Evaluation of Force Standard Machines by using Build-up System

TC3 Round Table

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KRISS

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- **Basic theory**
- **Application examples**
  - Dynamic behavior of deadweight force standard machines
  - Side force components of a deadweight force standard machine
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- **Summary & Discussion**

Keycomparison of Deadweight Force Machine

Relative deviation in the recent keycomparison: 1×10^{-5}

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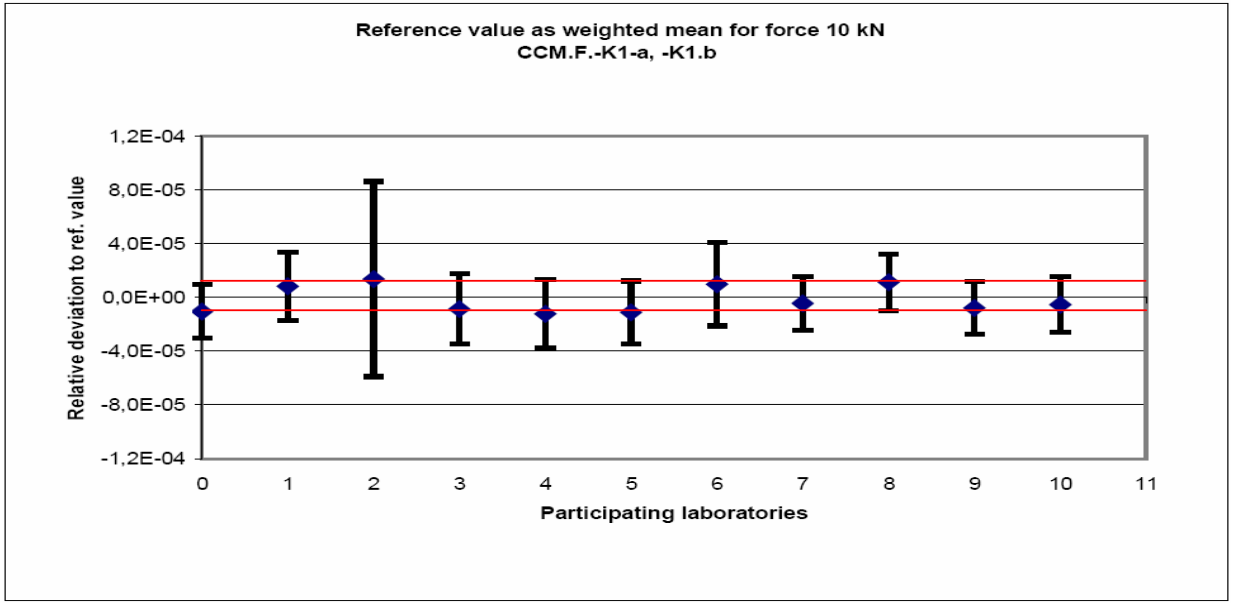
Declared uncertainty of deadweight force machine : 2×10^{-5}



→ Uncertainty of deadweight force standard machine: 1×10^{-5}

Uncertainty of Deadweight Force Machine

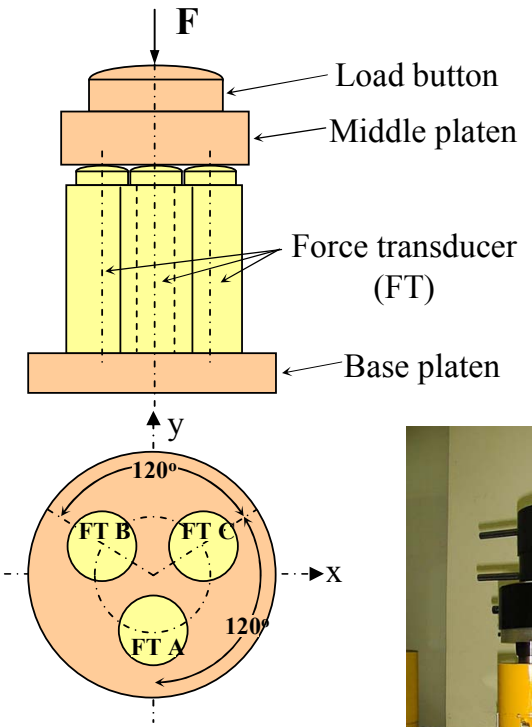
- **Uncertainty evaluation**
  - Analytically evaluated uncertainty < 1×10^{-5}
  - Unconsidered uncertainty components
    - Interaction between transducer and force machine
    - Parasitic force components, Dynamic behavior, etc.
- **Present key comparison**
  - Use of single force transducer
  - Response comparison of force transducer
  - → No measure of parasitic force component and dynamic behavior
  - → Other methods are necessary
- **Force working group meeting (March, 2004)**
  - Discussion of future KC method
  - Replacement of using a single transducer

