2 Torque measurement methods

2.1 Calculation from electrical power

Torque can be calculated from the electrical power and speed of rotation. Modern measuring equipment makes it easy to determine the electrical power and rotation speed of electrical machinery. However, when calculating torque there can be relatively large errors since dissipated power and the operating status of the machinery have considerable influence.

Today's instruments with their advanced computerized features take an ever-increasing number of parameters into account in order to raise the level of accuracy and dynamic response. The key application areas, however, are more commonly to be found in process monitoring, such as mechanical agitators, rabblers and the like, since this is where it is important to monitor additional electrical parameters such as reactive power or efficiency. A significant advantage of determining torque by this method is that there is no need for any kind of mechanical intervention in the power train.

However, this method is suitable to only a limited extent for accurate, dynamic torque measurement. It cannot be used if the torque information is needed referring to another point on the train of mechanisms, for instance downstream of a transmission or some other power sink.

The uncertainty involved in measuring torque by purely computational means can be several factors worse than using torque transducers fitted with SG measuring systems. Due to the greater accuracy of SG transducers, they are also commonly used as transfer transducers when calibrating electrical machinery.

2.2 Measuring reaction torque

2.2.1 Measuring the reaction force on a lever arm

Measuring reaction force according to the principle that in-line torque equals reaction torque is a method very frequently used to determine power. Fig. 2.1 shows an industrial measurement configuration with a pendulum mounted braking device. The force acting on the end of the lever arm is measured using a force transducer. This solution calls for complex mechanical arrangements. To avoid measurement errors it is necessary to take due account of disturbing influences such as changes in the pendulum bearing over time, expansion of the lever arm due to temperature changes, and the different states of operation.

