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DISSEMINATION OF THE TORQUE UNIT IN ITALY: INTERCOMPARISON RESULTS ON TORQUE WRENCHES

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Abstract - One of the most important activities of the National Accreditation Body (NAB) in the framework of the European cooperation for Accreditation (EA), is the organisation of a series of Interlaboratory Comparisons (ILC), to verify the measurements capability of the accredited calibration laboratories.
In 2002 one ILC, for the calibration of torque wrenches, was organised in Italy by SIT (Sistema Italiano di Taratura) with the IMGC-CNR as pilot laboratory. In the present paper the main results obtained during the ILC are discussed, in particular the differences on the repeatability and accuracy given by the different laboratories are compared and evaluated.

Keywords: torque-wrenches, dissemination

1. INTRODUCTION

The increasing demand, in Italy in particular, for calibration and certification work and for the accreditation of new calibration centres, is due to several factors, namely:

- the need for industry to operate in accordance with EN 45000, ISO 9000 and ISO17025 as regards quality;
- the Italian law 273/91 establishing the National Calibration System,

IMGC provides for traceability to the standards of mechanical and thermal quantities all over the country, so as to allow high-quality measurements and tests to be made.
At present the number of SIT centres is 135 in total, 22 for force quantity (load cell, testing machines, impact pendulum and torque). Table I, shows the evolution of the number of SIT Calibration Certificates issued by the Accredited Labs in the force field (with an improvement of more than 300% in 10 years).
One of the most important activities of the National Accreditation Body (NAB) is the organisation of a series of interlaboratory comparisons (ILC), at European (EA) and National level, to verify the measurements capability of the accredited laboratories.

In 2002 one ILC, for the calibration of Torque Wrenches (TW), was organised in Italy by SIT with the IMGC-CNR as pilot laboratory.
In the present paper the main results obtained during the ILC are discussed, in particular the differences on the repeatability and accuracy given by the different calibration laboratories are compared and evaluated.

2. GENERAL EVALUATION AND PROCEDURE

One of the difficulties for this kind of ILC is that the objects of the comparison (the torque wrenches) haven't the status of a reference standard. For this reason the ILC, for the calibration of TW, was organised in Italy with the following purposes:

1. to give an experimental validation of the torque dissemination in Italy;
2. to evaluate the calibration competence of the different laboratories;
3. to give a contribution to solve the problem for future international comparison for such kind of equipments.

Table 1. SIT calibration certificates issued in the force field

	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**2000**	**2001**
Testing machines	499	852	1023	1087	1200	1350	1520	1770	2010
Impact machines	27	47	68	67	75	83	95	115	130
Extensometers	153	175	171	220	230	240	250	270	290
Load cells	53	183	228	260	270	280	320	550	700
Torsiometers		120	200	420	550	650	850	950	1050
Total	632	1377	1690	2022	2195	2503	3035	3655	4180

At the experimental ILC participated 3 calibration centres. At each laboratory was asked to calibrate the TW by using their normal procedure (normally UNI – EN 26789). Usually the tests were repeated several times at 20%, 60% and 100% of the rated capacity of each TW.
In order to evaluate in the better way the calibration capability of each laboratory six torque wrenches were chosen of different capacity (from 70 Nm to 420 Nm), different type (1 and 2) and Class (A, B, C), respectively:

- Torque Wrench BETA (Capacity 210 Nm, Type 1, Class B);
- Torque Wrench BLM (Capacity 200 Nm, Type 2, Class C);
- Torque Wrench BLM (Capacity 70 Nm, Type 1, Class C);
- Torque Wrench FACOM (Capacity 100 Nm, Type 2, Class A);
- Torque Wrench FACOM (Capacity 180 Nm, Type 2, Class B);
- Torque Wrench USAG (Capacity 420 Nm, Type 1, Class B);

Each calibration centre was not able to carry out the calibration on all the ranges.
The results were evaluated using the En number according to the EA Guideline.

3. REFERENCE VALUE OF THE TORQUE

At the ILC participated three Calibration Centres with six torque wrenches of different capacity and type. For this reason was decided to consider as “reference value” for each range of the six TW’s, the average value of the calibrations carried out by the different laboratories.
With this method, it is possible to reduce strongly the effects due to the individual characteristic of the TW’s. These effects can be further reduced by considering the average value of the results obtained by all the laboratories participating at the ILC.
The differences evaluated from these mean value results could be considered mainly, if not exclusively, due to the calibration capabilities (technical, operational) of each calibration centres with only a limited contribution of the accuracy errors of the different torque wrenches, but not for the stability.

