Report of the CCM Working Group on Force & Torque

Andy Knott, Vice-Chair, CCM-WGFT

19th CCM meeting, 25-26 May 2023

CONSULTATIVE COMMITTEE
FOR MASS AND RELATED QUANTITIES

WG Meetings held since last CCM

- 23-24 September 2021
  - Online
- 19-20 April 2023
  - Delayed from November 2022
  - Online
  - 43 participants

WG Meetings planned

- February 2024
  - Online
- August/September 2024
  - Hybrid
  - Before / after IMEKO 2024 (in Hamburg, Germany)

Main actions taken and main achievements

- KCs
  - 4 underway
  - 2 planned
- CMCs
  - Review guidance being drafted
  - Harmonisation under discussion, guidance to be published

Progressing the state of the art

- Methods for continuous and dynamic force calibration
- Development and optimisation of technology including digitisation
- Digital SI and Digital Calibration Certificates (DCCs) in force and torque
- Methods for realisation of low-range force and torque with direct traceability to fundamental constants
- Traceability for time-dependent forces in different frequency ranges
- Traceable machines for continuous and dynamic measurements for testing in industry and research
- EMPIR 18SIB08 ComTraForce: https://www.ptb.de/empir2018/comtraforce/home/

Progressing the state of the art

- Torque measurement under rotation and dynamic torque
- Traceability for large torque in the MN·m range
- Traceable methods for mechanical power measurements and efficiency determination
- More interdisciplinary new topics for example in the field of renewable energies
- EMPIR 19ENG08 WindEFCY: https://www.ptb.de/empir2020/windefcy/home/

