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ANALYSIS OF RESULTS OBTAINED DURING CALIBRATION OF FORCE TRANSDUCERS

IGOR GORŠIĆ
Military technical institute, Belgrade, gorsic@gmail.com

SAŠA ANTONOVIĆ
Military technical institute, Belgrade, sale.antonovic82@gmail.com

VIOLETA BRNIN
Military technical institute, Belgrade, violetabrnin79@gmail.com

SAŠA GUNDELJ
Military technical institute, Belgrade, gundelj@yahoo.com

Abstract: *This paper demonstrates difference between results obtained during calibration of force transducers using standard method, which includes "warm up" of transducer before starting calibration, according to ISO 376 and calibration which does not include "warm up". Transducers were calibrated with dead weight machines Schenck Df-0.2 and DF-1.0. Paper will show is there significant difference between these two methods.*

Keywords: *force transducer, static calibration, method.*

1. INTRODUCTION

For the purpose of measuring, transducers with different ranges are used. Transducers that measure both compression and tension are in use. Transducers are regularly calibrated every two years, and more frequently if there is suspicion of damage to the transducer. For calibration Schenck machines Df-0.2 and Df-1.0 for applying force (in kN), with defined steps witch are depending of mass of weights, and HBM DMP41 machine for obtaining results that transducers show (mV/V), this unit also gives power supply to transducer.

Results of calibration are given in [mV/V] and they are used to calculate percentege of hysteresis and linear equation of right, percenage of deviation from right which is presented in coordinated system where on X-axis are values of force applyed to transducer and on Y-axis are values that are measured from transducers, hysteresis and deviation show is tranducer working properly.

In ecuasion constant is less important than cofficient because the constant represents a distance of point where right intersect Y-axis and that is corrected when taring and zeroing range on indicator HBM DMP41 and when measuring system is set to zero. Coefficient represents angle that right make with axis. Coefficient is used in acusition software during mesurment to calculate voltage [mV/V] to force [N].

2. CALIBRATION

2.1 Procedure

Transducers are calibrated according to ISO 376:2011 standard.

This standard defines conditions for calibration, temperature should be between 18 to 28ºC, with deviation of ±1ºC during calibration, reference temperature for transducers is 23^{0}C (Temperature range from -10^{0}C to +45^{0}C).

All calibrations were done at 20^{0}C to 25^{0}C, so temperature deviation wasn't calculated (Temperature coefficient is 0.015% per 10K)[2].

The transducer should be in the same room (with the same conditions) as the calibration machine for at least 12 hours before calibration. The cables should be approximately the same length as the one used during measurement.

Warm up is defined as a series of applying maximum force and realizing load to prepare the transducer for calibration.

Corresponding author: I.Goršić;
E-mail: gorsic@gmail.com
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The first three applied forces increase to their maximum without stopping at any value during the increase of force, and then they are reduced to zero without stopping. Next two passes are rising force and stopping at values that will be used during calibration, and then reducing force without stopping.

Then once more, without pausing either up or down.

The last four sets are two sets: one that involves applying and realizing with stopping, and one that involves no stopping.

After every realizing of force transducer is rotated approximately 120 degrees, value depends of connections on transducer [1].

The scheme for warming up is shown in Figure 1. The values of steps in force for calibration should be distributed evenly for full load and are depending of steps defined by machine (mass of weights).

The compression was used to calibrate all Transducers we considered in this paper. Transducers that measure tension force should be calibrated with a tension.

All transducers considered in this paper are class 1, meaning that the minimum force required is at least 1000 times the resolution of the indicator.

Resolution of both, force applying machine (Schenk machines) and indicator (DMP41) is 10^{-5}.

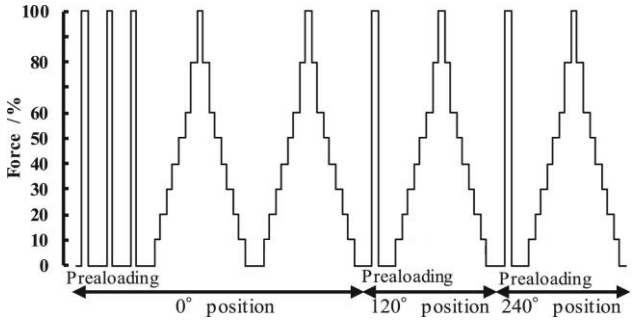

Figure 1. Scheme of warming up.

