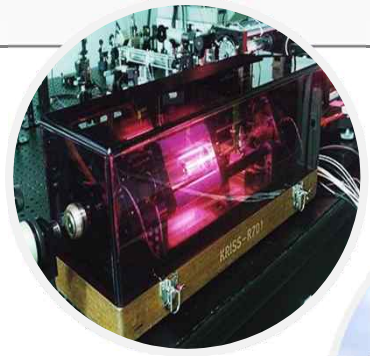
2017. 5. 31. (Wed)

KRISS

Realization of Large Force/Torque Standards and Applications



Dae-Im KANG

DGIST Convergence Research Institute

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Force Standard Machines in KRISS

Traceability of Force in KRISS

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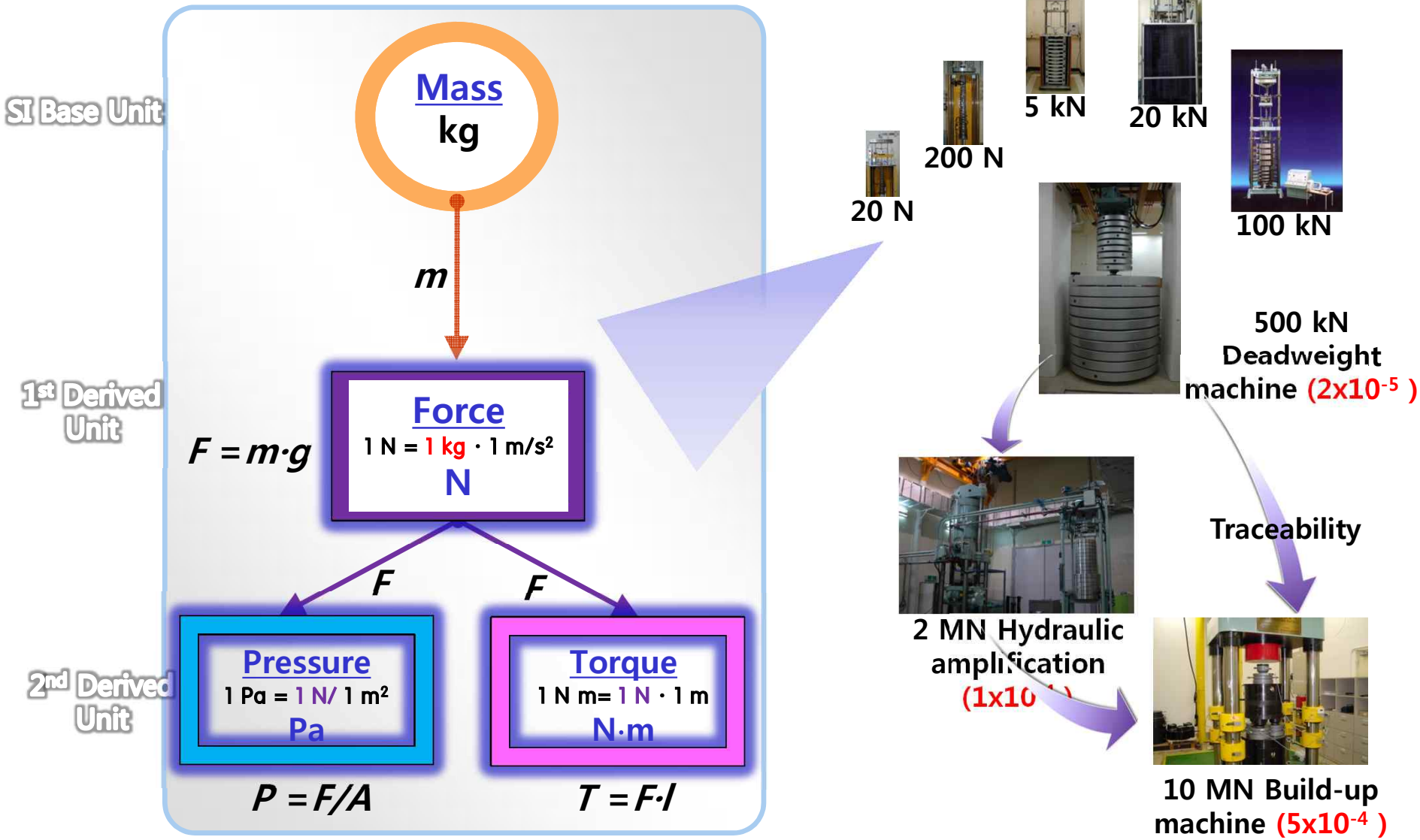


[Deadweight Force Machine]

100 kN Deadweight Force Machine

KRISS

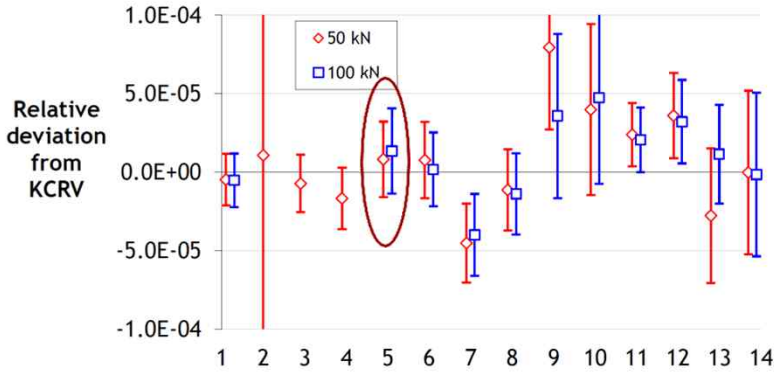
【Specification】

- Max./Min. Load : 110 kN / 2 kN
- Loading step : 1 kN
- Loading time
  - Pre loading : 90 s
  - Normal loading : 90 s
- Relative expanded uncertainty : 2×10^{-5}

KRISS 100 kN DFM

【Reference Force Machine for APMP.F-K2】

- Pilot: KRISS (No. of participants: 13 NMIs)
- Transfer Standards
  - 50 kN 2 ea/100 kN 2ea
- Measurement Points
  - APMP.M.F-K2.a: 2 points
  - APMP.M.F-K2.b: 1 point
- Measurement finished : Sep. 2014
- Draft A in preparation



Results of CCM.F-K2 (2012)