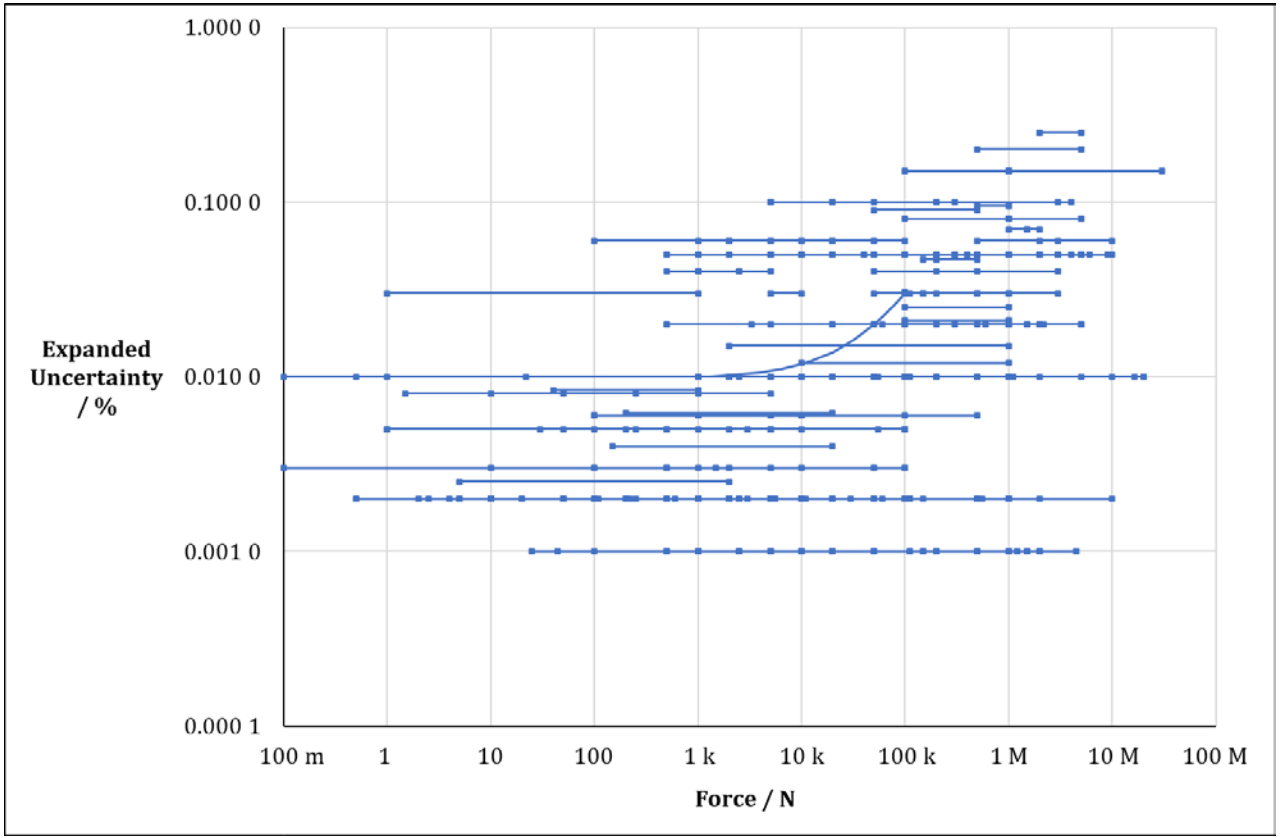
Liaison & stakeholders

- IMEKO TC3 – Measurement of force, mass, torque, and gravity
- ISO/TC 164 – Mechanical testing of metals
  - ISO/TC 164/SC 1 - Uniaxial testing
  - ISO/TC 164/SC 4 - Fatigue, fracture and toughness testing
- Industry
  - Manufacturers of force and torque measuring devices
  - Manufacturers of testing machines and test benches
  - Calibration and testing laboratories in force and torque
  - Automotive, aerospace, materials, offshore, renewable energy industries
  - Automation technology
  - Medical measuring techniques

