Rheo-art - Application of Fluid Dynamics to Art Creation

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It is well known that repeated unsteady motion of walls of a container filled with a highly viscous fluid can produce a chaotic mixing in the fluid, which is called "Lagrangian turbulence" (Ottino, 1989a,b). It can be visualized by adding some dyes with the same viscosity. The main interest in this phenomenon has been the mechanism of chaotic behavior as a result of accumulation of laminar flows. In fact, resultant dye patterns are similar to the Poincare maps of chaotic behavior of dynamical systems.

On the other hand, this phenomenon has been attracting people because of the beauty of resulting patterns. This fact suggests that this phenomenon can be applied as a new method of creating artworks. The term "rheo" in the title means a flow, and "rheo-art" is an art produced by application of the fluid dynamics. Since there are a lot of flow patterns, there should be also many kinds of rheo-art. But, in this paper we confine ourselves to the viscous mixing noted above.

The present author has recently made an attempt to apply 2D chaotic mixing to produce attractive patterns numerically (Takaki & Tomioka, 1997). It is here extended to 3D mixing case. The purpose of this paper is to present results of these attempts, and to make a fundamental discussion on the difference between art and science.

The 2D chaotic mixing is produced by a method similar to that first introduced by Aref (1984). Two circular cylinders are set vertically in a container filled with a viscous fluid. They are rotated very slowly by certain angles in turn, so that the fluid around them moves according to the Stokes flow theory (valid for slow viscous flows). Rotation angles of the right and left cylinders are denoted with surfices 1 and 2, respectively, and the clockwise rotation is denoted by a positive angle.

In the first case with two cylinders, one step of mixing processes is composed of the following set of rotations (Fig.1): $(\Omega_1, \Omega_2, -\Omega_1, -\Omega_2)$. Seven dye spots are put at the beginning in hexagonal configuration. After several steps we have delicate and beautiful patterns as shown in Fig.1. In the second case with four cylinders, one step of processes is composed of rotations $(\Omega_1, \Omega_2, \Omega_3, \Omega_4, -\Omega_1, -\Omega_2, -\Omega_3, -\Omega_4)$. Results in this case are shown in Fig. 2.

Note that these patterns are symmetry breaking, because the elementary processes have an asymmetry with respect to which cylinder is rotated first.

