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CROSSTALK CHARACTERISTIC OF A NEW COMPRESSION-TORSION SENSOR FOR MULTICOMPONENT MEASUREMENTS

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Abstract: In this contribution, a compression-torsion sensor with a low and reproducible crosstalk behaviour will be presented. This sensor type was especially developed to investigate the characteristics of a measuring machine designed for the calibration of friction coefficient sensors. The measurement range for this build-up compression-torsion sensor lies at a maximum torque of 500 N·m and a nominal force of 500 kN. The results with regard to the calibration on individual components (F_z and M_z) and the signal crosstalk have been investigated and shall now be presented.

Keywords: Multi-component measurement, friction coefficient sensor, crosstalk, compression-torsion sensor.

1. INTRODUCTION

Axial force and torque are necessary for the calibration of friction coefficient sensors (FCS). For the calibration of friction coefficient sensors, a novel measuring facility was designed and set up at the Physikalisch-Technische Bundesanstalt (PTB) to generate axial forces and torques. More details about this facility can be found in the literature [1, 2]. Precise axial forces up to 1 MN and very well known torques up to 2 kN·m are generated. The characterization of the measuring machine and the development of a complete measurement uncertainty budget require a thorough investigation of the interactions of a combined force-torque introduction. Due to this special requirement, a sensor is needed in the respective measuring range which is able to continually, parallelly and precisely detect axial force and torque. A necessary additional property of such a compression-torsion sensor is that it may only display minimum signal crosstalk.

2. POSTER CONTENT

This poster presents the results of the crosstalk effects, matrix and fit functions by applying individual axial force and torque components. This is a build-up system which – as a basis – consists of a force sensor of the type KA-K-250kN-F-1mV/V and a special, patented torque transducer mounted on it, see Fig. 1. This compression-torsion sensor allows us to cover a measuring range for the axial force of up to 500 kN and a torque of up to 500 N·m. Its use as reference sensor requires a calibration in a deadweight force standard machine for axial force and torque. The calibration for axial force was carried out in accordance with DIN EN ISO 376 in the 1 MN force standard facility [3] of PTB. In the torque range, the sensor was calibrated in accordance with DIN 51309 in the 1 kN·m torque standard machine [4].

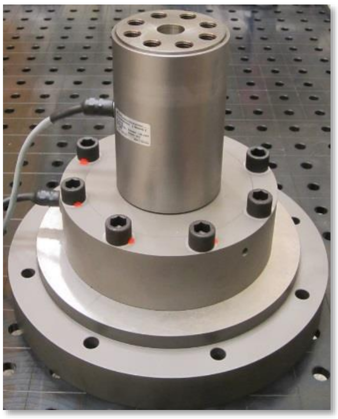

Fig. 1: The figure shows the build-up system consisting of a force transducer and a torque transducer which has been investigated with regard to its crosstalk behaviour.

2. 1. TORQUE CALIBRATION

The torque calibration was carried out at the 1kN·m torque standard machine [4] in accordance with DIN 51309. This means left and right-hand torques at the three positions 0°-120°-240° for an upward and downward load circle in 10% load steps. The required rel. measurement uncertainty has to be $<1\cdot10^{-4}$. The calibration result shows a rel. measurement uncertainty (k=2) in the range of $4\cdot10^{-5}$ for right and left-hand torques.

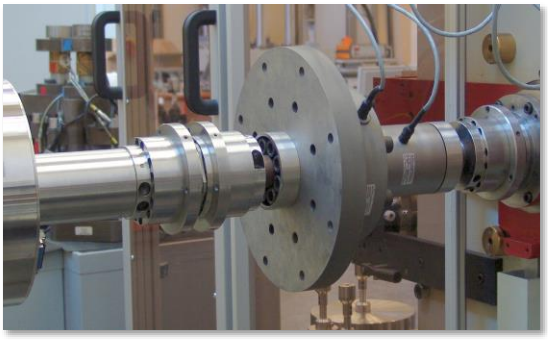

Fig. 2: The figure shows the build-up system mounted in the 1kN·m torque standard machine of PTB.