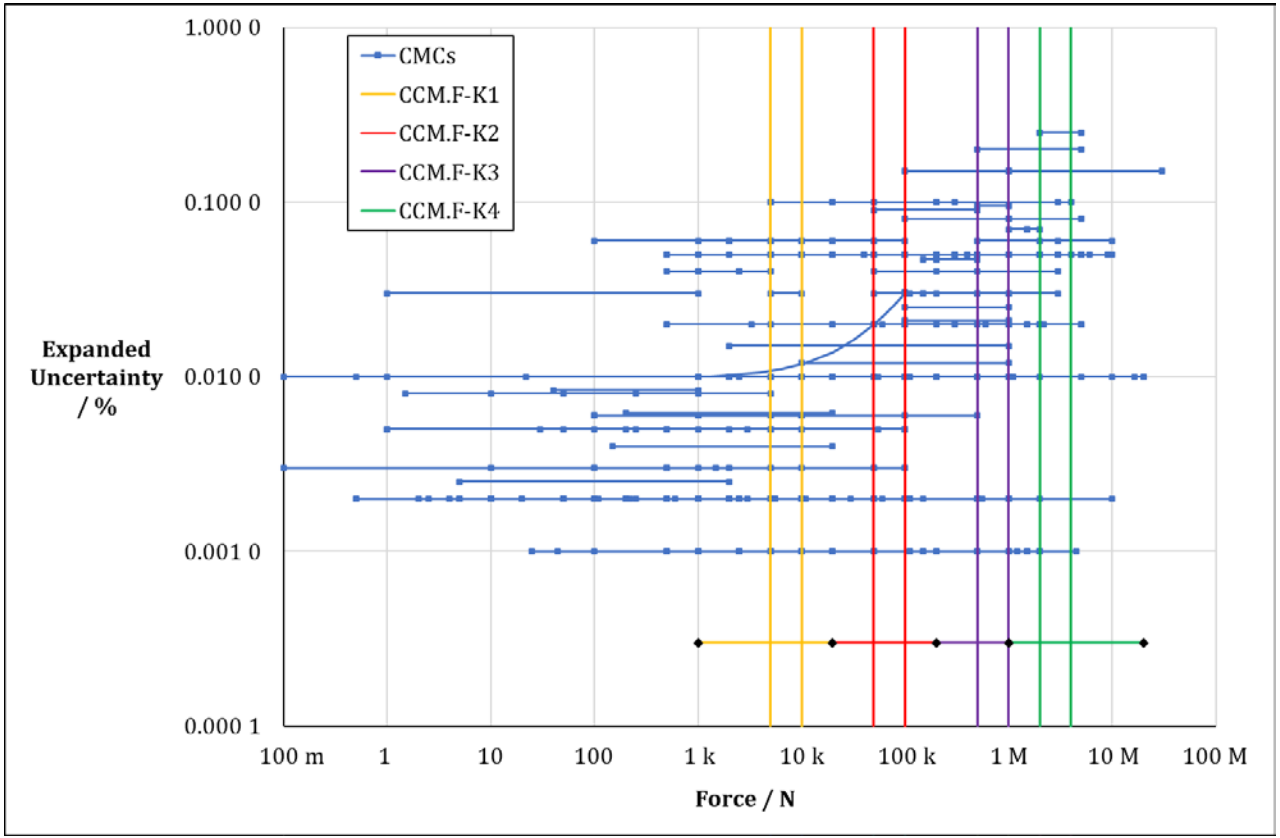
Terms of reference

- To study issues related to force and torque metrology, including dissemination, and to advise the CCM on these topics as well as on anticipated developments in this field
- To review the results of completed key and supplementary comparisons and plan and support new comparisons
- To facilitate the submission and review of CMCs by establishing technical review criteria and service categories and providing guidance on and coordinating the review process
- To provide liaison at the technical level with ISO/TC 164/SC 1 and SC 4 and to maintain good links with IMEKO TC3