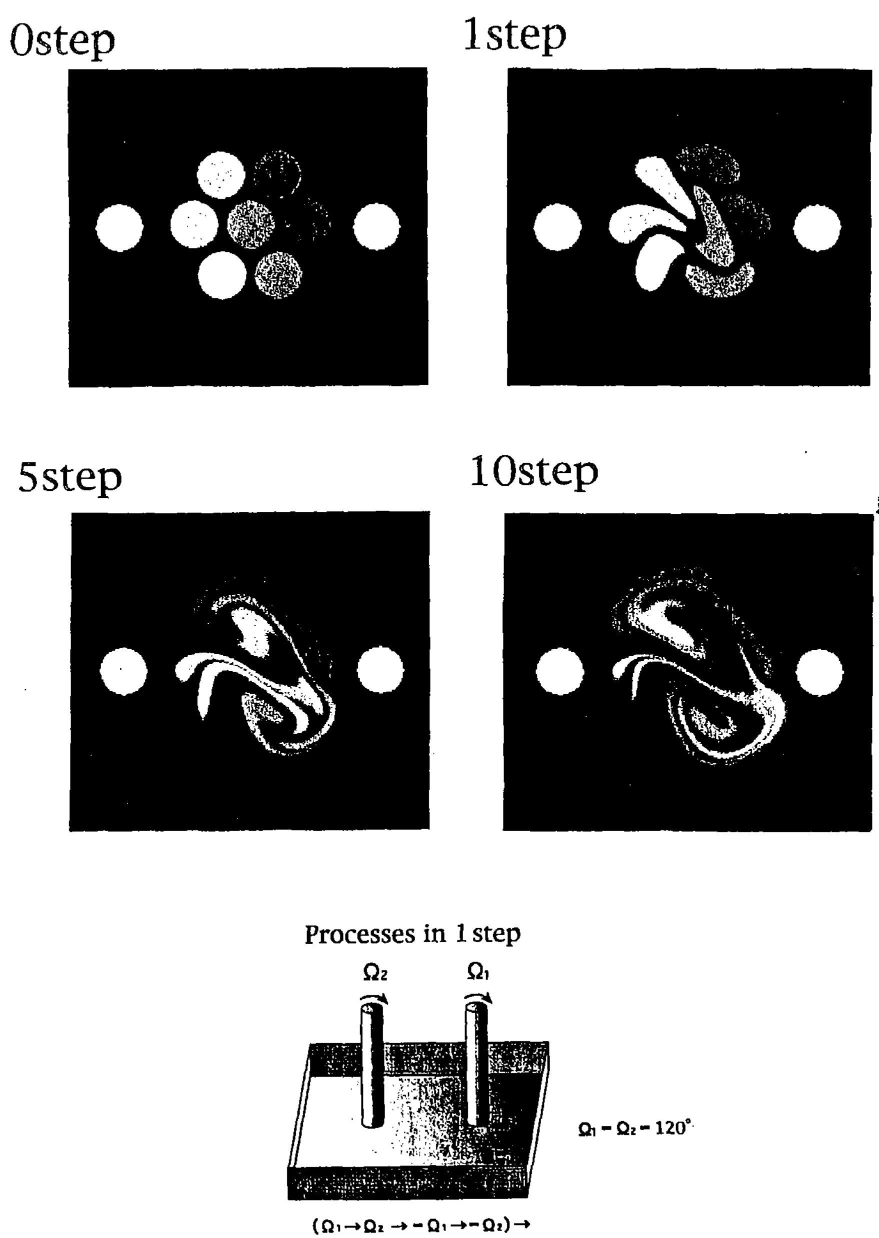

Fig.1. Configuration of 2 cylinders and created patterns.

