

The long-term behaviour of force transducers as a criteria for the selection of new transfer standards

Aimo Pusa

MIKES- Lahti Precision Force and Mass Laboratory
PL 22, FI-15801 Lahti, Finland
aimo.pusa@lahtiprecision.com

Introduction

The laboratory of MIKES-Lahti Precision Oy has made over almost twenty years comparisons with the PTB, utilizing more than ten different force transducers. These comparisons have been made regularly every year to supervise the traceability of force. The results of these comparisons are showing different kinds of behaviours. For the traceability the most important characteristic is the stability of the sensitivity. The change of the sensitivity directly influences the measurement uncertainty and as a result affects the final uncertainty of the intercomparison. The second characteristic is the zero reading, which can indicate the change of the measurement behaviour of the transducer.

Unfortunately the performance of transducers can be evaluated only after several years of use, if even then. The two characteristic electrical parameters of force transducers, sensitivity and zero reading, may be relative stable in the beginning. The presented results show that this kind of evaluation can be accomplished within two to three years in most cases. However, the behaviours are not necessary logical or linear for all transducers, since they may spread in a wide manner. A new force transducer, that is intended to be used as a transfer transducer, must be evaluated by measurements to confirm its adequate performance. The gained information only gives a rough idea about the transducers behaviour, but it is more than nothing.

By seeking the best measurement capability also mechanical problems cannot be avoided. Especially for lower capacities the parasitic components are relative more harmful. The handling and particularly the locating of the force transfer transducer in the force standard machine must be repeated exactly the same way. Very small parasitic components interacting with the body of the transducers may already result in a sensitivity change of some ten-ppm.

Evaluation of a new force transducer as transfer transducer:

The purchase of a new transfer force transducer is not very easy task from the technical point of view. The wanted characteristics of a new transducer are primarily a low creep effect and a low rotation effect. Certainly every laboratory wants that the parameters of characteristics are stable but unfortunately this is not the case. In our experience the creep effect and the rotation effect are mostly very stable parameters, all others like sensitivity and zero value can be stable or not. Also the sensitivity to parasitic components depends from the type of transducer and it is more significant for low capacity force transducers.

Creep effect:

This parameter depends mainly from the construction of the force transducers, from the material of the body, from strain gauges and from tempering procedure. Especially for transducers used as master cell the low creep plays an important role. The good value for the creep effect is lower than 50 ppm, which is not easy to get. Most often this value is between 50 ppm and 100 ppm. It should not be larger than 100 ppm. This value is normally very stable and is based on material properties. In the case that creep is increasing over several minutes the timing of reading is most important. It must happen always exactly in same period after every loading to avoid unnecessary scatter of the results.

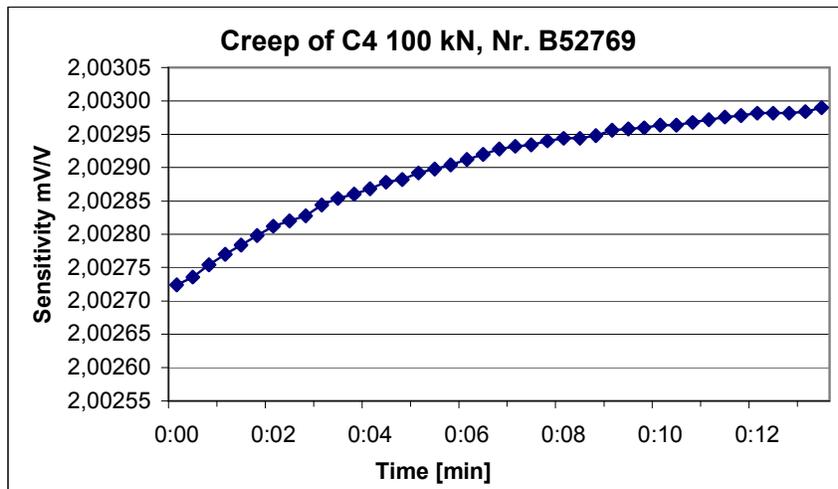


Figure 1. Creep of 100 kN force transducer over 12 minutes, the creep is relative high, 150 ppm. However the speed of creep is not very high, which gives possibility to read the results with a low deviation.

