

Synchronization of multifractal properties of continuous acoustic emission during the preparation and implementation of dynamic slip in model fault

¹ Ivan A. Panteleev, <https://orcid.org/0000-0002-7430-3667>, pia@icmm.ru

² Vladimir I. Okunev, <https://orcid.org/0000-0001-6024-0848>, viok56@mail.ru

² Victor A. Novikov, <https://orcid.org/0000-0001-9009-8862>, novikov_victor_a@mail.ru

¹ *Institute of Continuum Mechanics, Ural Branch of the Russian Academy of Sciences, Perm, Russia*

² *Joint Institute for High Temperatures of the Russian Academy of Sciences, Moscow, Russia*

[Abstract](#) [PDF](#) [ENG](#)

[Резюме](#) [PDF](#) [RUS](#)

[Full text](#) [PDF](#) [RUS](#)

Abstract. According to the stick-slip model, the relative movement of the fault planes is an act of unstable sliding, where movement begins when the stresses tangential to the fault plane reach a certain limit. The physical mechanism of dynamic slip along a fault consists of the sequential formation of conglomerates of loaded particles (force chains) in the contact zone and their subsequent destruction. These chains together form a force skeleton characterized by a specific spatial structure and strength properties. An increase in shear stress on the fault banks leads to local destruction of the strength skeleton; further evolution of the system brings destruction processes to higher spatial levels, ultimately leading to a shift in the fault banks. Since the evolution of the process of destruction of force chains in the contact zone of a fault along the hierarchy of scales from bottom to top is similar to the evolution of crack formation in a loaded medium from microscale to macroscale (specimen scale), the authors hypothesized the coherent behavior of acoustic noise accompanying the preparation of dynamic slip and recorded in different areas of fault zones. This work is devoted to testing this hypothesis on a laboratory scale, using an installation that simulates movement along a fault. As a result of the analysis, the hypothesis about the synchronization of the statistical properties of the acoustic emission during the preparation and implementation of the dynamic movement was confirmed. It is shown that the observation (detection) of the effect of the synchronization of the statistical properties of acoustic emission depends both on the set of parameters for which the spectral coherence measure is calculated and on the location of the recording of the initial data.

Keywords:

model fault, acoustic emission, synchronization, multifractal properties

For citation: Panteleev I.A., Okunev V.I., Novikov V.A. Synchronization of multifractal properties of continuous acoustic emission during the preparation and implementation of dynamic slip in model fault. *Geosistemy peredodnykh zon = Geosystems of Transition Zones*, 2023, vol. 7, no. 4, pp. 405–418. (In Russ., abstr. in Engl.). <https://doi.org/10.30730/qtr.2023.7.4.405-418>; <https://www.elibrary.ru/bpomeb>

Для цитирования: Пантелеев И.А., Окунев В.И., Новиков В.А. Синхронизация мультифрактальных свойств непрерывной акустической эмиссии при подготовке и реализации подвижки по модельному разлому. *Геосистемы переходных зон*, 2023, т. 7, № 4, с. 405–418. <https://doi.org/10.30730/qtr.2023.7.4.405-418>; <https://www.elibrary.ru/bpomeb>

References

1. Bykov V.G. **2005**. [Strain waves in the Earth: theory, field data, and models]. *Geologiya i Geofizika*, 46(11): 1176–1190. (In Russ.).
2. Seminsky K.Zh. **2008**. Hierarchy in the zone-block lithospheric structure of Central and Eastern Asia. *Russian Geology and Geophysics*, 49(10): 771–779. <https://doi.org/10.1016/j.rgg.2007.11.017>
3. Kocharyan G.G., Kishkina S.B., Novikov V.A., Ostapchuk A.A. **2014**. Slow slip events: parameters, conditions of occurrence, and future research prospects. *Geodynamics & Tectonophysics*, 5(4): 863–891. (In Russ.). <https://doi.org/10.5800/GT-2014-5-4-0160>
4. Borneyakov S.A., Panteleev I.A., Cheremnykh A.V., Karimova A.A. **2018**. Physical modeling experiments to study periodic activation of faults in seismic zones. *Geodynamics & Tectonophysics*, 9(3): 653–670. (In Russ.). <https://doi.org/10.5800/gt-2018-9-3-0366>
5. Brace W.F., Byerlee J.D. **1966**. Stick-slip as a mechanism for earthquakes. *Science*, 153: 990–992. <https://doi.org/10.1126/science.153.3739.990>
6. Kocharyan G.G., Markov V.K., Ostapchuk A.A., Pavlov D.V. **2014**. Mesomechanics of shear resistance along a filled crack. *Physical Mesomechanics*, 17(2): 123–133. doi:10.1134/S1029959914020040
7. Ben-David O., Rubinstein S.M., Fineberg J. **2010**. Slip-stick and the evolution of frictional strength. *Nature*, 463: 76–79. <https://doi.org/10.1038/nature08676>

