LINEARIZATION AND NUMERICAL STUDY OF A COMPLETE SYSTEM OF NAVIER-STOKES EQUATIONS

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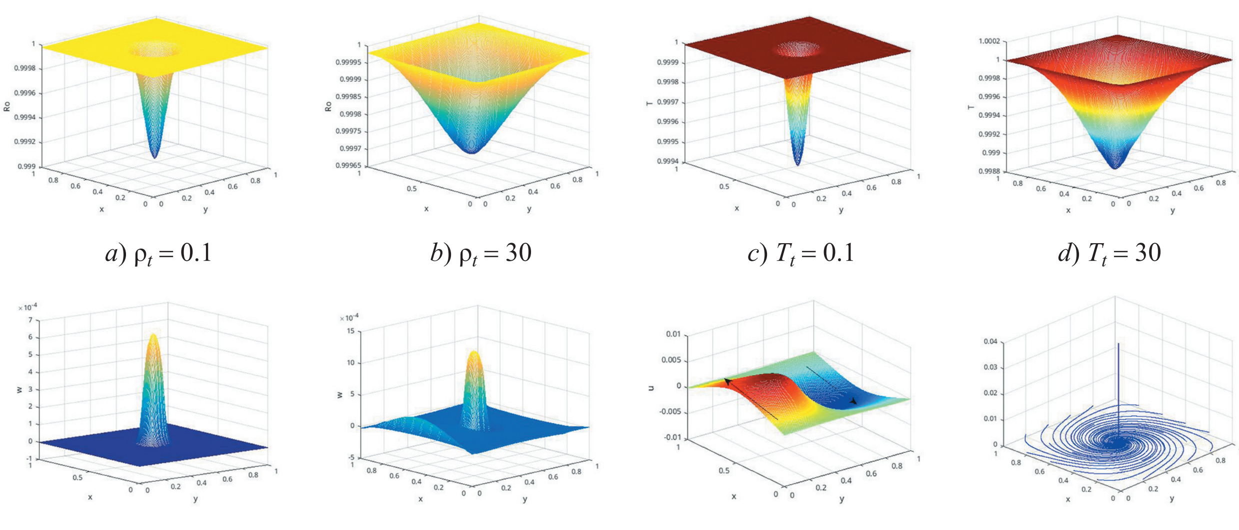
According to the mechanism proposed in [1] for the initiation and stable existence of skewed rising streams (SRS), the main reasons for their stable functioning include their long existence and Earth rotation that gives, via the Coriolis force, quite a high peripheral velocity to air particles near the stream bottom. The paper describes numerical studies aimed to develop the stable peripheral motion of air near the bottom of a skewed rising stream using a vertical pipe with a draft fan to make the air move upward through the pipe [2]. Numerical simulation of such gas flows helps formulate specific proposals and recommendations for the large-scale experimental swirling of large bodies of air.

The paper discusses linearization [3] of a complete system of Navier-Stokes equations that allow for gas compressibility and dissipative effects of viscosity and heat conduction so that the laws of mass, momentum and energy conservation hold. The laws of thermodynamics are also satisfied due to equations of state included.

Also, the paper describes our numerical study of the system with appropriate initial and boundary conditions. The computational domain is a rectangular parallelepiped whose sizes correspond to those of SRSs with different intensities [4]. Its lower plane coincides with the Earth surface. A square hole in its upper plane is intended for vertical air blowing.

Simulation of flows in a small-scale SRS. Fig. 1 presents densities, temperatures, and the third and second components of the gas velocity vector at a height of 0.25 m, and streamlines from calculations at two times (0.1 and 30 s).



a) $\rho_t = 0.1$ *b*) $\rho_t = 30$ *c*) $T_t = 0.1$ *d*) $T_t = 30$

e) $w_t = 0.1$ *f*) $w_t = 30$ *g*) $u_t = 30$ *h*) streamlines

Fig. 1 Gas dynamics characteristics of flows in a small-scale SRS

The density of gas along the perimeter of the calculation domain remains constant and equal to the density of the stationary distribution. At initial times we observe the density to smoothly reduce to the center of the calculation domain. With the increasing time the variation of density gets stationary as the time goes on to increase. The gas density surface becomes funnel-shaped with low densities in the center.

Despite that the air is blown through the upper hole, the solution of the linearized system gives a reduction of temperature in the center of the computational domain under the hole, while the peripheral temperature corresponds to its constant value in the initial stationary distribution.

Getting closer to the center of the domain one can notice the axial symmetry.

The vertical velocity of gas particles is close to zero everywhere on the periphery, while in the region of its blowing it gradually increases in accord with the law of blowing and reproduces in its section the contour of the square hole.

At initial times, in the entire region of zero velocities in the center of the computational domain, there appear zones where the *x* velocities differ from zero and are opposite in sign. Arrows in the figures show the directions of gas particles. Later the zones with the positive and negative *x* components markedly shift.

Such a redistribution of the x velocity in space means that the opposite and separated streams of gas appear near the center of the computational domain which is equivalent to a gas flow positively twisted around the vertical axis. The process is accompanied with the increase of velocity magnitudes and the growth of these zones, i.e., gas twisting in the positive direction enhances.

The second velocity component behaves similarly and we omit its description here.

The figures also show 3D results for instantaneous streamlines in the region close to the vertical part of the SRS. It is seen how gas gradually twists near the bottom and the rotary motion of the continuous medium transfers to the vertical part of the SRS. The vertical part seen in the figures is an analog (numerical model) of the trunk in a natural vortex.

References

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