STUDY OF THE VORTEX RINGS INTERACTION BY 3D VORTICITY PARTICLE–IN–CELL METHOD

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Summary The vortex rings interactions were studied. At first the leap–frogging phenomenon for inviscid flow was investigated. It was shown that dynamics of the vortex rings is very sensitive to the initial parameters like diameters of the rings, their mutual positions and circulations. For viscous flow the vortex rings reconnection was studied. The vorticity particle–in–cell method for three-dimensional, viscous flow was used.

VORTEX RINGS INTERACTION

The vortex rings are the simplest 3D vortex structure that can be observed in the turbulence flow. It is the structure that is relatively easy reproduced in the laboratory. The interaction of two vortex rings gives an interesting and good example of non–linear interaction of the regions with concentrated vorticity and it may serve as a clue to understanding them. Despite of the simple geometry the dynamics of the integrations of two rings are very reach and complex. It is very sensitive on initial parameters and circulation. One of the most fascinating phenomena relates to the interaction of two vortex rings moving along a common axis of symmetry in the same direction. In this case the effects of the mutual influence of two vortex rings consist in enlargement of the diameter and retardation of the former ring, and simultaneously, in contraction of the diameter and acceleration of the other one (leap–frogging phenomenon) [3]. The small changes in the initial in parameters produced different behavior of the vortex rings. The „vortex game" numerically can be demonstrated for inviscid fluid (Fig. 1).

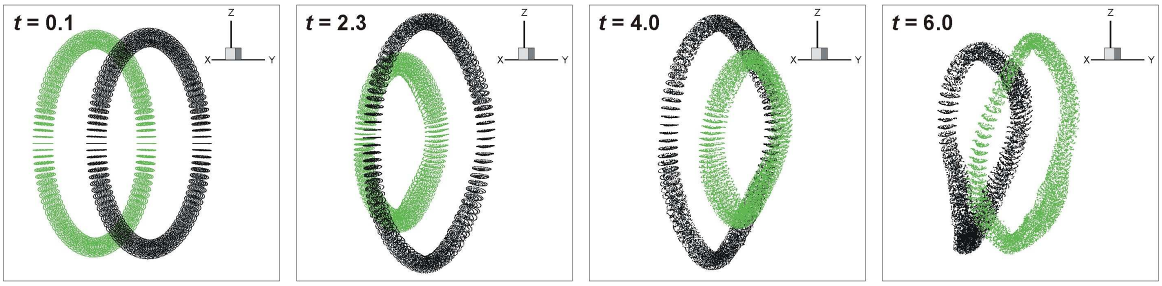

Figure 1. The sequence of the time position of the vortex particles for the leap–frogging phenomenon in the inviscid flow

One can observed „pure" form of the vortex game but also the appearance of the tail structure (Fig. 2) and some times the rearward ring becomes entrained into forward one.

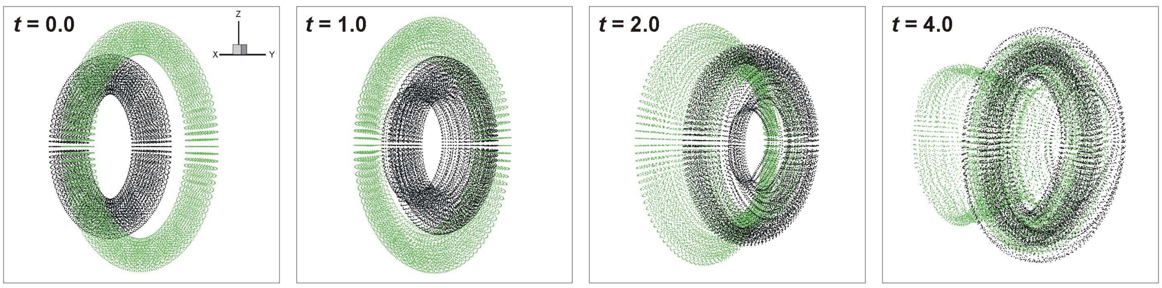

Figure 2. The sequence of the time position of the vortex particles for the tail structure in the inviscid flow

When the viscosity is taken into account the vortex ring reconnection can be observed [2, 5]. The term „reconnection" signifies a distinct change in the connectivity of configuration of two rings with opposite circulation that collide with each other (Fig. 3).

