53rd CONFERENCE ON EXPERIMENTAL STRESS ANALYSIS pp. 220–223
Český Krumlov, Czech Republic, June 1–4, 2015

Measuring of the Cutting Force During Drilling

A. Lufinka [1,*]

[1] *Technical University of Liberec, Studentska 2, 461 17 Liberec 1, Czech Republic*
* *ales.lufinka@tul.cz*

Abstract: A cutting force is one of the important parameters describing the drilling process because a drilling process quality and a drill life depend on the cutting conditions optimal setting. Real drilling parameters monitoring is essential during the research in the area of cutting fluid composition and drilling tools parameters for nonstandard material setting. The measuring device for the cutting force measuring which was built at Technical university of Liberec is described in this paper.

Keywords: Cutting Force; Measurement; Strain Gauges Sensor.

1 Introduction

The cutting force is one of the important parameters describing the drilling process. It acts on the drilling tool cutting edge and its vector direction is determined by the tool geometry. Direct measurement of this force is therefore very difficult but the cutting force vector can be decomposed according to the defined coordinate system. The normal and tangential parts are two fundamental elements of this decomposition.

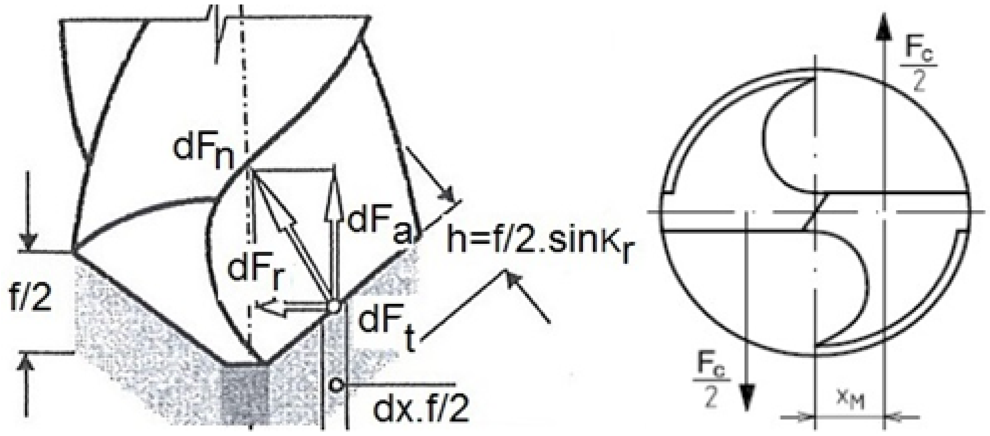

Fig. 1: Decomposition of the cutting force vector.

The tangential part dF_t and the normal part dF_n can be described by next equations [1]:

$$dF_t = k_t\left(r_{ef}\right) dS\left(r_{ef}\right) = k_t\left(r_{ef}\right) \frac{f}{2} dx = k_t\left(r_{ef}\right) \frac{f}{2} \cos\lambda_s\left(r_{ef}\right) \frac{D}{2} dr_{ef} \tag{1}$$

$$dF_n = k_n\left(r_{ef}\right) dS\left(r_{ef}\right) = k_n\left(r_{ef}\right) \frac{f}{2} dx = k_n\left(r_{ef}\right) \frac{f}{2} \cos\lambda_s\left(r_{ef}\right) \frac{D}{2} dr_{ef} \tag{2}$$

The tangential cutting force part F_t can be expressed using the torque M_t and its normal component F_n can be further decomposed to the axial dF_a and radial dF_r forces:

$$M_t = \int_{r_{ef(0)}}^{1} 2dF_t\left(r_{ef}\right) Rr_{ef} = \int_{r_{ef(0)}}^{1} 2k_t\left(r_{ef}\right) \frac{f}{2} Rr_{ef} \cos\lambda_s\left(r_{ef}\right) Rdr_{ef} \tag{3}$$

$$F_a = F_n \sin\kappa_r = 2\int_{r_{ef(0)}}^{1} dF_n\left(r_{ef}\right) \sin\kappa_r = 2\int_{r_{ef(0)}}^{1} k_n\left(r_{ef}\right) \frac{f}{2} \sin\kappa_r \cos\lambda_s\left(r_{ef}\right) Rdr_{ef} \tag{4}$$

These equations content a lot of constants which described drilling toll geometry. So, their calculation is relatively difficult. But the described decomposition also shows that the drilling force can be well described by the axial force and torque waveforms, so the axial force and torque can be well used for the drilling process monitoring. These two quantities can be relatively easily measured and the real drilling process can be well characterized by using them.

