

# APPLICATION OF MATLAB IN HIGH SPEED DRILLING RESEARCHES

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## Abstract

**This article is about application of Matlab for gathering and saving data from measurement system, consisting of: sensors of axial force and torque, sensors of vibrations, during a high speed drilling process, as well as for processing and analysis obtained data. An application was developed in Matlab for data visualization, comparative evaluation, statistical manipulation and frequency analysis. Results obtained by means of the program are represented in the article, also described future applications of Matlab features in related tasks.**

Processes research is a very actual subject being at the head of newest highly productive technologies. On the most difficult and less known is a high speed drilling process which has many interacted parameters: cutting speed is changing from its maximum value at the periphery to zero in the drill center, complex geometry of a drill (changing along cutting edge length effective rake and back clearance angle, existence of chisel edge), temperature distribution in cutting zone, cutting chips removing and other. When drilling machine invention allowed to increase performance significantly thanks to spindle speed up appeared need of explanation and of modeling processes, which is becoming a base for increasing holes property, drilling modes methods preparation, designing tools for high speed drilling, designing machining and supporting facilities.

For solving such researching tasks modern sensitive equipment and powerful software environment needed. We chose Matlab for its advantages:

- Easy to use and to create programs
- Big set of built-in functions for experimental data processing
- External hardware interfaces
- Good visualization facilities

For operation of high speed drilling we created experimental device based on boring machine 2B440A, which allows to measure axial force, torque and vibrations during the drilling process (Fig. 1).

Maximal spindle speed of machine is 2000 rpm, maximal tool feed 0,16 mm/rev, construction based on vibration-resistant stiff frame. For synchronous axial force and torque measurement is used system DDU4 by ARTIS, containing contactless sensor DDU and conversion device DDU4.

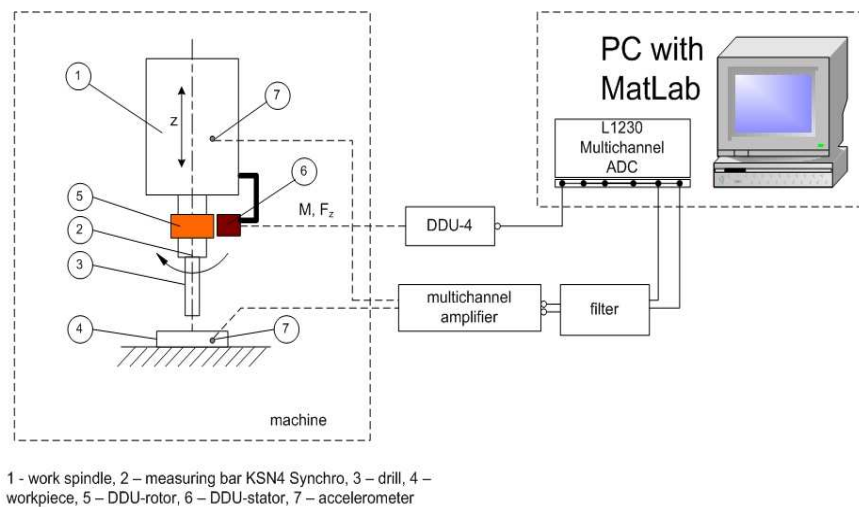


Figure 1: Experimental device scheme

Sensor consists of tensometric rotor DDU fixed on spindle block, and stator DDU receiving signal from rotor (Fig. 1). Both sensor elements have level of protection IP67. Measurement precision is  $\pm 1\%$  of measurement range. Analog data of axial force and torque are received from DDU to conversion device DDU4. Digital data from conversion device is transferred to PC through RS232. Obtained data is saved, proceed and visualized in MATLAB program.

The second part of measurement complex consists of vibration measurement devices: A-to-D card, inserted in PC PCI bus, filter and charge amplifier from vibration sensors, piezoelectric sensors. In our researches we used just two sensors, but filter and charge amplifier support 16 sensors connections. Data from A-to-D card is saved in binary file on PC for processing and visualization in MATLAB.

## Experimental investigation

Factors influencing on axial force and torque while cutting process are: peripheral cutting speed  $V$ , feed rate  $f$  and geometry of cutting tool. Those factors values are defined by devices characteristics. Cutting speed value was taken from values, characterizing crossover for high speed drilling (double traditional drilling speed values were taken [1]). Recommended cutting speed for traditional drilling with standard twist drill of HSS-R6M5, diameter 10mm is 25-30 m/min.

Experiments are made with standard twist drill of HSS-R6M5, diameter 10mm; cutting speed range 39-63 m/min; feed rate 0.16, 0.09 mm/rev; block material is steel-3. Each experiment was made twice. Blind holes 13 mm deep were drilled without liquid coolant. For each hole a new tool was taken with the same geometric and physical-mechanical properties. See experiments plan in Table 1.

Measured axial forces, torque and vibrations from two piezoelectric sensors values were saved on HDD for each experiment (See graphical representation of experimental data on Fig. 2).