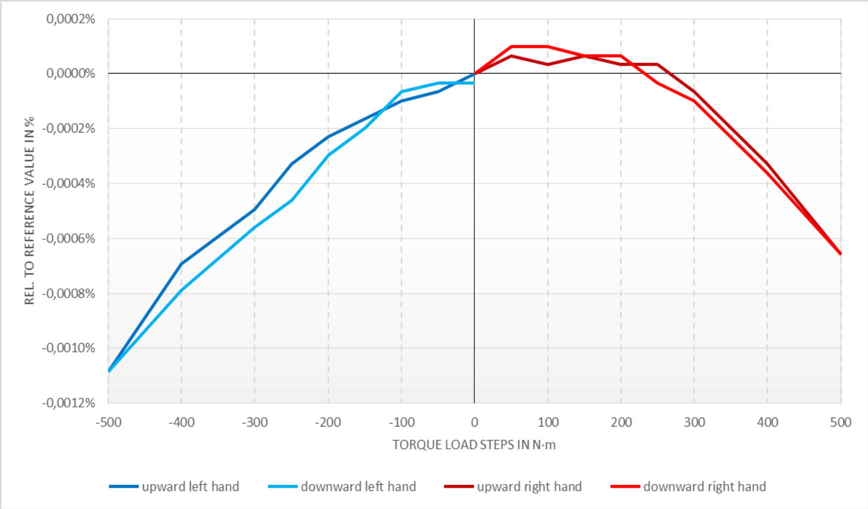

Fig. 3: The diagram shows the influence of a torque applied on the force transducer. The force transducer has a dependence to the applied torque step but the small relative crosstalk influence is still negligible.

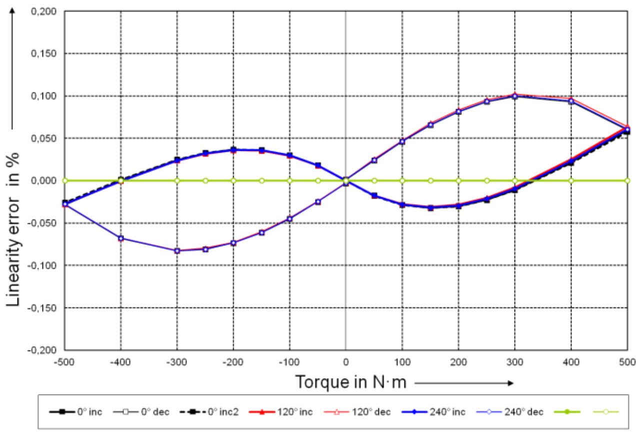

Fig. 4: The diagram shows the linearity error of the sensor during the calibration at a torque of up to 500 N·m which is oriented towards the left and towards the right.

Fig. 5: The figure shows the build-up system mounted in the 1MN force standard machine (fsm) of PTB.

The diagram, see Fig. 3, shows the crosstalk of the force transducer for left and right-hand torques up to 500 N·m. The relative influence on the signal of the force transducer is less than $1 \cdot 10^{-5}$. This means that in the first order a signal crosstalk caused by a torque need not be considered, because it is smaller than the relative measurement uncertainty of the 1MN fsm. The diagram, see Fig. 4, shows a significant linearity error. So we decided to characterize the transducer with a upper and a lower fit function.

2. 2. FORCE CALIBRATION

The force calibration was carried out at the 1MN force standard machine (fsm) [3] in accordance with DIN EN ISO 376. After a preload phase with 500 kN, the measurement was performed for a load circle (up- and downwards) in 10% load steps at the three positions 0°-120°-240°. The required rel. measurement uncertainty has to be $<1 \cdot 10^{-4}$. The calibration result shows a rel. measurement uncertainty (k=2) in the range of $3 \cdot 10^{-5}$. Moreover, a wide hysteresis was measured therefore two separate cubic fit functions for up- and downwards were calculated.