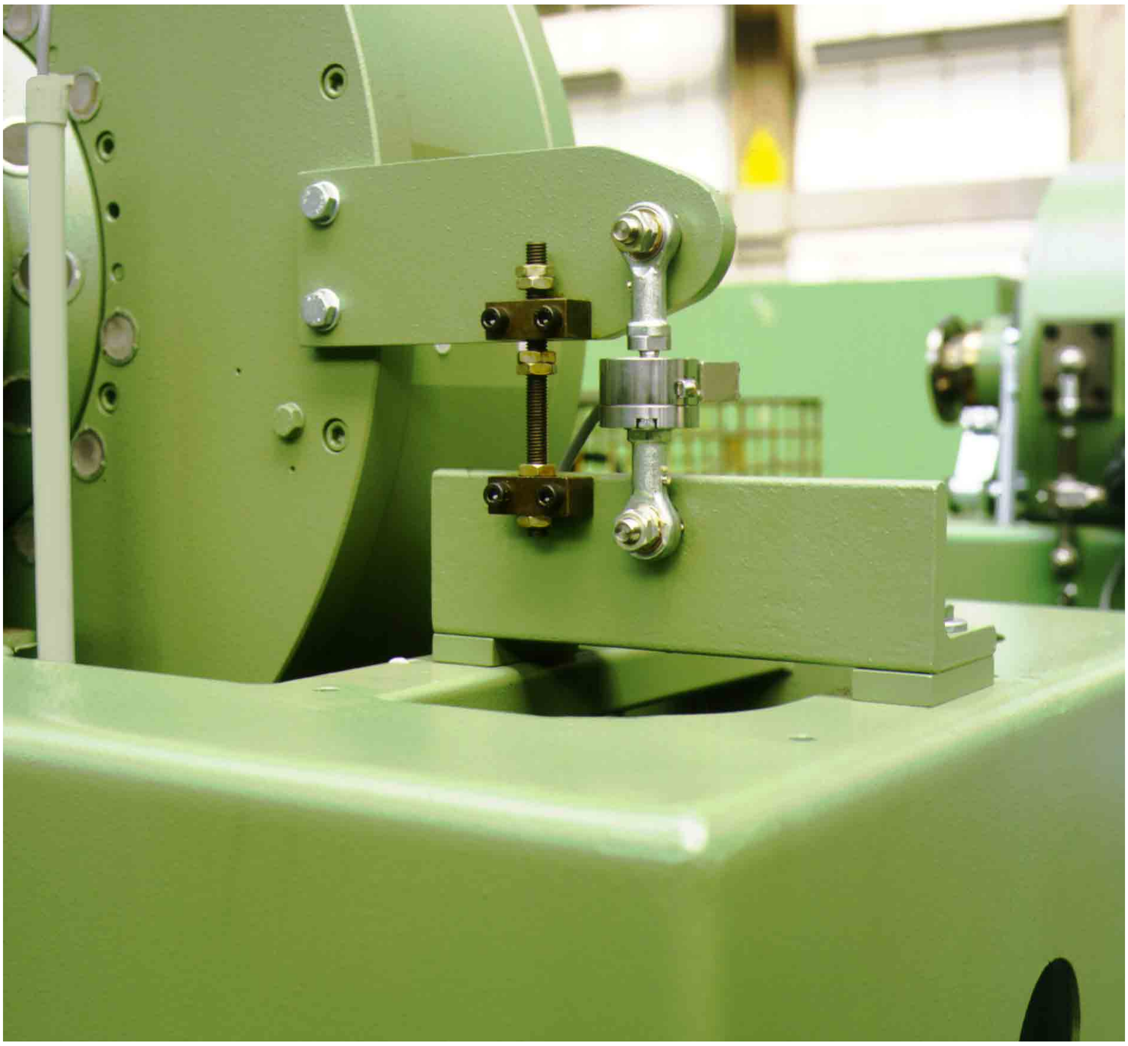

Fig. 2.1 Using a U2B force transducer to measure the reaction force acting on a lever arm

On the one hand, the inertia of the large masses involved make dynamic testing difficult. The mass moment of inertia acts as a mechanical low pass filter. On the other hand this characteristic can also be an advantage in cases where there is no necessity to measure dynamic moments. Dynamic torque components which are of no interest do not impinge on the force transducer. Another key application area for reaction force measurement is determining the viscosity of a medium for the purpose of process control via the supporting force of a motor in an agitator. Fig. 2.2 shows a simplified sketch of a suggested design.