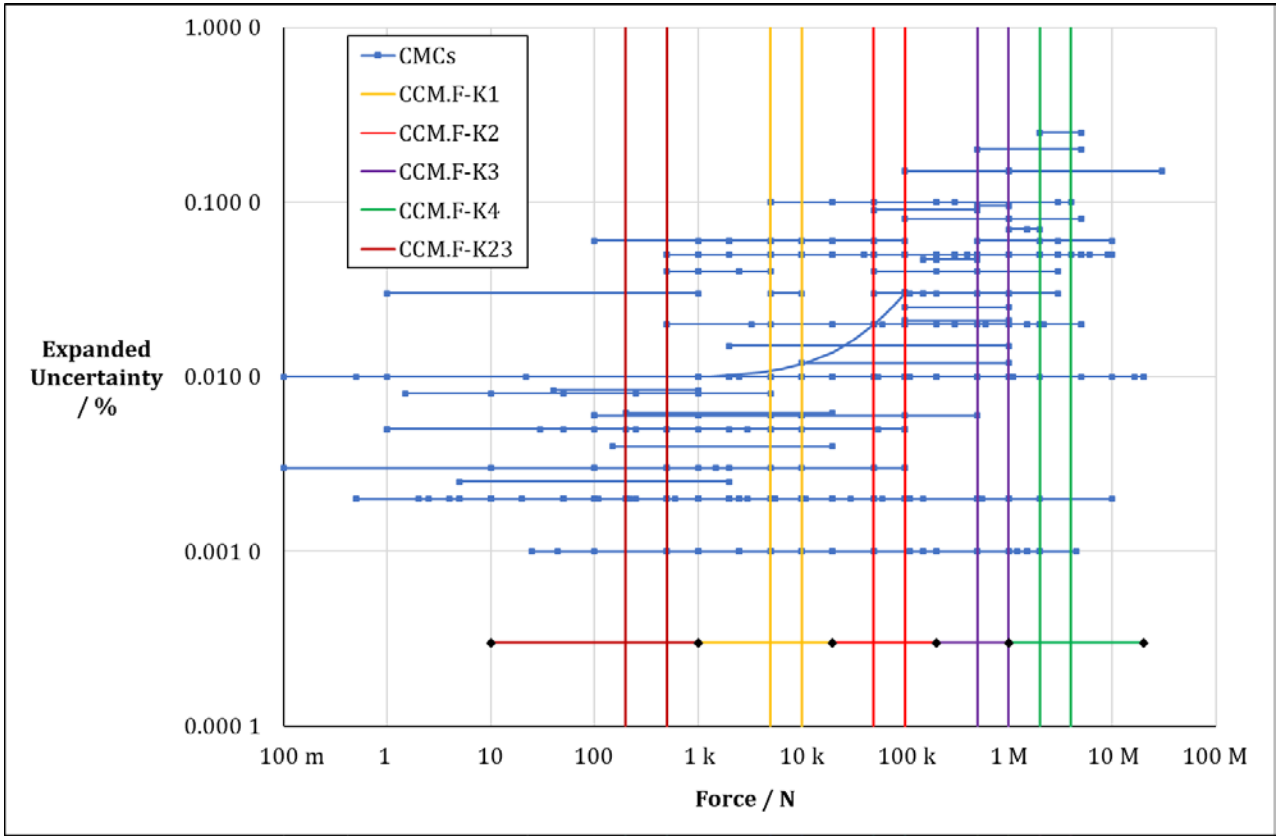
Force CMCs


1.000 0
0.100 0
0.010 0
0.001 0
0.000 1
Expanded Uncertainty / %
100 m
1
10
100
1 k
10 k
100 k
1 M
10 M
100 M
Force / N

