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Live torque comparison exercise

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ANAMET-982: Live torque comparison exercise

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1. Introduction

This report presents results obtained from a “live” comparison exercise of coaxial connector torque spanners. The measurements were made during the eleventh ANAMET meeting held on 25th November 1998 at SESC, DERA Aquila, Bromley, UK. The comparison was assigned the identifier ANAMET-982, in line with other exercises in the ANAMET series of comparisons.

In precision microwave metrology torque spanners are used to achieve both reliable and repeatable connections, and to prolong the life of the precision connector. A previous ANAMET Report [1], suggests suitable torque values that should be used in order that these criteria are satisfied. However, an earlier investigation [2] has shown evidence for a large degree of variability in the applied torque on a coaxial connector, when using a commercial torque spanner. This variability is caused by many factors associated with the operator and the spanner itself.

The purpose of this exercise was to invite participants to bring to an ANAMET meeting, the torque spanner they would normally use in their laboratory to connect a precision 7 mm coaxial connector, and have the torque applied by the participant / spanner combination measured. It should be made clear that there was no requirement made concerning the rating of the torque spanner - this was left to the participants' discretion.

2. Comparison details

The comparison exercise consisted of measuring the torque applied by participants and their spanners using a Norbar digital torque meter supplied by Hewlett-Packard Ltd., Winnersh. This meter had a resolution of 0.1 lb.in and registered the maximum torque during the operation of the torque spanner. The meter display was hidden from view of the participant so as not to introduce any operator bias into the comparison. As they were generated, the results were input into a Microsoft Excel spreadsheet specifically designed for this exercise, for subsequent statistical analysis. The recorded values and the summary statistics were presented at the meeting and copies distributed to all participants.

3. Results

Two different statistical methods were used to analyse the results. The first was using the arithmetic mean and standard deviation, and the second, the median [3] and M.A.D. [4]. These summary statistics are presented in table 1. Also calculated were the minimum, maximum and range of torque values obtained by the participants.

<i>Mean</i>	14.8	<i>Standard deviation</i>	7.6
<i>Median</i>	12.9	<i>M.A.D.</i>	1.5
		<i>Minimum value</i>	8.2
<i>Number of torque values</i>	31	<i>Maximum value</i>	38.8
		<i>Range</i>	30.6

Table 1 - Summary statistics of comparison exercise (units: lb.in)

During the exercise, it was noted that several participants performed two measurements using the same spanner in two orientations. This arose because of a suspicion that different torque values could be obtained depending on which direction the torque handle was operated. In addition to this, one spanner was used by two participants, and one participant performed two measurements with different spanners. As a consequence of these combinations, the data represented by the statistics in table 1 are not strictly independent.

4. Discussion

The striking observation is the large range of torque values obtained and suggests that there are outlying values present in the sample. This is supported by the discrepancy between the mean and median, and the standard deviation and M.A.D. The median and its associated M.A.D. are known to be robust estimators of a typical value and spread of values in the presence of a significant number of outlying measurements. However, the mean and standard deviation can be adversely affected by such outlying values since they are only good estimators when the sample has been drawn from a normal distribution.

Figure 1 shows the results obtained from the exercise in the order in which the measurements were performed. As a consequence of this ordering, it is observed that there is no significant correlation between the torque measured and the participant number. From figure 1 it can be clearly seen that there are three abnormally high torque values greater than 30 lb.in! It was observed that these three measurements originated from the same torque spanner being used on three separate occasions. The remainder of the values are between 8 lb.in and 16 lb.in.

