Increased Requirements for Higher Nominal Forces, Necessities and Possibilities to Measure Them

Dr. Schäfer, André
Hottinger Baldwin Messtechnik GmbH
Im Tiefen See 45, 64293 Darmstadt
andre.schaefer@hbm.com

Abstract

With the further advance in industrial applications the task of measuring high forces is getting increasingly important. Several new fields of application such as wind energy generation require forces of up to 5MN or higher. But also requirements in terms of accuracy are rapidly growing.

1. The favourite measurement principle for the measurement of high forces

So called foil type strain gauges are widely used as pick-up principle in force measurement. The vast majority of force transducers as well as load cells are based on them. They are available in a wide variety of measuring bodies such as column type, ring torsional design, S-shape type or simply bending beams. Measurement of both, tension and compression force, can be realised without additional effort [1].

Force transducers based on foil type strain gauges can be used to build up until highest nominal loads and there is no reason for a limit. Outstanding features are highest accuracy and long term stability. Also, higher nominal forces do not inevitable mean large geometries and e.g. designs based on the measurement of shear forces can be quite compact, especially in vertical direction [2].

2. Examples of different industries demanding higher forces

Over the last decades we got used a certain technological leadership of the automotive industry. Especially in Germany many innovations made and patents applied for origin from automotive industry or its sub suppliers. Good examples are calibration requirements in automotive industry. Of course In ISO 9001 it is a must to carry out traceable calibrations at regular intervals. However ISO / TS 16949 in automotive industry is going beyond ISO 9001 and contains very strict instructions for calibration. Thus high accuracy has been always required by existing branches of industry, but e.g. to automotive industry measurement of forces in a range of up to 500kN has been enough.

Nowadays things are changing. For instance aerospace and railroad industries need higher forces. The force measurement needed in Aerospace is ranging from 10kN to 2MN, while both power test of locomotives as well as break test in Railway industry need forces of approx. from 1kN to 2MN. The best example however is wind power systems. Nowadays wind turbines are considerably bigger and taller than in the past. This is especially true for wind turbines off-shore. There is a clear trend of going offshore and this potential is tremendous.

Finally more than half of the power of renewable sources will come from Wind energy [3]. Of course the major element of progress in energy generation has also the highest demands and an average life time of 20 years corresponds to very high numbers of life cycles, in fact one can expect about 3 billion load cycles. In building up wind turbines beside of gearboxes bearings are vitally for the lifetime of the unit. Very high bending moments, similar to those occurring in actual operation, are applied to these bearings for testing and development. Such bearings are tested on test stands, which require force transducers with a range of 5 Mega Newton, and up to 15MN in the medium to long term.

As a summary from the above mentioned application fields one has to be prepared to measure higher nominal values with forces up to approximately 15 MN. Traceable calibrations of suitable transfer standards should improve the measurement of force in industrial applications. This trend will continue and it is expected that by 2015 even larger nominal values may be required. So it is estimated that there is a need of forces up to 30 MN.

3. Solutions offered for measurement of high forces

3.1. Transducers for high nominal forces

The transducer family C18 is available in 11 models with different nominal (rated) forces ranging between 10 kN and 5 MN, allowing it to be used in a wide range of applications. The complete measuring body and the force applications parts (base and thrust piece) included in delivery are made from stainless steel. They ensure optimum test results and at the same time prevent error loads. The force transducer is distinguished by its precision. Class 0.5 according to ISO 376 is guaranteed. Class 00 is even possible on request for anominal (rated) force of 500 kN. Since last year it is also available in the range 5MN (Fig. 1)

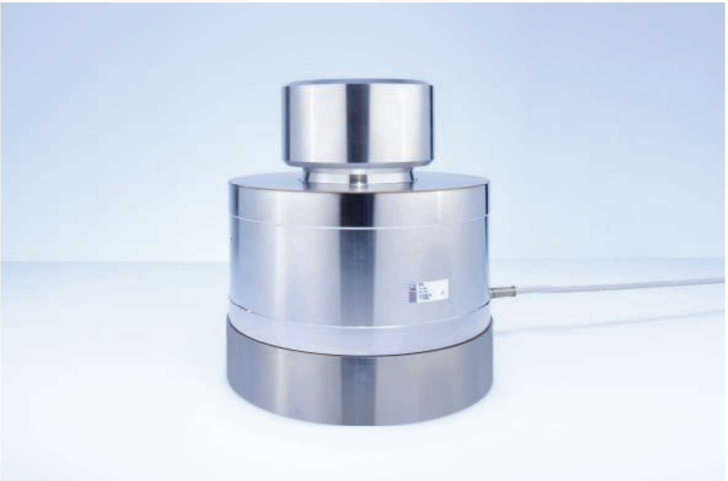


Fig.1 Force transducer C18 (5MN)

Fig.2. Force transducer KDB (5MN)

A further example for a force transducer with a comparable high nominal force designed for the dedicated needs of a specific industry is the KDB transducer (Fig.2) For the use in civil engineering he meets DIN 51302-2 or EN 12390-4, appendix A, and is therefore suitable for verifying compression testing machines for building materials. The four strain gage full bridges that have been attached at the circumference of the transducer spring body and offset by 90° each enable the transducer to be used for the tests required by the standard including the centric transmission of the testing force and the free movement or locking of the upper compression plate. Each of the four strain gage full bridges is equipped with a separate output which can be connected to 4 independent amplifier channels and thus can be used for bending moment measurement.