2.2. Transducers

All transducers used for this paper were calibrated at the end of two-year period. For purpose of measuring without worm up all other conditions are followed (temperature, time spent on same temperature with machine…), every transducer is first measured without worm up and then, at least one day later, according to IS0 376 with warm up, except two of them that have two channels, they were first calibrated with warm up and then ware "on shelf" for 30 days, then measured first day channel A, then another day channel B.

For the purpose of this paper, we tested and calibrated six transducers of different ranges, producers, types, and channels, as shown in Table 1.

Transducers are of different production years. One was not used for this calibration (new), while for another it was the second calibration (almost new), and others have been used for a couple of years.

Newer transducers (number I and VI) are produced by HBM and are model U10M (number I) and Z4A (Number VI), others are produced by BLH and are C3P1 (Number II), U3G2 (Number III, IV) and U3G1 (Number V), all transducers showed in this paper are compression used and calibrated.

Transducers are considered working properly when percentage of hysteresis and deviation from right are less than 0.3%.

Capacity of Transducer are given as they are in their properties, new transducers are given in [kN], old in [lbs] and calculated to [kN].

Two new transducers have larger capacity then capacity of Df-1.0 Schenk machine, so they were calibrated up to maximum force of machine, with is 80% for one and 50% of capacity for another. It is considered to be enough, according to ISO 376[1], if transducer is accurate in half of range it can be extrapolated to be accurate in full range.

Calibrations were done by stopping at the same values as once used during 'warm up', and at every stop, the transducer was given enough time to stop changing the value of the voltage.

Table 1. List of transducers

No.	Capacity	Channels	Age
I	125kN	2	*Almost New*
II	200lbs/0.9kN	1	*Old*
III	500lbs/2,2kN	2	*Old*
IV	20000lbs/90kN	1	*Old*
V	10000lbs/45kN	1	*Old*
VI	200kN	1	*New*

3. RESULTS

Results of calibration without worms are given in Table 2. The results of calibration with worms are given in Table 3.

In tables with yellow, markes values that are out of limits for valid transducers.

In tables, letters A and B indicate the channels of the transducer. When there are two channels, as here, number 1 indicates that the transducer has only one channel.

Table 2. Results of calibration without „warm up“

No.	Channels	Deviation from right	Hysteresis	Constant [N/(mV/V)]
I	A	*0,42*	*0,72*	*-61.061,87*
	B	*0,15*	*0,21*	*-59.771,87*
II	1	*0,10*	*0,11*	*-297,3*
III	A	*0,08*	*0,15*	*-745,27*
	B	*0.06*	*0.11*	*-745.99*
IV	B	*4,19*	*2,51*	*-29.704,68*
V	1	*6,83*	*1,14*	*-13.601,10*
VI	1	*0*	*0*	*100.170,84*

Table 3. Results of calibration with „warm up“

No.	Channels	Deviation from right	Hysteresis	Constant [N/(mV/V)]
I	A	*0,22*	*0,11*	*-61.215,58*
	B	*0.06*	*0,02*	*-60.251,84*
II	1	*0,10*	*0,11*	*-297,3*
III	A	*0,06*	*0,12*	*-745,16*
	B	*0,07*	*0,21*	*-745,74*
IV	1	*4.41*	*5.44*	*-28.935.03*
V	1	*0.03*	*0.01*	*-14.808,19*
VI	1	*0*	*0*	*100.202,89*

Transducer number IV was in an accident where it was overloaded few years ago, back then channel A was destroyed, but channel B showed correct values and now its deviation and hysteresis are our limits, so it is considered not working properly, and it can't be used for measuring any more.

Differences in deviation from the right and hysteresis are shown in Figures 2 and 3. Yellow collor in the figures shows data from tests without 'warm up', and blue shows data from tests in accordance with ISO 376.

Data shows that transducer which is not working properly shows too big deviation and hysteresis in both tests. Another two transducers (channel A on transducer I and transducer V) are under limit for both criteria and are working properly, but when testing without "warm up" test showed too big deviation and hysteresis.

