TEMPORAL ANALYSIS OF STICK-SLIP RECORDS

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Summary: *In this research the results of analysis of time interval (interevents sequences) between bursts of Acoustic Emission (AE) data sets were investigated. External influences on laboratory stick-slip processes induce changes in dynamical features of AE record. Stick-slip laboratory experiments have been carried out for three types of stiffness of driving springs (78.4 N/m, 235.2 N/m and 1705.2 N/m). The records have been investigated under different conditions: frequency in range 5-120 Hz and voltage in range 0-3V applied on the 20 Hz vibrator attached on upper (sliding) plate. For the analysis of interevents sequences of Acoustic Emission (AE) we have carried out dynamical, nonlinear methods: DFA (Detrend Fluctuation Analysis), Recurrence plot (RP) analysis.*

Key Words: *Stick-slip, nonlinear analysis, interevents sequences.*

Introduction. Dynamical characteristics of nonlinear stick-slip process under a weak external forcing were investigated. The stick-slip process of rock samples represents a model for the seismic process [1]. From the results of laboratory experiments the stick-slip process was observed at relatively low velocities of movement and at low stiffness. Natural seismic activity may be influenced by different external, including periodic, impacts. External influences on laboratory stick-slip processes induce changes in dynamical features and investigate by nonlinear analysis of interevents sequences of Acoustic Emission (AE) records. Analysis of the dynamics of interevent sequences is an important subject of researches in geosciences and in geocomplexity [2,3].

Methods. In the present research we analyzed AE data sets recorded from the laboratory set up, which represents a system of two horizontally oriented saw-cut basalt plates with height of surface about 0.1-0.2 mm. Influence force was applied to the upper (sliding) plate on 20 Hz vibrator. The weight of the sliding plate was 700 gr. In our experiments we have changed the frequency and the amplitude of periodical mechanical forcing [4].

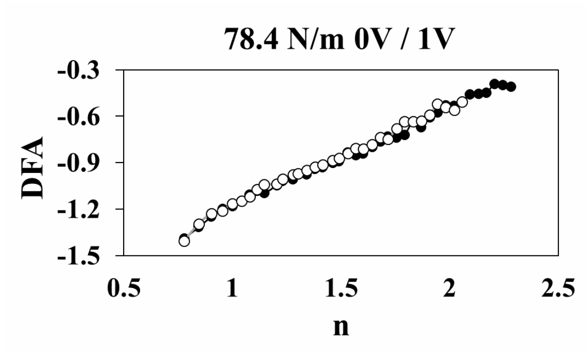
Stick-slip records were registered as acoustic bursts by the sound card of personal computer (PC). For testing three types of springs were chosen: 78.4 N/m, 235.2 N/m and 1705.2 N/m. The forcing frequency varied in range 0.5-120 Hz for different 0-3V voltages, applied to 20 Hz vibrator. The experimental records on PC were transfered by 100 Hz Piezo-Transmitter.

Nonlinear analysis have been carried out on time intervals (interevents sequences) between the bursts of laboratory AE records of stick-slip processes. $\Delta t = t(i+1) - t(i)$

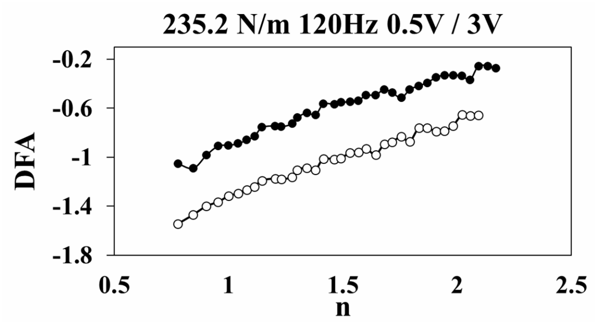
Long-term correlation and scaling features of the interevents sequences of AE have been assessed by DFA method [5]. Analysis represent quantitative parameters (DFA scaling parameter) and include full information about correlation of signals and used in different research fields: geophysics, meteorology, biology, economics, etc. The analysis shows self-similarity of the part of the system and it finds long-range correlations embedded in non-stationary time series.

