Dynamic calibration of fatigue machines (Presentation of experiments carried out in Brazil using ISO 4965)

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Introduction

ISO 4965 – "Metallic materials - Fatigue testing - Uniaxial dynamic force calibration - Part 1: Testing systems"

- Until now, to evaluated the machine performance it is used only the ISO 7500-1
- Then comes the necessity to test these machines dynamically
- The standard was recently reviewed in its bases (ISO TC 165/SC 5)
- The standard ISO 4965 is divided in two parts:
  - ✓ Part 1 – Dynamic calibration of the machine force indication
  - ✓ Part 2 – Calibration of the indication device

- Give the highlights of **Part 1**
- Show the methods proposed
- Present an experimental example

The standard

BS ISO 4965-1:2012

INTERNATIONAL STANDARD

ISO 4965-1

First edition
2012-07-15

Metallic materials — Dynamic force calibration for uniaxial fatigue testing —

Part 1:
Testing systems

Matériaux métalliques — Étalonnage de la force dynamique uniaxiale pour les essais de fatigue —

Partie 1: Systèmes d'essai

BS ISO 4965-2:2012

INTERNATIONAL STANDARD

ISO 4965-2

First edition
2012-07-15

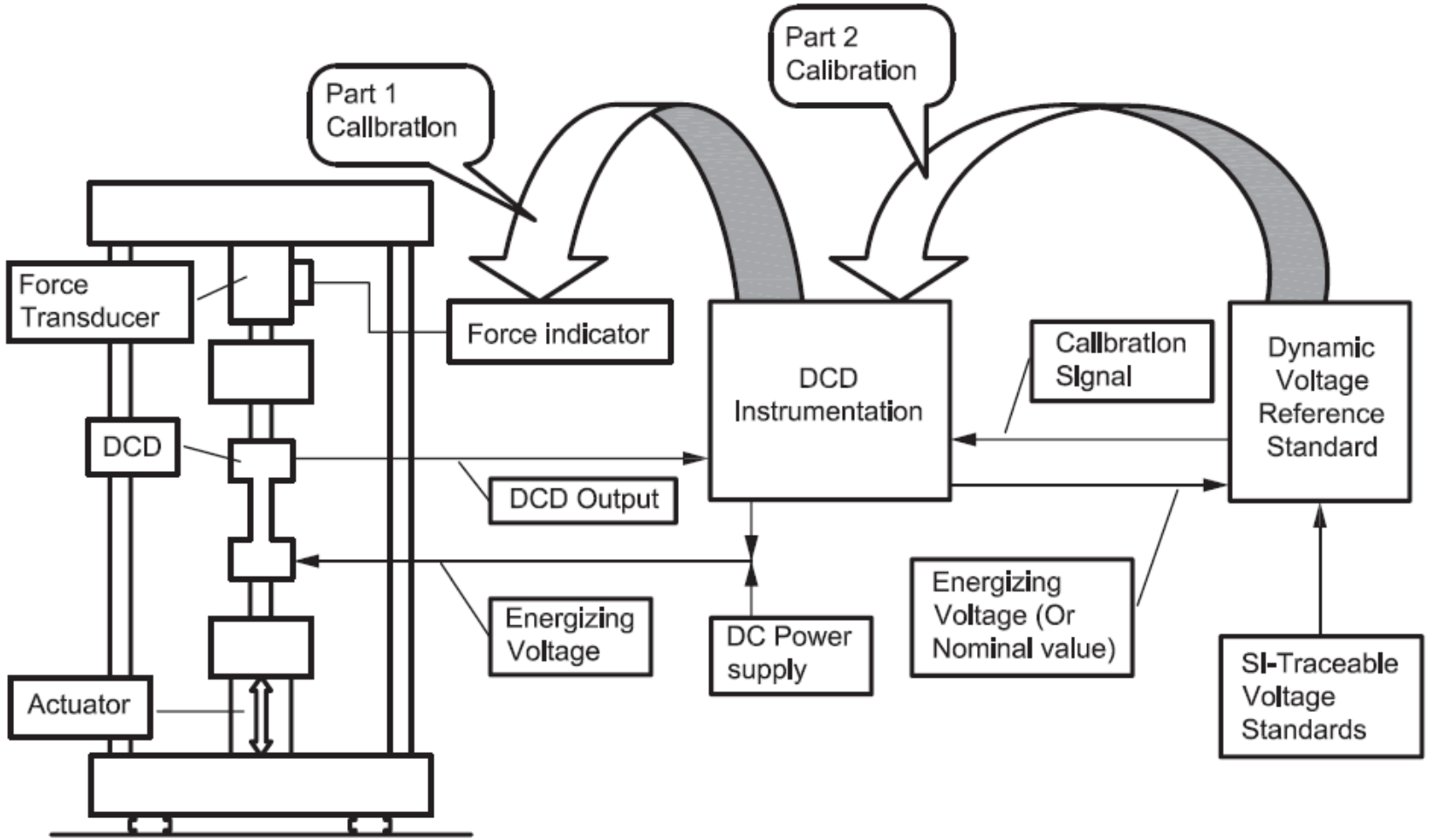
Metallic materials — Dynamic force calibration for uniaxial fatigue testing —