VORTICITY PARTICLE–IN–CELL METHOD

For the study of the vortex ring interactions we used the vorticity particle method that in 2D version is known as a vortex–in–cell method [1]. One can distinguish two different types of vortex methods: the direct method based on the Biot-Savart

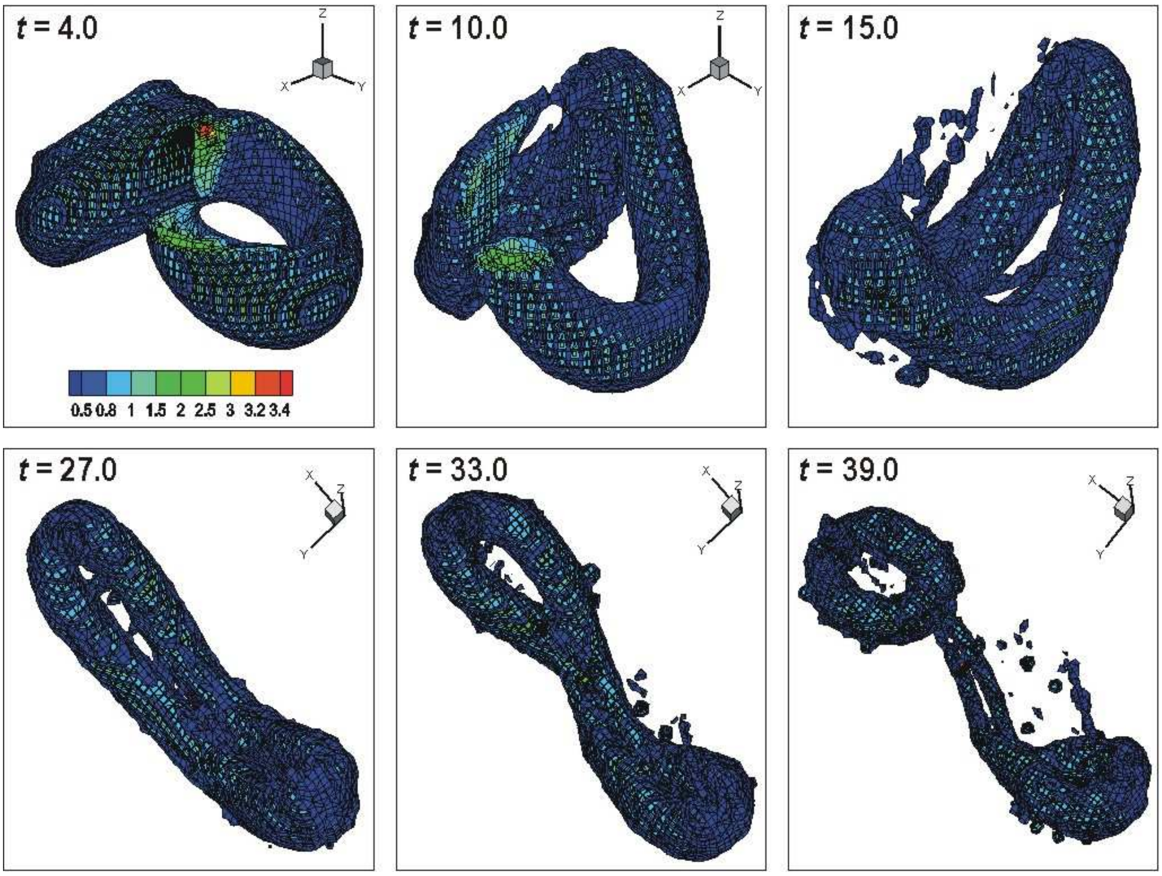

Figure 3. Time evolution of $|\omega|$ surface during the reconnection phenomenon of two vortex rings. For better viewing, the bottom diagrams show the vorticity field from a different direction than the top ones do

law where the velocity of each vortex element is calculated by summing up the contribution of the all particles in the domain, and the vortex–in–cell method where the velocity is obtained on the grid nodes by solving Poisson equations for the vector potential [4]. Then the vector potential is differentiated numerically by the finite difference method in order to obtain the velocity on the grid nodes and interpolate its value to the particle position. Most of the published results relate to the 2D VIC method and one can find very few application of this method for 3D flows. Despite the fact that vorticity is divergence free we introduced to the computation a vector particle that carries the „mass" of the vorticity. Due to that fact during the computation we monitored the divergence of the vorticity, velocity and vector potential fields. We also monitored invariants of the motion like kinetic energy, helicity and enstrophy. To simulate the viscous effect we used the viscous splitting algorithm: at first we solved the Euler equations by VIC method and next the viscous effect was taken into account by particle strength exchange method.

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