The diagram, see Fig. 6, shows the oscillating crosstalk of the torque transducer for different up- and downward load steps. The reason for this behavior is the oscillating motion of the total mass stack. The average value of this vibration provides a conclusion about the signal crosstalk of the torque sensor by applying a force. One question is the reproducibility of the measured oscillations. Hence two different measurements were carried out at the same sensor position. The diagram, see Fig. 7, reveals that both results are almost identical even in the oscillation phase. Conversely, this means that the CT-transducer can be used to characterize the oscillation behavior of an fsm.

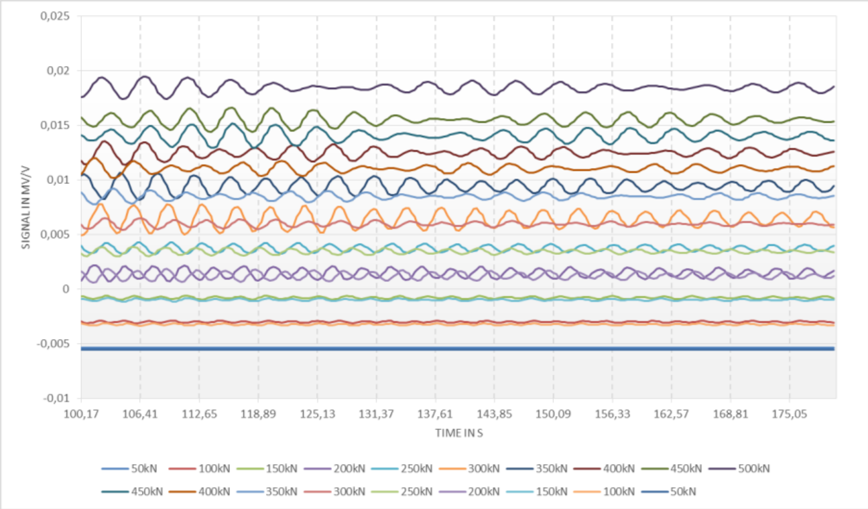

Fig. 6: The diagram shows the oscillation of the fsm masses. It caused an additional torque into the CT-transducer system. You can see the correlation for a up-down cyclus of 10% load steps.

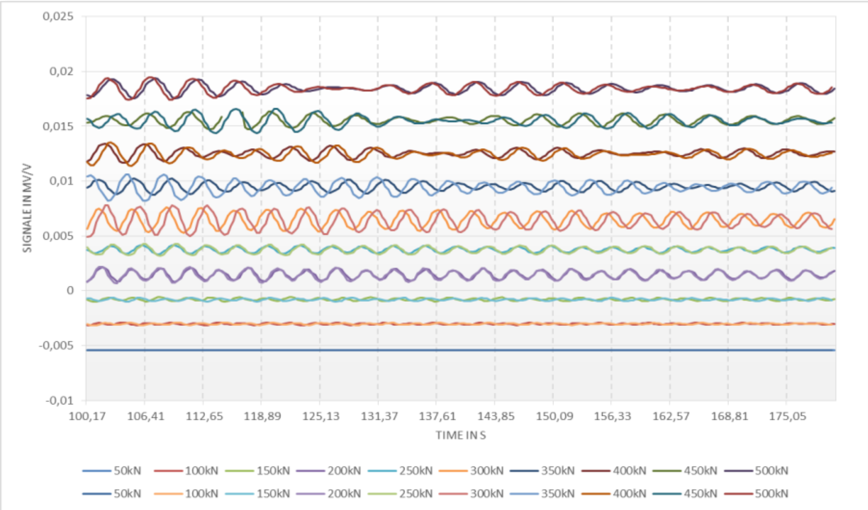

Fig. 7: The diagram shows the comparision of two measured oscillation at the same CT-transducer position. It shows a high repeatibility of the oscillation characteristics like amplitude and phase.