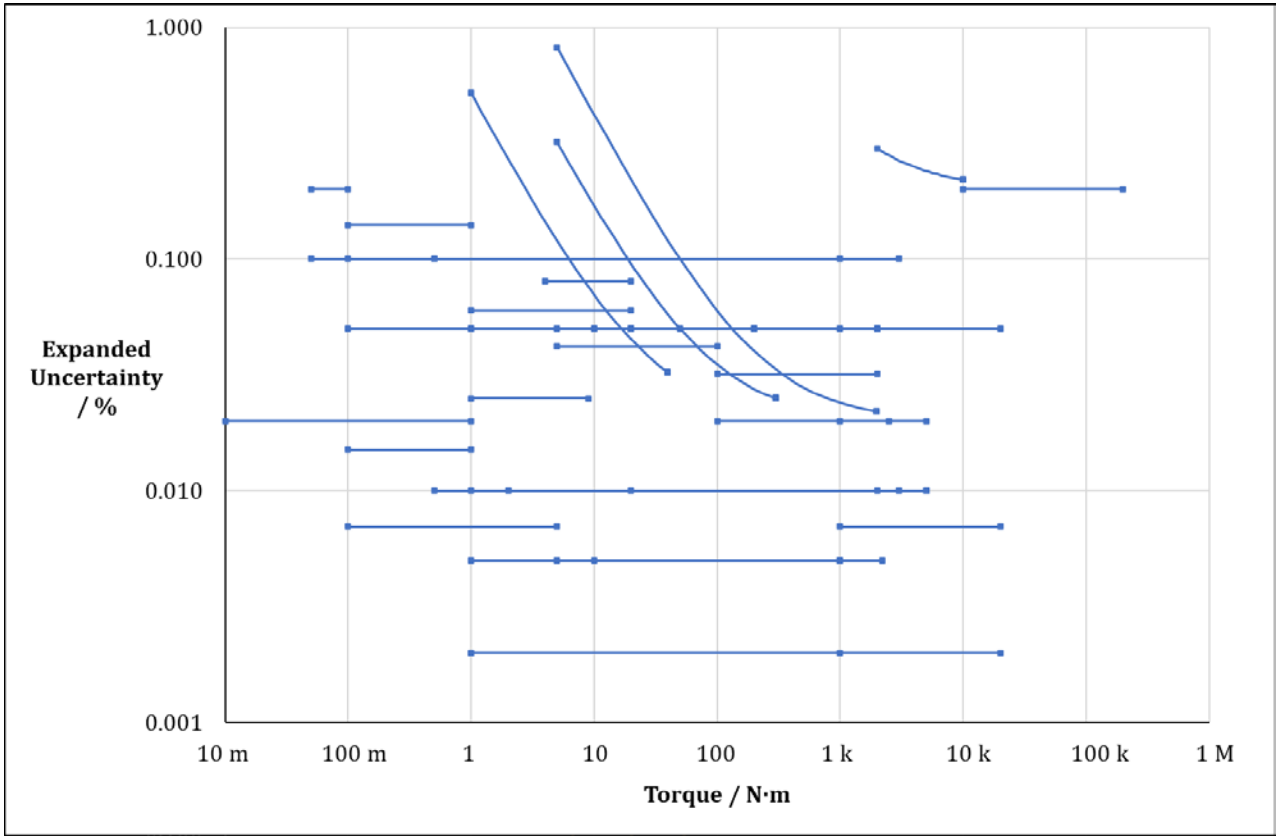
Force CMCs + original CCM KCs



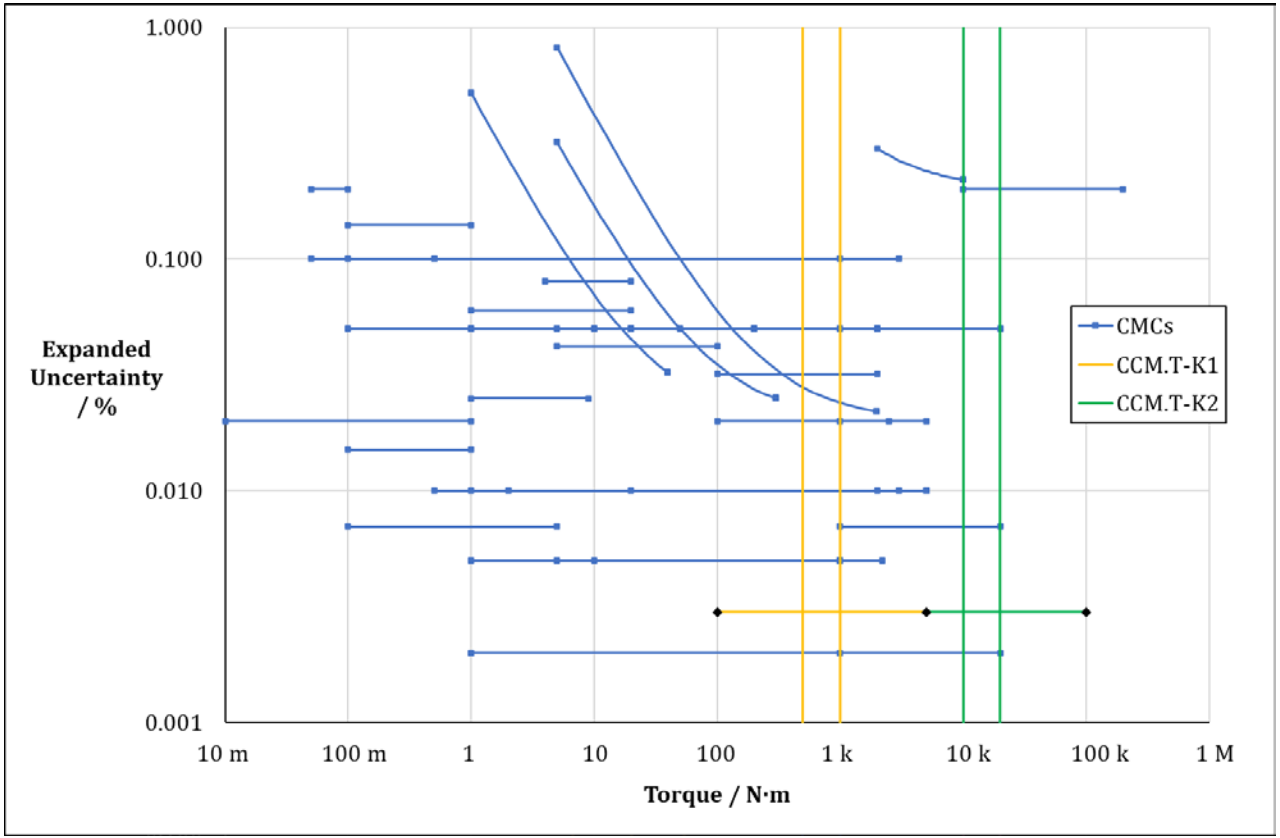
Force CMCs + all CCM KCs



