

Experience with Torque Measurement on Rotating Shaft

Zdeněk Foltá¹⁾, Milena Hrudíčková²⁾

¹⁾ VŠB-Technical University of Ostrava/Faculty of Mechanical Engineering, Ostrava, Czech Republic, e-mail: zdenek.folta@vsb.cz

²⁾ VŠB-Technical University of Ostrava/Faculty of Mechanical Engineering, Ostrava, Czech Republic, e-mail: milena.hrudickova@vsb.cz

Abstract — This article deals with problem of torque measurement on the turning shaft and the signal transmission to the measuring equipment. There is described the experience with contact transmission and both non-contact and high frequency transmission (with ESA Messtechnik equipment). Also the examples of the practical realization are presented.

Keywords — Torque measurement, telemetry, strain gauge measurement, experiment

I. INTRODUCTION

Torque measurement on rotating shaft by the method of strain gauge measurements, especially with the existing equipment, brings usually two problems:

- the first problem is the installation of the strain gauge to places giving representative data. These are usually areas without mounting, the groove for tongue area and similar discontinuities – simply such location on the shaft, where the relative deformation is in accordance with the torque value (under known formulas);
- the second problem is the transmission of the measured signal from the rotating shaft to the recording apparatus.

Our article deals with these issues.

II. CONTACT TRANSMISSION

The contact transmission by means of rings and brushes used to be the only option for the signal transmission in the past. There were usually the direct signals from strain gauges transmitted, that is why the apparatus had to be reliable and with only very low transition resistance values. Despite the use of high quality materials – especially precious metals – such devices were not only liable to failure but also unfit for measurements on the existing equipment.

Contact transmission of signal is still used at present – the Hottinger sensor is one of the examples (see Fig. 1 and Fig. 2).

The torque measurement by means of the existing equipment is very often required in practice. For this purpose one very simple, cheap and at the same time reliable signal transmission method was developed by professor Dejl and his colleagues – the signal transmission by means of rings and „wire“ brushes. There are rings with peripheral groove mounted on the insulation lining. The signal is then transmitted by a wire encircling the rings which is tighten by means of springs or coils.



Fig. 1: Hottinger torque sensor

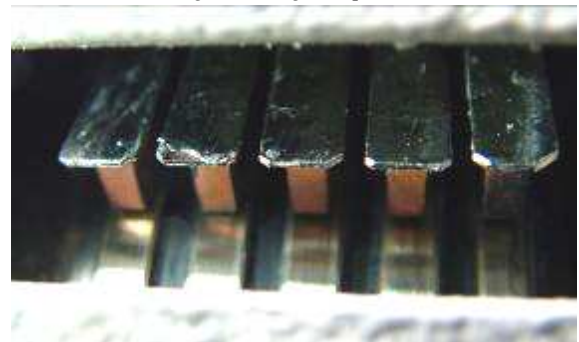


Fig. 2: Hottinger torque sensor - detail of the signal transmission

This system was used successfully in many applications – for example for signal transmission of strain gauge data of the industrial automatic washer drum and shaft (Fig. 3 and Fig 4), or articulated cardan shafts of a rolling mill (Fig. 5 and Fig 6).