8. Kocharyan G.G., Ostapchuk A.A., Pavlov D.V., Gridin G.A., Morozova K.G., Hongwen J., Pantelev I.A. **2022**. Laboratory study on frictional behavior of rock blocks of meter scale. Methods and preliminary results. *Izv., Physics of the Solid Earth*, 58: 929–940. <https://doi.org/10.1134/s1069351322060064>
9. Lyubushin A.A., Sobolev G.A. **2006**. Multifractal measures of synchronization of microseismic oscillations in a minute range of periods. *Izv., Physics of the Solid Earth*, 42: 734–744. <https://doi.org/10.1134/S1069351306090035>
10. Lyubushin A.A. **2008**. Microseismic noise in the low frequency range (periods of 1–300 min): Properties and possible prognostic features. *Izv., Physics of the Solid Earth*, 44: 275–290. <https://doi.org/10.1134/s11486-008-4002-6>
11. Lyubushin A.A. **2009**. Synchronization trends and rhythms of multifractal parameters of the field of low-frequency microseisms. *Izv., Physics of the Solid Earth*, 45: 381–394. <https://doi.org/10.1134/s1069351309050024>
12. Lyubushin A.A. **2010**. The statistics of the time segments of low-frequency microseisms: Trends and synchronization. *Izv., Physics of the Solid Earth*, 46: 544–554. <https://doi.org/10.1134/s1069351310060091>
13. Lyubushin A.A. **2011**. Seismic catastrophe in Japan on March 11, 2011: Long-term prediction on the basis of low-frequency microseisms. *Izv., Atmospheric and Oceanic Physics*, 46: 904–921. doi:10.1134/S0001433811080056
14. Lyubushin A.A. **2012**. [Forecast of the Great Japan Earthquake]. *Priroda = Nature*, 8: 23–33. (In Russ.)
15. Myachkin V.I., Kostrov B.V., Shamina O.G., Sobolev G.A. **1975**. [Fundamentals of focal physics and earthquake precursors]. In: *Physics of earthquake source*. Moscow: Nauka, 9–41. (In Russ.)
16. Lockner D.A., Byerlee J.D., Kuksenko V.S., et al. **1992**. Observations of quasistatic fault growth from acoustic emissions. In: Evans B., Wong T.-F., et al. (Eds.). *Fault mechanics and transport properties of rocks*. London: Acad. Press, p. 3–31.
17. Sobolev G.A., Ponomarev A.V. **2003**. [*Earthquake physics and precursors*]. Moscow: Nauka, 270 p. (In Russ.)
18. Sobolev G.A. **1993**. [*Fundamentals of the earthquake prediction*]. Moscow: Nauka, 313 p. (In Russ.). EDN: TGSIGH
19. Pantelev I.A., Bayandin Yu.V., Plekhov O.A. **2022**. Effect of synchronization of continuous acoustic emission statistical properties during structurally heterogeneous materials deformation. *Vestnik PNIPU. Mekhanika = Bulletin of PNIPU. Mechanics*, 3: 5–13. (In Russ.). <https://doi.org/10.15593/perm.mech/2022.3.01>
20. Ostapchuk A.A., Pavlov D.V., Markov V.K., Krashenninikov A.V. **2016**. Study of acoustic emission signals during fracture shear deformation. *Acoustical Physics*, 62(4): 505–513. <https://doi.org/10.1134/s1063771016040138>
21. Kocharyan G.G. **2016**. *Geomechanics of faults*. Moscow: GEOS, 424 p. (In Russ.)
22. Kocharyan G.G., Novikov V.A. **2016**. Experimental study of different modes of block sliding along interface. Pt 1. Laboratory experiments. *Physical Mesomechanics*, 19: 189–199. <https://doi.org/10.1134/s1029959916020120>
23. Gerasimova E., Audit B., Roux S.-G., Khalil A., Gileva O., Argoul F., Naimark O., Arneodo A. **2014**. Wavelet-based multifractal analysis of dynamic infrared thermograms to assist in early breast cancer diagnosis. *Frontiers in Physiology*, 5: 176. <https://doi.org/10.3389/fphys.2014.00176>
24. Ghost D., Dutta S., Samanta S. **2012**. Fluctuation of gold price: a multifractal approach. *Acta Physica Polonica B*, 43(6): 1261–1274.
25. Absil P., Sepulchre R., Bilge A., Gerard P. **1999**. Nonlinear analysis of cardiac rhythm fluctuations using DFA method. *Physica A: Statistical Mechanics and its Applications*, 271: 235–244. [https://doi.org/10.1016/s0378-4371\(99\)00295-2](https://doi.org/10.1016/s0378-4371(99)00295-2)
26. Makoviec D., Galaska R., Dudkowska A., Rynkiewicz A., Zwierz M. **2006**. Long-range dependencies in heart rate signals – revisited. *Physica A: Statistical Mechanics and its Applications*, 369: 632–644. <https://doi.org/10.1016/j.physa.2006.02.038>
27. Biswas A., Zeleke T.B., Si B.C. **2012**. Multifractal detrended fluctuation analysis in examining scaling properties of the spatial patterns of soil water storage. *Nonlinear Processes in Geophysics*, 19: 227–238. <https://doi.org/10.5194/npg-19-227-2012>
28. Movahed M.S., Jafari G.R., Ghasemi F., Rahvar S., Reza Rahimi Tabar M. **2006**. Multifractal detrended fluctuation analysis of sunspot time series. *Journal of Statistical Mechanics: Theory and Experiment*, 2006(02): 02003. <https://doi.org/10.1088/1742-5468/2011/09/e09001>
29. Pedron I.T. **2010**. Correlation and multifractality in climatological time series. *Journal of Physics: Conference Series*, 246: 012034. <https://doi.org/10.1088/1742-6596/246/1/012034>
30. Pantelev I.A., Bayandin Yu.V., Naimark O.B. **2016**. [Spatial and temporal patterns of damage development during deformation of a glass fiber woven laminate according to acoustic emission data]. *Fizicheskaya mezomekhanika = Physical Mesomechanics*, 19(4): 64–73. (In Russ.)
31. Lyubushin A.A., Jr. **1998**. Analysis of canonical coherences in the problems of geophysical monitoring. *Izv., Physics of the Solid Earth*, 34(1): 52–58.
32. Lyubushin A.A. **2007**. [*Analysis of data from geophysical and environmental monitoring systems*]. Moscow: Nauka, 228 p. (In Russ.)