Part 2:
Dynamic calibration device (DCD) instrumentation

Matériaux métalliques — Étalonnage de la force dynamique uniaxiale pour les essais de fatigue —

Partie 2: Instrumentation pour équipement d'étalonnage dynamique

Schema for the parts 1 and 2



Introduction – ISO 4965 Part 1

- According to the standard, the dynamic errors of the force experienced by the test-piece and force indicated by the fatigue machine come from the result of the inertial forces acting on the force transducer and any dynamic errors in the electronics of the force indicating system

  I. Depending on the Frequency range and …

  II. force amplitude/range and …

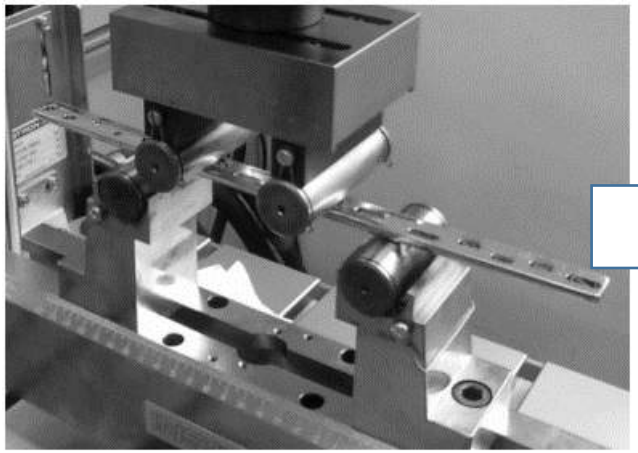
  III. different combinations of compliance …

  - ✓ result in different **amplitudes of motion!**
  - ✓ relationship between force amplitude (ΔFt) applied to a test-piece in a uniaxial, sinusoidal, constant amplitude test and the force amplitude indicated (ΔFi) by the testing system.
  - ✓ The reference system is called a **Dynamic Calibration Device** (DCD)

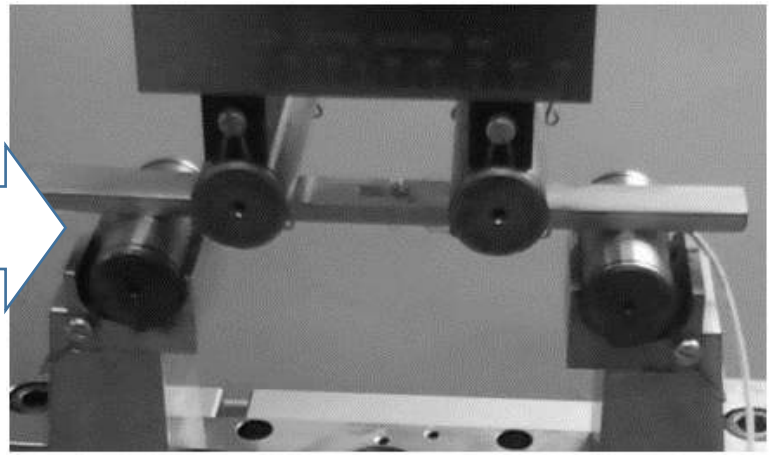
What is a DCD?

