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A NUMERICAL RESEARCH OF HELICOPTER ROTORS SPECIAL REGIMES AERODYNAMICS

BY

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A NUMERICAL RESEARCH OF HELICOPTER ROTORS SPECIAL REGIMES AERODYNAMICS

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Nonlinear unsteady theory of helicopter rotors aerodynamics allows modeling real processes occuring on helicopter rotors in numerical experiment. This possibility was used to learn special reqimes aerodynamics. Impossibility of precise forecast of the form and behavour of the vortex sheet significantly influencing on rotors aerodynamic charecteristics is typical for these regimes.

One of these reqimes is a vortex ring regime which realizes in some velocity range at the main and tail rotors movement to the side opposite to the rotor thrust force action.

The research shows the existance of two stages the regime goes by. A ring vortex torus forms in the rotor spinning plane and the vortex wake sums in it on the first stage. On the second stage the summary vortices begin to separate by the running flow and a structure looking like the Karman path is created.

Completely the vortex ring regime on the different schemes rotors occurs in the same way. But there are their own particularities for each of them.

The ring vortex torus in the rotor spinning plane is accepted as a typical signature of the vortex ring regime. To suppose it, the rotor thrust of the vortex ring regime can be less or more than in case of its action on a place depending on the altifude of rotors arrangement in the ring torus. The vortex ring regime ifself is unsteady by its nature and the forus moves near the rotor plane at a constant descent velocity, thus causing the unsteady character of change of the rotor aerodynamical load for example as it is shown on fig. 1. The corresponding velocity fields are performed on fig. 2. The paths of airparticles coming down from rotor blades sections r=r/R=0,39 and 0,83 are shown on fig. 3. The end of qiven rotor frequency is marked by figures. Case on fig. 1...3 corresponds to the rotor action at the regime of the single rotor arrangment on the average at the center of the torus.

At the rotor disk movement to the upper (the reduction of the descent velocifies, the increase of the rotor angle) or to the lower part of the torus, the thrust reduction decreases, and at significant movement to the lower part (fig. 4) the rotor thrust becomes more than one at the action on a place. In this case the time unstability significantly increasesi (fig. 5).

At slope descent the ring torus moves to azimuths $\psi = 0$ (fig. 6) and destructs at all at some combination of V_y and V_x.

A single rotor is proved to have two zones of the vortex ring regime (fig. 7):

1 - by the thrust reduction; 2 - by rising aerodynamical load pulsation (fig. 5). Change of the angle of setting φ_0 changes the borders of zones 1 and 2 (fig. 8, zone 2).

The regime goes smoother on the coaxial-type rotors, because, at least, one of the rotors places higher or lower than a torus kernel (fig. 9).

The ring toruses break, as a rule, in place of intersection on the tandem-type and side-by-side-type rotors.

The vortex ring can occur on the tail rotor of a single-rotor helicopter. As the tail rotor is in the influence zone of the main rotor flow with a part of its spinning disk, so the flow particularities typical for the vortex ring realize only on the part of the disk distant from the main rotor (fig. 10)

The reseach shows the same rotor ring regime is one of the causes the helicopter gets into the uncontrolable rotation regime.

The second stage of the rotor ring regime begins after the vortex wake sums in the rotor spin plane till the level higher some critical one. It is characterized by much more unstability accompanied by periodical flow separations from the part of the rotor disk. The flow plane before the rotor approaches to the rotor spin plane that occurs in the lower part of the half-destructed forus and the average value of the rotor thrust increases. The velocity field and the thrust change character by time are shown corrspondently on fig. 10 and 11.

Next let us examine the rotor action regime near the boundary no-penetrated airfoil which can be oriented to the rotor free enough.

The research set up the number chracteristics of the horizontal located undes the rotor surface influence in the wide range of rotor action regimes and their geometrical parameters. Fig. 12 performs, as an example, the velocity fields of a rofor acting near the ground (right) and in the endless space, and fig. 13 performs the load distribution laws (the normal section force coefficient Cy') by the rotor blades span on the place (V=0) and on different distances from the ground H=H/R .

At research of the rotor action by the vertical located boundary surface (a wall) on the part of the disk close to the wall the nozzle effect accompanied by inductive velocities increase (fig.14) and corresponding rotor thrust reduction on this part of the disk realises. As a result a moment overturning the rotors on the wall and a force pulling it to the wall appear.

Acting under the slope rotor is forced by two effects: the air cushion and the nozzle effect, and the influence at both of these effects and either rotor thrust increase (at small

γ) or its reduction depend on the slope angle γ (fig.15).