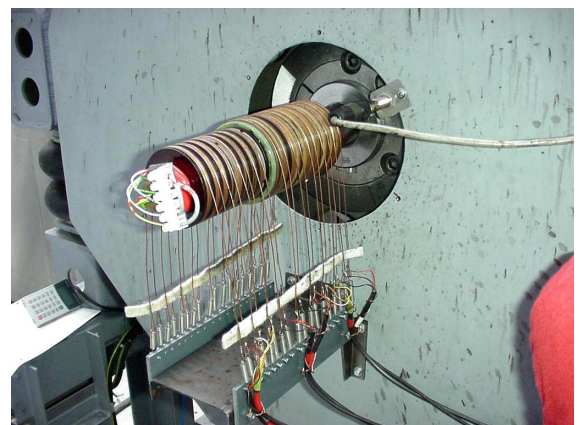


Fig. 3. Wired signal transmission on industrial automatic washer drum

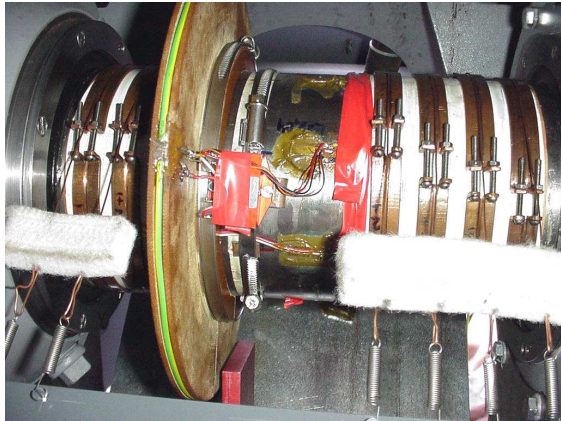


Fig. 4. Wired and wireless transmission on shaft of an industrial automatic washer drum



Fig. 5. Torque measurements on the cardan shaft of rolling mill vertical cylinders

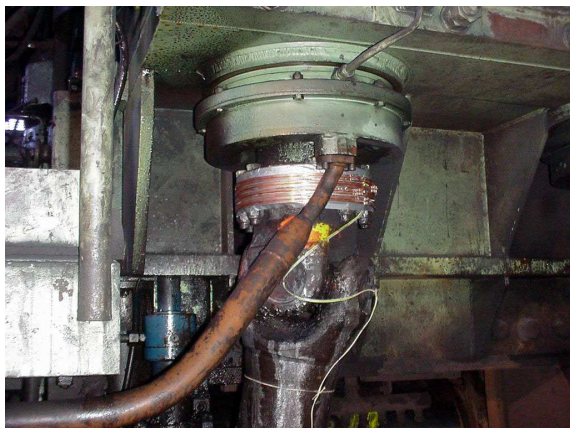


Fig. 6. Torque measurements on the cardan shaft - detail

The application of this system depends on certain experience; it is necessary to set the angle of wire encircling, the tension of springs and also the dimensions and material for the wire and the groove in a appropriate ratio in accordance with the shaft diameter and its peripheral velocity.

By means of this equipment it is possible to transmit not only the torque measuring strain gauge signal, but also signals from the strain gauge measuring any other quantities or from quite different sensors. The strain

gauge measurement on the automatic washer drum serves as an example (Fig. 7 and Fig. 8).

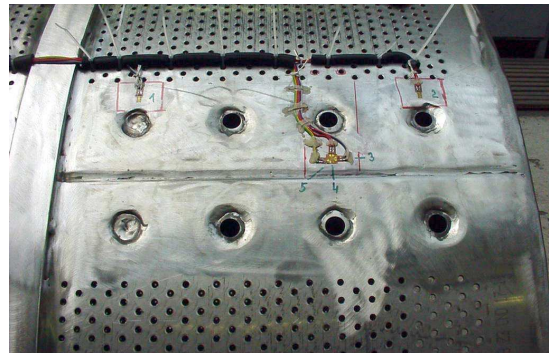


Fig. 7. Some strain gauges placed on the automatic washer drum

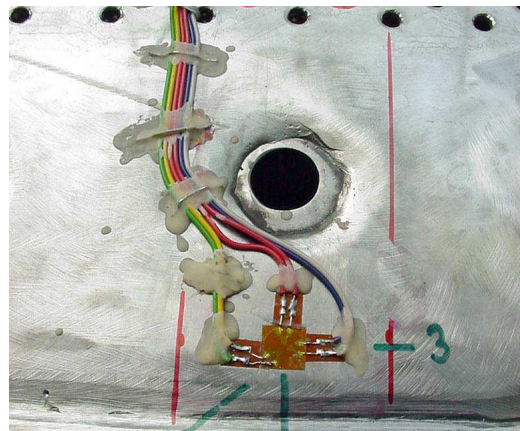


Fig. 8. Detail of strain gauges

III. TELEMETRY WITH DISC AERIAL

Modern electronics has brought a miniaturization and also possibilities of non-contact signal transmission telemetric systems. The telemetric system by ESA Messtechnik GmbH, Munich is an example. Its principle is described in Fig. 9, one of the practical realizations (experimental stand – Faculty of Mechanical Engineering, STU Bratislava) is in Fig. 10. The strain gauges are connected in the module with strain gauge amplifier, bridge charger and transmitting block. By means of a fixed aerial and a rotational aerial system both the power supply of strain gauge module and the signal transmission from the strain gauge bridge to the evaluation unit are secured.