500 kN Deadweight Force Machine

KRISS

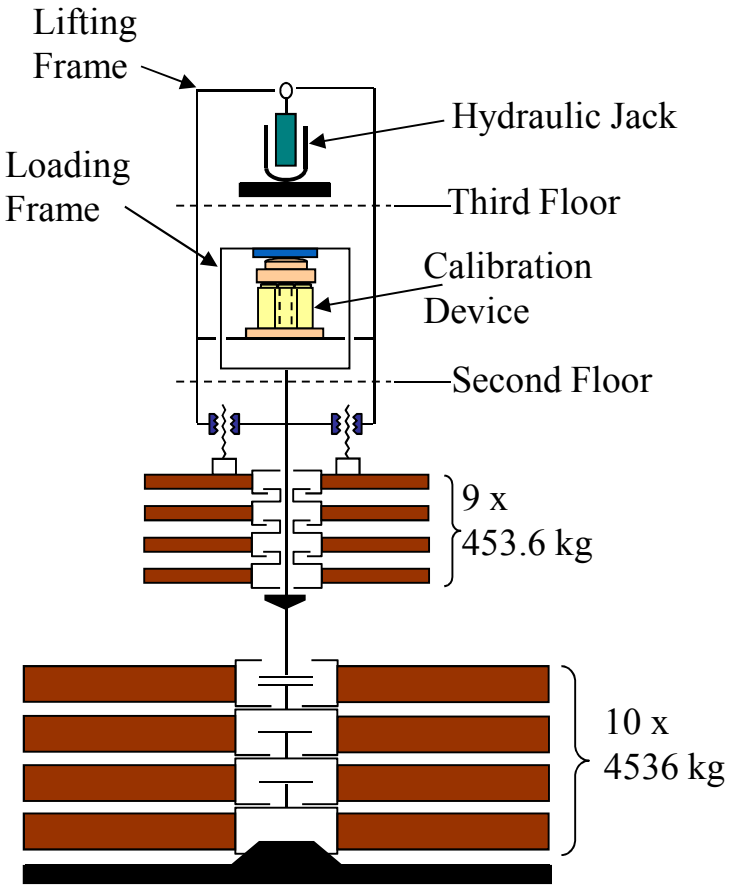
【Features】

- Largest deadweight force machine
- Force range : 13.3 kN ~ 498 kN
- Uncertainty : 2×10^{-5} (?)
- Problem : Old and stability issue (1926, Cast iron)

➔ Motivate development of a new force machine

1st Floor

2nd Floor



1 MN Deadweight Machine

KRISS

【Specification】

- Max. Capacity: 1.1 MN
- Relative Uncertainty: 0.002 %
- Height: 17 m
- Gross Weight: 180 t

【History】

- Decision on developing the machine for replacement of the old 500 kN force machine: 2010
- Start Mega Mechanical Metrology Project: Jan. 2011
- Design 1 MN Deadweight Force Machine: Oct. 2011
- Selection of Manufacturer: Jan. 2012, Poongsan Holdings
- Machining and Weights Calibration: Oct. 2013
- Test at manufacturer's site: Dec. 2013
- Installation at the new mechanical metrology building: Jan.,2015
- Inauguration of the new building: 20th May, 2015

5 t Mass Standards

5 t mass standards

5 t mass comparator

No.	Conventional mass (kg)	Expanded Uncertainty (g)
1	999.997 0	2.7
2	999.996 6	2.7
3	999.997 4	2.7
4	999.998 2	2.7
5	999.997 3	2.7

Weight comparison

Assembly and Test in the Yard

KRISS

- Assembly check
- Performance check

Concrete base

Structure to install DFM

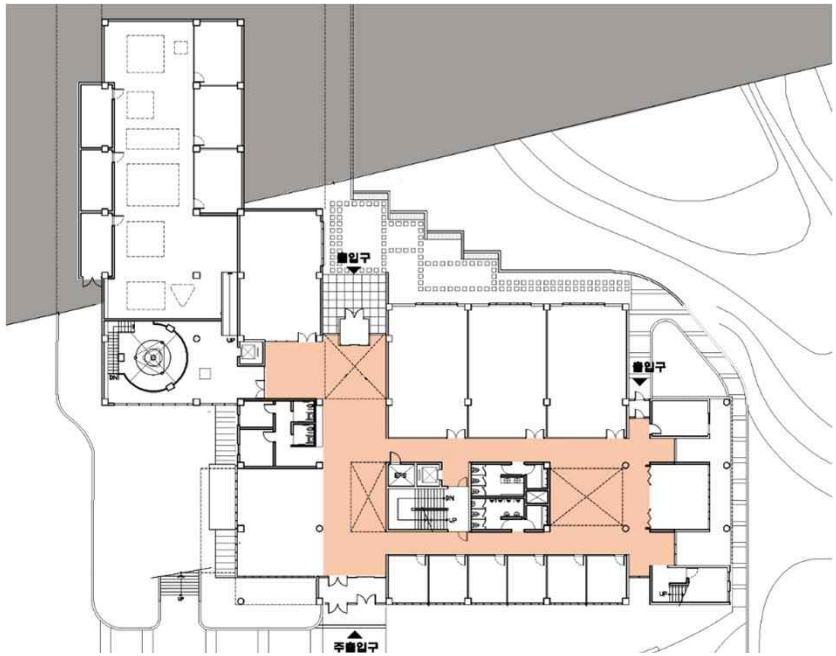
- Problem

→ Quick correction

New Building to install 1 MN DFM

KRISS

- Construction was finished in May 2015
- Building brand: M3
  - Mechanical Metrology from micro to Mega



Installation in the New Building

KRISS

- Installation
  - Dec. 2014 ~ Jan. 2015

- Opening Ceremony
  - May 20, 2015

Uncertainty Evaluation of 1 MN DFM

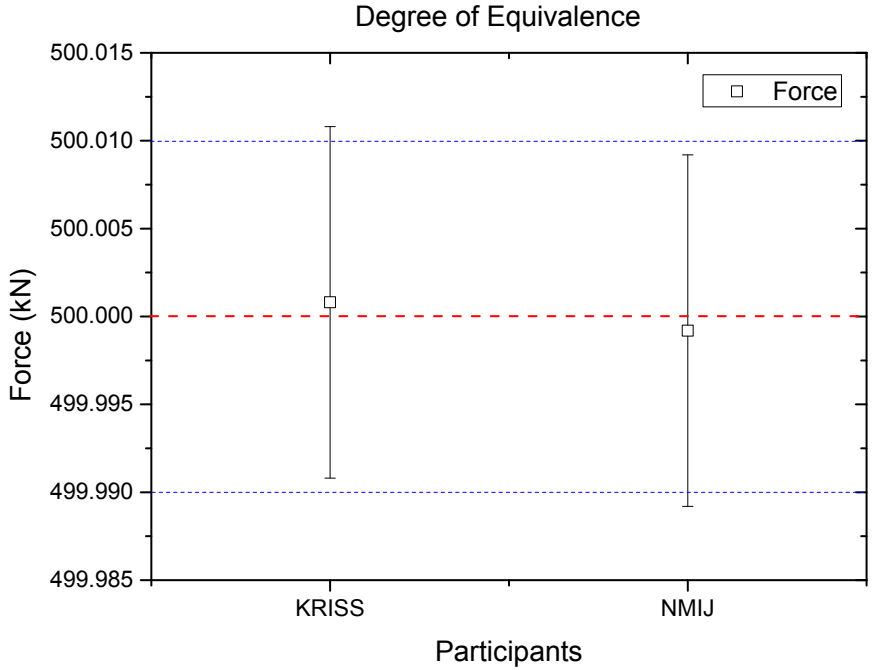
KRISS

Uncertainty component	Sensitivity Coeff.	Uncertainty
Uncertainty due to mass	1	1.9×10^{-6}
Uncertainty due to gravitational acceleration	1	1.0×10^{-7}
Uncertainty due to density of air	1.5×10^{-4}	2.5×10^{-2}
Uncertainty due to density of deadweight	1.5×10^{-4}	5.8×10^{-3}
Uncertainty due to inclined base plate	1	1.5×10^{-8}
Uncertainty due to swing motion of deadweight	1	7.9×10^{-8}
Combined uncertainty		4.3×10^{-6}
Expanded uncertainty		**8.6×10^{-6}**