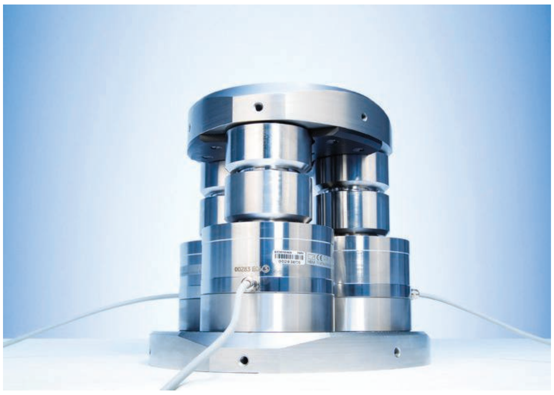
Thus from the examples above one can see, that for the more and more popular range of 5MN there are several offers and there will be even more in future [4].

3.2. A build-up system as an effective way to reach higher nominal forces

In recent years build-up systems have made remarkable progress. Effects like the rotation effects of force transducers on the output of a build-up system have been well researched [5]. Thus their use is getting more practical. In the high force range build-up systems such as BU 18 are getting more and more popular as it is an effective method to increase the nominal range. Normally direct loading calibration machines are used for calibrating force transducers in national institutes and industrial calibration laboratories. With very large forces in the range of MN these machines are extremely large and also expensive. Furthermore build-up systems like shown in Fig. 3. and 4. are also a method which can be applied to industrial applications. In the latter use economics are even more important. Such systems are compact in height, weight and space–saving. In addition the systems allow the evaluation of parasitic components.

The BU18 build-up system, made by HBM, was developed to measure or calibrate large compressive forces as a smaller and less expensive alternative to existing direct loading machines. The system comprises three precision force transducers mounted in parallel onto which the force is distributed. The BU18 build-up system is based on HBM's type C18 compressive force transducer. This transducer provides compact dimensions and high accuracy. So C18 can attain an accuracy of Class 00 per ISO 376 (in combination with a DKD calibration certificate).

With the BU18, based on 3 force transducers with a nominal force of 1 MN each, it can measure compression forces with a nominal (rated) force of 3 MN. The single transducers can be used for subsequent measurements on calibration machines with lower nominal (rated) forces. Electrically a junction box switches the output signals of the three transducers in parallel.



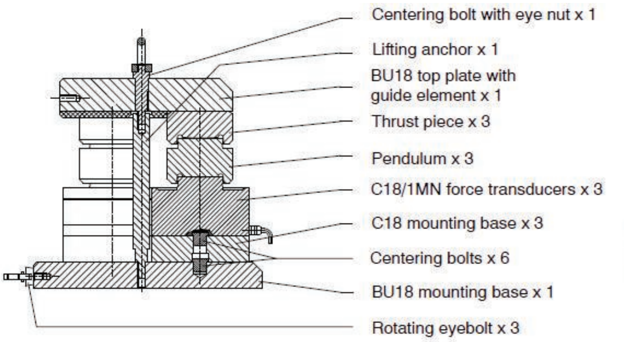


Fig. 3. View of built-up system BU18

Fig. 4. Principle scheme of build-up system BU18

Normally direct loading calibration machines are used for calibrating force transducers in national institutes and industrial calibration laboratories. With very large forces in the range of MN these machines are extremely large and also expensive. Furthermore build-up systems like shown in Fig. 3 and Fig. 4 are also a method which can be applied to industrial applications. In the latter use economics are even more important. Such systems are compact in height, weight and space−saving. In addition the systems allow the evaluation of parasitic components.

The BU18 build-up system, made by HBM, was developed to measure or calibrate large compressive forces as a smaller and less expensive alternative to existing direct loading machines. The system comprises three precision force transducers mounted in parallel onto which the force is distributed. The BU18 build-up system is based on HBM's type C18 compressive force transducer. This transducer provides compact dimensions and high accuracy. So C18 can attain an accuracy of Class 00 per ISO 376**.** In combination with DKD calibration certificate the whole built-up unit can obtain Class 00 to ISO 376.