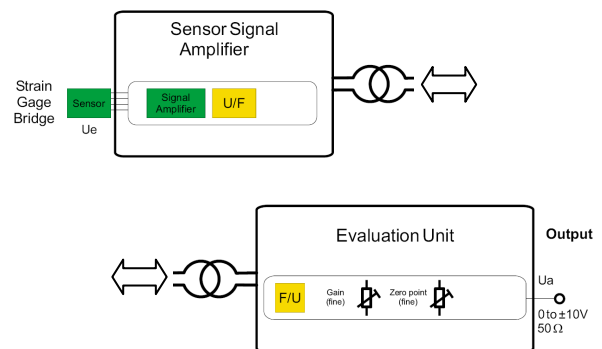


Fig. 9: Telemetry block diagram

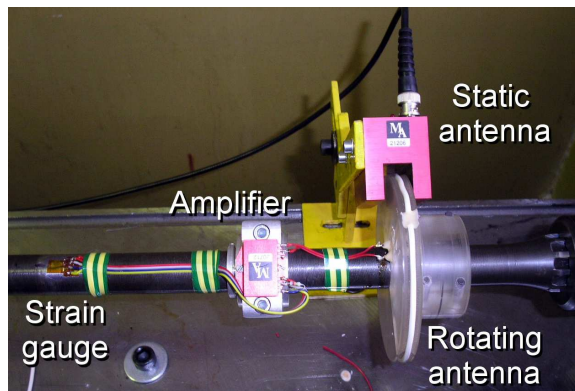


Fig. 10: Torque sensing on the experimental stand

The example of such telemetry usage in practice may be torque measurement of a conveyor belt drive. The space for the sensor locating was very limited and confined (see Fig. 11) and besides this fact it was necessary to place the strain gauges near the shaft mounting, which required additional specification of the scale between the measuring voltage and torque by means of FEM (Fig. 12).

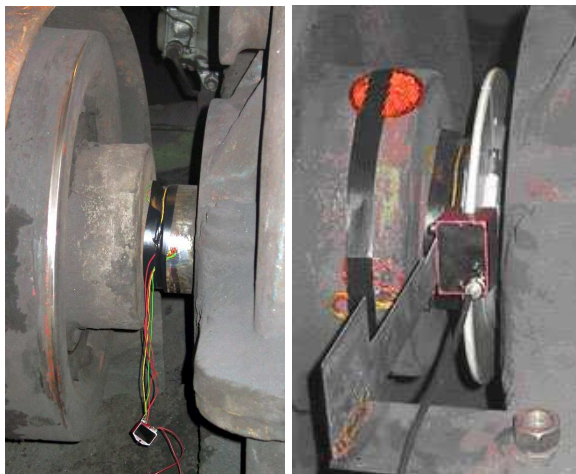


Fig. 11: Torque measurement of a conveyor belt drive

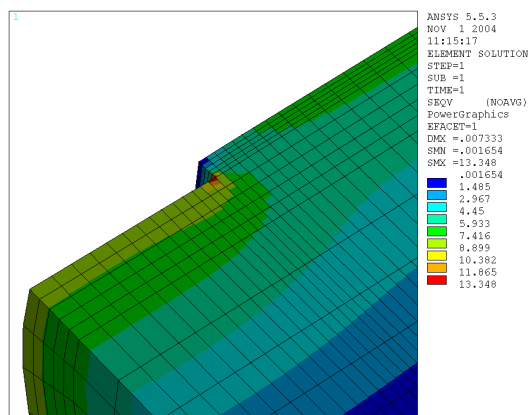


Fig. 12: Calculating of conversion scale „measuring voltage – torque“ by means of FEM

Above described system is relatively simple as for installation and usage; it is necessary to have space for placing of the rotational and fixed aerals. Maximum possible diameter of the rotational aeral depends on the power supply unit output. The output 1 W is enough for the diameter of 400 mm, the output 3 W is suitable for the diameter of 750 mm.