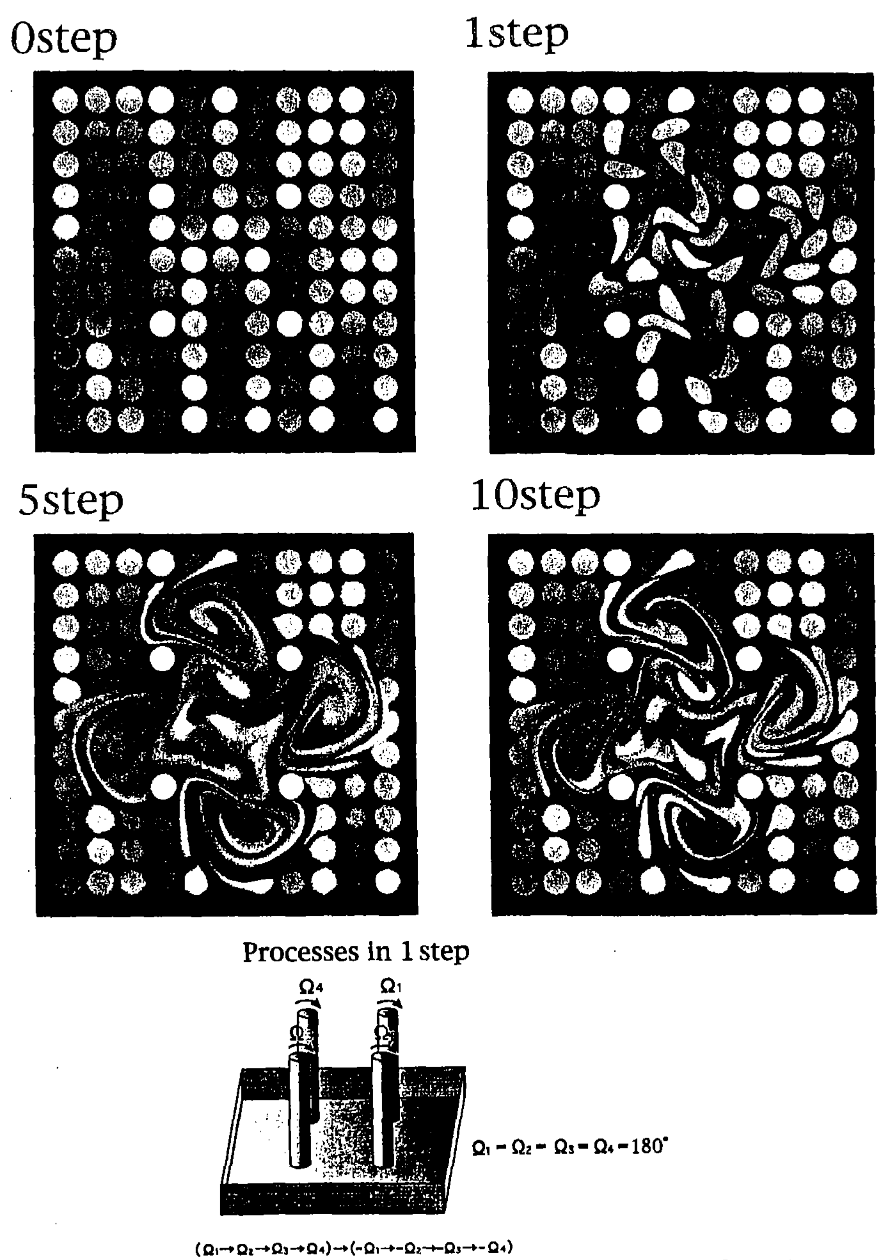

Fig.2. Configuration of 4 cylinders and created patterns.

Similar operations are made in the case of 3D viscous mixing. Two cylinders are placed perpendicularly with their axes apart, and a spherical dye is placed as an initial condition between the two cylinders. Each cylinder is rotated by 180^o always in the same direction, but one after another . Dye deformation after 9 steps is shown in Fig. 3, which is drawn by the use of a software of ray-tracing.

The resulting 3D dye shape was reproduced fairly faithfully to a solid model (called a scientific model) with a help of a sculpture artists, Nakatsugawa. At the same time the author asked him to create a new shape (called a artificial model) inspired by this solid model (see Fig. 4). There are some differences between these models. First, the artificial model lacks the thin tail and has a spherically concave part. Secondly, the scientific model has more monotonically changing parts, while the artificial model has more wavy parts.

Discussions are given here as to the present results. The difference of art and science would be discussed based the difference of these two models. The scientific model is an outcome of a deterministic physical process, while the artificial one is hand-made and not described mathematically. In the scientific model artificial controls are confined only to selections of parameters (such as Ωs), initial positions and initial shapes of dyes. These points could be generalized as an essential difference of art and science. The term "science art" may be defined in this context as something in between.

In the examples the resulting patterns are nearly symmetrical, while a certain degree of asymmetry is mixed. This coexistence of order and disorder seems to be an origin of attractiveness.

Finally, it is suggested that the present attempt may be developed to a new method of creating art, where our sensitivity is respected in selecting patterns while scientific method is conserved.

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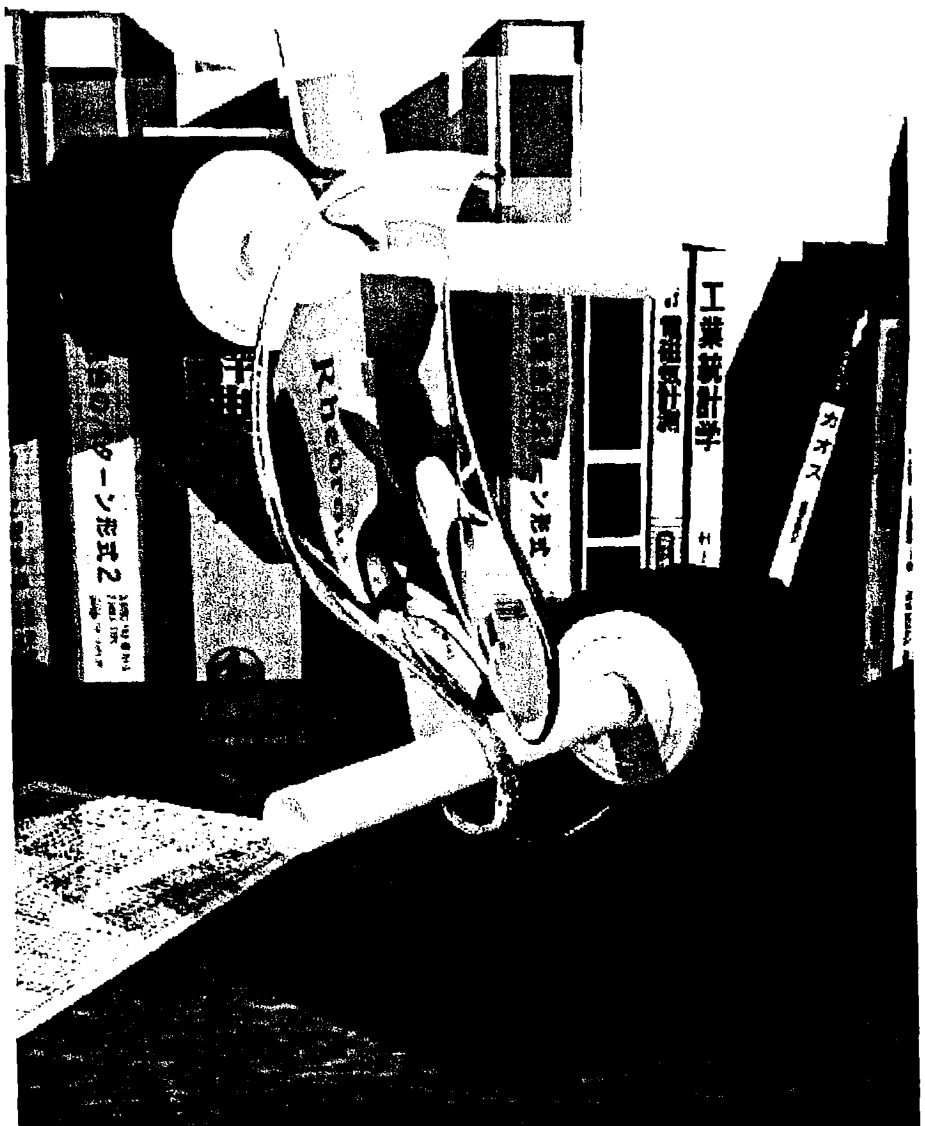