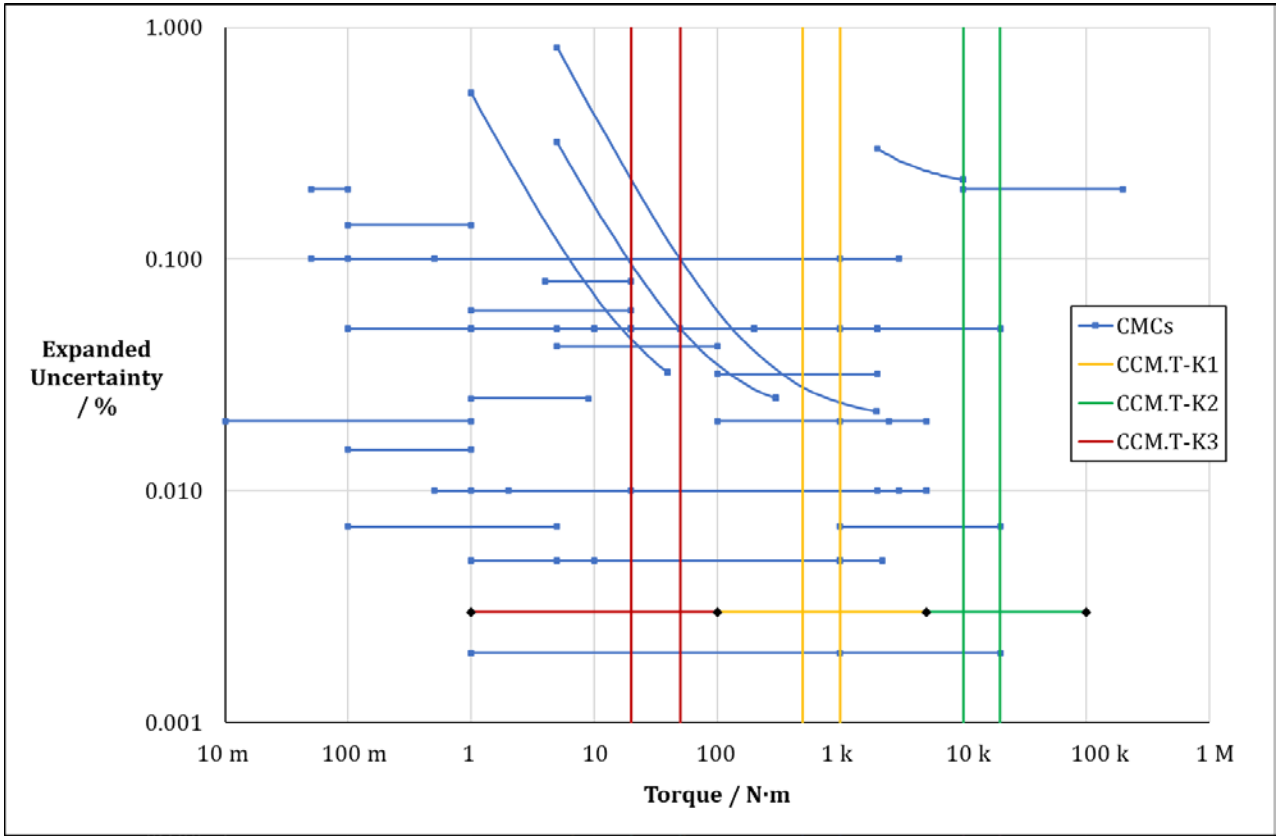
Torque CMCs


1.000
0.100
0.010
0.001
Expanded Uncertainty / %
10 m
100 m
1
10
100
1 k
10 k
100 k
1 M
Torque / N·m