Parasitic Component Measurement

- **Dynamometer**
  - Proposed by InRIM(Dr. Ferrero)
  - Advantage
    - Possible to measure whole parasitic components
  - Disadvantage
    - Complex structure → Difficult to handle
    - Only InRIM can make the dynamometer

- **Build-up system**
  - Advantage
    - Simple structure → Easy to handle
  - Disadvantage
    - Possible only for side force components

Build-up System

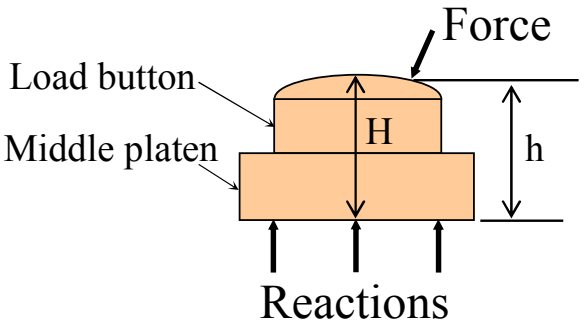


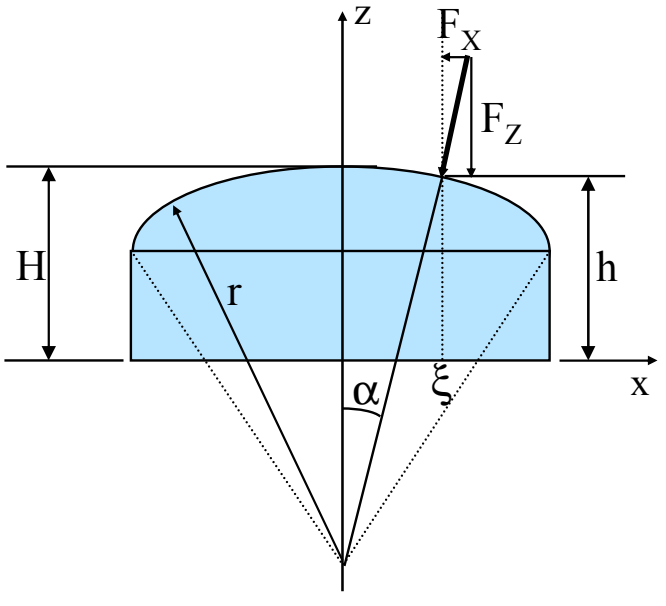
- **Build-up system**
  - 3 force transducers
  - Efficient method for large force (3 times of individual transducer)
- **Build-up system set in a force machine**
  - Easy to measure disturbance signal components due to lever mechanism

