# DYNAMIC CALIBRATION OF FATIGUE TEST MACHINES USING A DYNAMIC CALIBRATION DEVICE

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**Abstract:** This paper describes the practical application of method B of the ISO 4965-1 standard for the dynamic force calibration of a fatigue test machine. The experiment focuses on detailing the main proceedings involved such as the load series, the frequency sweep range and the data acquisition and processing parameters applied to the Dynamic Calibration Devices (DCDs), used with different compliances. The calibration results are shown and a discussion is proposed.

**Keywords:**ISO 4965-1; Dynamic Force Calibration; Dynamic Traceability, Fatigue Test Machines.

## 1. INTRODUCTION

The ISO 4965-1 [1] standard deals with the dynamic force calibration of fatigue test machines. The main idea of the standard is to compare the force values measured by the so called Dynamic Calibration Devices (DCDs), which was previously statically verified and adjusted, and the values measured by the machine system. The DCD also works as the specimen's compliance emulator and different configurationsof parts can be used to cover a range of compliances to be evaluated, such as defined by the Method B of the standard.

A study about method A of the standard had been previously presented in [2-4] and some issues about the load sequence, the stability of the measured data and the DCD design were argued.

The main purpose of this work is to present an analysis of a practical application of method B to the dynamic force calibration of a fatigue test machines. The proceeding is reviewed, the main issues identified and in the end, a result of a calibration is presented with critical points highlighted.

## 2. METHODOLOGY

The DCD is composed by a force transducer, able to produce an electrical signal proportional to the force applied on the machine, and two pairs of beams which will define the compliance of the whole assembly (Figure 1). All parts are well tightened using screws.

For the experiment three assemblies with beams of different compliances were used coupled to a 5 kN force transducer. The averaged compliance values shown in Table 1 were determined experimentally by the static force and displacement measurements in the machine. The force values applied were in the range from 500 N to 1500 N (1000 N $DC$) in compression, same amplitude applied for the dynamic tests.
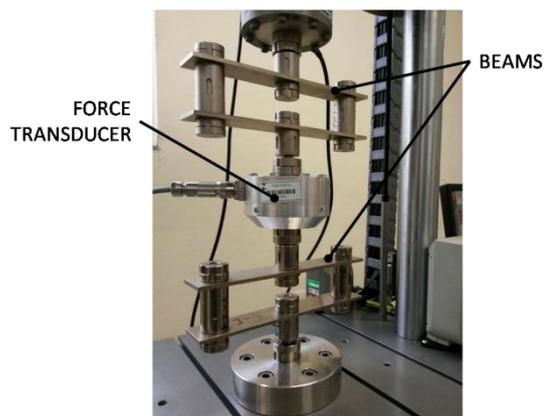


Figure 1 - DCD mounted in the machine load frame.

Table 1 – Compliance values of the DCDs.

| Assembly | Compliance |
|---|---|
| *DCD #1* | $4.18 \times 10^{-4}$ mm/N |
| *DCD #2* | $4.00 \times 10^{-3}$ mm/N |
| *DCD #3* | $1.83 \times 10^{-3}$ mm/N |

The range of frequencies tested was from 1 Hz to 15 Hz, testing first upwards (1 Hz, 3 Hz… 15 Hz) and then downward (14 Hz, 12 Hz... 2 Hz).

The tests were done with the application of oscillatory forces and the measurements were started only after a perceptible stabilization of the peaks and valleys.

Both force measurements, from the DCD ($F_{DCD}$) and from the machine ($F_i$), were recorded and post processed to extract an effective number of peaks and valleys.

It was used an INSTRON E3000 electromechanical fatigue machine for the DCD tests on the dynamic force

calibration. The acquisition parameters were adjusted to 300 Hz and 50 Hz for acquisition and filtering respectively.

The errors ($e$) for each frequency were evaluated according to the equations below.

$$\Delta F_{DCD} = \bar{F}_{DCD}(p) - \bar{F}_{DCD}(v) \qquad (1)$$

$$\Delta F_i = \bar{F}_i(p) - \bar{F}_i(v) \qquad (2)$$

$$e = \frac{(\Delta F_i - \Delta F_{DCD})}{\Delta F_i} \qquad (3)$$

## 3. PRELIMINARY RESULTS

Due to the long time needed to stabilize the force (each frequency had its own period for that stabilization), the DCD recording was made only after reaching this period, in order to avoid very large files. Figure 2 shows an example of this need for stabilization in the test of DCD#3 at 7 Hz, where only the last 10 s were considered reliable.
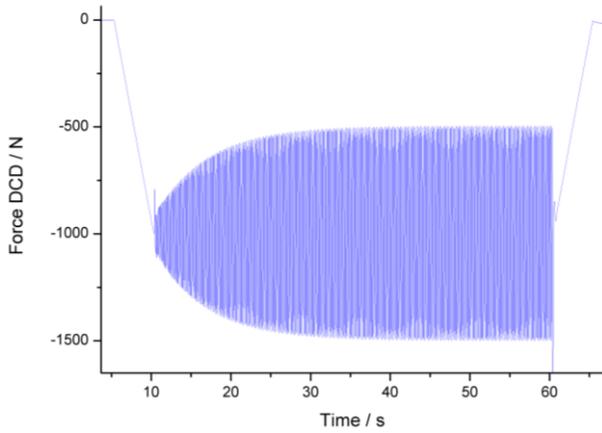