With the BU18, based on 3 force transducers with a nominal force of 1 MN each, it can measure compression forces with a nominal (rated) force of 3 MN. The single transducers can be used for subsequent measurements on calibration machines with lower nominal (rated) forces. Electrically a junction box switches the output signals of the three transducers in parallel.

By the help of the new C18 force transducer and its top range customers such as primary standard instiututes can even build up such systems of up to 15 MN. Calibration demands behind are mostly from civil engineering and mechanical engineering but also from wind energy generation.

4. HBM's Calibration services and it´s extension by a machine for forces of up to 5 MN

HBM has a long history as a calibration laborotory. In 1977, the first accredited German Calibration Service (DKD) Laboratory was based at HBM. Even nowadays the high quality of our calibration equipment is often unique. Force transducers with such high capacities will have to be calibrated at regular intervals on several fronts - of course with high precision and at low cost. [4] This requires reference transducers providing sufficiently high capacities. Generally the HBM calibration laboratory at its headquarters in Darmstadt (Germany) is quite well known for the force measurement and is accredited from 2.5 N to 1 MN (Fig. 5). The machine uncertainties certified by the German Calibration Service (DKD) range from a mere 0.02 % to 0.005 % of the actual value. However for the above mentioned reasons more and more applications required 5 MN.

Fig. 5 Different force cilibration machines for capacities 2,5kN; 25kN and 240 kN at HBM

Fig. 6 Calibration machine with capability 5MN

In direct connection to the growing importance of higher forces HBM decided on investing in a new calibration machine for forces up to 5 MN (Fig. 6). The machine uses a hydraulic unit to generate the high forces. Calibration is performed by comparing the signal generated by the test specimen with those of the force reference transducer integrated in the machine. Under DKD-accreditation, the degree of uncertainty is verified under supervision of the German National Metrology Institute (PTB). Subsequently the uncertainty of only 0.02 % of the particular force has been stated.

5. Conclusion

There are two major trends toward higher efficiency in measuring fores. The first one is getting faster and the second one is using bigger units. For the second trend the further development will require even higher forces, one has to be prepared for measurement of higher values. Also other quantities will have to meet these demands [6], [7].

Large forces are the domain of strain gage based transducers. One can summarise, that from the engineers point of view there is no reason why force transducers based on foil type strain gauges would not be the ideal way for measuring the highest forces. For all the complex needs and the various demands of the different branches of industry, there are integrated solutions with standard force transducers up to 5MN and in case of customised solutions even up to 20 MN [8].

These transducers come with a comprehensive range of state of the data acquisition units, software as well as services for force calibration, traceable to the national standard. By the described “tool kit” a further advance in industry arising from mechanical engineering, civil engineering, force testing& wind power [9] can be served.

6. References

[1] A. Schäfer, “Analogy observation of force transducers compared to strain and pressure transducers based on foil type strain gauges and the piezoelectric principle“, Proceedings of Asia-Pacific Symposium on Measurement of Mass, Force and Torque, Tokyo, Japan, 2009

[2] A. Schäfer, “Force, strain and pressure transducers based on Foil Type strain gauges as well as the piezoelectric principle for the use in industrial applications” Proceedings of “Eurosensors 2008”, Dresden, Germany, 2008

[3] H. Albers, Plenary paper „Markets, trends and visions for Wind energy“, VDI conference „Vibrations in Wind energy units“, VDI report No. 2088, VDI Publishing house, Düsseldorf, 2010

[4] Hu Gang, Zhang Zhimin and Zhang Yue „Internal Large Force Comparison in China”, Mechanics and Acoustics Division, National Institute of Metrology, Beijing, P. R. China, Proceedings of Asia-Pacific Symposium on Measurement of Mass, Force and Torque, Tokyo, Japan, 2009

[5] Dae-Im Kang and and Chang-Sun Hong “Rotation effects of force transducers on the output of a build-up system” Measurment Volume 14 Issue 2December 1994, Pages 147-156, Published by Elsevier Ltd.

[6] A. Schäfer, et al. “A new type of transducer for accurate and dynamic pressure measurement up to 15000 bar using foil type strain gauges”, XVII IMEKO World Congress 2003, Metrology in the 3rd Millennium, Dubrovnik, Croatia

[7] P.D. Hohmann and A. Schäfer, “Combined Calibration of Torque and Force in a 3in 1 Calibration unit”, “APMF 2000”, Proceedings of Asia-Pacific Symposium on Measurement of Mass, Force and Torque, pp. 204, Tsukuba, Japan, 2000

[8] A. Schäfer “Examples and proposed solutions regarding the growing importance of calibration of high nominal forces” Proceedings of the IMEKO 2010, pp. 56, TC3, TC5, TC22 Conferences, Pattaya, Thailand, 2010

[9] A. Schäfer “Wind energy as an alternative source of energy”, Editorial of the HBM Customer Magazine “HBMhotline”, issue Nr. 1-2011 pp. 2