→ **Parasitic force component of force machine**

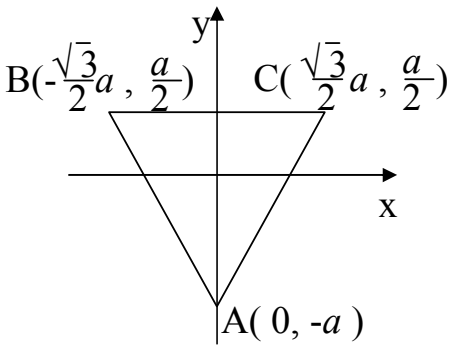
→ **Dynamic behavior of force machine**

Force and Momentum Equilibrium



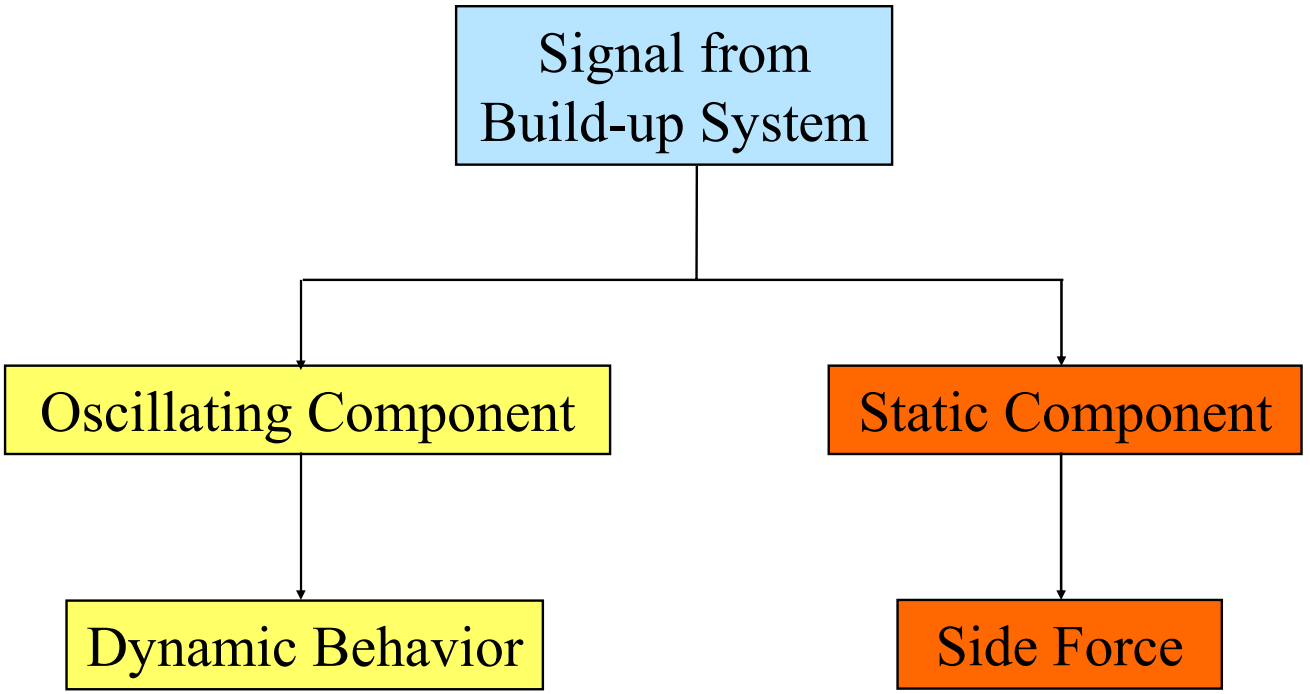


Position of F/T



Force equilibrium + Geometrical consideration → Analysis

Overall Procedure



Example of Dynamic Motion Analysis

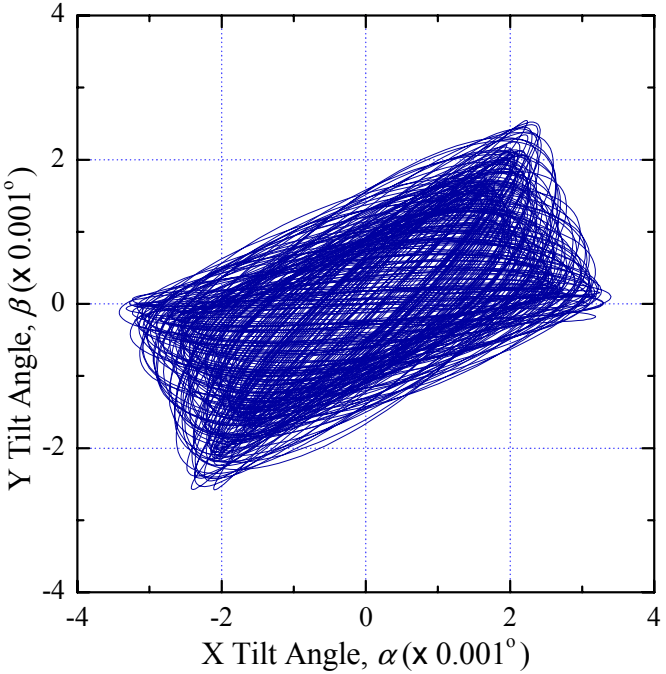
- PTB 100 kN and 1 MN force standard machines