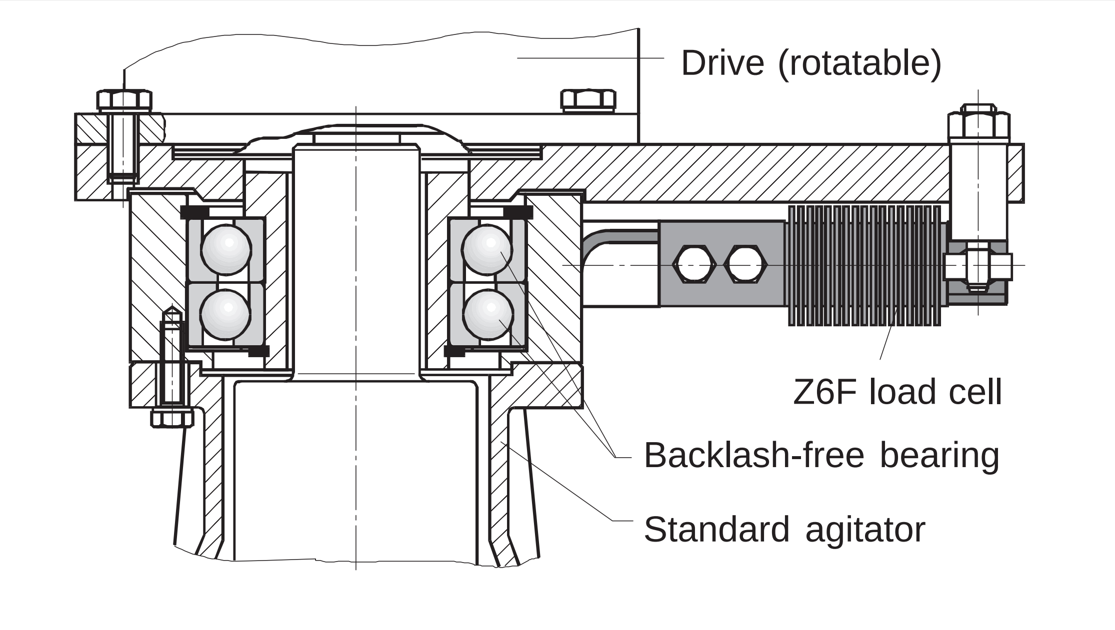

Fig. 2.2 Measuring viscosity with the aid of a Z6F load cell

The HBM range includes many forms of force transducers and load cells suitable for measuring reaction force by means of a lever arm. The main selection criteria are:

- Stiffness: a high degree of stiffness allows higher mechanical natural frequencies. Lower stiffness results in greater displacement during measurement, which can be helpful if overload stops or damping techniques become necessary.
- Design
- Direction of force: tensile and/or compressive force
- Required accuracy
- Cost

2.2.2 Reaction torque transducers

Reaction torque transducers combine into one device the functionalities which the bearing and the force transducer have in the case of the lever arm-based torque measurement described in the previous section. Their main application is non-rotating torque acquisition. Typical examples are process monitoring in agitators, rabblers and similar types of mixing equipment. In such applications the transducer is located directly between the container and the drive on the agitator. The drive shaft goes right through the transducer. Fig. 2.3 shows a suggested configuration for measuring viscosity on the basis of reaction torque measurement.

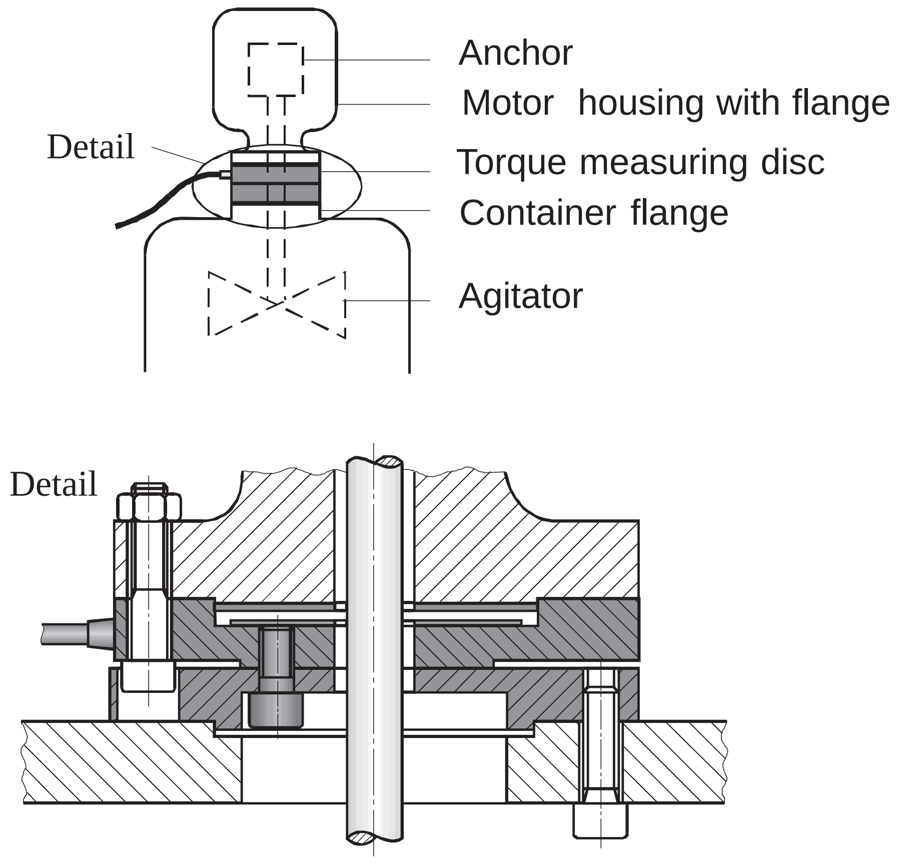

Fig. 2.3 Reaction torque measurement using a TB1A torque measuring disk between the motor housing and the container

The driving torque introduced into the agitator must be transmitted from the motor housing to the container flange in the form of a reaction torque. A TB1A torque measuring disk is fitted at precisely this point, between the motor housing and the container. The agitator shaft projects upward through the center hole and the motor is supported on the measuring disk. Interestingly enough the bearing friction in the motor, unlike the bearing friction on the bottom end of the agitator, does not give rise to measurement errors.