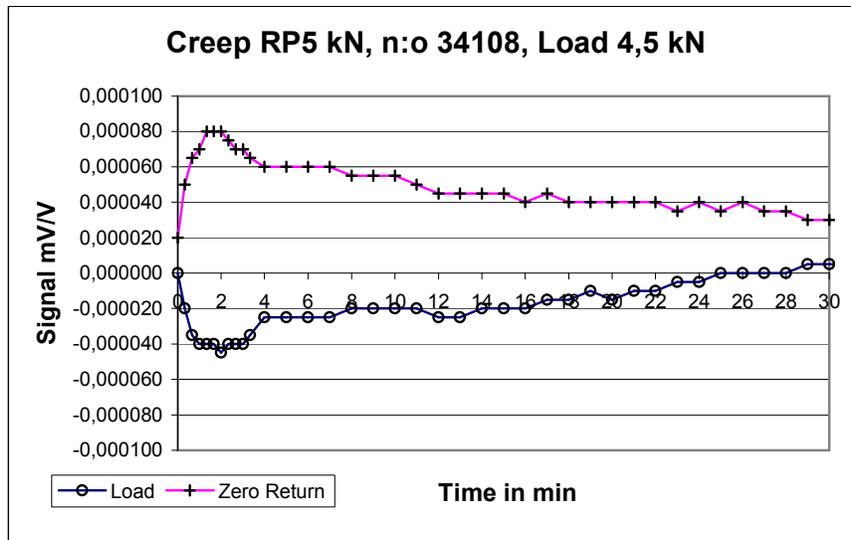


Figure 2. Creep and zero return of 5 kN force transducers over 30 min. The creep is about 20 ppm.

The rotation effect:

This effect is based as well on the mechanical behaviours and the most important property is the accuracy of the mechanical production of the body. The mechanical symmetry is the main parameter for this effect including the symmetry of the force transfer; the contact point should be on the combined centre line of the body. The second property is the homogeneity of the material such that the elongation of the body under load happens symmetrical. The third property is the symmetry of the measurement axle based on location of the strain gauges on the body, including the homogeneity of the strain gauges itself. Every of these properties builds an own centre line in the body and the requirement is that all these lines must be as close as possible. The behaviour of these properties is stable so far if the transducer is loaded correct. Inclination by the load can lead to damage of this property. A good value for this parameter is below 100 ppm, it is possible to find values below 50 ppm as well. It is very important to understand that the rotation effect depends as well from the loading pad. That means every force transducer should have an own “personal” loading pad. The evaluation of the rotation effect can be done during the purchasing procedure, but it is to remember that the evaluation depends as well from the force standard machine itself. The measurement is always a combination from the transducers rotation sensitivity and from the rotation effect of force standard machine. A force standard machine can be as well more sensitive for force transducers with higher shape.

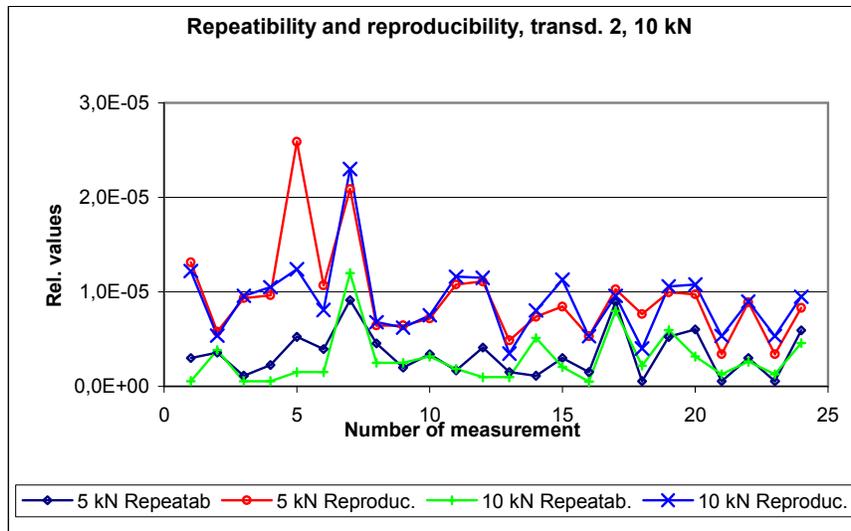


Figure 3. Summary of repeatability and reproducibility by Key Comparison for force transducer of 10 kN. Every value is result from the complete run of intercomparison by one laboratory.