4. EXPERIMENTAL RESULTS AND ANALYSIS

At each laboratory was asked to calibrate the TW by using their normal procedure (derived from UNI – EN 26789). Usually the tests were repeated several times at 20%, 60% and 100% of the rated capacity of each TW. The number of cycles applied by each Laboratory is reported in the tables.
The values obtained by each lab’s are represented as “accuracy errors”. The accuracy error is evaluated by the average value, over the 3 to 10 measurements at each torque level. The relative accuracy errors are calculated as the differences of this individual average value and the “reference value” (as defined in Ch. 3), divided by the nominal torque.

Table 2a shows the average value and the accuracy error given by the participating laboratories (A, B, C) for the torque wrench FACOM (Capacity 100 Nm, Type 2, Class A).

TAB 2a

Torque [Nm]	**A** (10 cycles)		**B** (20 cycles)		**C** (10 cycles)	
	Average [Nm]	Error %	Average [Nm]	Error %	Average [Nm]	Error %
20	19.55	-1.76	19.7	-1.15	20.03	0.15
40			38.67			
60	58.7	-2.17	58.07	-3.22	60.37	0.60
80			77.23			
100	97.93		96.5	-3.5	100.15	0.15

Table. 2b gives the measurement uncertainty declared in the Calibration Certificates by the different lab’s and the En, as determined on the same torque wrench, by using equation (1).

TAB 2b

Torque [Nm]	**A**	**B**	**C**	**En**	**En**	**En**
	Uncert. %	Uncert. %	Uncert. %	**A**	**B**	**C**
20	1.65	5.9	0.21	0.36	0.24	0.60
40						0.75
60	1.33	2.24	0.96	0.29	0.46	1.00
80						
100	1.17	1.77	0.36	0.13	0.86	

Table 3 shows the average value and the accuracy error given by the participating laboratories (A, B, C) for the torque wrench FACOM (Capacity 180 Nm, Type 2, Class B); and gives the measurement uncertainty dlared in the Calibration Certificates by the different lab’s and the En, as determined on the same torque wrench

TAB 3

Torque [Nm]	**A** (10 cycles)		**B** (20 cycles)		**C** (10 cycles)	
	Average [Nm]	Error %	Average [Nm]	Error %	Average [Nm]	Error %
180	180.25	0.14	178.38	-0.65	18.67	0.37
En		0.09		0.26		0.17

Table 4a shows the average value and the accuracy error given by the participating laboratories (A, B, C) for the torque wrench USAG (Capacity 420 Nm, Type 1, Class B);

TAB: 4a

Torque [Nm]	**A** (10 cycles)		**B** (20 cycles)		**C** (10 cycles)	
	Average [Nm]	Error %	Average [Nm]	Error %	Average [Nm]	Error %
85	87.54	2.99	85	00.0	85.37	0.44
160			160			
250	255.20	2.08	250	0.0	250.40	0.16
320			320			
400			402	0.5		
420	422.52	0.60	420		421.36	0.32

Table 4b gives the measurement uncertainty declared in the Calibration Certificates by the different lab's and the En, as determined on the same torque wrench

TAB 4b

Torque [Nm]	**A**	**B**	**C**	**En**	**En**	**En**
	Uncert. %	Uncert. %	Uncert. %	**A**	**B**	**C**
85	1.19	1.45	0.26	0.91	0.56	0.35
160						
250	1.16	0.49	0.26	0.66	0.37	0.29
320						
400		0.31				
420	1.16	0.50	0.16	0.15	0.15	0.01

Table 5a shows the average value and the accuracy error given by the participating laboratories (A, B, C) for the torque wrench BETA (Capacity 210 Nm, Type 1, Class B);

TAB 5a

Torque [Nm]	**A** (10 cycles)		**B** (20 cycles)		**C** (10 cycles)	
	Average [Nm]	Error %	Average [Nm]	Error %	Average [Nm]	Error %
40	40.15	0.37				
45	45.20	0.38	45.70	1.56	44.9	-0.24
120	120.30	0.25				
135	136.30	1.00	138.00	2.22	136.4	1.07
200	202.40	1.20				
210	211.80	0.90	2.12.70	1.30	212.8	1.30

Table 5b gives the measurement uncertainty declared in the Calibration Certificates by the different lab's and the En, as determined on the same torque wrench.