Theoretical and sometimes experimental interest is a case of the location of bonudary surface above the rotor from the sucking in side zone (fig. 16). It is known the rotor thrust increases in this case (a ceiling effect), so that the ceiling effect is fwice weaker than the air cushion effect.

There are two effects at the rotor acting under a slope of the seiling and of the nozzle.

The common result of the research of the influence of the boundary surface on the trust and overturn moment M_x acting on the rotor with hard blades fixing in dependence on γ and H is performed on fig. 17.

Some particularities of the influence of the boundary surface on the rotors combination aerodynamics are set up. For example, at coaxial combination acting over the ground, the main thrust increase occurs on the lower rotor (fig.17). The upper rotor seems to screen by the lower one and the thrust on it increases miserably. At the main and fail rotors combination approachment to the ground, the tail rotor thrust can either increase or reduce independence of the tail rotor spin direction (fig.19). The cause of such influence is in the influence of the flow cast by the main rotor and reflected by the earth on the fail rotor (fig.20).

L I T E R A T U R E

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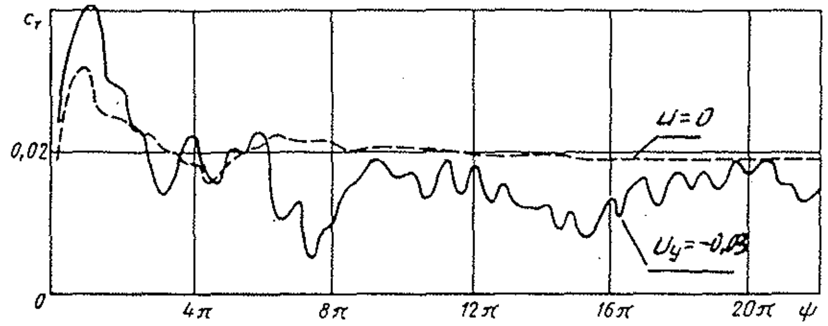


Fig. 1

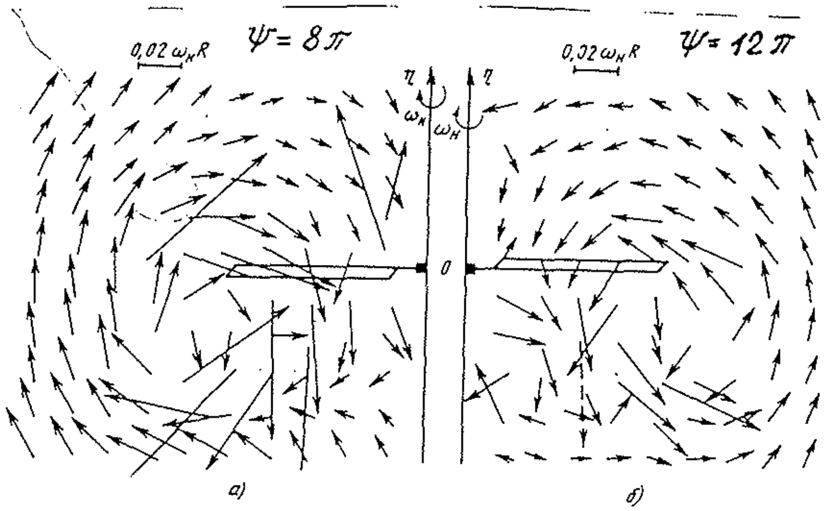


Fig. 2

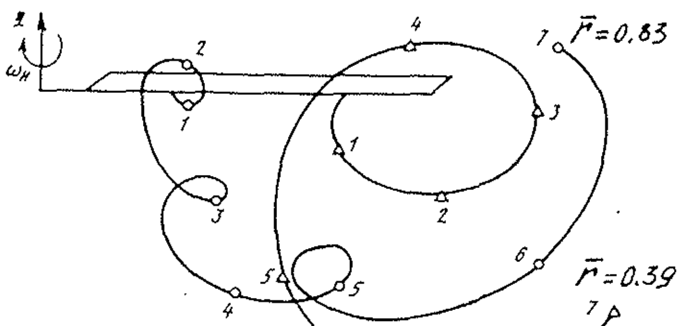
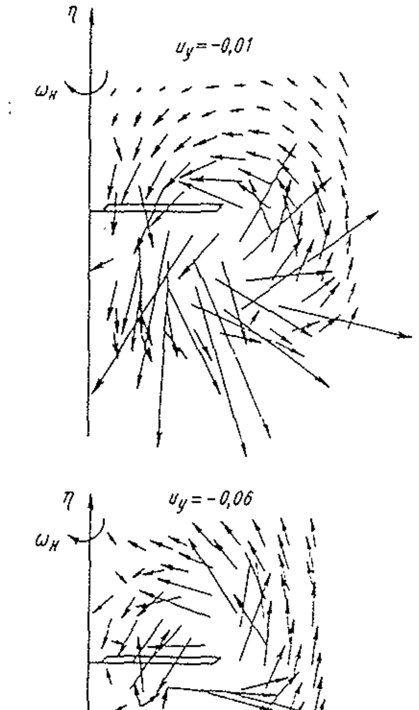