The zero value:

The importance of the zero value has more than only one purposes. First the change of the zero value can indicate the quality of the electrical circuit if e.g. the isolation is damaged, humidity can influence the indication, the zero value changes from its original and fluctuates as well. An unstable zero value can indicate as well some problem in the electrical circuit, e.g. a bad contact. In the case that the force transducer has been overloaded or loaded with an inclination from the correct force direction, the value of zero can change. However as result of the incorrect loading of the transducer, the indicated value is stable and only absolute indicated value compared to earlier measurements has changed and indicates the problem. For force transducers with lower capacity the zero value is very important for supervising the correct handling of the transducer.

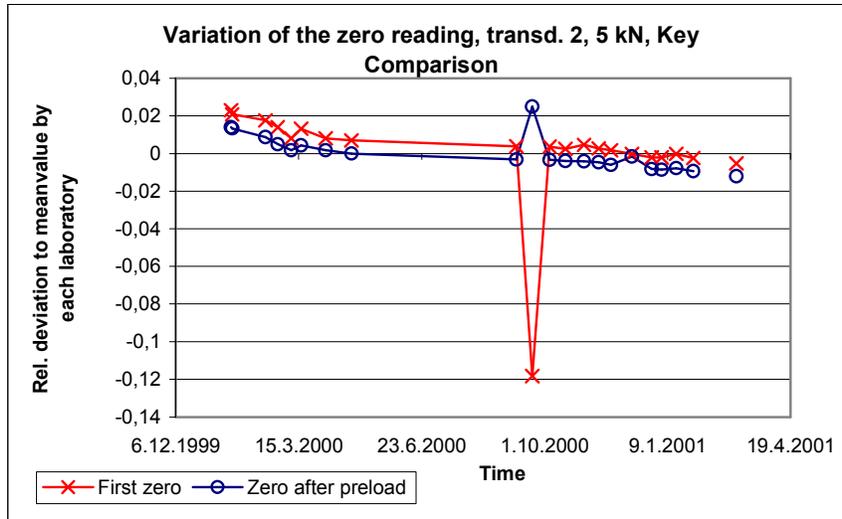


Figure 4. Change of zero value during the Key Comparison for force transducer 5 kN. The value of zero is very stable only for one laboratory the indication has deviating values, which is coming presumable from misreading of the measurement device.

If these long terms effects are excluded then for the measurement it self is important, that the zero value does not change during the measurement period, which is normally some hours. A small change of the zero value is normally coming from the creep effect and is repetitive. The figures 5 and 6 show some behaviour of the zero value over longer period. It is important that the value is read always systematically, e.g. before the measurement (transducer is not loaded for at least 24 hours) and without loading pad.

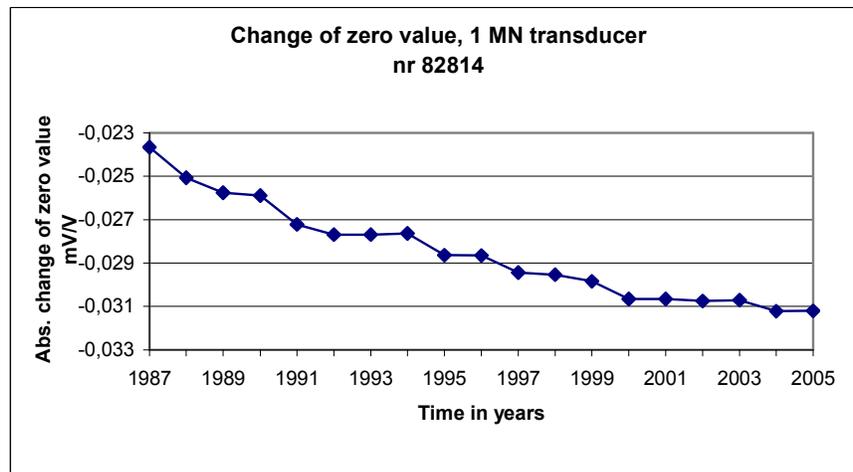


Figure 5. The change of zero value of 1 MN force transducer over a period closely 20 years, taken from our measurement