- By considering unknown uncertainty components, the relative expanded uncertainty of the 1 MN deadweight force standard machine was declared as 2×10^{-5} with a confidence limit of approximately 95 %.

Installation in the New Building

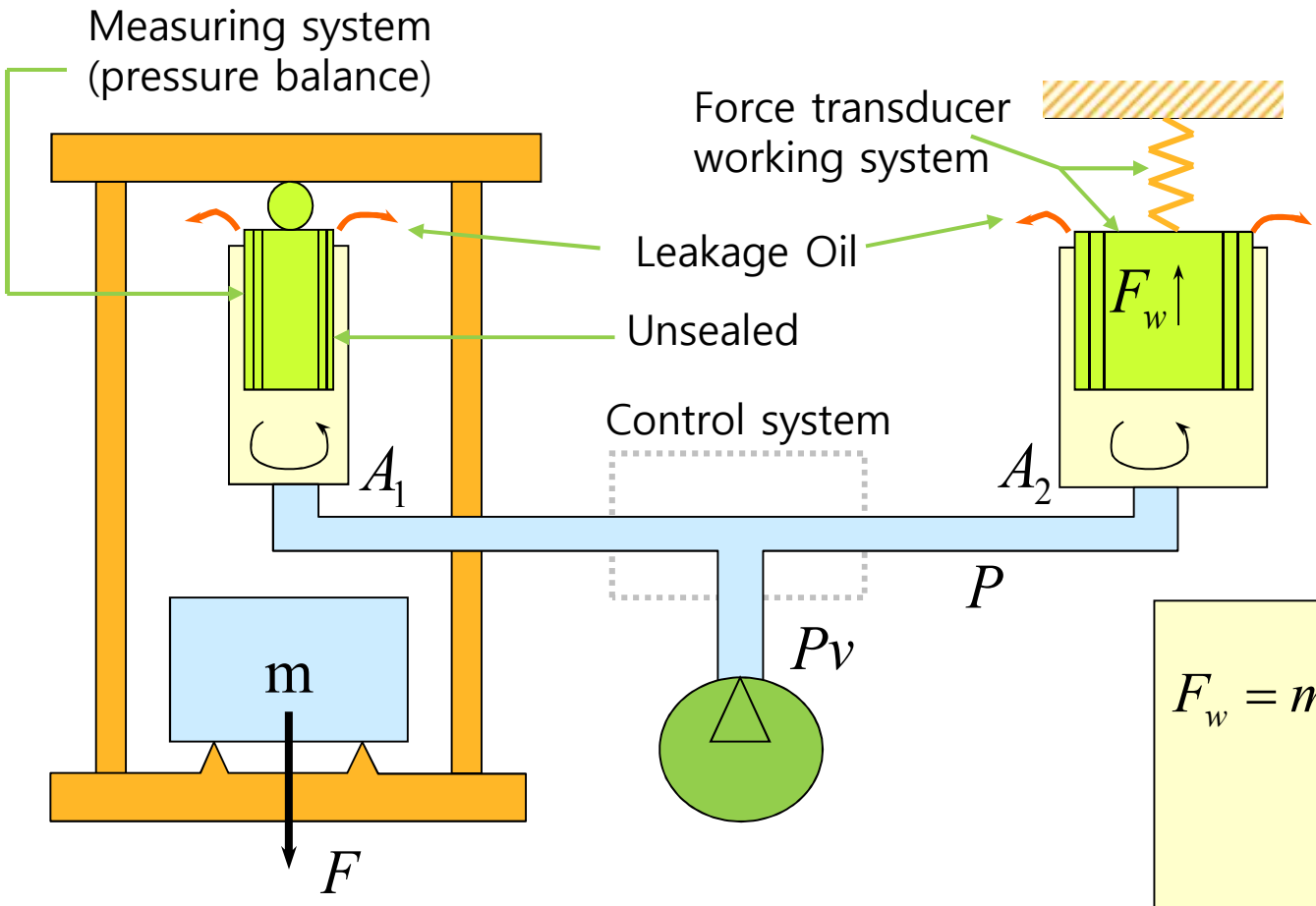
- **Bilateral comparison with 500 kN DFM of NMIJ, Japan**
  - Protocol: Modified KC protocol
  - Measuring time: 6 minutes
  - Measuring directions: 0°, 90°, 180°, 270°, 360° (1 rotation)
  - Measuring force: 500 kN



- **Degree of Equivalence**
  - En Value = 0.11
  - Equivalence was confirmed
- **Key Comparison**
  - Supplementary comparison of CCM.F-K3 at 1 MN will be conducted with PTB

[Hydraulic Force Machine]

Force Generation by HFM



$$F_w = mg_{loc}\left(1-\frac{\rho_a}{\rho_w}\right)Q$$

$$Q = \frac{A_2}{A_1}$$

Hydraulic Force Standard Machines

KRISS

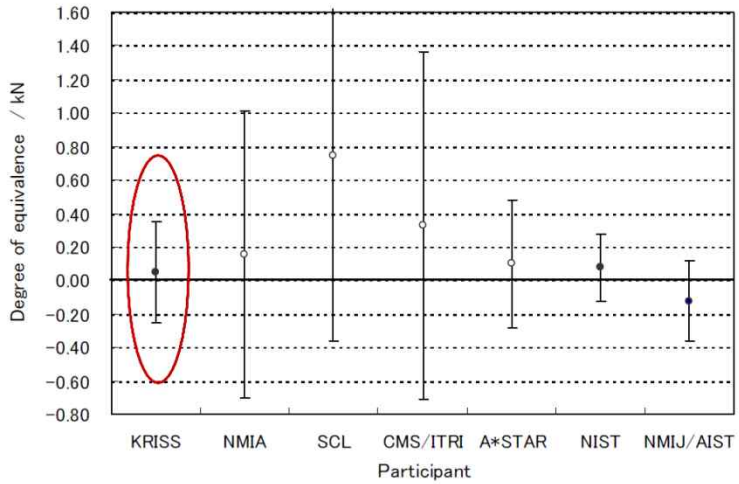
【Specification】

- Maximum load: 2.2 MN
- Minimum load: 50 kN
- Relative expanded uncertainty : 1 x 10-4
- Amplification factor: about 200
- Deadweight set
  - 250 N (2 ea), 500 N (10 ea), 1000 N (6 ea)
- Relative expanded uncertainty : $2x10^{-5}$