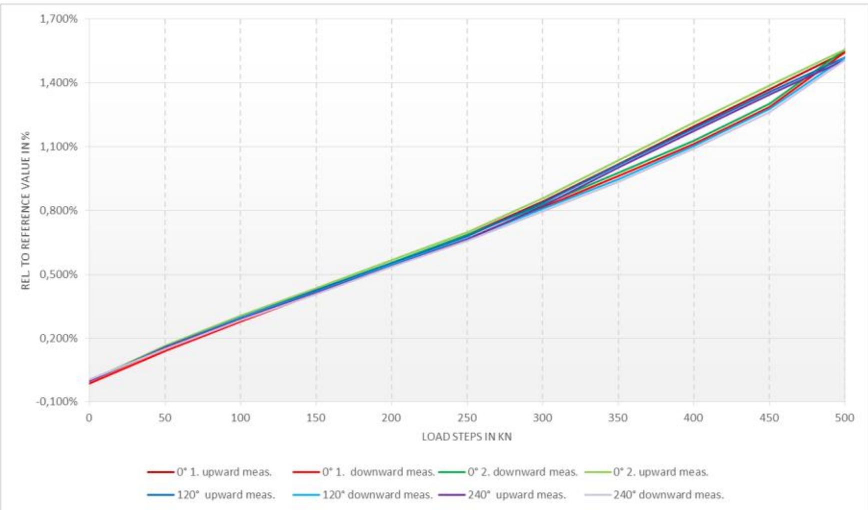

Fig. 8: The diagram shows the calculated average values of the oscillation over a measuring time of 300 s. There is a dependence of the transducer position but the functional relationship is nearly identical.

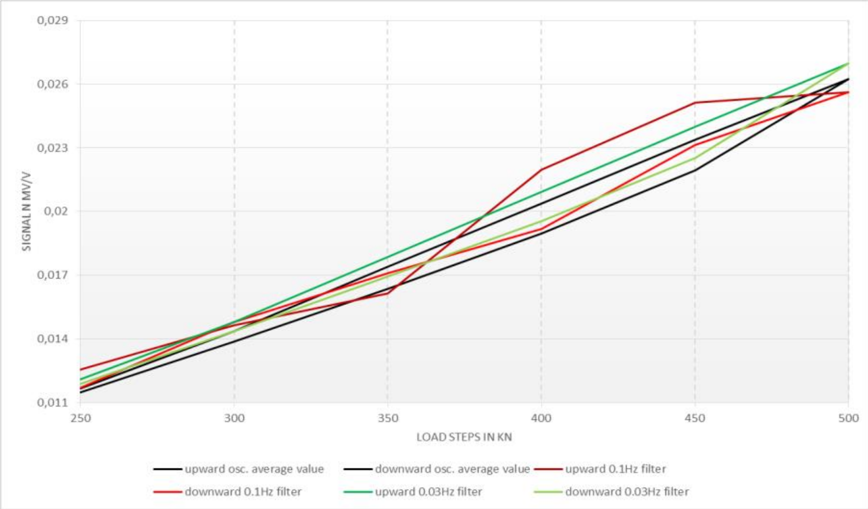

Fig. 9: The diagram shows the comparison of the calculated average values and the values calculated by the amplifier using different low pass filters. It shows that only the using of a low pass filter with 0.03 Hz makes sense.