Despite some problems with sufficient space this equipment was installed into the gearbox of fork-lift truck Jungheinrich Hamburg (Fig. 13) and performed measurements during test operation with the option of switching between strain gauges for the tensile-pressure strength and strain gauges for torque measurements on the conical gear pinion (Fig. 14).

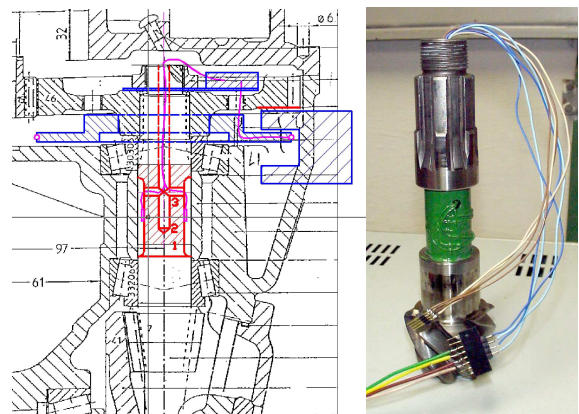


Fig. 13: Location of aerals and strain gauges in the gearbox of fork-lift truck

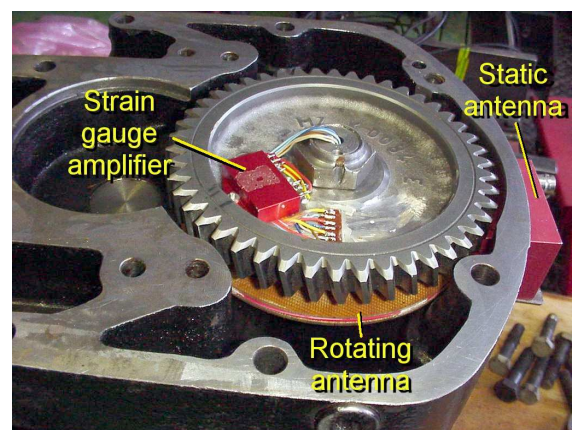


Fig. 14: Location of the amplifier and connecting bar for strain gauges

This equipment can be used (after applying some suitable insulation measures) even in environment with running water – we have tested it during measurements on a running mill in Budapest (Fig. 15).

The conditions of cylinders fixing unfortunately caused such shifts of the cardan shaft both in horizontal and vertical directions that the fixed aeral could not be installed properly – so the data obtained were only informative.



Fig. 15: Telemetry on the cardan shaft of a rolling mill in Budapest

IV. TELEMETRY WITH AERIAL RIGHT ON THE SHAFT

If there is not enough space in the vicinity of the shaft, it is possible to install the rotational aerial right on the shaft. In our case this solution was used during measurements of torque on Škoda Fabia half-axes.

The rotational aerial is installed right on the shaft (see Fig. 16 and Fig. 17)) and the fixed aerial is in this case closer to the shaft.



Fig. 16: Torque sensing on a car half-axe



Fig. 17: Torque sensing on a car half-axe

The used aerial incorporates also the revolution sensor. At each shaft revolution there is a short rectangular pulse on the output connector. Then it is possible to calculate the current revolutions from the pulse frequency – and in this case also the vehicle velocity (speed).

V. TELEMETRY WITH HIGH FREQUENCY TRANSMISSION

This telemetry is used in more difficult conditions. The transmission is realized by means of high frequency of 433 MHz. The strain gauge (or other sensor) signal is filtered for values over 1 kHz (antialiasing) and digitized by the 12-bit converter. The digital signal is then transmitted at a distance of minimum 50 m (in free space), then decoded – and the final output is an analogue signal again.

The block diagram of this telemetry is in Fig. 18, its realization in Fig. 19. This system is now being tested and will be used for measurements on an experimental car in Josef Božek Competence Centre for Automotive Industry.