KRISS
2 MN HFM

【Degree of Equivalence, APMP.F-K4】

- Pilot: NMIJ
- Period: 2005~2007



KC results

5 MN Hydraulic Force Machine

KRISS

【Features】

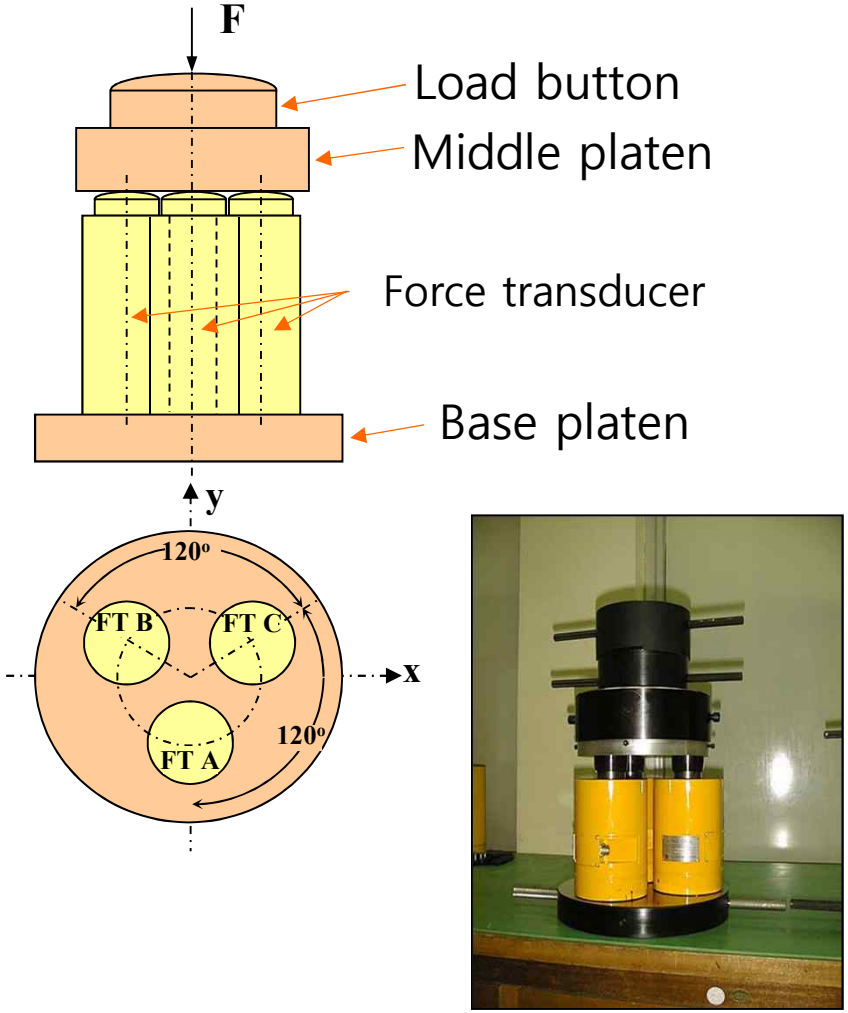
- Force capacity: 5.5 MN
- Uncertainty: 1×10^{-4}
- Amplification factor
  - 250
- Dimension
  - Height: 9.2 m
  - Main ram internal diame
- Schedule
  - Project start: 2013
  - Finish developing: 2017
  - Service start: 2019

[Build-up Force Machine]