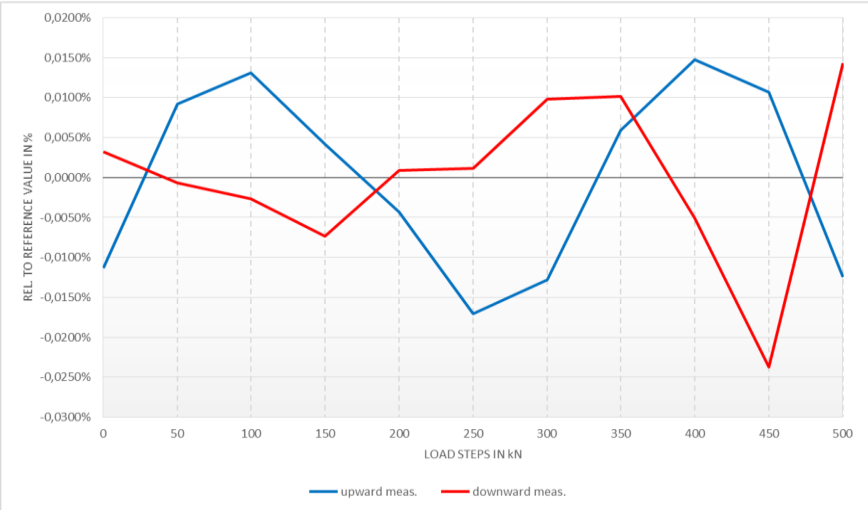

Fig. 10: The diagram shows the remaining influence of an applied force to the torque transducer by using the fit functions of Tab. 1.

The oscillation average value for the positions 0°-120°-240° was calculated and is shown in the diagram, see Fig. 8. There is a dependence on the position, but the shape of the curves is identical. The influence relative to the torque signal is in the range of 2%. Thus the influence is definitely not negligible and it is necessary to calculate fit functions for the up- and downward behaviour when the torque transducer is loaded with a axial force. The computation of the average value from a long-term oscillation measurement is time-consuming. The results of the amplifier's (DMP40) low pass filters 0.1Hz and 0.03Hz were compared to the average values. They show, see Fig. 9, that the 0.1Hz filter is not sufficient, although the oscillation rate is greater than 0.3Hz. The 0.03Hz filter shows good agreement, and based on these data a cubic fit function was calculated.

Tab. 1: The figure shows the build-up system mounted in the 1MN force standard machine (fsm) of PTB.

upward	S_{F_z}	S_{M_z}
F_z	$246{,}9 \cdot S_{F_z} + 0{,}317 \cdot S_{F_z}{}^2 - 0{,}1897 \cdot S_{F_z}{}^3$	$< 1 \cdot 10^{-5}$
M_z	$2.01 \cdot 10^4 \cdot S_{F_z} + 3.9 \cdot 10^3 \cdot S_{F_z}{}^2 - 3.45 \cdot 10^6 \cdot S_{F_z}{}^3$	$292{,}8 \cdot S_{M_z} - 0{,}742 \cdot S_{M_z}{}^2 + 0{,}151 \cdot S_{M_z}{}^3$
downward		
F_z	$246{,}3 \cdot S_{F_z} + 0{,}195 \cdot S_{F_z}{}^2 + 0{,}027 \cdot S_{F_z}{}^3$	$< 1 \cdot 10^{-5}$
M_z	$1.88 \cdot 10^4 \cdot S_{F_z} + 3.46 \cdot 10^5 \cdot S_{F_z}{}^2 - 1.31 \cdot 10^7 \cdot S_{F_z}{}^3$	$291{,}5 \cdot S_{M_z} - 0{,}214 \cdot S_{M_z}{}^2 + 0{,}09 \cdot S_{M_z}{}^3$

Based on the measuring results, a crosstalk matrix, see Tab. 1, was calculated with different cubic fit functions for up- and downward behavior. The fit function for the torque crosstalk signal was used and the upper diagram, see Fig. 10, shows the remaining influence on the torque. Without fit function the influence was 2%, and with correction function it is below 0.02%.

3. CONCLUSION

The conclusion of this calibration process is illustrated by three different points.

1) Crosstalk effects have to be considered for this type of CT-transducer
2) Oscillations of the mass stack using a direct deadweight fsm may produce an oscillating crosstalk signal which has to be observed.
3) Conversely, the CT-transducer can be used to investigate the oscillation behavior of different fsm types.

4. REFERENCES

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