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Contactless torque measurement in BTA/STS deep hole drilling by using the Villari effect – a first proof of concept

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Summary:
Based on a contactless torque sensor for pedelec application, the first exemplary tests were carried out on BTA/STS deep hole drilling machines at the TU Dortmund to verify the general functional principle in use with machine tools. Initial data show direct proportionality to reference data from the strain gauge, confirming that torque can be reliably measured with the contactless sensor. The following describes the basic principles of contactless magnetic torque measurement, its application on BTA/STS deep hole drilling machines and presents some of the results of the associated proof of concept.

Keywords: Torque Measurement, Contactless Measurement, BTA/STS deep hole drilling, Villari effect, Micromagnetic method

Introduction

Nowadays, various processes are used in manufacturing to produce precise and deep bores. The high metal removal rate, the quality of the bores and the achievable surface qualities show that this is a very economical process. In particular, the BTA (Boring and Trepanning Association) deep hole drilling process fulfills these characteristics for larger bore diameters (D ≥ 30 mm) [1]. Figure 1 a) shows a schematic sketch of a BTA/STS deep hole drilling machine with a total length of approx. L ~ 12 m.

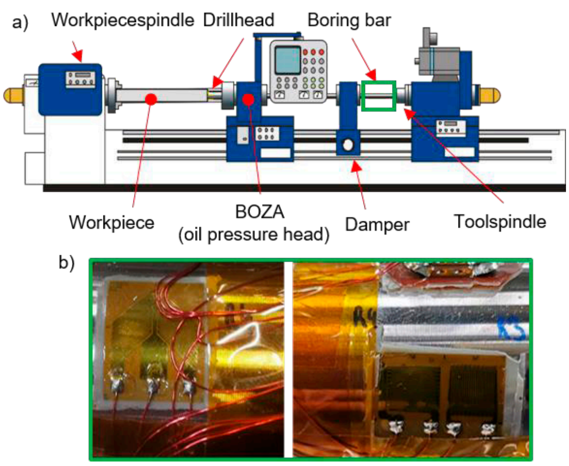

Fig. 1. a) The BTA deep hole drilling machine Guiseppe Giana GBB 560. b) Strain gauges applied to the boring bar

Due to the two spindles, it is possible to rotate either the tool, the workpiece or both sides, which increases the flexibility of the process. The bore moment and the thrust force of the process are often measured at the boring bar to obtain information about the cutting forces at the drill head and the dynamic state of the process. Therefore, strain gauges are applied to the boring bar as shown in Fig 1 b). Due to the cables from the strain gauges, the boring bar cannot rotate which reduces the flexibility of the process. However, there are techniques to use strain gauges with a rotating tool. These techniques either use a sensible telemetric transmission unit or integrate the measurement equipment and the power supply inside the tool spindle. Both techniques still rely on strain gauges, which require careful preparation of the boring bar before application and are not suitable for usage outside of the laboratory.

Description of the measurement principle

The relative permeability of ferromagnetic materials changes when mechanical load is applied. This effect is called inverse magnetostriction or Villari effect [3].

By exploiting the inverse magnetostriction, it is possible to electrically detect the change in the magnetic properties of a shaft under mechanical load.

For this purpose, the sensor imprints an alternating magnetic field into a shaft via generator coils. When applying torque, the material of the shaft is compressed and stretched at the same time, as shown in Fig. 2. This causes a change of relative permeability in the two depicted directions. These changes are then detected by measuring

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the change in amplitude of the magnetic flux coupled with the four sensor coils. The simultaneous evaluation of the signals in the directions of compressive and tensile stress allows a statement on the torque direction.