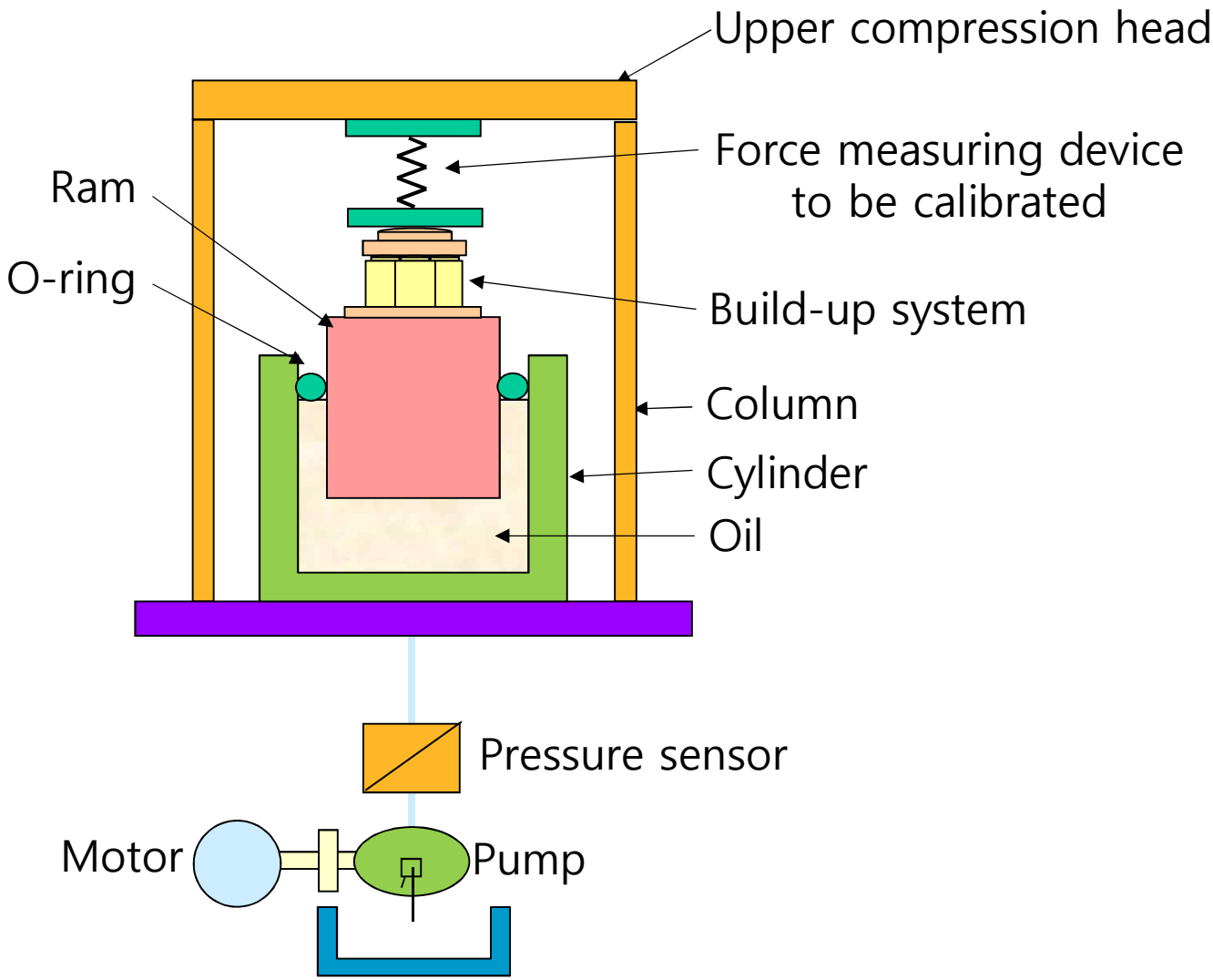
Build-up Force Measuring System

KRISS

- Three equal force transducers loaded in parallel
  - →**Force measurement capability increased to three times**
- Calibration of each force transducer in a deadweight or a hydraulic force machines
  - →**Evaluation of the build-up system**
- Used in combination the output have to be added or averaged



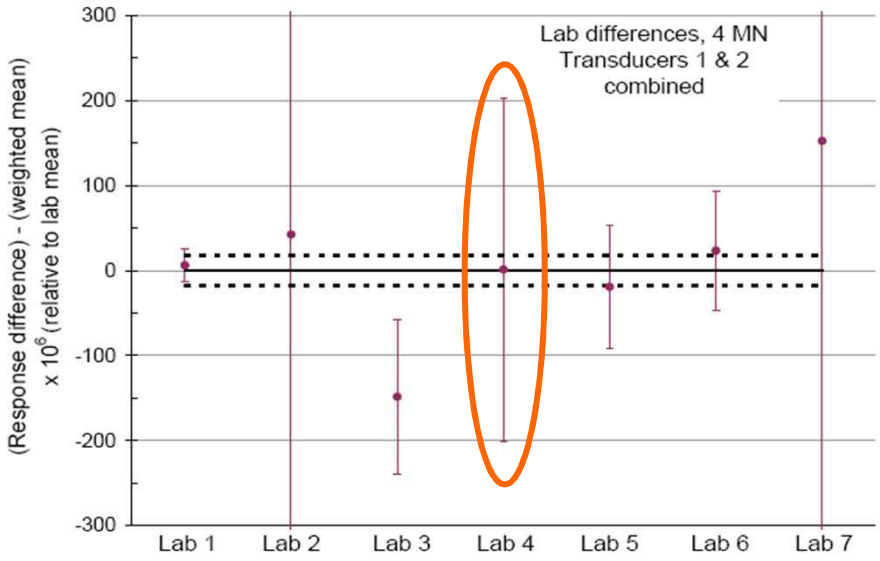
Force Generation by BFM

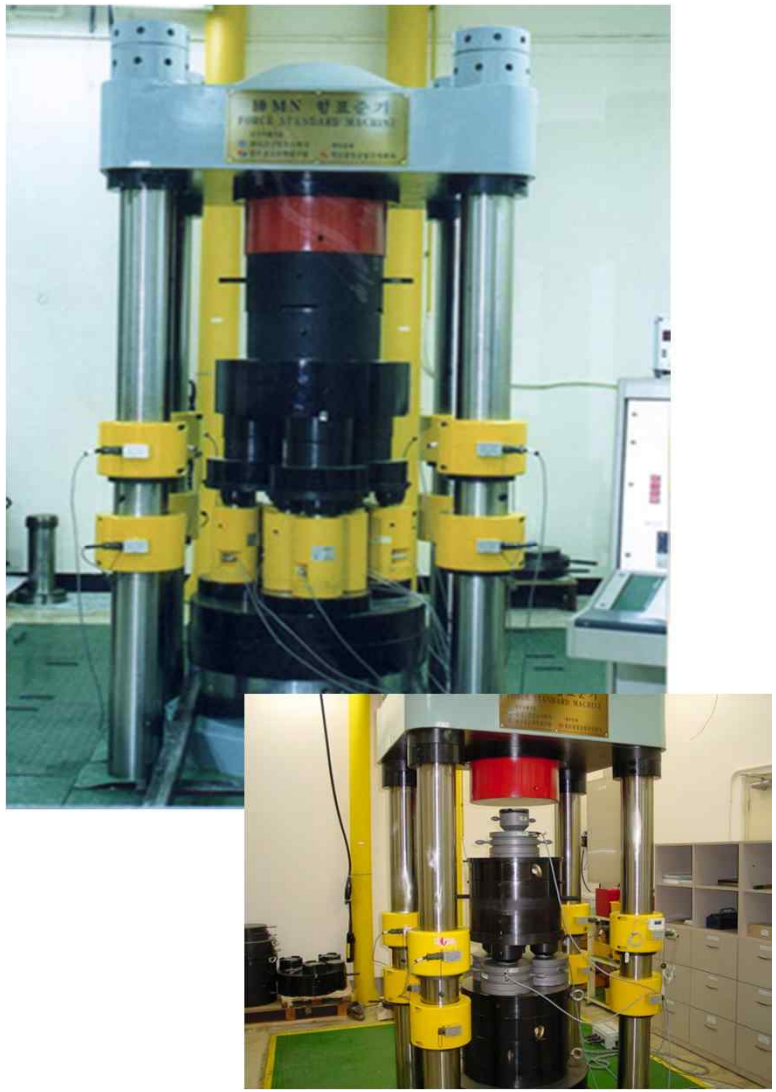


10 MN Build-up Force Machine

KRISS

- Force range: 10 MN
- Uncertainty: 2×10^{-4} (~5 MN)
  5×10^{-4} (~10 MN)
- Comparative force machine using build-up system
- CCM.F-K4 KC