2 Torque and Axial Force Sensor

The sensor was made for the torque and axial force direct measuring [2]. The sensor is composed of two steel rings connected by four steel elastic beams. The outer sensor ring is fixed to the drilling machine base and the drilled material is anchored to its inner "floating" ring. The sensor beams are loaded by the drilling process in two directions. Vertical load corresponds to the axial drilling force and horizontal load is caused by the torque. Both deformations are measured by foil strain gauges HBM 1-LY11 [3] by Hottinger Baldvin Messtechnik. Each beam is fitted with four strain gauges and two of them are used for each load direction. The sensor is used during real drill process all strain gauges are protected by elastic sealant and shielding foil and whole sensor is covered against chips and cutting fluid ingress.

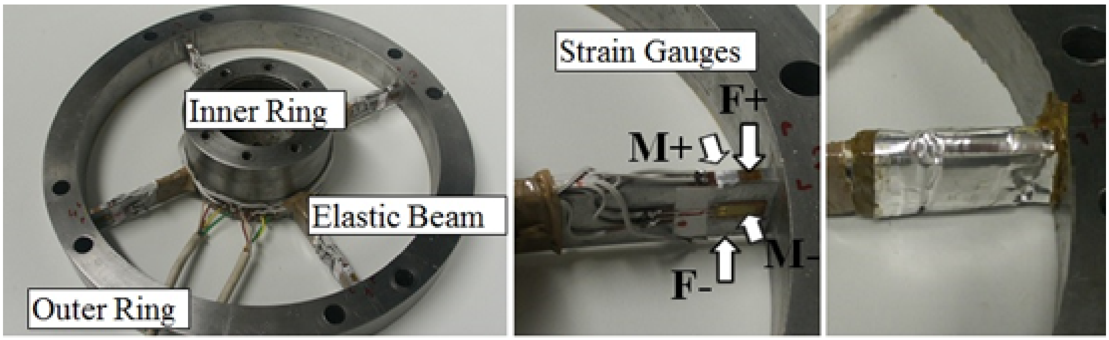

Fig. 2: The sensor design, strain gauges location and covering.

Because the sensor has four beams each deformation is measured by eight strain gauges. Two strain gauges from the opposite beams are serially connected in one branch of the bridge. Both deformations are measured independently by strain gauges connected for each direction in a separate full bridge. So, the sensor contents two independent full bridges, one for the axial force and the second for the torque measuring.

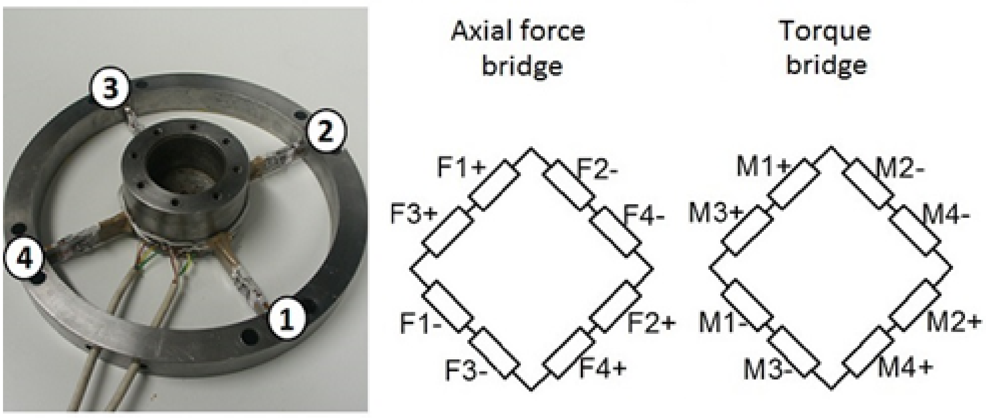

Fig. 3: The strain gauges wiring.

3 Electronic Unit

The electronic unit is relatively simple. It contains only two strain gauges bridge amplifiers Burster 9236 [4] for strain gauge bridges supply and amplification. National Instruments data acquisition module NI USB 6009 is used for the amplifier analog output digitization. This module has four differential analog inputs (only two are used in this case) and these inputs are digitalized by 14bit A/D converter. The module is connected to the user computer USB port and controlled by a control application.

