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Coupled phase oscillator lattices and plastic flow

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Globally coupled phase oscillators have been studied as a solvable model of phase transitions via mutual synchronization. In oscillator lattices, phase oscillators are set on a lattice point of square and cubic lattices and they interact with the nearest-neighbors. A vortex is a topological defect in the oscillator lattices. If the phase is interpreted as a displacement of an atom in a crystal, a vortex corresponds to a screw dislocation in a crystal. Plastic flow is induced by the dislocation motion in crystals. Similarly, phase slips are induced by the vortex motion in oscillator lattices. The frequency profile in the oscillator lattice corresponds to the velocity profile in plastic flow in crystals. The shear stress is applied as plus and minus forces at the upper and lower boundaries. We will show several numerical results of the vortex motion under the shear stress. The vortex begins to move above a critical value of the shear stress. Two vortices of plus and minus signs can pass through each other. The desynchronization is induced by the reciprocal motion of a single vortex. The single vortex moves like a random walker in a tilted potential even below the critical shear stress if thermal noises are added. If the temperature of the thermal noises is higher, many vortices are spontaneously generated and the desynchronization is induced by the random motion of vortices. The frequency profile is not a linear function of y between the upper and lower boundaries, but the frequency profile is fairly flat in the central region and changes rapidly near the boundaries. Our phase oscillator lattice model might be useful as a simple model to understand the complicated plastic flows in solids.