TAB 5b

Torque [Nm]	**A**	**B**	**C**	**En**	**En**	**En**
	Uncert. %	Uncert. %	Uncert. %	**A**	**B**	**C**
40	1.22					
45	1.20	3.40	0.40	0.07	0.48	0.41
120	1.16					
135	1.16	0.36	0.20	0.22	0.40	0.18
200	1.16					
210	1.15	0.73	0.30	0.15	0.06	0.09

Table 6a and 7a show the average values and the accuracy errors given by the participating laboratories (A, B, C) for the torque wrench BLM (Capacity 200 Nm, Type 2, Class C) and the Torque Wrench BLM (Capacity 70 Nm, Type 1, Class C);

TAB 6a

Torque [Nm]	**A** (10 cycles)		**B** (20 cycles)		**C** (10 cycles)	
	Average [Nm]	Error %	Average [Nm]	Error %	Average [Nm]	Error %
40	40.65	1.6	39.9	-0.25	40.6	0.15
80			80.0	0.0		
120	120.69	0.58	120.0	0.0	250.51	0.42
160			160.0	0.0		
200	200.98	0.49	200.1	0.05	201.4	0.70

TAB 7a

Torque [Nm]	**A**	**A**	**B**	**B**	**C**	**C**
	Average [Nm]	Error %	Average [Nm]	Error %	Average [Nm]	Error %
14	14.28	1.97	14.01	0.07	14.52	3.7
15			15.01	0.07		
30			30.01	0.03		
42	42.49	1.15	42.00	0.00	42.91	2.17
45			45.01	0.01		
60			59.96	-0.07		
70	70.73	1.04	69.95	-0.07	71.55	2.2

The results were evaluated using the Normalised Error En, according the EA guideline:

$$En = \frac{\left| X_{LAB} - X_0 \right|}{\sqrt{U^2_{LAB} + U^2_0}} \qquad (1)$$

Where:
X_{LAB}= the calibration result given by the laboratory
X_0 = the reference value
U_{LAB}= the accredited uncertainty reported by the laboratory
U_0 = the uncertainty of the reference value.

Tables 6b and 7b give the measurement uncertainty declared in the Calibration Certificates by the different lab's and the En, as determined on the same torque wrench.

The Normalised Error (En), evaluated from the calibration values (accuracy errors) obtained by the three laboratories on the six torque wrenches of different nominal capacities and different types, is in general less than 1: only 5 En values, over 45, are greater than 0,85.
These results underline the coherence of the resultants obtained in the intercomparison with the measurement uncertainty dlared by the three calibration centres and the reference values

TAB. 6b

Torque [Nm]	**A**	**B**	**C**	**En**	**En**	**En**
	Uncert. %	Uncert. %	Uncert. %	**A**	**B**	**C**
40	1.16	0.31	0.07	0.56	0.38	0.18
80		0.18				
120	1.16	0.14	0.15	0.12	0.17	0.05
160		0.12				
200	1.16	0.12	0.12	0.04	0.18	0.14

TAB 7b

Torque [Nm]	**A**	**B**	**C**	**En**	**En**	**En**
	Uncert. %	Uncert. %	Uncert. %	**A**	**B**	**C**
14	1.17	0.35	0.20	0.04	0.91	0.88
15		0.28				
30		0.14				
42	1.17	0.12	0.09	0.03	0.55	0.52
45		0.12				
60		0.11				
70	1.20	0.11	0.50	0.01	0.56	0.57

5. CONCLUSION

At the ILC participated 3 calibration centres with six torque wrenches. For this reason was taken as “reference value”, for each range of the six TW’s, the average value of the calibrations carried out by the laboratories.
The differences evaluated from these mean value results could be considered mainly, if not exclusively, due to the calibration capabilities (technical, operational) of each calibration centres with only a limited contribution of the accuracy errors of the different torque wrench, but not for the stability.
The results given by all the different laboratories are in good agreement as regards repeatability, accuracy (usually well inside +/-4 % as required by the EN Standard) as well for the En number.

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