- A DCD will be the reference for the machine calibration
- The DCD shall be able to produce an electrical signal proportional to the force applied on the machine under some specific mechanical condition
  - ✓ but it doesn't need to be a "best sensor"
- DCD shall have some mechanical parts attached to the force transducer in order to reduce the stiffness of the overall device
- DCD is either:
  - ✓ Replica specimen (with instrumentation)
  - ✓ Devices of different compliances

What is a DCD?



real specimen



instrumented specimen

different compliances

Methodology

There are two methods for testing a machine:

- **Method A** (Replica test-piece method): applicable over the range of frequencies applied for one specific type of test-piece only.
  - ✓ A correction factor is applicable for dynamic force measurement errors of up to 10 % of dynamic force range.
  - ✓ After the correction factor, the actual force measurement error will be reduced to less than 1 % of the dynamic force range
- **Method B** (Compliance envelope method): the dynamic calibration over the range of test frequencies validated for test-pieces whose compliance lies between those of the two DCDs.
  - ✓ No correction factor is applicable
  - ✓ Force measurement errors above 1 % of the dynamic force range are not allowed

Requirements

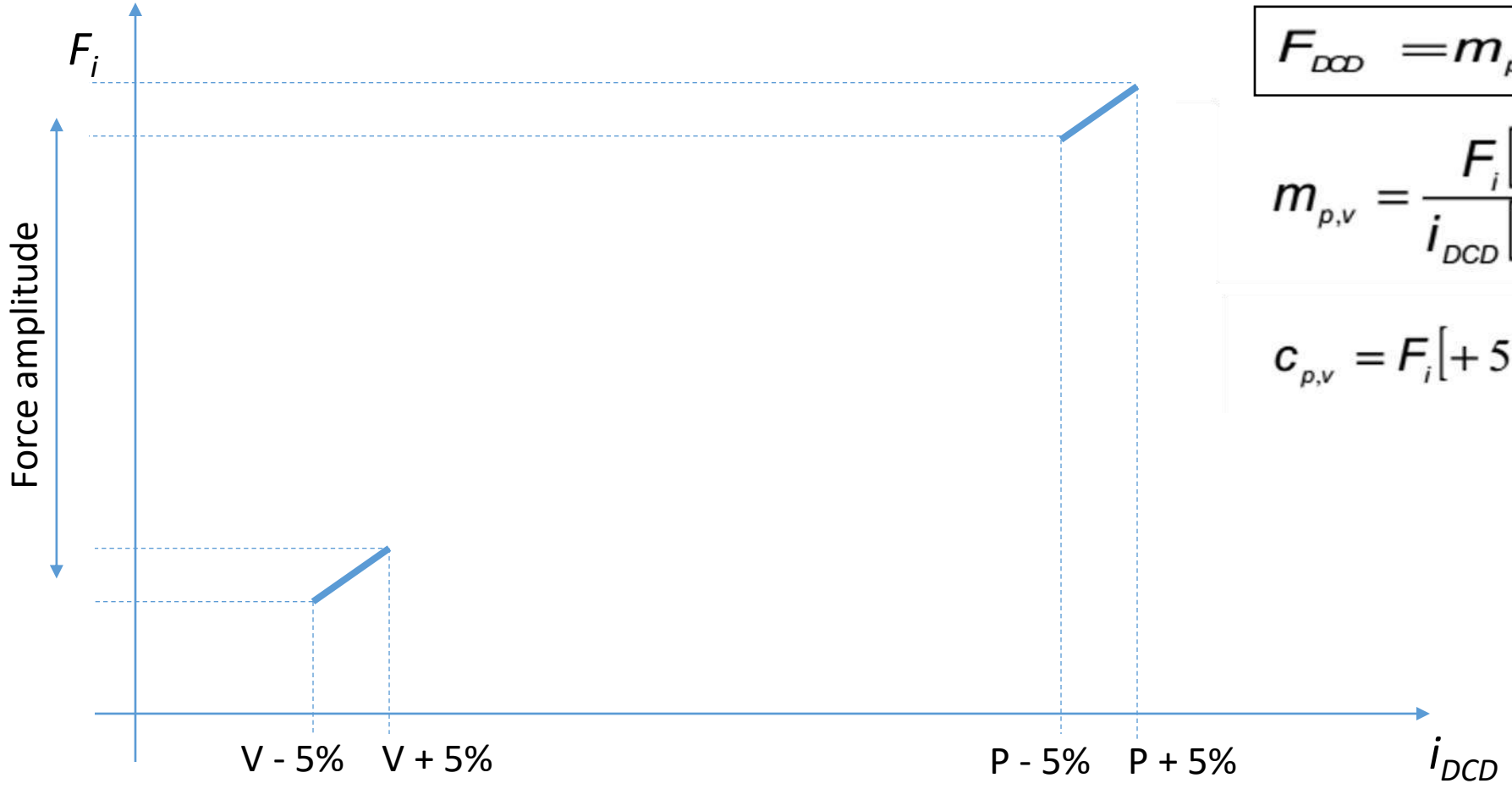
- Machine is previously calibrated by ISO 7500, class 1 or better
- Avoid resonance frequency ranges (frequency sweep before the calibration)
- Set filters before calibration begins
  - ✓ The calibration will be valid for the configuration of filters at that time
- Force direction can be: compression, tension or compression+tension (pass through zero)
  - ✓ Results are valid only for the direction tested
- In Method B: Force ranges can be different for each DCD