Fig.3. 3D viscous mixing visualized by a ray-tracing method drawn by a CG designer, Tomioka.

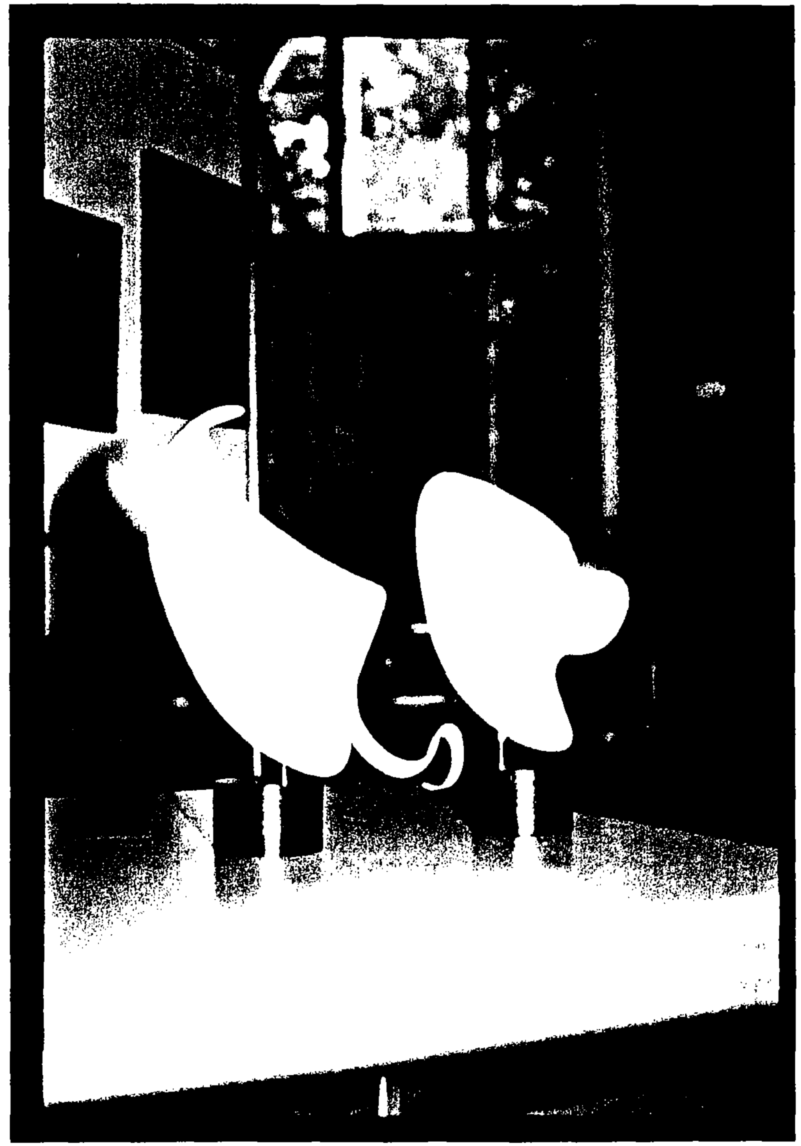

Fig.4. Scientific model (left) and artificial model (right) hand-made by an artist, Nakatsugawa.