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Aperiodic, chaotic lid-driven square cavity flows

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Abstract

At any Reynolds number the temporal limit satisfies two principles. One concerns the arousing of tiny counterclockwise- or clockwise-rotating eddies attached to a rigid wall; the other, the merging and splitting of counterclockwise- or clockwise-rotating eddies, accounting for the tails and the drops. At high Reynolds numbers at the bottom right corner a wide secondary eddy stands out downside attached to both the bottom wall and the right wall. At intervals the primary eddy flips it away from the bottom right corner, and then, loose, it loops clockwise—twice at most. At ultra-high Reynolds numbers the secondary eddies widen further and further. And the loose secondary eddies looping clockwise do so permanently and number more and more, often merging on the fly. At intervals they provoke a pouring of tiny secondary eddies attached to the right wall a little bit below the top right corner. Up to Re = 200, 000 the temporal limit is aperiodic. Always the primary eddy rotates clockwise. Yet, at Re = 500, 000 the temporal limit is chaotic. At the upside of the total kinetic energy range, at first the primary eddy rotates clockwise, but then a competition for becoming the primary eddy sets up, the counterclockwise-rotating eddies widening enough, until a counterclockwise-rotating primary eddy prevails. At the downside, the primary eddy rotates counterclockwise. At the midside, at first the primary eddy rotates counterclockwise, but then a competition for becoming the primary eddy sets up, the clockwise-rotating eddies widening enough, until a clockwise-rotating primary eddy prevails. This alternating behavior persists, the temporal limit emerging: complex, sensitive—unpredictable.

Keywords: Navier–Stokes equations; Lid-driven square cavity flows; Aperiodic flows; Chaos

1. Introduction

What is the nature of the temporal limit [12] of the lid-driven square cavity flow at a fixed Reynolds number Re, and then how it evolves as $\mathrm{Re} \to \infty$?

This question is investigated by numerical experiments which run for a sufficiently long time $t_\infty = 150,000$ to make sure it has been reached.

At any Reynolds number it satisfies two principles:

First principle: A strong, still clockwise- or counterclockwise-rotating eddy attached to a rigid wall leaves it somewhere to turn away from it, arousing nearby, within itself a tiny counterclockwise- or clockwise-rotating eddy attached to it—perhaps stirring this up.

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