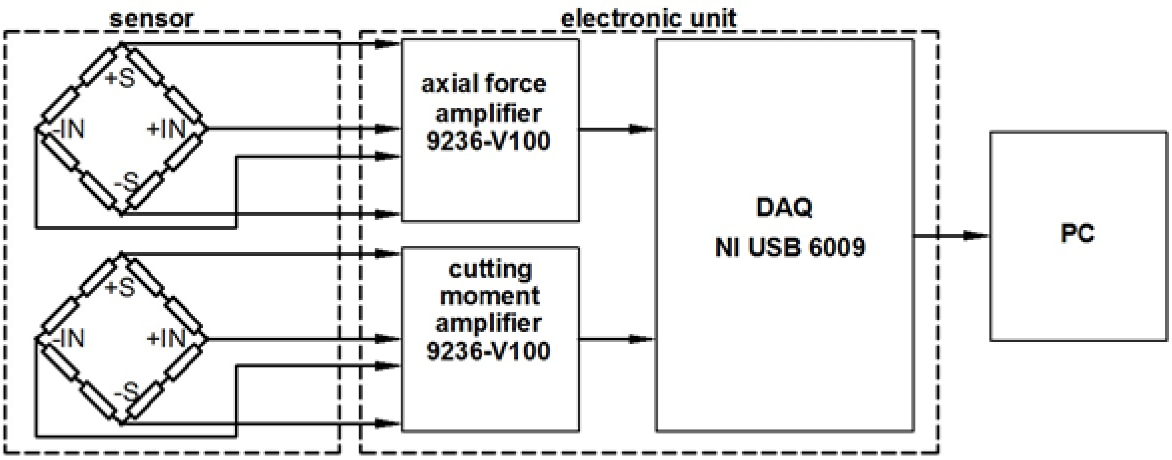

Fig. 4: The electronic unit block diagram.

The amplifier gain and zero balance were set using a measurement force and moment standards and acquired calibration constants were then used in the user control application.

4 Measurement and Display Application

A special software application was programmed in Labview 2009. Real-time numerical and graphical displaying of monitored parameters is possible by this application (see Fig. 5.). Of course, measured values can be stored in the data files, too. A simple analysis (for example maximum and minimum value detection, average value calculation) can be carried out with the stored waveforms. Stored data can be exported to the .csv format for further processing by spreadsheet software.

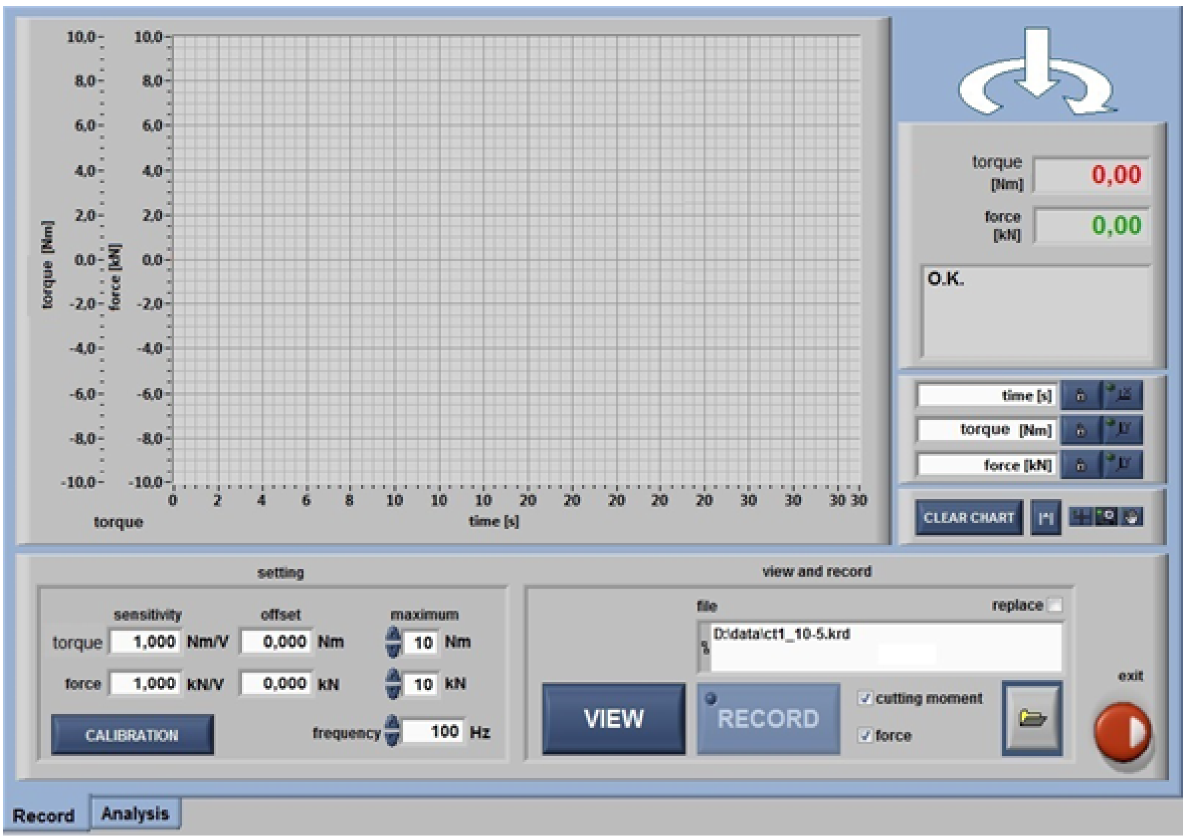

Fig. 5: The measurement and display application user window.