  Frequency range must be the same

Calibration proceeding - static

- Methods A and B have the same load sequence
- The DCD output (i_{DCD}) is in electric units (Ex.: mV/V)
- Do a static "calibration" of i_{DCD} against the machine force signal (F_i):
  I. Define the peak and valley values of the force amplitude to be applied
  II. Apply static and stable load to peak value +5% of the amplitude and read both signal
  III. Apply static and stable load to peak value -5% of the amplitude and read both signal
  IV. Apply the same loads for analyzing the valley
- Coefficients "m" and "c" are calculated for both peak and valley
- Indication of the DCD can now be made in unit of force as F_{DCD}

Calibration proceeding – static – Linearization of the extremes



$$F_{DCD} = m_{p,v} \cdot i_{DCD} + c_{p,v}$$

$$m_{p,v} = \frac{F_i[+5\%] - F_i[-5\%]}{i_{DCD}[+5\%] - i_{DCD}[-5\%]}$$

$$c_{p,v} = F_i[+5\%] - m_{p,v} \cdot i_{DCD}[+5\%]$$

Dynamic Calibration proceeding

- Divide the frequency ranges in 9 values (Ex.: 1 Hz, 2 Hz, … , 9 Hz)
  I. 5 increasing frequencies spaced (Ex.: 1 Hz, 3 Hz, 5 Hz, 7 Hz, 9 Hz)
  II. 4 decreasing frequencies half-spaced (Ex.: 8 Hz, 6 Hz, 4 Hz, 2 Hz)
- Apply the dynamic cycles (standard doesn't define the number of cycles)
- Calculate the dynamic amplitudes of each frequency

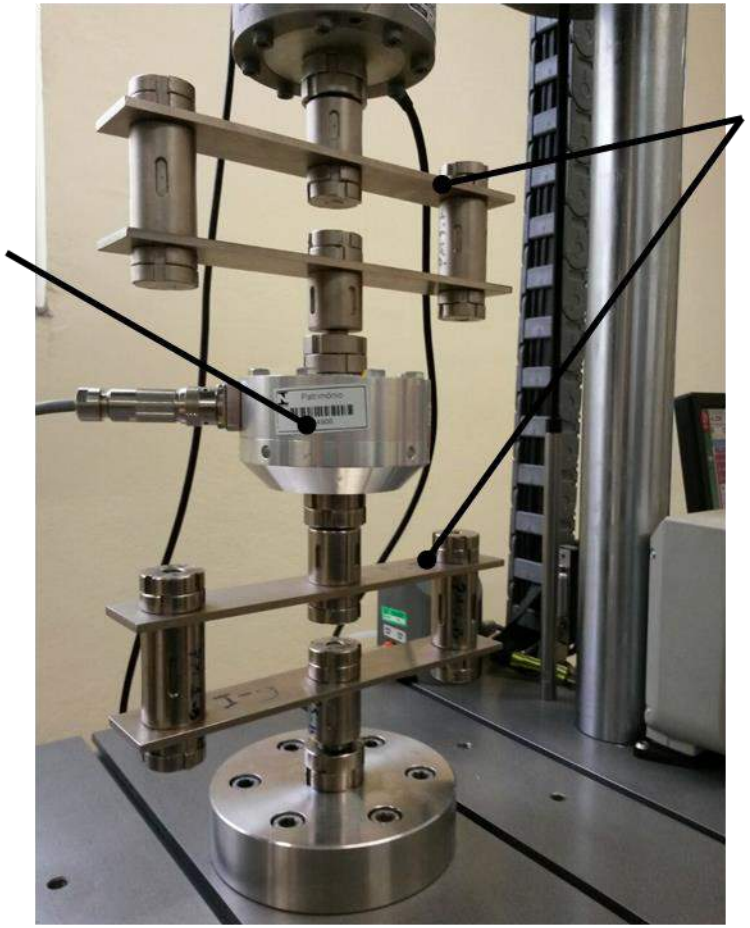
$$\Delta F_{DCD} = F_{DCD}(p) - F_{DCD}(v)$$