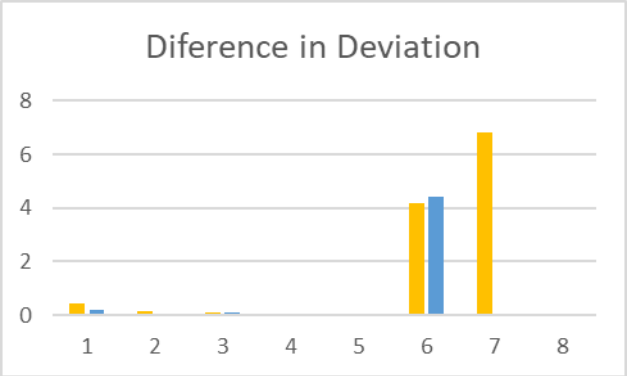

Figure 2. Diference in Devioation from right

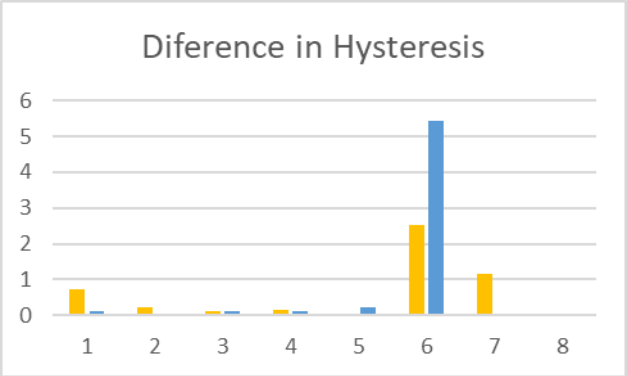

Figure 3. Diference in Hysteresis

Figures 4 and 5 show difference in constant of right (angle between right and axis). They are shown in two diagrams because of big difference in values.

In Figure 4 Transducers I, IV, V and VI are shown and first two columns are channels A and B for transducer I. In Figure 5 Transducers II and III are shown where first column are transducer II and second and third are channels A and B for transducer III.

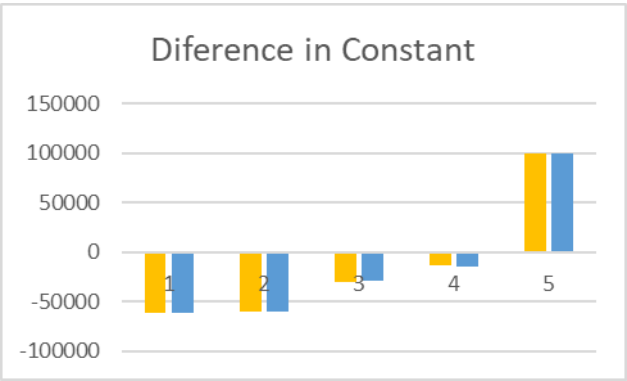

Figure 4. Diference in Constant for biger values

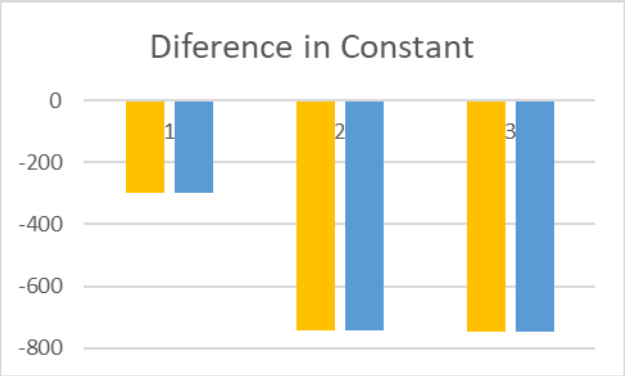

Figure 5. Diference in Constant for smaller values

In Figures and Tables, it is shown that there is no significant difference between constants when testing with and without “warm up”.

4. CONCLUSION

Results show that there is no significant difference in constants when calibrating transducer without “warm up” and calibrating in accordance with ISO 376, this characteristic allow transducers to be used without “worming up” for measuring. Difference is becoming more obvious when calculating hysteresis and deviation from right, calibration without “warm up” even showed some transducers (I-A and V) not working properly, and they are showing working properly when calibration is done in accordance with standard.

All this show that calibration of transducer demands worm up. It shows can it be avoid in case we are certain transducer is working properly and we need only to calculate constant, for example for new transducer (Transducer VI – hysteresis and deviation in both cases are close enough to zero – they have value on fifth or sixed position after decimal point), but every regular calibration after few years or when suspecting on damage of transducer must be done according to ISO 376 standard.

References

[1] ISO 376:2011 *Metallic materials – Calibration of force-proving instruments used for the verification of uniaxial testing machines*, 2011, last reviewed 2023, no changes

[2] *Mounting instructions for transducers* (HBM U10M and Z4A and BLH C2P1, U3G1 and U3G2).

Operating manual Digital precision measuring device DMP41