If a transmission is located between the transducer and the point on the drive train where the torque is actually intended to be acquired, the transmission ratio must be taken into account without fail in the choice of measuring range and in the scaling of the measuring amplifier. The torque that is actually to be measured will then be displayed with figures in the appropriate range. Torsion fatigue tests on components are yet another field of application. Fig. 2.4 shows a typical application of this kind.

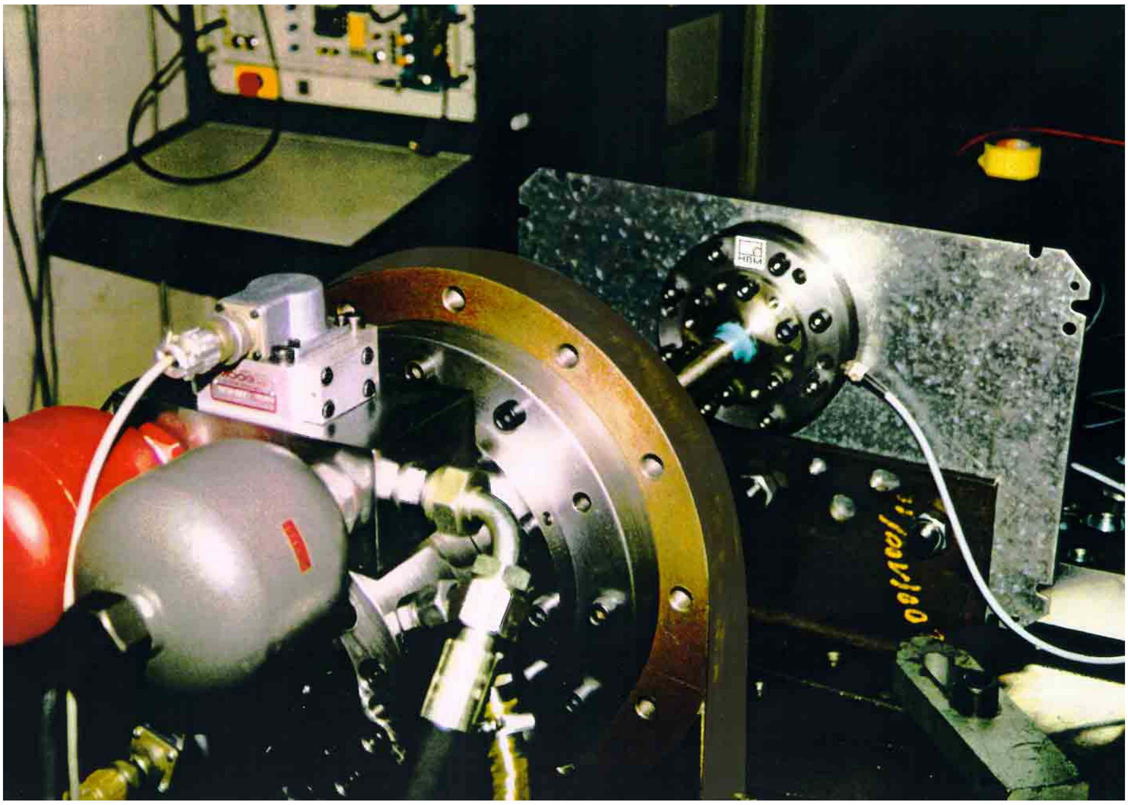

Fig. 2.4 Using a TB1A to conduct torsion fatigue tests on a rod

2.3 Measuring in-line torque

This method acquires the torque in a rotating train of shafts and is commonly known as in-line torque measurement. Fig. 2.5 shows the principle by which in-line torque measurement works. Torque transducers are conventionally divided into three product groups: torque shafts, torque hubs and torque flanges.