The qualitative assessment and analysis of dynamic features of interevents sequences of AE of stick-slip process, we have used Recurrence Plot (RP) analysis method, which represents the best method of quailtative analysis of complex time series and allows us to assess the behavior of complex dynamic systems [6]. RP plots represent graphs with horizontal and vertical lines/clusters which correspond to different states of stick-slip process, which shows system regulation. From this plots we got information about changes structure of the stick-slip acoustic emission complex system under different external influence.

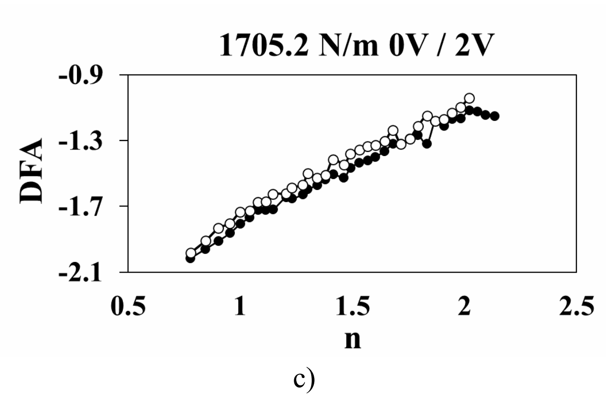
Results and discussion. Nonlinear analysis of interevents sequences of laboratory AE records of stick-slip processes clearly shows changes in dynamical structures. From the results of DFA analysis of interevents sequences AE records, we can see that long-range correlation and scaling features of AE undergoes clear changes under external influences (applied different voltage and frequency) and creates the regularity of the system. In the present research DFA has been accomplished at a polynomial fitting p=2 (see Fig. 1).



a)



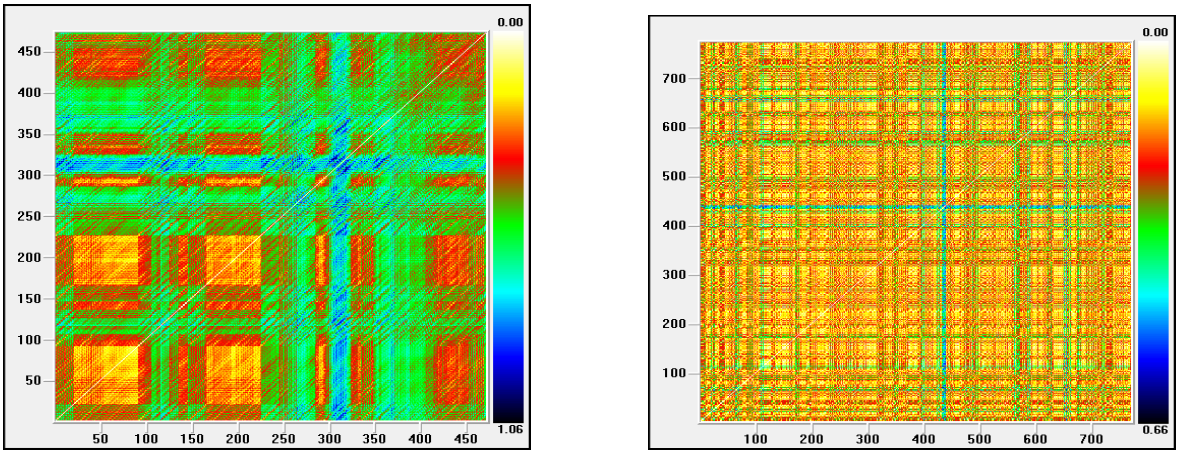
b)



c)