Torque CMCs + original CCM KCs



Torque CMCs + all CCM KCs

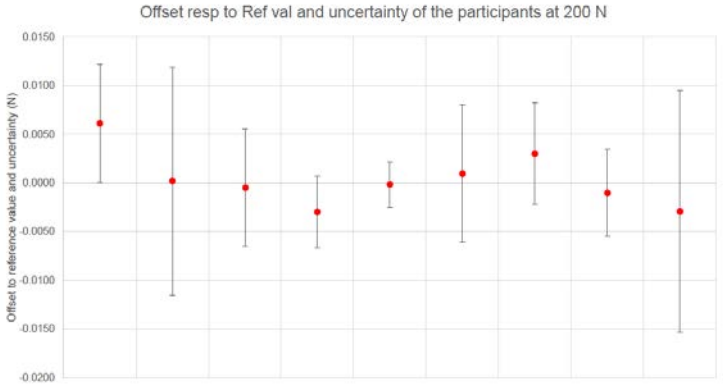


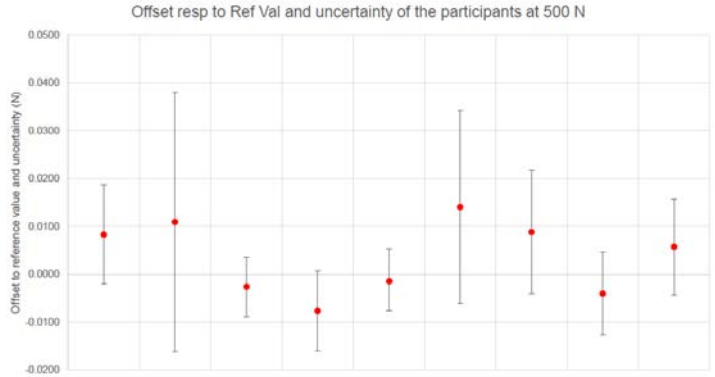
KC schedule

ID	Points	Range	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CCM.F-K23	200 N, 500 N	10 N – 1 kN	X										
CCM.F-K1	5 kN, 10 kN	1 kN – 20 kN		X									
CCM.F-K2	50 kN, 100 kN	20 kN – 200 kN								X			
CCM.F-K3	500 kN, 1 MN	200 kN – 1 MN											X
CCM.F-K4	2 MN, 4 MN	1 MN – 20 MN					X						
CCM.T-K3	20 N·m, 50 N·m	1 N·m – 100 N·m			X								
CCM.T-K1	500 N·m, 1 kN·m	100 N·m – 5 kN·m				X							
CCM.T-K2	10 kN·m, 20 kN·m	5 kN·m – 100 kN·m						X					

KCs completed and underway

- CCM.F-K23
  - 200 N, 500 N
  - Pilot: METAS
  - Multiple sensors
  - 15 months duration (11 months at pilot)
  - Final report circulated April 2023
  - All labs demonstrate equivalence

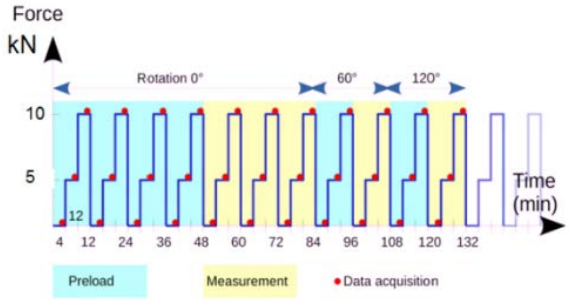




KCs completed and underway

- CCM.F-K1.a.2022
  - 5 kN, 10 kN
  - Pilot: UME
  - Work progressing, 4 participants completed work, but 1 year behind schedule due to transportation logistics

Year	Time period	Laboratory	Address
2021-2022		UME (Pilot)	Turkey
		PTB	Germany
		UME (Pilot)	Turkey
		UME (Pilot)	Turkey
		GUM	Poland
		UME (Pilot)	Turkey
		INRIM	Italy
		UME (Pilot)	Turkey
2023		LNE	France
	April 23	UME (Pilot)	Turkey
	May.23	METAS	Switzerland
	June 2023	UME (Pilot)	Turkey
	July 2023	NPL	UK
	August 2023	UME (Pilot)	Turkey
	September 2023	VTT MIKES	Finland
	October 2023	UME (Pilot)	Turkey
	November 2023	NMISA	South Africa
	December 2023	UME (Pilot)	Turkey
2024	January 2024	KRISS	Korea
	February 2024	UME (Pilot)	Turkey
	March 2024	NIM	China
	April 2024	UME (Pilot)	Turkey
	May.24	NMC/A*STAR	Singapore
	June 2024	UME (Pilot)	Turkey
	July 2024	NMIJ	Japan
	August 2024	UME (Pilot)	Turkey
	September 2024	NMIA	Australia
	October 2024	UME (Pilot)	Turkey
	November 2024	NPLI	India
	December 2024	UME (Pilot)	Turkey
2025	January 2025	IDIC	Chile
	February 2025	UME (Pilot)	Turkey
	March 2025	CENAM	Mexico
	April 2025	UME (Pilot)	Turkey
	May.25	INMETRO	Brazil
	June 2025	UME (Pilot)	Turkey
	July 2025	INTI	Argentina
	August 2025	UME (Pilot)	Turkey
	September 2025	IPQ	Portugal
	October 2025	UME (Pilot)	Turkey