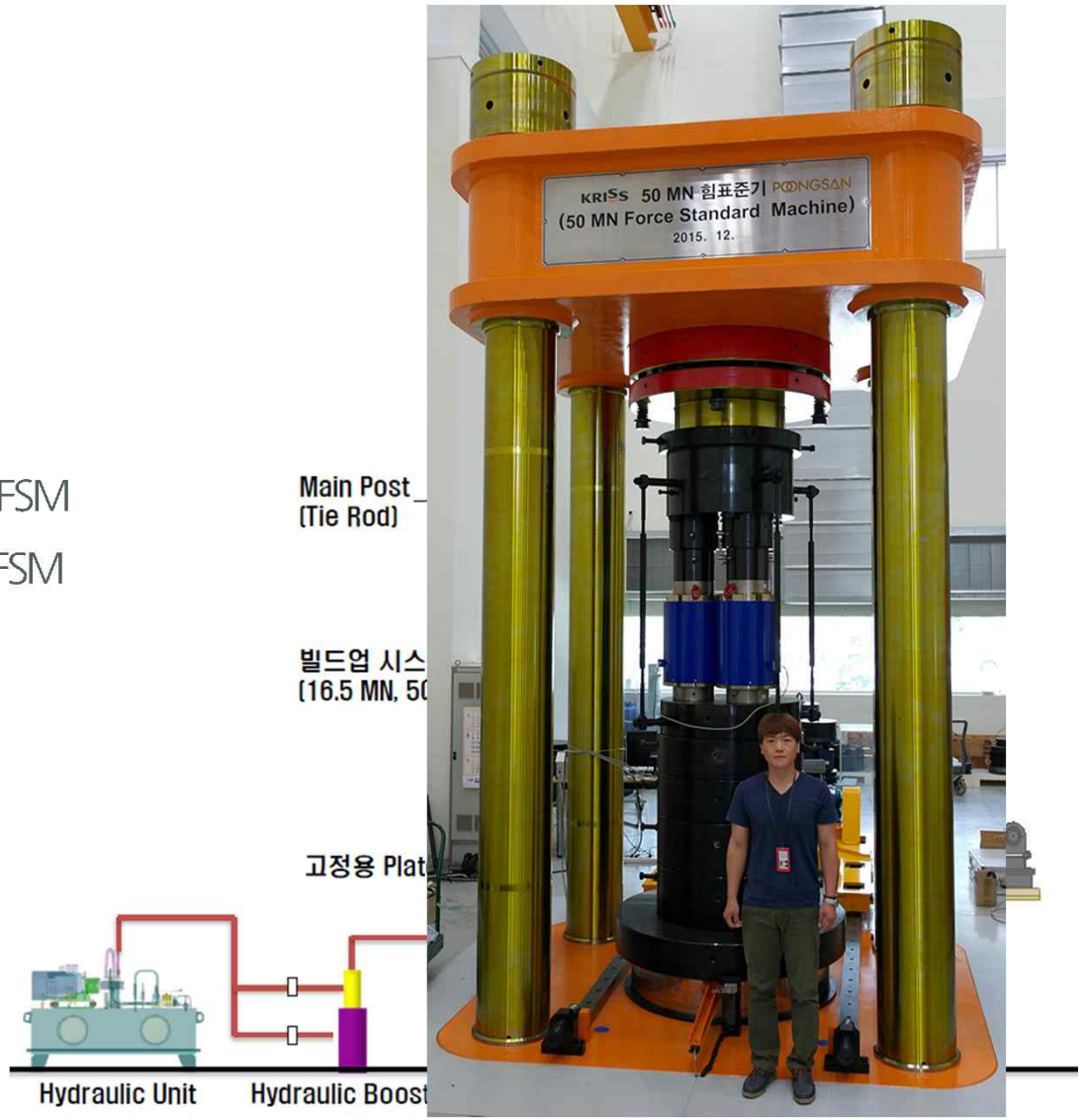


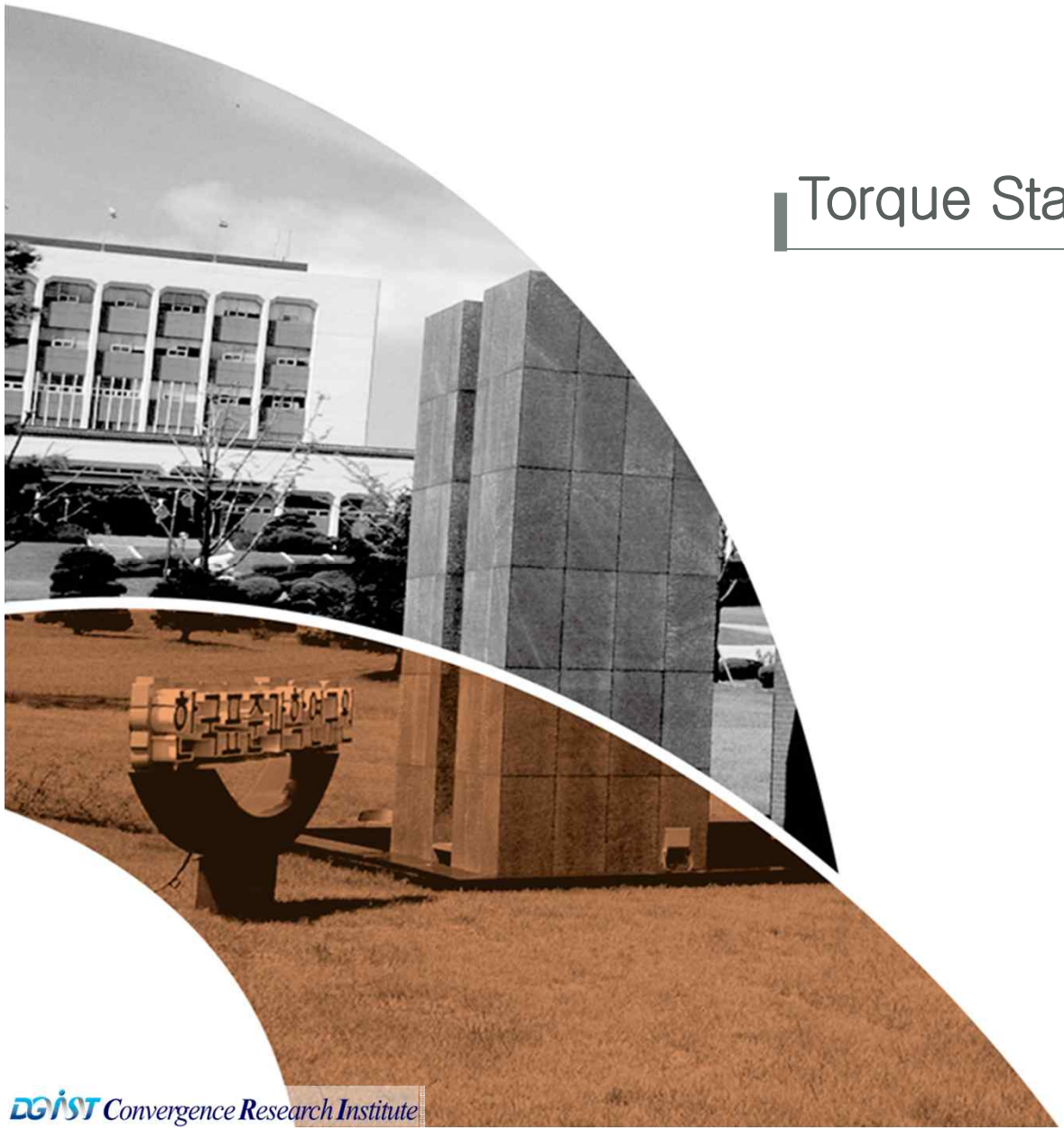


50 MN Build-up Force Machine

KRISS

- Force range: 50 MN
- Uncertainty
  - 2×10^{-4} (~16.5 MN)
  - 5×10^{-4} (~50 MN)
- Reference build-up system
  - 16.5 MN: Traceable to 5.5 MN HFSM
  - 50 MN: Traceable to 16.5 MN BFSM
- Schedule
  - Project start: 2014
  - Installation: Dec. 2015
  - Finish of development: 2018
  - Service start: 2020