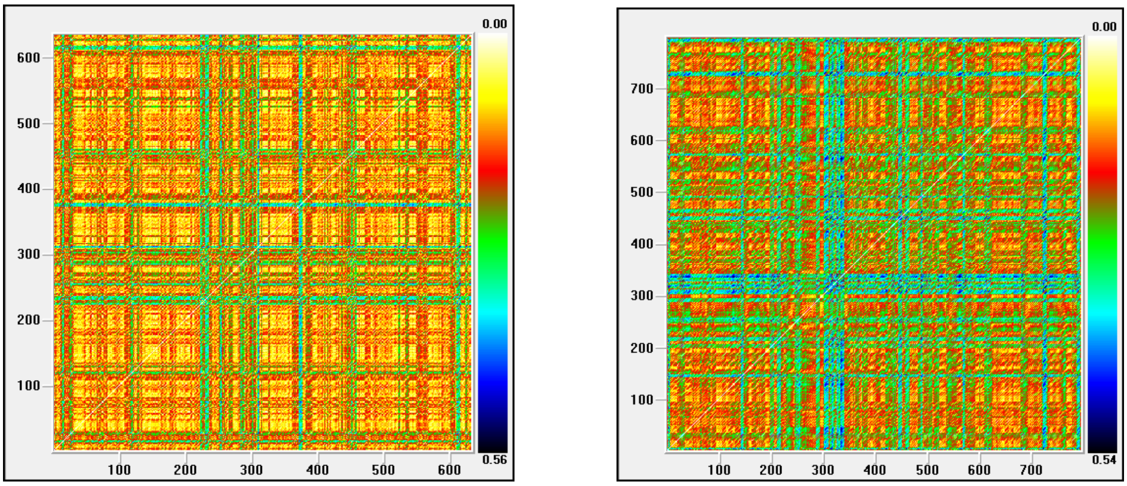
Fig.1 DFA analysis of interevents sequences of AE records: a) spring stiffness 78.4 N/m (white circles –natural conditions 0V, black circles – applied voltage 1V on 20Hz vibrator); b) spring stiffness 235.2 N/m (white circles – applied voltage 0.5V, black circles – applied voltage 3V and frequency 120Hz on 20Hz vibrator); c) spring stiffness 1705.2 N/m (white circles – natural conditions 0V, black circles – applied voltage 2V on 20Hz vibrator).

Results of RP analysis shows qualitative changes in regularity of interevents sequences of AE records. From RP plots we can see changes of recurrence structures at frequencies 20Hz and 120Hz (spring stiffness 235.2 N/m) under forcing intensity 01V, 2V). The recurrence structures are not clear for spring stiffness 78.4 N/m and 1705 N/m and the plots are similar to RP of random sequences (see Fig.2 – Fig.4).



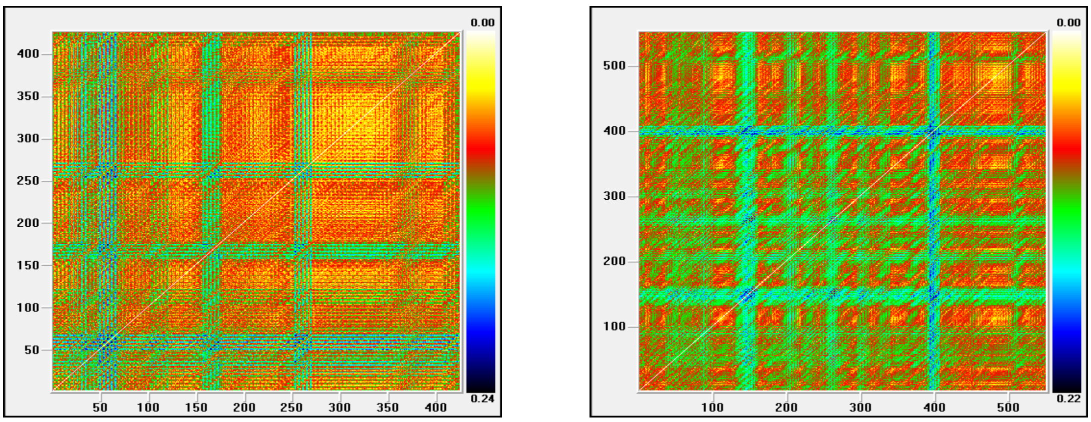
a) b)

Fig. 2. RP analysis of interevents sequences of AE records, spring stiffness 78.4 N/m: a) natural conditions 0V and b) – applied voltage 1V on 20 Hz sensor.



a) b)

Fig. 3. RP analysis of interevents sequences of AE records, spring stiffness 235.2N/m: a) applied voltage 0.5V and frequency 120Hz on 20 Hz sensor and b) – applied voltage 3V and frequency 120Hz on 20 Hz sensor.



c)

Fig. 4. RP analysis of interevents sequences of AE records, spring stiffness 1705.2 N/m: a) natural conditions 0V and b) – applied voltage 2V on 20 Hz sensor.

Conclusion. Time interval (interevents sequences) of laboratory AE records of stick-slip process have been analyzed. Results were observed at different applied voltage and frequency. For nonlinear analysis of laboratory AE data were used DFA and RP analysis. We observed changes occurred in the regularity of stick slip process under different external influences.

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