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PARALLEL COMPUTATIONS ON GPU OF VORTEX TUBES RECONNECTION USING VORTEX PARTICLE METHOD

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Understanding the dynamics and the mutual interaction among various types of vortical motions, including vortex reconnection, is a key ingredient in clarifying and controlling fluid motions. There is much experimental evidence that tube-like vortex regions evolve and interact at high Reynolds number in 3D turbulent flow. One can imagine that most of the physical space is filled with irrotational or very weakly rotational fluid and that the flow is driven by “small” diameter vortex tubes. The breaking and rejoining of vortex lines may be a fundamental process in the evolution of three-dimensional vortices and the mechanics of turbulence (Saffman, 1990).

In the paper it was simulated the reconnection process for two vortex tubes with the same intensity. The Vortex-In-Cell (VIC) method was used. Due to problems with very long time of computations on the single processor we decided to use the parallel implementation of the VIC method on the multicore architecture of the graphics card. Graphics Processing Units (GPUs) that were developed for video games can provide cheap and easily accessible hardware for scientific calculations.

The VIC method is very well suited for parallel computation. Test concerning movement of a vortex ring in inviscid fluid was carried out. The calculations were done on a single processor (CPU – Intel Core i7 960) and on a graphics card (GPU – NVIDIA GTX 480). Execution time for the application running on the GPU was 46 times shorter then the one using CPU. This is a very significant speed up.

In viscous fluid a test with reconnection of two antiparallel vortex tubes was carried out. There are some common mechanisms in the reconnection process of two vortex tubes with nearly the same intensity. We noticed a typical sequence of physical events that was observed also by the others (Kida, Takaoka, 1994), (Zabusky, Melander, 1989). First, the tubes tend to approach each other in antiparallel fashion advected by the mutual- and self-induction velocity. As the two vortex tubes get closer, the shape of the vortex core is deformed typically in to so-called head-tail structure. Then viscous cancellation of opposite signed vorticity in the interaction zone initiates vorticity reconnection. Advected by a complicated three-dimensional velocity field, the vorticity lines now experience a cross-linking, or bridging.

In the Figure 1 one can see comparison between results from (Zabusky, Melander, 1989) and current work. The agreement is very good which shows correctness of the code.

As typical in numerical simulations the denser numerical grid gives better results. The problem with computation on denser grids is the small amount of RAM memory on GPU (NVIDIA GTX 480 used in current work had only 1.5GB). To overcome this problem one have to use many GPUs for computations. Method of conducting computations on many GPUs will be shown as well as results and scaling on multiGPU cluster environment.

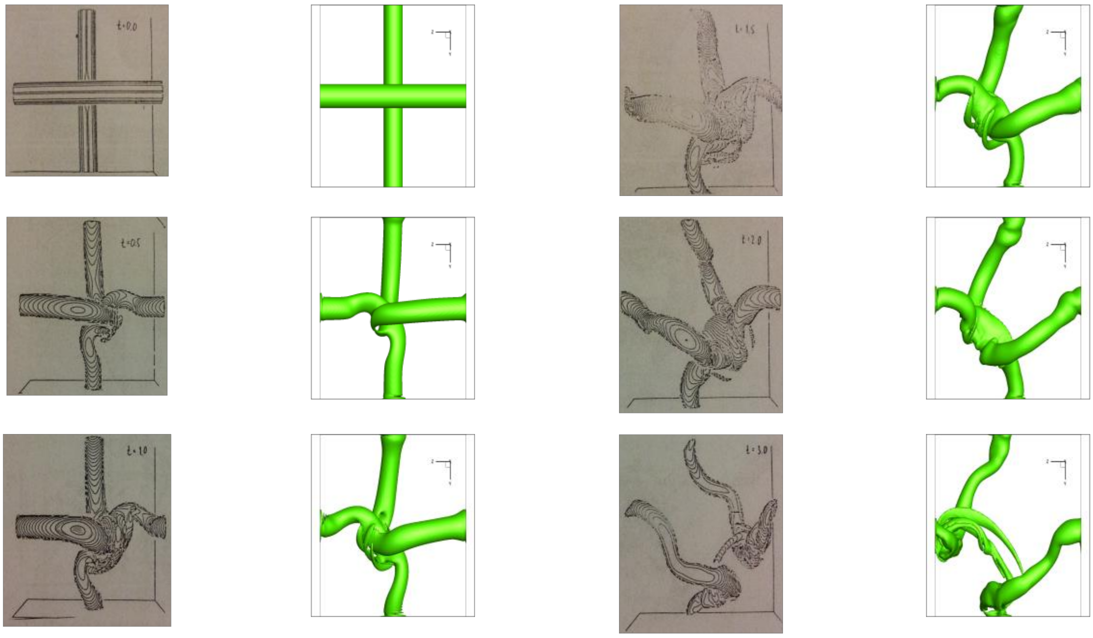

Fig. 1. Vortex tube reconnection. Comparison between (Zabusky, Melander, 1989) – left and current work – right.

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References

Kida S., Takaoka M. (1994): *Vortex Reconnection*, Annual Review of Fluid Mechanics, Vol. 26, pp. 169-189

Saffman P. G., (1990): *A Model of Vortex Reconnection*, Journal of Fluid Mechanics, Vol. 212, pp. 395-402

Zabusky N. J., Melander M. V., (1989): *Three-dimensional Vortex Tube Reconnection: Morphology For Orthogonally – Offset Tubes*, Physica D, Vol. 37, pp. 555-562