KCs completed and underway

- CCM.T-K3
  - 20 N·m, 50 N·m
  - Pilot: PTB
  - Other participants: CENAM, GUM, INMETRO, KRISS, LNE, METAS, MIKES, NIM, NMIJ, NPLI, UME
  - Protocol drafted
  - Practical work delayed until 2024, due to maintenance activities within torque laboratory
  - Participants of proposed GULFMET comparison (SASO, EMI) over similar torque range to investigate participating in this one instead

KCs completed and underway

- CCM.T-K2.1
  - 10 kN·m, 20 kN·m
  - 2021 - 2022
  - Pilot: NMIJ
  - Other participant: NMISA
  - Measurements completed
  - Draft A being prepared
  - Results to be circulated / presented at next CCM-WGFT meeting

KCs planned

- CCM.F-K4
  - 2 MN / 4 MN
  - 2024+
  - Pilot: NIST (CMC: 0.001 %)

NMI	Machine Capacity	Expanded Uncertainty
CEM, Spain	2 MN / 10 MN	0.02 % / 0.05 %
CENAM, Mexico	5 MN	0.05 %
FORCE, Denmark	2 MN	0.02 %
INRIM, Italy	9 MN	0.05 % *
KRISS, Republic of Korea	5 MN	0.01 %
LNE, France	3 MN / 9 MN	0.03 % * / 0.05 % *
NIM, China	20 MN	0.01 % *
NIS, Egypt	5 MN	0.02 % *
NIST, United States of America	4.448 MN	0.001 % *
NMIJ, Japan	20 MN	0.01 % *
NPL, United Kingdom	5 MN	0.05 % *
NPLI, India	2 MN	0.05 %
PTB, Germany	2 MN / 5 MN	0.002 % * / 0.01 % *
RISE, Sweden	6 MN	0.05 % *
SASO, Saudi Arabia	5 MN	tbc
VNIIM, Russia	2 MN / 4.8 MN	0.01 % / 0.05 %
		* agrees with existing CMC

This would give 6 NMIs + pilot participating in the 2 MN-only protocol and 13 NMIs + pilot participating in the 2 MN / 4 MN protocol.

KCs planned

- CCM.T-K1
  - 500 N·m, 1 kN·m
  - Original comparison measurements in 2005 - 2006
  - 2023+
  - Pilot: CEM (CMC: 0.002 %)
  - Pilot Team: CEM, LNE, PTB
  - Participants: CEM, CENAM, EMI, INMETRO, KRISS, LNE, NIM, NMIJ, PTB, RISE, SASO, UME, VTT

Program of work for the next 2 years

- Completion of guides on CMC submission/harmonisation and review
- Completion of CCM.F-K23 and CCM.T-K2.1
- Continuation of CCM.F-K1.a.2022 and CCM.T-K3
- Initiation of CCM.F-K4 and CCM.T-K1
- Discussion of new topics
  - Traceable methods for dynamic force & torque
  - Traceable methods for mechanical power measurement for wind industry, electromobility & engines
  - Methods for traceability in small force & torque ranges
  - Digitisation in force & torque, D-SI, DCC, digital twins

Proposed changes

- Membership
  - No proposed changes
- Chairmanship
  - Rolf Kumme (PTB) to step down as Chair, after 16 years in post
  - Andy Knott (NPL) to move from Vice Chair to Chair
  - Philippe Averlant (LNE) to become Vice Chair
  - Unanimously agreed at last CCM-WGFT meeting in April 2023
- Terms of Reference
  - No proposed changes

Thank you.

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