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DYNAMIC CALIBRATION OF A FATIGUE TESTING MACHINE ON ORTHOPAEDIC IMPLANTS IN ACCORDANCE WITH THE ISO 4965-1

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Abstract – The main purpose of the work was to carry out a dynamic calibration of a fatigue testing machine in accordance with the revised draft of ISO 4965-1. The machine had previously been calibrated dynamically, with the results presented at the IMEKO World Congress in September 2009 – one of the reasons for repeating the calibration was to see if the anomalous results would be repeated and, if so, to investigate the reasons behind them further and use then to improve the analysis of the orthopaedic implant testing results.

Keywords: ISO 4965-1; dynamic force calibration; orthopaedic implant.

1. INTRODUCTION

The main purpose of this work was to carry out a dynamic calibration of a fatigue testing machine in accordance with the revised draft of ISO 4965-1 [1]. The machine had previously been calibrated dynamically, with the results presented at the IMEKO World Congress in September 2009 [2]. One of the reasons for repeating the calibration was to see if the anomalous results taken at that occasion would be repeated and, if so, to investigate the reasons behind them further.

The machine calibrated was an Instron model 8872 installed at the National Institute of Technology (INT) facilities. That machine is used to perform orthopaedic implants testing in accordance with ISO, ASTM and national standards.

The machine was to be calibrated in the range from 80 N to 800 N as this is a representative range of forces applied during four point bend testing of the orthopaedic implant plate-type components (Fig. 1).

2. METHODS AND PROCEDURES

As specified in the latest draft revision of ISO 4965-1, the first step should be calibrating the machine using ISO 7500-1 [3] as standard proceeding.

Fig. 1. Machine used in four point bending testing in orthopaedic



implant plate-type components

The ISO 4965-1 presents two different methods to calibrate a machine dynamically. Method A uses one instrumented replica specimen as DCD (Dynamic Calibration Device) with compliance similar to the pieces to be tested at the machine. Method B is used to calibrate a dynamic testing system for use with varying test-piece configuration, using two DCDs of different compliance.

In our study, only one instrumented specimen will be used as similar to the orthopaedic implant plate-type components.

The second step should be calibrate the replica specimen statically. Although the draft standard specifies that the calibration points should be at the minimum and maximum forces $\pm 5\%$ of the force range (i.e. $\pm 5\%$ of 720 N (800 N – 80 N) = ± 36 N), it was decided to replicate the original dynamic calibration and carry out the work at $\pm 5\%$ of actual force (i.e. $\pm 5\%$ of 80 N and 800 N). The replica specimen was connected to a high-speed data acquisition system, measuring its output in nominal units of strain. The results of this static compression calibration are given in Table 1.

Table 1. Initial static calibration results

Force F_i (N)	Output i_{DCD} (units)		
	Run 1	Run 2	Run 3
840	-0,000 779	-0,000 779	-0,000 779
760	-0,000 709	-0,000 709	-0,000 710
84	-0,000 090	-0,000 091	-0,000 092
76	-0,000 082	-0,000 083	-0,000 083

After the static calibration of the DCD, the dynamic calibration was carried out at frequencies of 2 Hz, 6 Hz, and 10 Hz, with an amplitude from 80 N to 800 N in compression, covering the most common range for testing the orthopaedic implant components. Figure 2 shows an example of the output i_{DCD} from the replica specimen at a frequency of 2 Hz during the first 20 seconds.

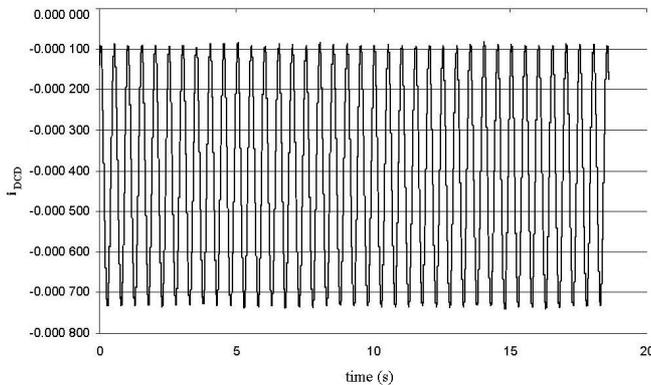


Fig. 2. Plot of output i_{DCD} (in units) against time (in seconds) during dynamic calibration at 2 Hz

A plot like that could be done for each calibration frequency and the values for peaks and valleys can be taken. Figure 3 shows the plot for the output of readings for valleys and peaks covering the specified ranges of frequencies.

