1 Introduction

Though torque is unquestionably an important mechanical quantity in the field of machine building, its significance is not confined to that area alone. The precise measurement of torque, particularly that which occurs in rotating components, places heavy demands on manufacturers and users of test benches. The situation is further complicated by the trend towards improving the mechanical performance of modern engines by increasing their speed of revolution, coupled with a desire for greater accuracy in such areas as the measurement of efficiency.

This challenge is met by continuous development taking into account the ongoing advances in the application fields. Whilst torque shafts according to the original design principle are still used for certain applications, the full range of transducers now includes torque measurement hubs and torque flanges. Innovations in contactless torque transducers concern the transfer of power from the stator to the rotor and the transmission of measurement signals.

But even the most advanced measurement technology can only show its strength when specific rules are followed. This book is a comprehensive revision of the 1989 HBM publication “The Proper Use of Torque Transducers”. It gives an overview of important aspects concerning the use of torque transducers and provides a source of reference for resolving issues affecting applications.

The information given can be adapted and applied by everyone who uses torque measurement devices. On the other hand it is not possible to put forward suggested designs for highly specialized problems. There are many torque measurement tasks which can be solved only after the problem has been clearly defined and all parameters have been taken into account. However, this does not come within the duties of a component supplier. This book can therefore give no assurances about specific characteristics or fitness for purpose in the legal sense, and no responsibility can be accepted for the use to which products are put.

This book describes the principal methods of torque measurement with particular reference to the mechanical and electrical configuration of torque transducers based on the strain gage principle (also called the SG principle) which are those most commonly in use at the present day.

The main fields covered by this publication are selection criteria, the environment within which applications operate, installation, startup, vibration analysis, calibration, and the metrological principles applicable to measuring with torque

transducers. It should be especially beneficial to those readers who do not have much practical experience in torque measurement.

Profound theoretical discussion has been avoided. However, for those approaching the subject afresh an appendix sets out the technical terms for the specification of torque transducers. There is also a brief outline of vibration engineering, together with the most important relationships in the form of tables and a collection of equations complete with short explanatory notes.

1.1 The significance of torque as a measured quantity

In a highly mechanized world, torque is among the most important of all the measured quantities. It plays a highly significant role not only in such products as gas turbines with 50 kN·m of nominal torque at 8000 min^{-1} and a mechanical output of over 40 MW, or Formula 1 test benches with nominal torque in the range 1 to 2 kN·m at 20,000 min^{-1}, but in fact in virtually everything including screw caps on medicine bottles. And for many products the permitted tolerances are mandatory.

There are countless applications for torque measurement in test bench engineering, process monitoring and control, drive and conveyor engineering, quality assurance and R&D.

Recent years have seen rapid market growth. Faced with consumer demand for vehicles which offer lower fuel consumption, higher levels of comfort, greater operating safety and longer-lasting reliability, the automobile industry is highly oriented toward innovation. The industry's requirement for metrological and test techniques to match this demand has therefore grown and is growing. This trend is being accelerated by ever stricter legal requirements for lower emissions.

Increasing importance is being attached to acquiring relevant data reliably and reproducibly. Torque is the key quantity in all investigations and refinement operations, particularly for the development of internal combustion engines and transmissions since, in combination with rotation speed, it provides the possibility to calculate mechanical power. Whereas at one time, particularly in the case of engine test benches, this measuring task was fulfilled by the use of braking devices with a measurement capability, nowadays the trend is toward in-line torque measurement with the aid of rotating torque transducers.

The main reasons for this are that the processes are always dynamic and the interplay between mechanisms such as the engine and the transmission is becom-

ing an increasingly important consideration when it comes to optimization. And in the matter of the torque transducers used in power and functionality test benches, HBM is the worldwide market leader.

HBM has over fifty years of experience in the electrical measurement of mechanical quantities. Production of the first transducer for measuring the torque in a rotating shaft train began over forty years ago. Fig. 1.1 shows a first generation torque shaft in comparison with modern torque transducers. Even today first generation transducers are still being sent to HBM for testing, overhaul or calibration, having been faithfully carrying out their tasks for more than thirty years. This is testimony to the quality and durability of HBM products.

Fig. 1.1 Different generations of torque transducers

HBM was accredited as a DKD calibration laboratory for the measured quantity force as long ago as 1977. This made HBM the first calibration laboratory to be accepted into the DKD (German Calibration Service). Accreditation for the

measured quantity torque followed on July 13th, 1990. For many years HBM was the only calibration authority for torque in Germany and practically set the national standard.

HBM now offers calibration steps from 2 N·m up to 20 kN·m which is the widest range available in the DKD. The equipment used possesses an extremely high level of accuracy thanks to mass-lever systems in which the force is directly generated by the action of a mass in the earth's gravitational field.

As a manufacturer of precision measuring instruments and also of sturdy industrial transducers, HBM takes its responsibilities for quality and reliability very seriously. Logically it was just a short step to a quality management system meeting the requirements of the relevant standards. In 1986 HBM was the first company in Germany to be accredited in accordance with ISO 9001. Then in 1996, in the context of a year-long active campaign for protection of the environment, HBM's environmental management system was accredited to ISO 14001.