Figure 2 – Error plot for each frequency

The algorithm for finding peaks and valleys, a kind of threshold filter, was automated and post processed. Some issues were found, highlighting the dependence on the agreement of acquisition rate and excitation frequency at an acquisition setting.

As a first example, Table 2 shows part of DCD#2 results at 15 Hz. Columns "Time" and "Force extremes" on the left are resulted after the algorithm. But some values could not be considered as representative of the peaks and valleys, what brought the need for a more rigid manual proceeding to detach and then delete these values (red boxes).

On the other hand, Table 3 shows part of DCD#1 results at 1 Hz, where columns "Time" and "Force extremes" on the left are resulted after the application of the algorithm. But here, sometimes the algorithm found two consecutive values (green numbers), so the extremes are calculated as the corresponding averaged values (green cells).

After the reliable peaks and valleys are defined, the errors ($e$) could be calculated. Figure 3 shows the error plot for each frequency and with each DCD. It is important to highlight that these errors do not consider the contributions or correction due to the inertial forces originated from the displacement of the parts involved in the method proposed by ISO 4965-1.

Table 2 – Peaks and Valleys identification for DCD#2 at 15 Hz.

| Time / s | Top Forces / N | Reliable Peaks / N | Reliable Valleys / N |
|---|---|---|---|
| 116.42 | -1499.34 | -1499.34 | |
| 116.45 | -501.251 | | -501.251 |
| 116.48 | -1488.12 | | |
| 116.52 | -502.63 | | -502.63 |
| 116.55 | -1497.33 | -1497.33 | |
| 116.58 | -512.616 | | |
| 116.62 | -1498.84 | -1498.84 | |
| 116.65 | -502.376 | | -502.376 |
| 116.68 | -1488.37 | | |
| 116.72 | -501.706 | | -501.706 |
| 116.75 | -1497.47 | -1497.47 | |

Table 3 – Peaks and Valleys identification for DCD#1 at 1 Hz.

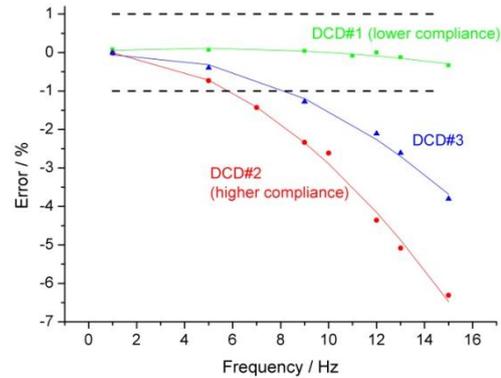| Time /s | Top Forces /N | Peaks /N | Valleys /N | Reliable Peaks /N | Reliable Valleys /N |
|---|---|---|---|---|---|
| 105.81 | -1499.20 | -1499.20 | | -1499.20 | |
| 106.32 | -500.16 | | -500.16 | | -500.16 |
| 106.81 | -1499.70 | -1499.70 | | -1499.72 | |
| 106.83 | -1499.74 | -1499.74 | | | |
| 107.32 | -499.72 | | -499.72 | | -499.72 |
| 107.83 | -1499.29 | -1499.29 | | -1499.29 | |
| 108.31 | -500.95 | | -500.95 | | -501.09 |
| 108.32 | -501.23 | | -501.23 | | |
| 108.82 | -1499.85 | -1499.85 | | -1499.85 | |



Figure 3–Error plot for each frequency and each DCD.

## 4. PRELIMINARY DISCUSSION AND CONCLUSION

The experimental application of the standard ISO 4965-1 is very important in order to obtain empirical substrate for the interpretation of the whole proceeding.

From the tests it was clear that, although the standard presents a very simple proceeding for applying and measuring oscillatory forces, there are some points which demand for more detailed instructions. The user of the standard must build a kind of parallel proceeding for

checking the applied parameters, algorithms and mechanical characteristics of the DCDs.

Once this was the first time the group investigated the Method B, it is interesting to do, in the near future, more experiments with different configurations, assemblies and machines. For example, a method for the investigation of the inertia effects on the calibration procedure must be developed for Method B but also for Method A.

On the other hand, some changes should be discussed during the next revision period of the standard in the ISO TC164 committee.

## ACKNOLEDGEMENTS

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