Table 1: PLAN OF EXPERIMENTS

Test №	d, mm	f, mm/rev	n, rpm	$V_{CUT}$ , m/min
1,2	10	0,16	1250	39,25
3,4			1600	50,24
5,6			2000	62,8
7,8		0,09	1250	39,25
9,10			1600	50,24
11,12			2000	62,8

On the left side placed graphics of axial force and cutting torque. There are clear penetration intervals, tool return from cutting zone on graphics, also dynamics of changing force values with depth changing (drilling time). Because of active vibration processes, caused by material structural irregularity, machine and tool limiting stiffness, we got axial force fluctuation and cutting torque in wide range. For carrying out analysis and comparing values of axial forces and cutting torque, obtained in experiments with different cutting speeds and feed rate, we used Matlab abilities and calculated average values on intervals, and also mean-square deviation of calculations. Those values are outputted in text fields below graphics on the left side (see Fig. 2).

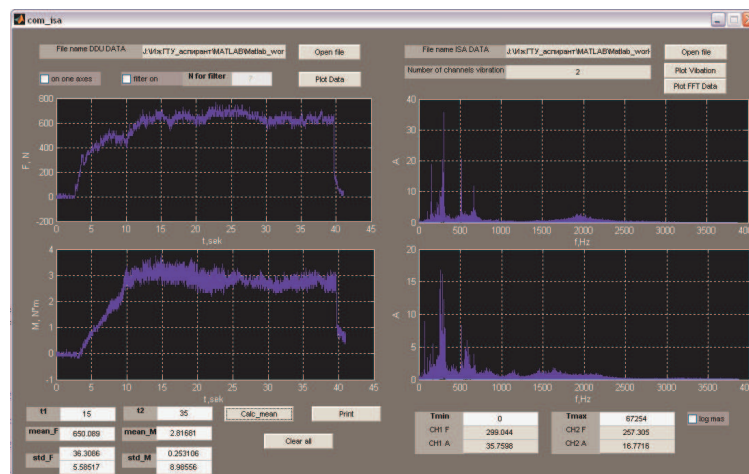


Figure 2: Experimental data of one test in Matlab

On the right side there are two windows for vibrations output from two piezoelectric sensors. Program has output both for vibrations itself and signals spectrums, because vibration values are interesting only in the moments of tool entering and returning. Signal spectrum is created using Discrete Fourier transform -  $fft(x,n)$ .

Program has output for experimental data values obtained with different processing environment in the same axis - Fig. 3.

The response surfaces were built based on received experimental data after calculation of average values and standard deviations of axial force and cutting torque. See the example of response surfaces on Fig. 4.

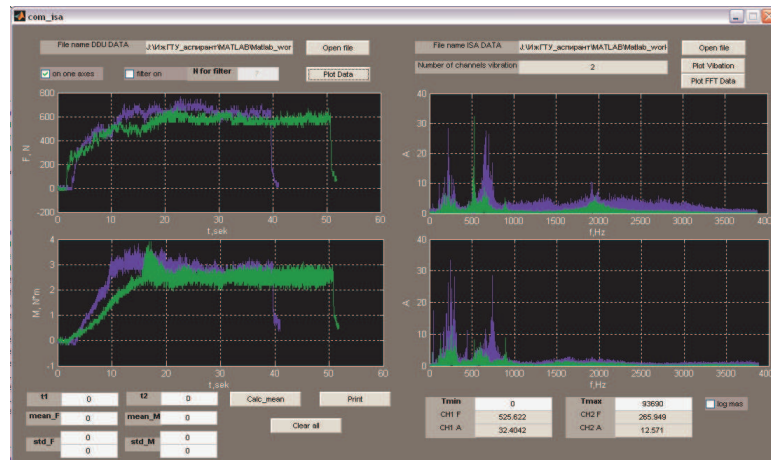


Figure 3: Graphical representation of experimental data (two tests) in MATLAB program

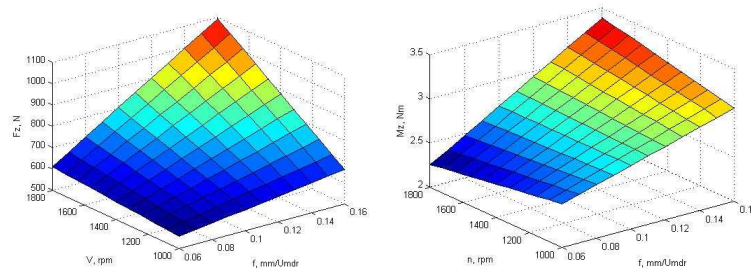


Figure 4: Response surfaces of axial force  $F_z$  and cutting torque  $M_z$  built in MATLAB program

## Conclusion

This work confirms Matlab effectiveness in research of high-speed drilling processes, namely Matlab environment allows to accept the data from external devices through various interfaces, represents a wide spectrum of options for processing and visualization of experimental data. That makes researcher's work easier, automates experimental data processing and relieves him from low-level coding knowledge need.

## References

- [1] Leopold J. *Werkzeuge für die Hochgeschwindigkeitsbearbeitung*. Carl Hanser Verlag, München, Wien, 1999.
- [2] Marchand P., Holland T. *Graphics and GUIs with MATLAB*. Chapman & Hall/CRC, USA, 2003

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