Torque Standard Machines in KRISS

2 kNm Deadweight Torque Standard Machine

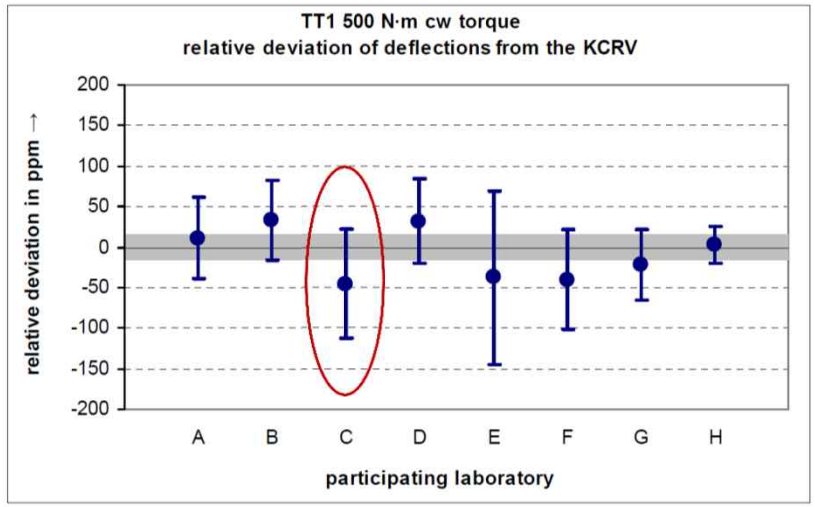
【Specification】

- Measuring range: (100 ~ 2000) Nm
- Minimum loading step: 10 Nm
- Measuring uncertainty: 0.005 % (5 parts in 10^5)
- Speed: less than 50 s for one point measurement
- Pilot Machine for CCM.T-K1.3

KRISS
2 kNm TSM

【Degree of Equivalence, CCM.T-K1】

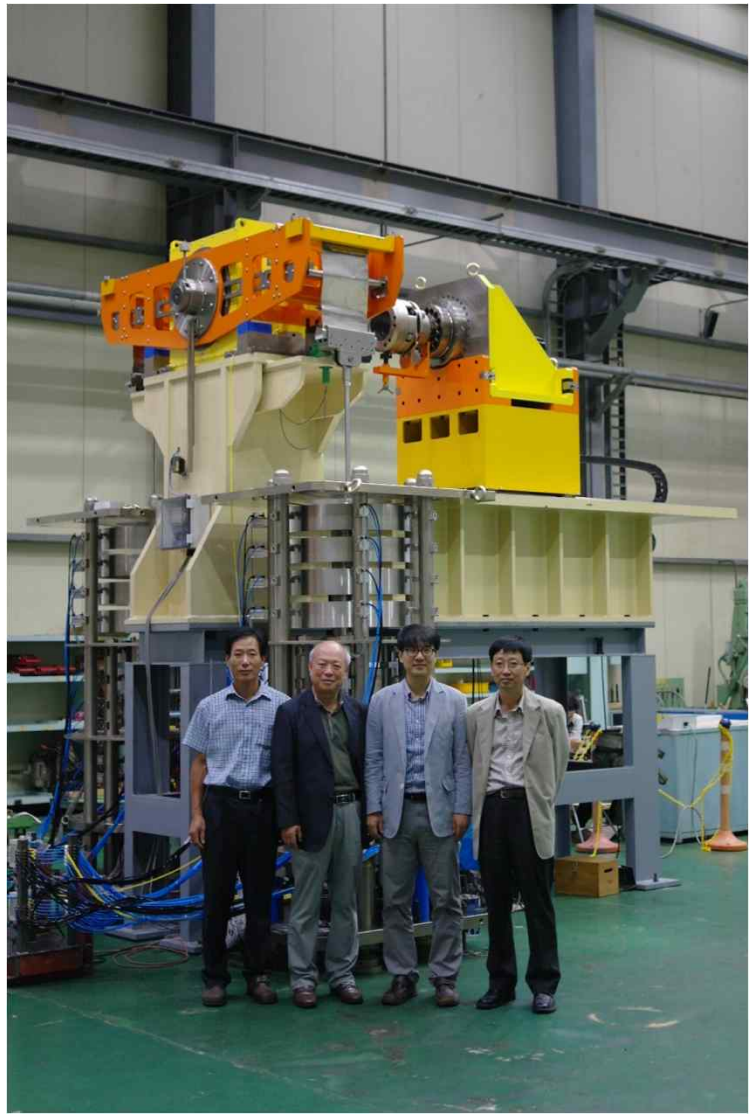
- Pilot: PTB
- Period: 2005~2006



KC results

20 kNm Deadweight Torque Standard Machine KRISS

- **Specification**
  - Min. torque step: 100 Nm
  - Max. torque: 22000 Nm
  - Uncertainty: 0.005 %
  - Lever length (one side): 1 m
  - L×W×H = 4.3 m × 3.4 m × 4.0 m
  - Working space: 110 mm dia. (max), 1000 mm in length
- **Schedule**
  - Project start: 2013
  - Installation: Dec. 2015
  - Finish of development: 2017
  - International Comparison with NMIJ: 2018
  - Service start: 2018



[Applications of Force Standard]

Applications of Large Force

KRISS

Arian 5 Rocket

Mass of Satellite: 2460 kg

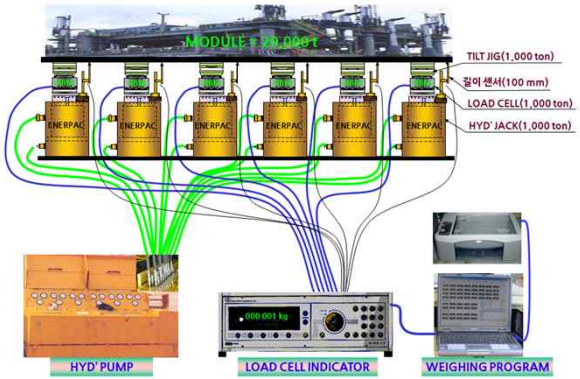
Thrust force: : 1400 ton (14 MN)

Nuclear Power Plant

Tension: 400 ~ 800 ton (4 ~8 MN)