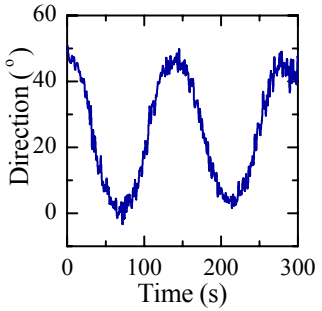
100 kN DFM

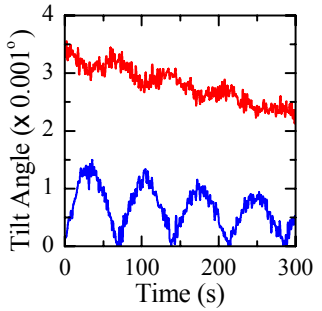
1 MN DFM

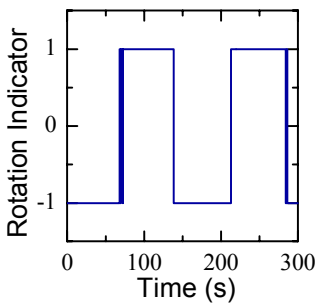
Example of Dynamic Motion Analysis

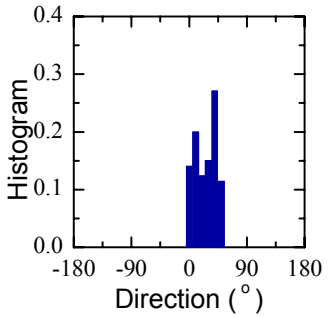
- **PTB 100 kN force standard machine, Load = 20 kN**









