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Synchronization effects in systems with dry friction

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Abstract of doctoral dissertation

Synchronization is an interdisciplinary phenomenon which was successfully studied from different perspectives. Synchronous behaviour of many dynamical systems has been observed for a long time. Recent developments in non-linear dynamics and computing enabled researchers for further investigations in that topic. The study of synchronization properties in systems with friction lies in the scope of the present doctoral thesis. In order to describe nature of friction, various models have been developed, which take into account various properties of friction. However, none of them fully describes friction phenomenon in all its aspects.

The presented direction of the research has determined the main goal of the doctoral thesis, which is to investigate the synchronization properties of dynamical systems with dry friction. The main objective is achieved by investigation of friction with respect to its macroscopic properties, numerical modelling of coupled oscillators with dry friction and comprehensive analysis of synchronization effects of the investigated systems. As a result of aforementioned considerations, the main thesis of the dissertation assumes that in mechanical dynamical systems with dry friction phenomenon, it is possible to observe synchronization between coupled elements of the system.

The concept of the studied systems is implemented by coupled self-induced dry friction oscillator model. Stribeck model with exponential non-linearity serves as a benchmark model in this study. The discontinuity typical for the friction model is smoothed with help of arctangent function to ease the numerical calculations. Additionally, a non-smooth approach using so called switch model is presented for comparison.

The focal point of the doctoral thesis was to determine synchronization thresholds in the networks of identical stick-slip dry friction oscillators connected in open and closed ring topologies using nearest-neighbour principle.

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This is done by numerical computation of global and cluster synchronization errors. Networks of different length are verified in one and two-parameter space (coupling coefficient vs. angular frequency of excitation) for the existence of complete and cluster synchronization. The analysis of synchronous regions showed that complete synchronization occurs more likely for low coupling coefficients in both tested topologies. Results obtained from the brute force numerical integration are compared against the outcome of the master stability function (MSF) realized by means of two-oscillator probe. Numerous examples of complete synchronization and cluster synchronization have been shown in both network topologies. In case of closed ring networks the cluster synchronization appears in wide variety of clusters configuration. The synchronization thresholds obtained using numerical simulation corresponds to the one obtained by the MSF method. One can observe that increase of the network size leads to scaling down of the level of synchronizability of the system. It is shown that the MSF based on two-oscillator probe can be applied for the prediction of synchronization thresholds in systems with stick-slip phenomenon. The detected synchronization regions confirm the main thesis of the dissertation mentioned above.

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