To test the validity of using the mean and standard deviation in this exercise, the results shown in figure 1 were converted into a histogram and are shown in figure 2. In this histogram, the frequency (number of occurrences) of a particular torque value was plotted, shown by solid bars. To achieve a meaningful graph, the results were binned in 1 lb.in ranges, for example a value of 11.5 lb.in would register in the bin

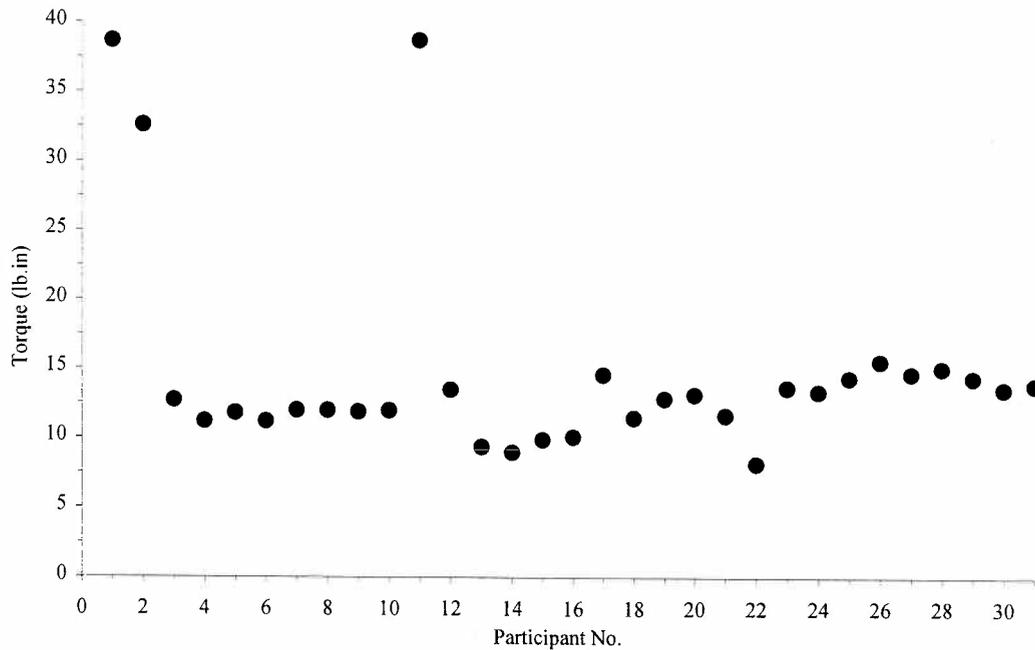


Figure 1- Participants' results from the comparison exercise

marked 12 lb.in as it falls between 11 lb.in and 12 lb.in. Also shown in figure 2 are two theoretical normal distribution curves [5] which represent the expected frequency of a particular torque value if the sample were infinite in size. A normal (Gaussian) curve is defined by two parameters: the mean which defines the location of the peak of the curve, representing the typical value of a sample; and the standard deviation which defines the width about the mean position indicating the spread of data. The dotted line in figure 2 is a normal distribution which is defined by the mean and standard deviation given in table 1. The solid line represents a normal curve specified by the median, replacing the mean, and the M.A.D. multiplied by a factor of 1.486 in place of the standard deviation. This factor effectively converts the M.A.D. into an equivalent standard deviation [4].

It is clear to see that the distribution defined by the median and M.A.D. gives a more accurate description of the obtained data and is not influenced by the three unusually high values. The dotted distribution is rather misleading since it implies that much higher values should have been expected. The tail of the distribution also extends beyond zero, implying negative torque values which, of course, are nonsense.

5. Observations

The M.A.D. value presented here represents a combination of between-operator and between-spanner reproducibility. The former is an indication of the variability in torque values obtained by several operators using one particular spanner. The latter is a measure of how well each spanner produces torque values similar to other spanners' values.