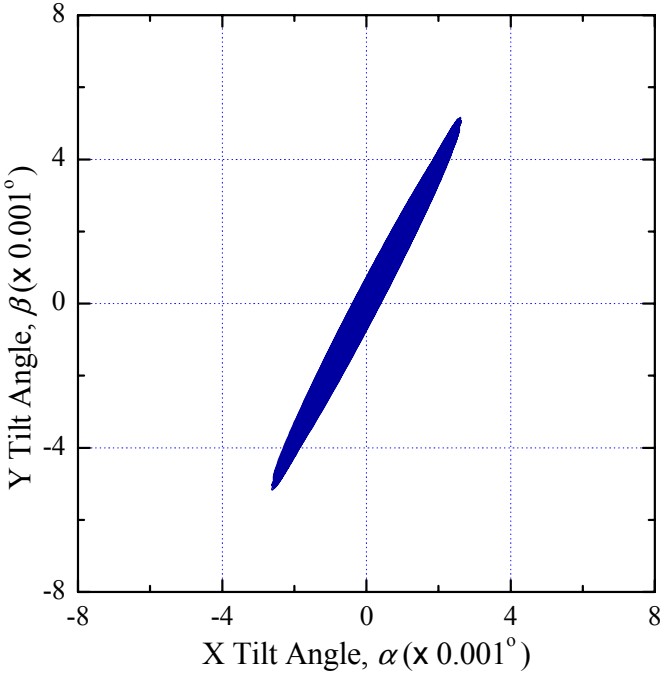


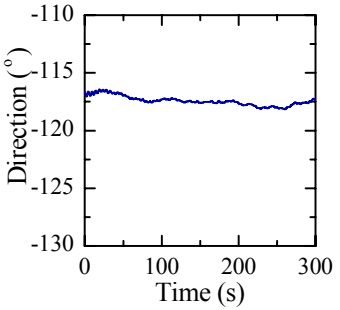
+1 : Counter clockwise
-1 : Clockwise

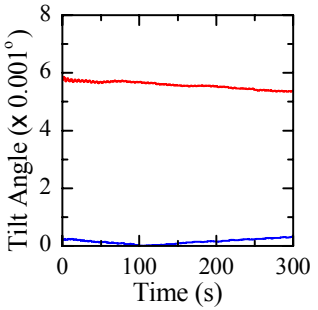
*** Rotational direction changes with time**

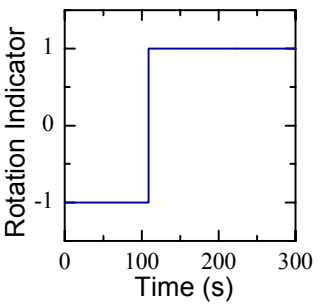
Example of Dynamic Motion Analysis

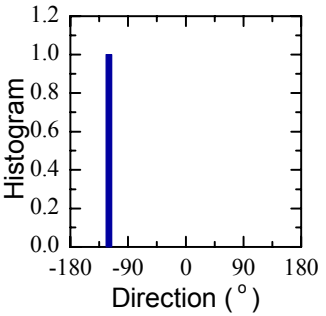
- **PTB 1 MN force standard machine, Load = 300 kN**