After the completion of the dynamic work, the static calibration was repeated once – these results demonstrated that the sensitivity of the system had changed, probably as a result of specimen movement resulting from the dynamic application of force. It was decided that it would be more metrologically sound to use these results and so the analysis was based on this final calibration run, the results of which are given in Table 2.

Table 2. Final verification of the static calibration results after dynamic measurements

Force F_i (N)	Output i_{DCD} (units)
	Run 4
840	-0,000 769
760	-0,000 699
84	-0,000 090
76	-0,000 082

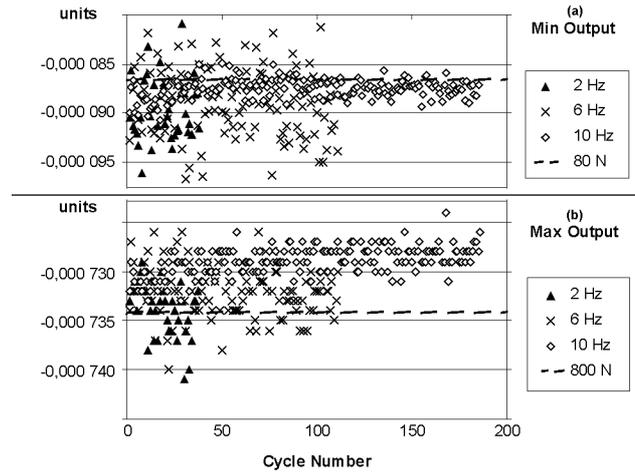


Fig. 3. Plots for the output of readings for valleys (a) and peaks (b) covering the specified ranges of frequency

At each frequency, these peak and valley outputs were converted to the force values F_{DCD} , using the results of the final static calibration, enabling a force range to be calculated, as in (1) using (2) and (3).

$$F_{DCD} = m_{p,v} \cdot i_{DCD} + c_{p,v} \quad (1)$$

with,

$$m_{p,v} = \frac{F_i [+5\%] - F_i [-5\%]}{i_{DCD} [+5\%] - i_{DCD} [-5\%]} \quad (2)$$

and

$$c_{p,v} = F_i [+5\%] - m_{p,v} \cdot i_{DCD} [+5\%] \quad (3)$$

These force ranges were then compared with the nominal force range of 720 N, the difference being expressed in both absolute and relative terms. The results of this analysis are given in Table 3.

Table 3. Final data analysis

Freq.	i_{DCD}		F_{DCD}			Difference to F_i range of 720 N	
	i_{max}	i_{min}	F_{max}	F_{min}	F_{range}	(N)	(%)
(Hz)	(Units)		(N)				
2	-0,000 734	-0,000 090	799,7	83,2	716,5	3,5	0,48
6	-0,000 732	-0,000 090	797,8	82,4	715,3	4,7	0,65
10	-0,000 728	-0,000 087	794,0	80,9	713,1	6,9	0,95

CONCLUSION

The previous anomalous results, in which a difference of up to 5 % across the frequency range was apparent, were not replicated and the differences are now under 1% for all frequencies tested. From this, some conclusions about the loading and measuring proceeding can be taken.

It is important to fully exercise the machine dynamically before carrying out the static calibration and a check static

calibration at the end of the procedure is recommended to ensure that the specimen has not shifted – it is important that the specimen is kept under load throughout the whole process, including the static calibration of the DCD.

Analysis of the stability of the measured peaks may provide the required evidence on whether or not this specified repeatability target is being met

At this point, a check of the electronic acquisition instrumentation can be also needed and the second part of the standard, ISO 4965-2, deals with the verification of the DCD instrumentation. In the case of this study specifically, the instrumentation used was a modulus from National Instruments[®] with a reading rate of 1,6kHz, very nice for this kind of application.

The draft ISO 4965-1 is contradictory in its requirements for the repeatability of the applied force, calling for both 1 % of value and 1 % of force range – it should be amended so that only the second condition is called for.

Although all force range differences were within 1 %, the 10 Hz results are approaching this level, then a smaller mass between the load cell and specimen may help to reduce this value and repeat tests would be informative

As the specimen used is not an exact replica of a standard testpiece, these results should strictly be treated as from the first of two DCDs (dynamic calibration devices) required for the “Compliance Envelope” method.

REFERENCES

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