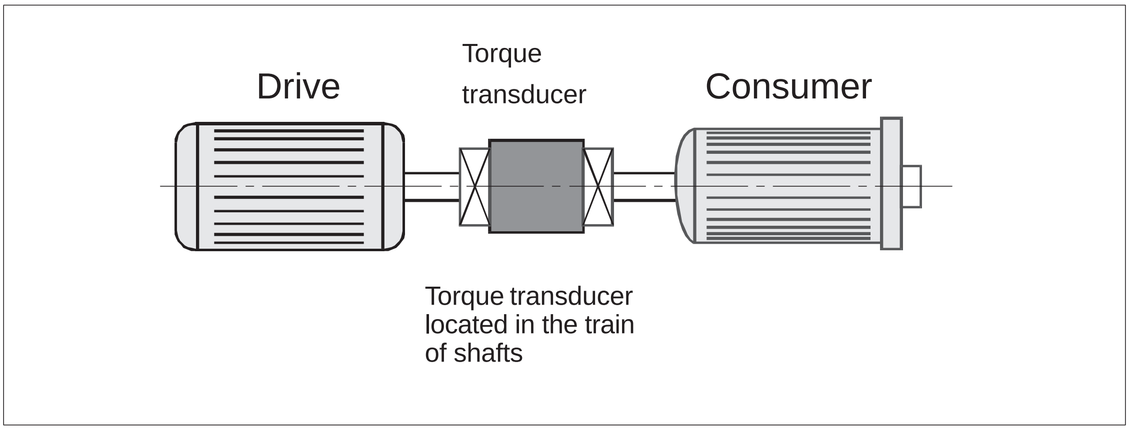

Fig. 2.5 The in-line torque measurement principle

Signals can be obtained by using a number of different physical principles:

- Hydraulic, pneumatic
- Translating an elastic deformation into a change in capacitance, inductance, resistance, permeability or phase.

Nowadays the most commonly used approach is to measure deformation with the aid of strain gages (SGs), which change their resistance in proportion to the strain involved. All torque transducers in the HBM range are constructed on this principle. This technology, together with the core skills of HBM in the field of the development and manufacture of measurement bodies (spring elements), has fully proven its advantages by producing the highest levels of accuracy and dynamic response.

2.4 SGs in torque measurement

SG torque transducers consist mainly of spring elements combined with strain gages (SGs) and compensation elements as well as adaptation accessories for the torque connections to input and output sides. The main features of the strain gage principle mentioned in [1] as being of importance to torque measurement are set out in concrete terms below:

- Strain gages used in the SG measuring bridge (or Wheatstone bridge circuit, named after the English scientist Sir Charles Wheatstone) together with their means of compensating for the effects of interference variables, have excellent characteristics with regard to linearity, hysteresis and reproducibility.
- Because SGs have negligible mass, the frequencies involved in processes under investigation can be very high (> 50 kHz). Centrifugal acceleration in excess of 10,000 m/s^2 is not critical.
- Static and dynamic moments can be acquired.
- SGs exhibit excellent strength in the presence of vibration, making them highly stable under alternating loads.
- Torque transducers with SGs exhibit excellent long-term stability when suitably configured for the application concerned.
- Because of the way they are manufactured and the fact that they are produced by the same company, SGs and measuring bodies (spring elements) can be individually adapted to work with one another to optimum effect.

- Due to the use of SGs specially adapted to show only minimal effects of temperature variation on the output signal, combined with the properties of the measuring bridge and the use of additional compensating elements, temperature has minimal effect on such devices. They can therefore be used in a wide range of temperatures.
- Torque can be measured in positive and negative directions regardless of whether the shaft train is rotating.
- The SG measuring bridge can compensate for the highly critical mechanical variables which can cause interference during torque measurement, namely bending moments, axial forces, lateral forces and rotational effects.