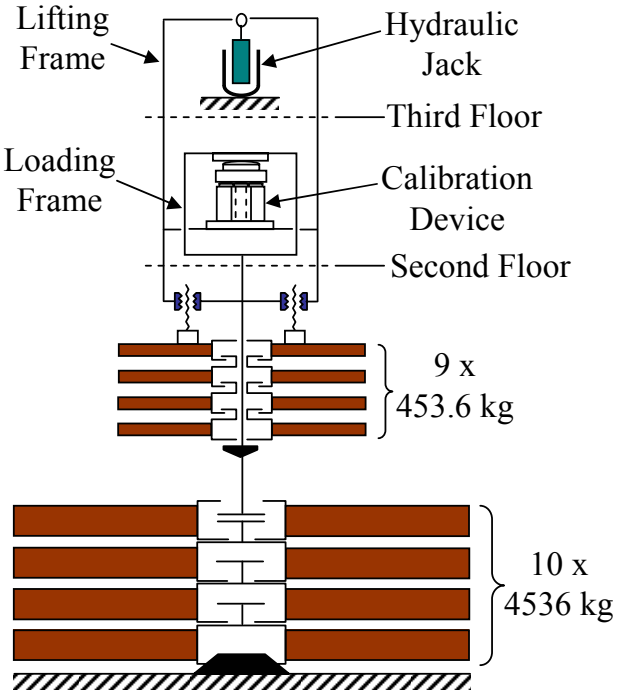


+1 : Counter clockwise
-1 : Clockwise

*** Rotational direction doesn't change with time**

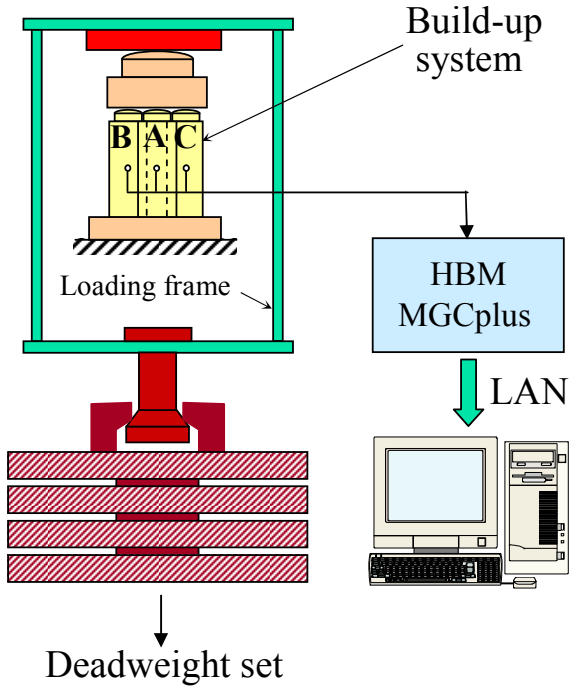
Example for Side Force Measurement

- **KRISS 500 kN deadweight force standard machine**
- **Force range**
  - 13.3 kN ~ 498 kN
- **Weights**
  - 1360 kg : Tare weight
  - 9 x 450 kg
  - 10 x 4500 kg
- **Dimension**
  - Height : 15.4 m
  - Width : 2 m
- **Total weight : 78,600 kg**
- **Relative uncertainty : 2 x 10^{-5}**

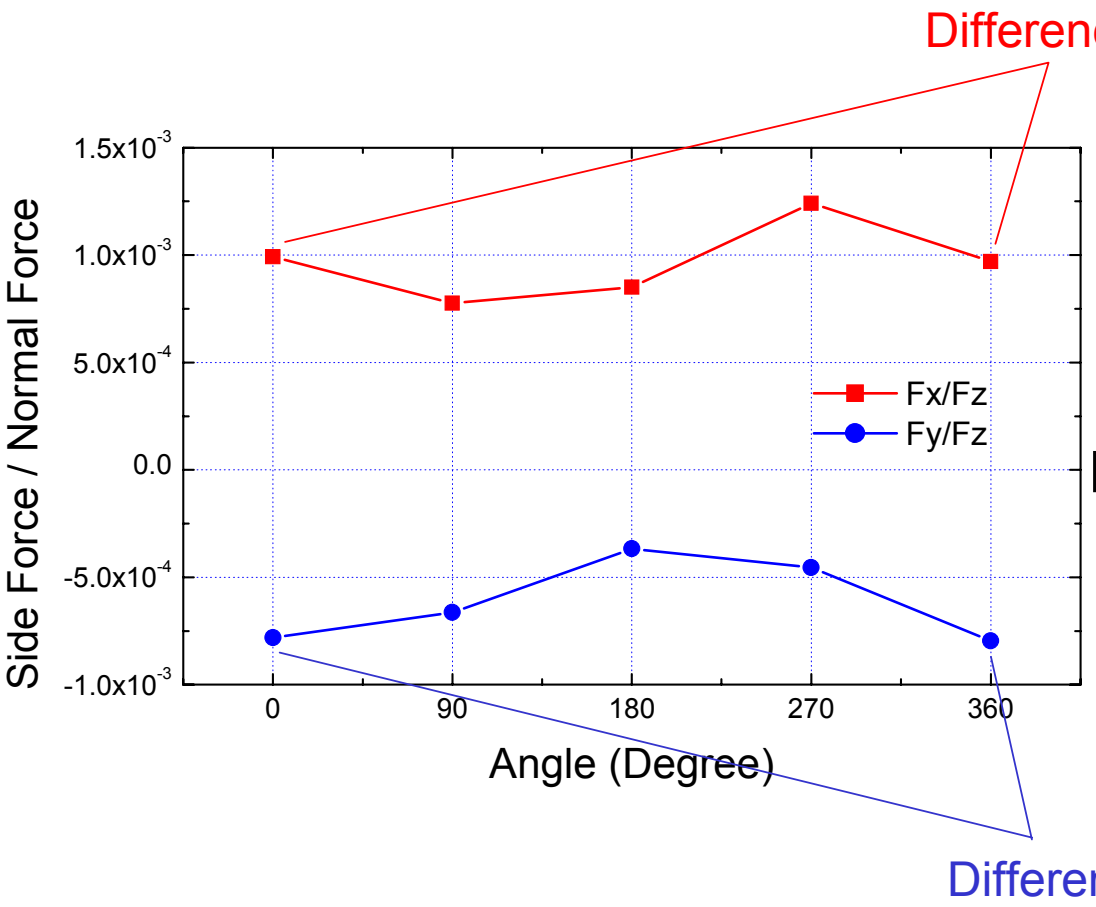


Experimental Set-up

- **Measuring quantities**
  - 3 force signals
- **Measurement position**
  - 0°, 90°, 180°, 270°, 360°
- **Force step**
  - 200, 300, 400, 500 kN
- **Measurement procedure**
  - 3 pre-loading
  - 2 measurements at 0°
  - 1 measurement at 90°, 180°, 270°, 360°
- **Time interval**
  - 6 minutes for pre-loading and unloading
  - 3 minutes for measurement