$$\Delta F_i = F_i(p) - F_i(v)$$

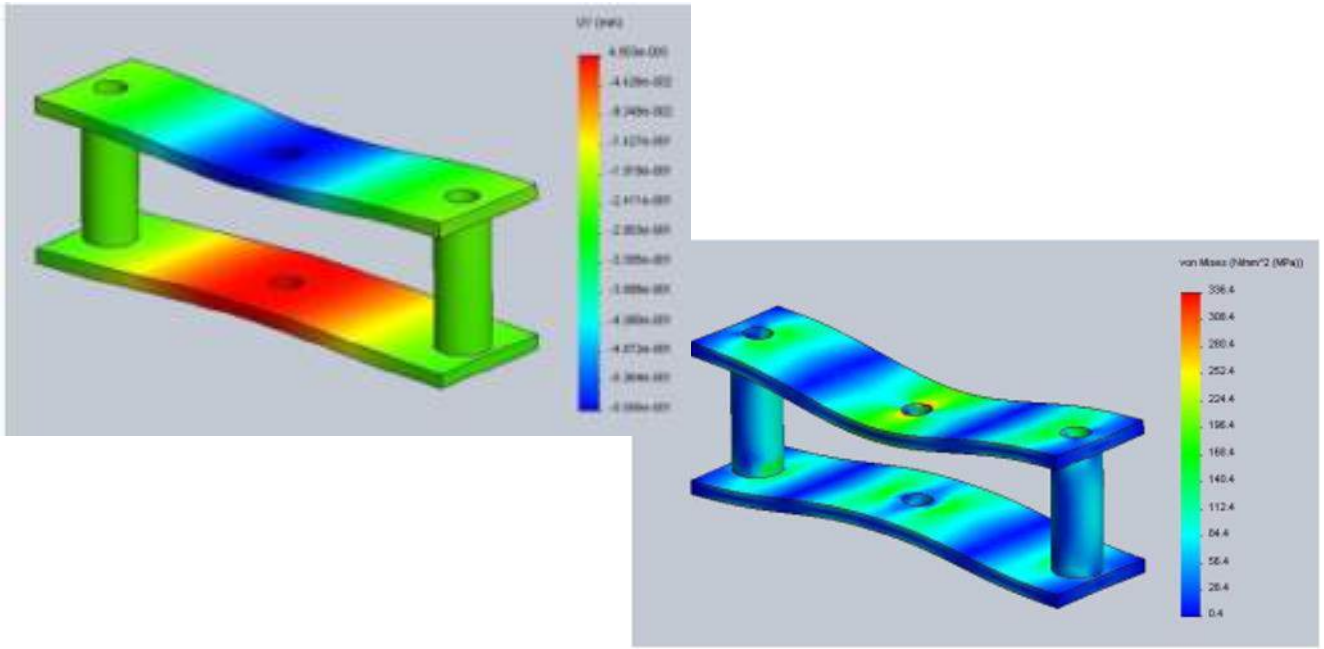
- Calculate the indication error

$$e_i = \frac{\Delta F_i - \Delta F_{DCD}}{\Delta F_{DCD}} \times 100$$

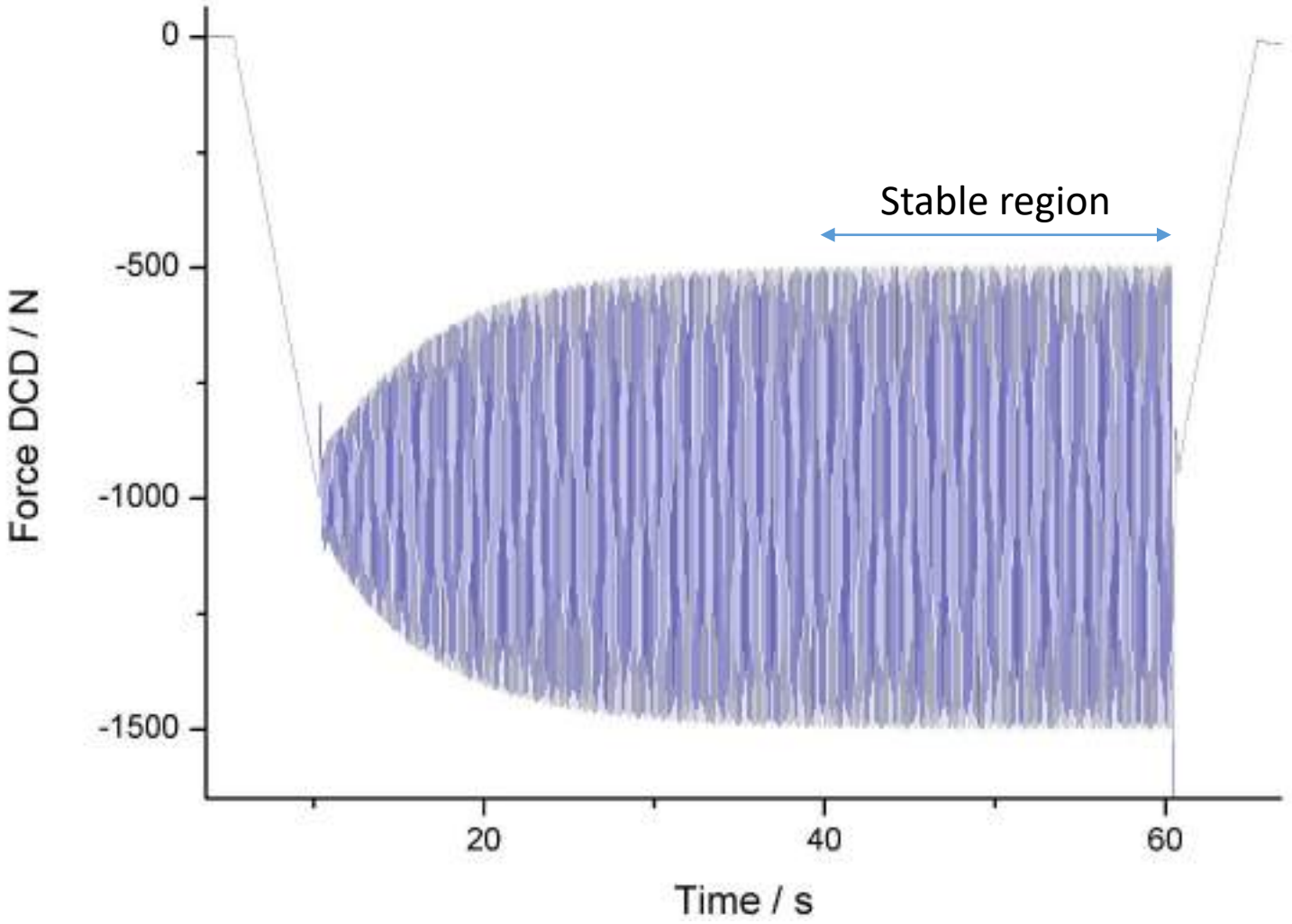
Dynamic Calibration - Example



- Beams with different geometry
- Theory for calculating nominal force capacity and displacements
- Force transducer working as the instrumentation
- Acquisition unit with dynamic capacities