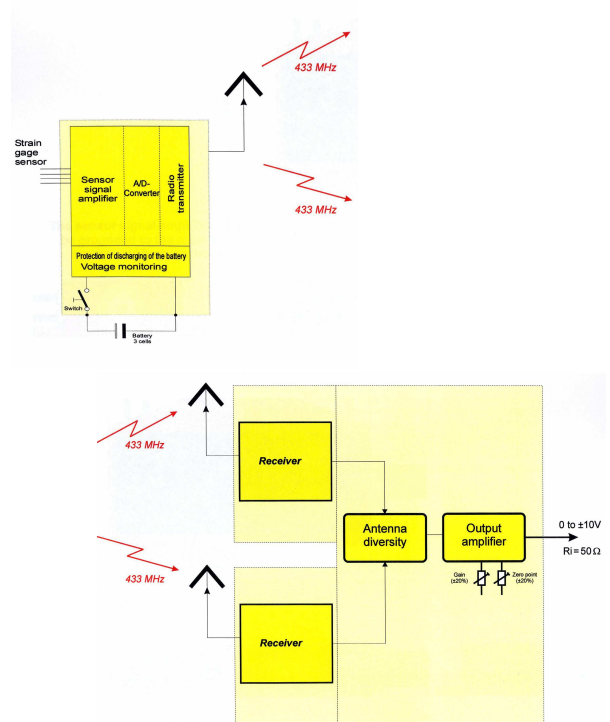


Fig. 18: Block diagram of the high frequency telemetry



Fig. 19: High frequency telemetric system real appearance

The device can be also used for the signal scanning from moving objects. An example is the measurement of the go-karts frame loading, which realized a student of our university as part of his thesis.



Fig. 20 –Telemetry on the go-car frame



Fig. 21 – Receiving point

CONCLUSION

Despite this article looks rather as an advertising leaflet for ESA Messtechnik products, its aim is to inform colleagues in our branch. Especially those of them who need to measure the torque or other tensile strength of a rotating equipment – we would like to inform them of some options we have experience with.

While the strain gauge system is based on the evaluation of the voltage on the Wheatstone bridge measurement diagonal, it is possible to connect any other sensor (which output is voltage) to the amplifier - and then transmit this signal to the evaluation unit. For example temperature, force, vibrations and other quantities can be transmitted in this way.

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REFERENCES

- [1] Dejl, Z., Folta, Z., Zieschang, T. Zkrácené životnostní zkoušky kuželočelní převodovky vysokozdvizného vozíku Retrak. (Shortened life tests bevel gear forklift reach truck Retrak). In Proceedings konference Trwalość elementow i wezlow konstrukcyjnych maszyn górniczych. Gliwice-Ustoń: TEMAG, 2004. ISBN 83-917265-4-1.
- [2] Folta, Z., Polák, J., Nečas, J., Vrána, V. *Ověření účinnosti pohonu pásového dopravníku. (Verification of the effectiveness of belt conveyor drive)* Liberec: TU Liberec, 2005. International conference of Departments of Machine Parts and Mechanisms anthology 2005.
- [3] Dejl, Z., Folta, Z. *Měření zátěžného spektra automobilové převodovky. (Measurement of the automotive gearbox loading spectra.)* Bratislava: STU Bratislava, 2007. International conference of Departments of Machine Parts and Mechanisms anthology 2007. ISBN 978-80-227-2708-2.
- [4] Folta, Z., Hrudíková, M. *Zpracování zátěžných spekter převodovky osobního automobilu. (Processing of loading spectra of a car gearbox.)* Košice: TU v Košiciach, 2010. International conference of Departments of Machine Parts and Mechanisms 2010. ISBN 978-80-970-294-1-8.
- [5] Dejl, Z., Němček, M.: Research results in the field of automotive transmissions on dept. of Machine Parts and Mechanisms VŠB – Technical University of Ostrava. In: Proceedings of abstracts of Conference „Mechanical Engineering 2006, Bratislava, Slovak University of Technology, p. 46, ISBN 80-227-2513-7.
- [6] ESA Messtechnik GmbH Munich, Technical documentation.