Complexity of Nonlinear Waves Observed in a Large Array of Fluid-elastic Oscillators

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ABSTRACT

For centuries in engineering fields, researchers have examined the flow of a fluid around an object and vibration of such an object. However, pattern-formation phenomena appearing in an oscillatory system with numerous degrees-of-freedom such as those of a system including up to 1000 oscillators have never been explored. Therefore, through experimentation, we investigate this well known and persistent fluid-engineering problem.

As a model experiment, we chose complex fluid-excited vibrations exhibited by an array of vertically cantilevered elastic rods arranged on a lattice in a uniform cross-flow [1]. Nonstationary complex phenomena occurring in large arrays of up to 1000 vibrating rods in a wind tunnel were investigated in this experiment [2]. First, a critical flow velocity triggers emergence of a global dynamic pattern throughout the rod array. Second, a power law governs the scaling relationship between the rod impact rate and the flow velocity. Accelerometer data show that the rod impact rate versus the flow velocity shows a power-law scaling relation. Third, a global spatiotemporal order emerges along with local complexity as the flow speed increases. As the intensity of interaction among neighboring elements (in this case, frequency of collisions among rods) increases, the set of elements (in this case, the rod array) achieves globally patterned behavior. Video images reveal that, initially, each rod moves individually; then clusters comprising several similarly moving rods become apparent. Finally, a wave motion is visible along the edges of the array of 1000 polycarbonate rods. A global wave-like motion occurs at higher flow velocities [3].

Results of this study are directly applicable to nonlinear vibration associated with heat exchanger pipes, pin-fin-type heat-sinks for personal computer components, and so on. In addition, it can be a model experiment for countermeasures against wind damage in agriculture or civil engineering applications.

REFERENCES

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