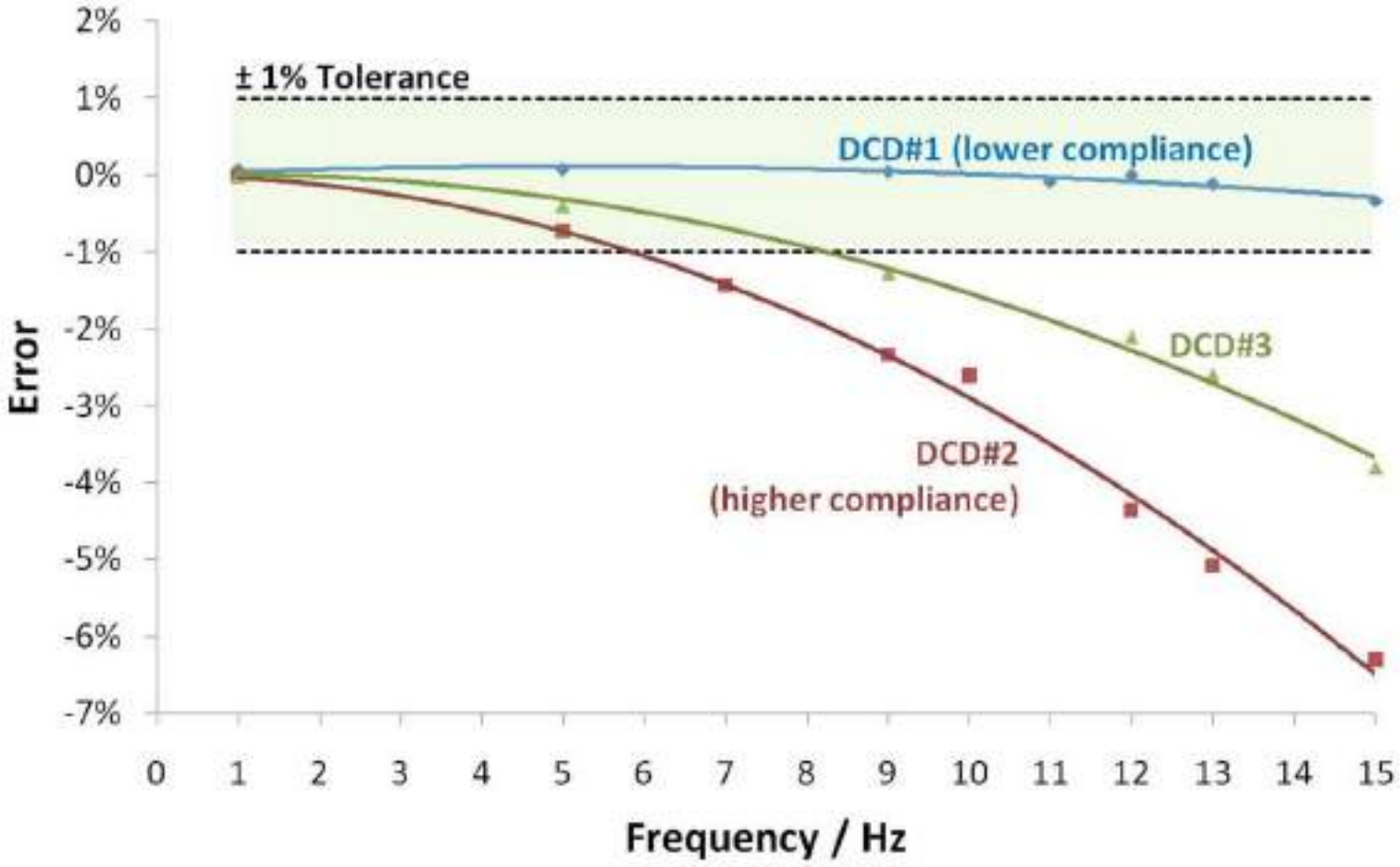


Dynamic Calibration - Example



- Acquisition rate *versus* size of data
- Storing data in the computer
- There is a similar plot for the F_i signal
- No need for synchronization
- Algorithm for **finding peaks and valleys**
- Work with data in the stable region
  - ✓ a minimum **50 cycles**

Dynamic Calibration - Example



- Low compliance give better results
- Need to calculate some inertial influences
- Graphic is the better way to show these results together with the table giving each frequency error for each DCD
- The standard doesn't mention the calculation of measurement uncertainty

MUITO OBRIGADO !