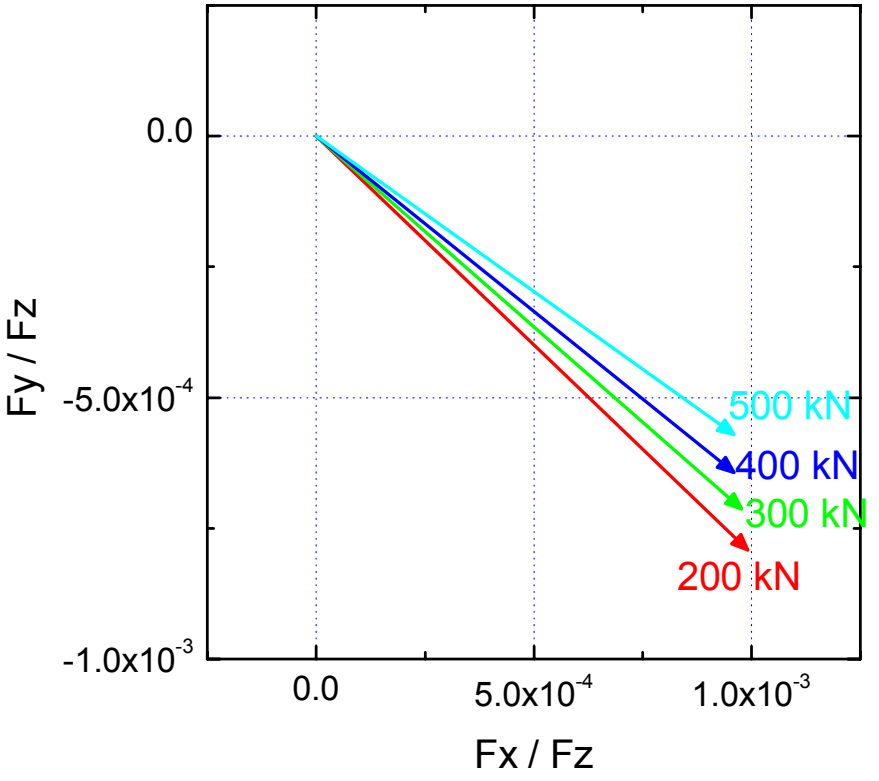
Reproducibility



Good Reproducibility

Side Force Components

- **Average of 90°, 180°, 270° and 360°**
- **Unsymmetrical factors of a build-up system**
  - Geometrical asymmetry
  - Sensitivity difference between F/T
  - Etc
- **Averaging → unsymmetrical effects can be reduced**



Future Works

- **Verification of the method**
  - Comparison with a multi-component force sensor
    - Dynamometer proposed by InRIM
  - Effect analysis of build-up system structure
    - Curvature of load button
    - Hardness of load button
    - Height of build-up system
    - Etc
  - Measurement of additional parasitic components
    - Parasitic moment components

- **Development and verification of measurement protocol**
  - Estimation of force machines in Korea
  - Estimation of force standard machines of other NMIs

Summary & Discussion

- **Summary**
  - Evaluation of deadweight force machine by using build-up system
  - Static analysis → Estimation of Side force components
  - Dynamic analysis → Pendulum motion of deadweights

- **Discussion**
  - Should we measure parasitic components for accurate uncertainty evaluation of deadweight force machine?
  - Is it possible to use multi-component measurement for the next force key comparison?
    - Which parasitic component?
    - Which method?