5 Example of Results

The measuring device was used during the cutting fluid composition and drill tool geometry optimization for special steel drilling. The biaxial sensor was fixed to the machine base and the drilled material specimens were anchored to the chuck assembled to its inner ring. Drills with different cutting edge geometry and various cutting fluids were then tested. Waveform examples are shown in the Fig. 6.

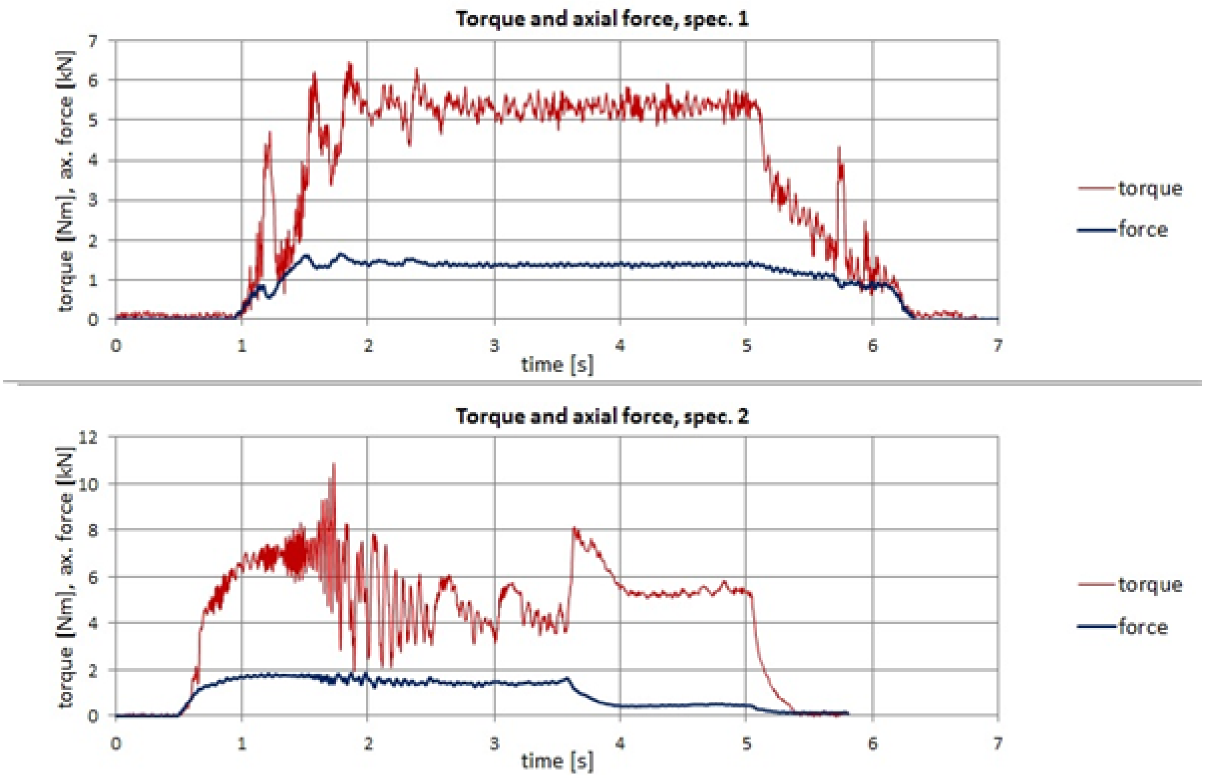

Fig. 6: Measured waveform examples.

6 Conclusion

Described device is used at the Department of Machining and Assembly of Technical university of Liberec. Its real application shows that the device is fully functional and meets the required parameters. This measuring device main usage is the research in the area of cutting fluid composition and drilling tools parameters for nonstandard material setting and it can be used for demonstration of the drilling parameters during student practical lessons, too.

References

[1] J. Beňo, Theory of metal cutting, Košice, Technical university of Košice, 1999.

[2] V. Dráb, Technology 1 – Practical lessons, Liberec, Technical university of Liberec, 1989.

[3] Retrieved from: http://www.hbm.com/en/menu/products/strain-gages-accessories

[4] Retrieved from: http://www.burster.com