Health Monitoring of Large Structure

Force: ~ 100 MN

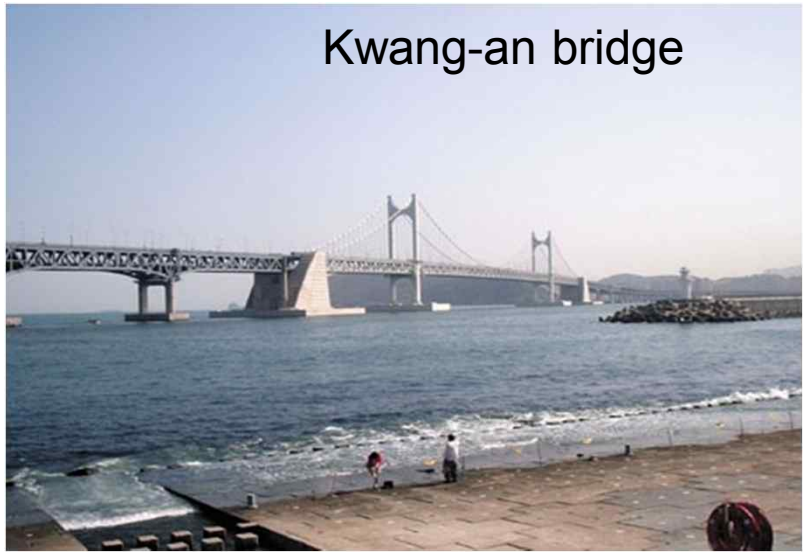


Weighing of Mega-Structure

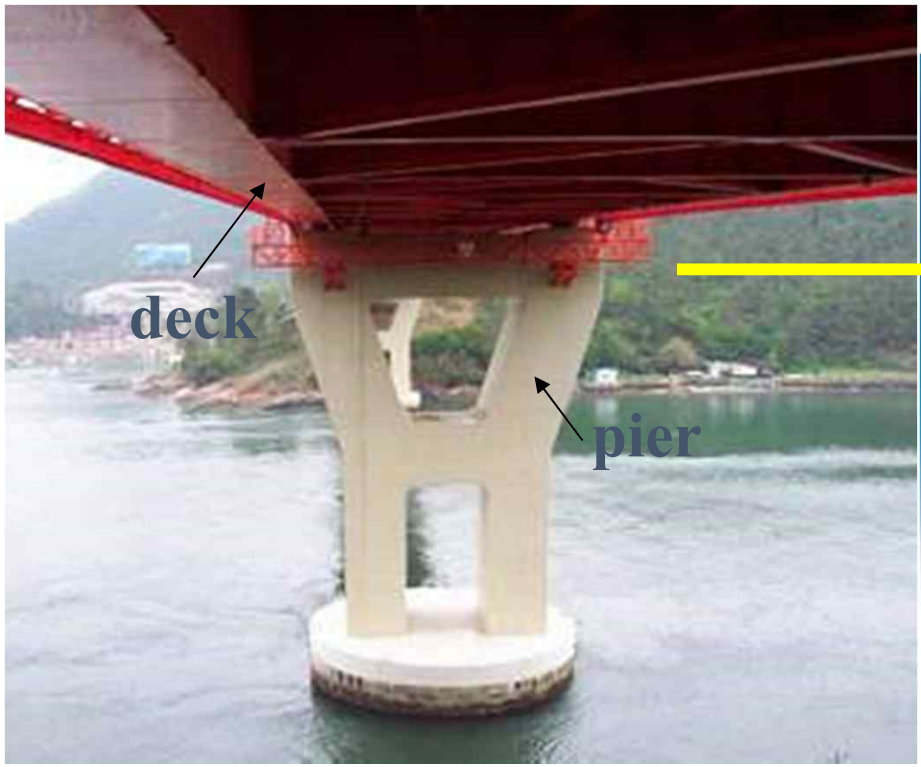
Gross weight: 1,000 ton ~ 100,000 ton (10 ~ 1000 MN)

Big Bridges in Korea

KRISS



Elastomeric Bearing for Bridges



Elastomeric bearing used between deck and pier provides a flexibility of bridge against forces caused by earthquake and passage of vehicle on the bridge.

Large Force Machines in Industries

KRISS

- Increase of heavy industries
  - Needs of larger force
- Needs for evaluation of mechanical components such as pot bearings
  - Testing machines with capacities greater than 10 MN
- 15 testing machines in Korea

30 MN Pot-bearing Testing Machine

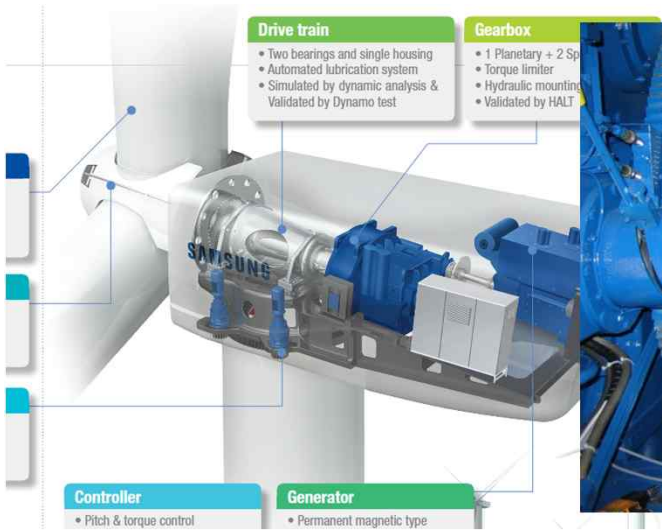
[Applications of Torque Standard]

Applications of Large Torque

KRISS

- **Demands for High-capacity Torque in Korea**
  - Torsion Tester, Airplane Brake Tester
  - Testing electrical motors, Turbine generator
  - Engine Tester

Airplane Brake Tester



Wind Turbine

Ship Engine

[Summary]

Summary of Large Mechanical Standards

KRISS

- **New Standard Machines**
  - 5 t mass standards
  - 1 MN deadweight force machine
  - 5 MN hydraulic amplification force machine (2019)
  - 50 MN build-up force machine (2020)
  - 20 kNm deadweight torque machine (2018)

- **Before and After Mega Mechanical Metrology Project**

	Mass	Deadweight force (2×10^{-5})	Hydraulic force (1×10^{-4})	1st Build-up force (2×10^{-4})	2nd Build-up force (5×10^{-4})	Deadweight torque (5×10^{-5})
Before	1 t	0.5 MN	2 MN	5 MN	10 MN	2 kNm
After	5 t	1 MN	5 MN	16.5 MN	50 MN	20 kNm
Ratio	5	2	2.5	3.3	5	10


KRISS
Better Standards, Better Life!
Thank you very much!
DGIST Convergence Research Institute