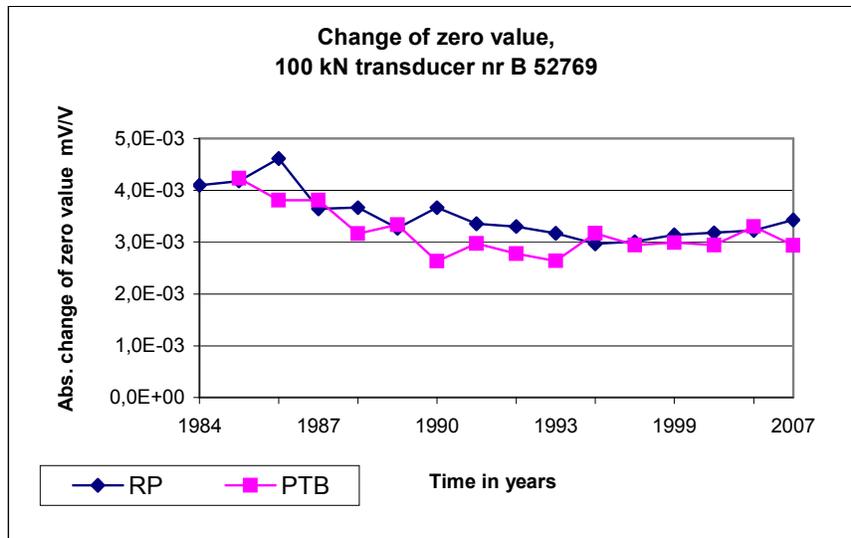


Figure 6. Change of the zero value measured in two laboratories indicates, that the zero value is not stable, even transport influences this value.

The sensitivity:

The sensitivity is the most important parameter. General is accepted that a force transducer cannot have enough stable sensitivity over longer period. For intercomparison it is relevant that the sensitivity is stable over the period for intercomparison, what means from the first measurement until the return measurement. This period can normally be some weeks. With our 15 transducers we have seen both small changes and random changes. For the long-term stability of the relative deviation has a maximal value of $1...3 \cdot 10^{-4}$, the deviation of short-term stability is normally less than $2 \cdot 10^{-5}$ but can be also larger. The worst case is that the sensitivity changes during intercomparison substantially. In the case that the value of change is close to the required accuracy level the only way is to repeat the measurement. We do not find any difference in the behaviour for different construction of transducers. The reason for the change of the sensitivity can be different, partially is coming from the force transmitting parts and partially from the electrical circuit, so mainly from the stability of the electrical components. The figure 7 shows the variation of the sensitivity of the 1 MN force transducer. There are some stable periods but also very quick changes have happened twice. We keep the force transducers all time connected to the supply voltage (5 V) and we load them regularly at least three times per year. The careful and correct handling of the transducers is a prerequisite for good results. To get the correct and always similar function of the force transducer, it is absolutely important to use the same loading pad.

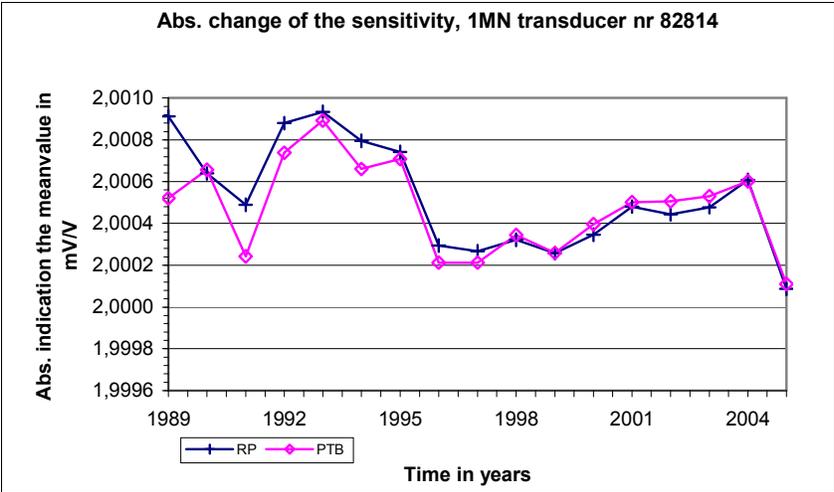


Fig 7. Change of the sensitivity of the 1 MN force transducers over years. The “big” unexpected change has happen twice; the reason is unknown.