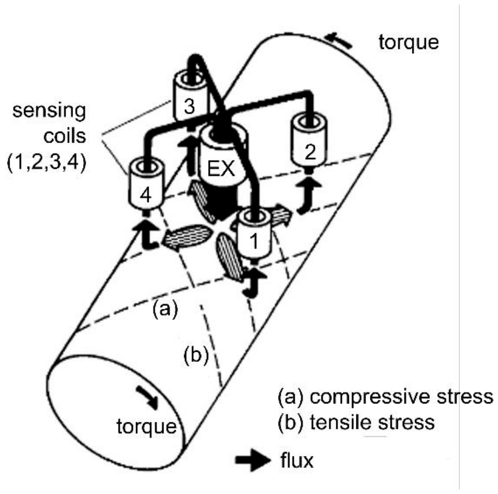

Fig. 2. Schematic representation of the basic principle [3]

Description of the Proof of Concept

For the proof of concept, strain gauges were applied onto the boring bar of a BTA deep hole drilling machine as shown in Fig.1 (b). At the same time, the contactless torque sensor is positioned around the boring bar with an adapter as shown in Fig.3. Subsequently, a defined torque is applied at the drill head and into the boring bar to measure, evaluate and compare both signals.

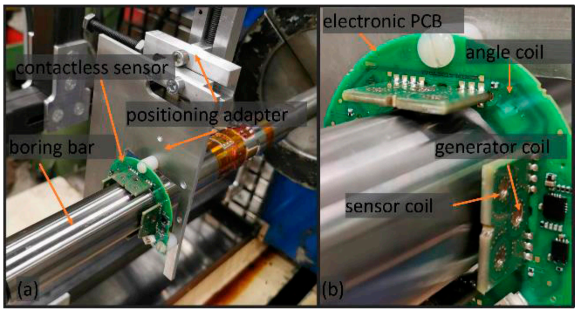

Fig. 3. a) Test setup with strain gauges b) and contactless torque sensor

Results of the Proof of Concept

In Fig. 4 the measurement signals of both methods are shown. The diagrams show a proportional relationship between the introduced torque and the measured signal in both measuring methods is visible. In the case of the strain gauge, a strain is measured and compared to the applied torque. The contactless torque sensor, on the other hand, outputs an electrical voltage value in V. Both output values must be converted into torque via a material-specific proportionality constant.

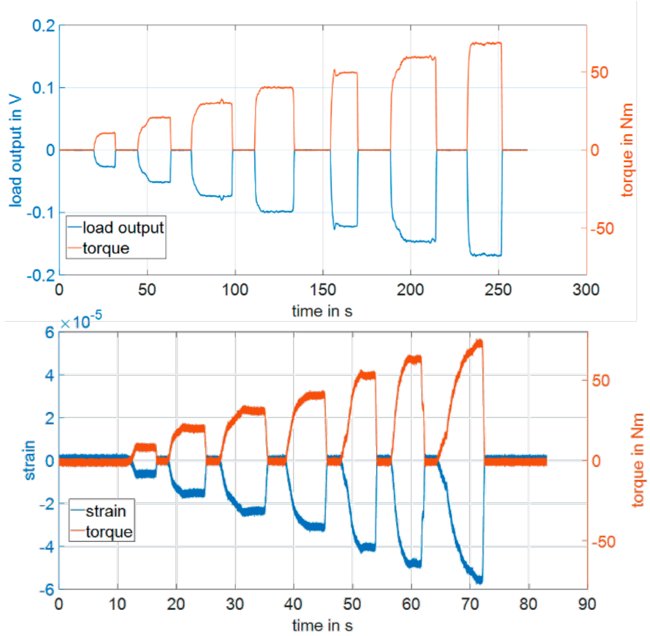

Fig. 4. Top: Measurement signal from the contactless sensor; Bottom: Measurement signal from the strain gauges

Conclusion

The proof of concept was successful. The contactless torque sensor measures at a similar level of linearity and precision as strain gauges while offering additional functions such as:

- Measurement of additional parameters and forces should be possible
- Increased flexibility of the process due to contactless measurement
- Variable placement of the sensor and operator-friendly setup

In future investigations measurements while drilling with a rotating workpiece and rotating tool will be carried out. Here the influence of the process dynamic on the contactless torque sensor will be investigated.

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