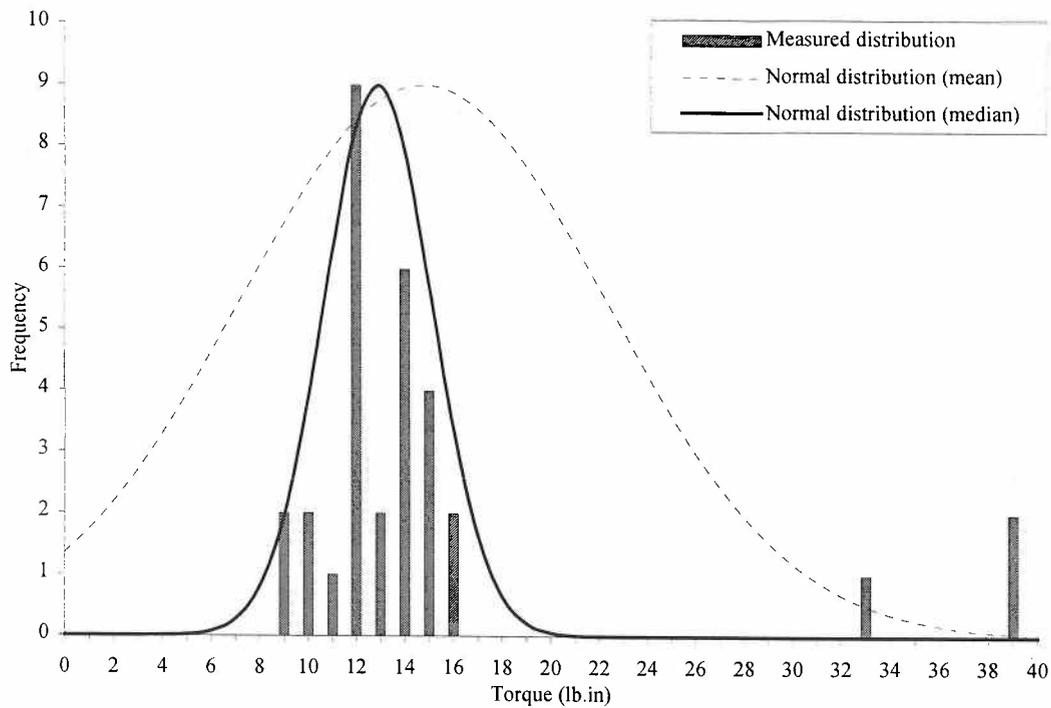


Figure 2 - Histogram of the recorded torque values

In an earlier report [2], these two measures of variability were based on a sample of six members of the RF and Microwave Guided-Wave Group in the Centre for Electromagnetic Metrology, NPL, using torque spanners whose stated torque was 12 lb.in. The reported values were in terms of standard deviation and range, and are reproduced in table 2.

By combining the two standard deviations given in table 2, which in the worst case is the sum of the two (0.9 lb.in + 0.6 lb.in = 1.5 lb.in), a comparison can be made with the M.A.D. obtained in this exercise. Converting the M.A.D. from table 1 to an equivalent standard deviation ($1.486 \times 1.5 \text{ lb.in} = 2.2 \text{ lb.in}$), it can be seen that the measure of variability obtained in this exercise is significantly larger than the worst-case combination of the reproducibility values quoted in table 2 (1.5 lb.in). This is also supported by a much larger range obtained in this exercise, even when the excessively high values of torque have been rejected.

<i>Type of variation</i>	<i>Standard deviation (lb.in)</i>	<i>Range (lb.in)</i>
Between-operator reproducibility	0.9	2.4
Between-spanner reproducibility	0.6	1.7

Table 2 - Summary statistics from ANAMET Report 018 [2].

Despite the large discrepancy between the variability in the results obtained in this exercise and those quoted in table 2, the median value of 12.9 lb.in agrees reasonably well with the nominal torque of 12 lb.in which was used in the experiment described in [2] and suggested as an appropriate value in [1].

6. Summary

A comparison exercise has been undertaken to investigate the variability in torque used to connect 7 mm coaxial connectors. The statistical analysis showed that the median value (12.9 lb.in) agreed reasonably well with the generally accepted torque of 12 lb.in suggested by an earlier report [1]. This is particularly significant, since no torque specification was given before the exercise. Nevertheless, the spread of data, taken to be a measure of reproducibility, was significantly larger than that achieved during an earlier exercise undertaken within NPL.

However, the results of this report could have further implications. It is possible that in some instances, torque variability may cause an associated variability in the electrical performance of some connectors, thus introducing an operator-induced systematic error into any subsequent electrical measurement. Such errors would be extremely difficult to quantify. Potentially of more concern though, is the number of recorded torque values greater than the recommended limit (17 out of the 31 values). Applying torque that is higher than the nominal value may lead to costly damage to connectors on both devices under test and/or the ANA test ports.

7. Acknowledgements

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8. References

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