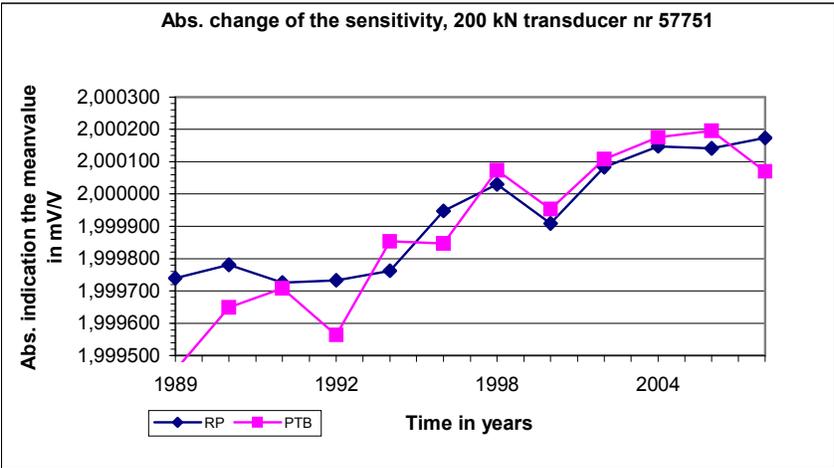


Figure 8. The change of the sensitivity of 200 kN force transducer, it is more stable but shows continuously increase of the sensitivity.

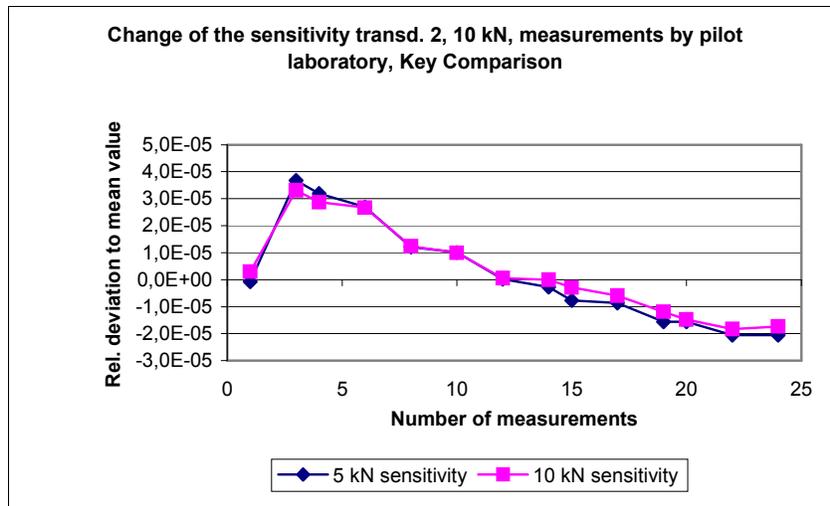


Figure 9. 10 kN force transducer used in the Key comparison shows very stable change during a period over two years.

Evaluation of a new force transducers:

When a transducer for comparison purposes is to be purchased, some actions are reasonable. A transducer for comparison purposes needs a lot of work and is coming more valuable due to more measurements. It is wise to do several tests before starting the routine to use it.

The creep effect and rotation effect can be measured before acceptance of the delivery. Practical evaluation of the long-term characteristic is possible just after several years. However some tests can be done to see the behaviour of the force transducer. The transport is most critical for the transducer due to the mechanical vibration and change of temperature. The best test is to prove the transducers behaviour in real circumstances; send transducer in its own case away e.g. to other laboratory. After the trip should all parameters measured by regular measurement method. It is recommended to repeat this kind of test and be sure that the temperature under trip varies.

Conclusion:

There is no simple way to analyse the usability of new transducers as transfer standards. The results gained during almost twenty years of investigations give some indications of the behaviour of the transducers. They should be tested for at least some months and they should have exposure to different temperatures during storage period. The creep, as well as the rotational effect, can be tested very quickly. Nevertheless the stability of span is more problematic and needs time to investigate it. However the stability of span is always only a hint. If the stability over a few months is good, the probability for a stable sensitivity over several years is quite high. The mechanical construction gives as well some hints for possible problems. Every construction has own behaviours and as well pros and cons. It seems to be difficult to buy a

new transducer for comparison purposes particularly with a wish to manufacturer to give the needed information for evaluation.

And after all the practical evaluation can be worked out after several years. During the 20 years we have changed from the 13 transducers in the long run four transducers due to problems with the stability of sensitivity. A transducer with a long history is a very valuable object and all measurements during the years cannot be easily substituted with a new transducer.

Keywords: Force transducer, long term stability, force intercomparison