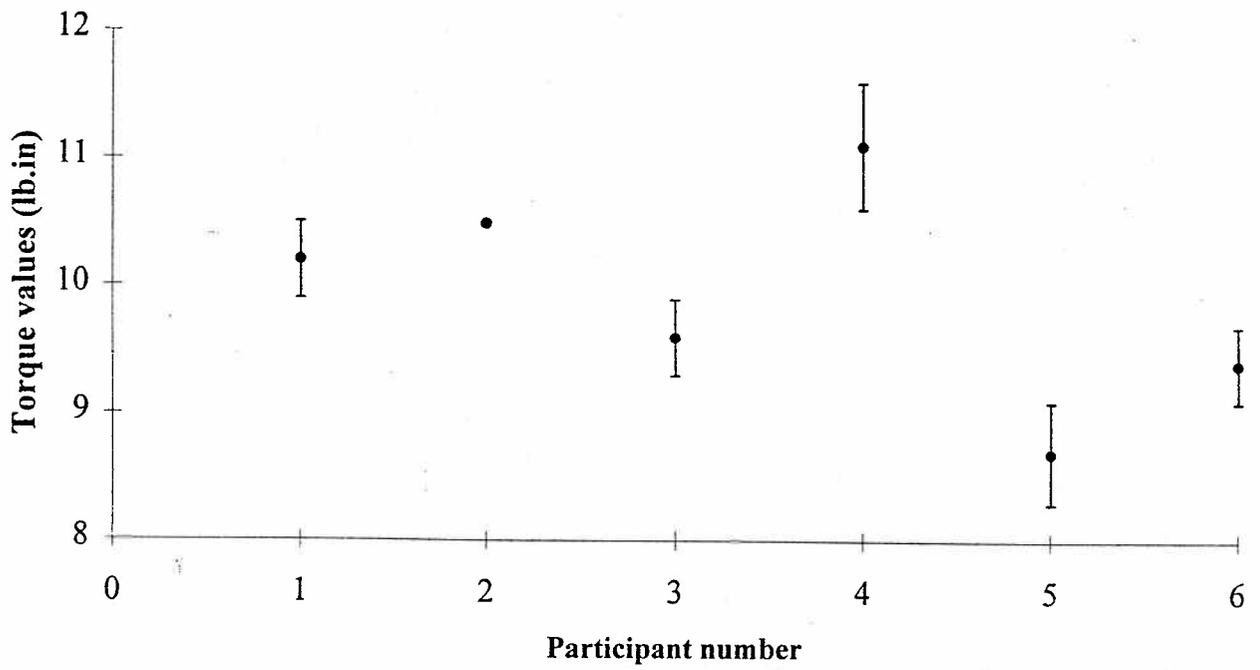


Figure 2: Graph showing the results from experiment 2, involving one operator and multiple spanners