Fig. 3



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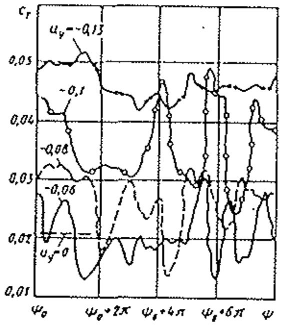


Fig. 5

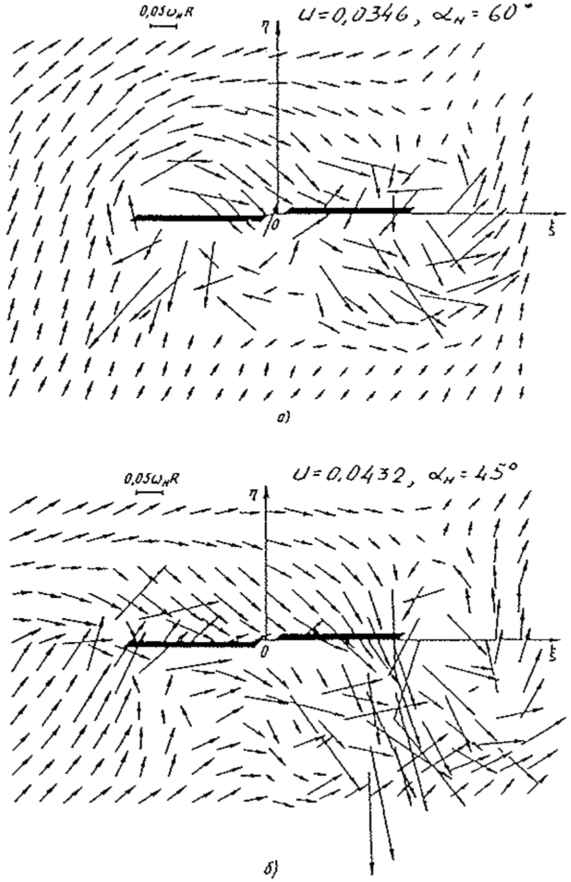


Fig. 6

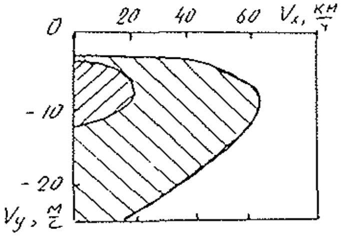
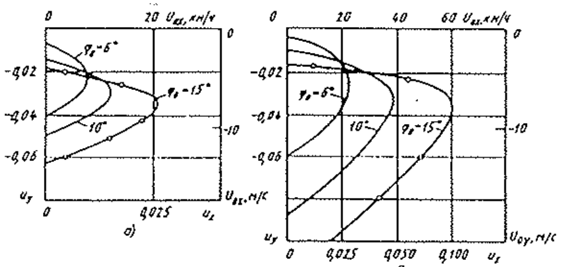


Fig. 7



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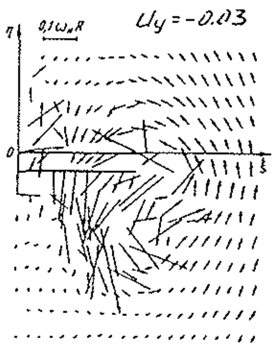


Fig. 9

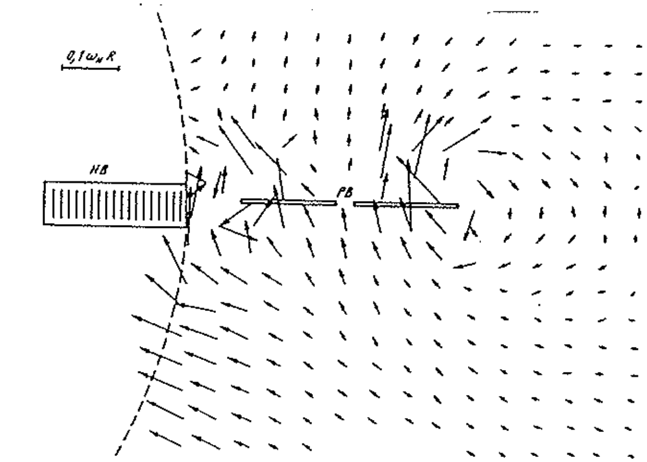
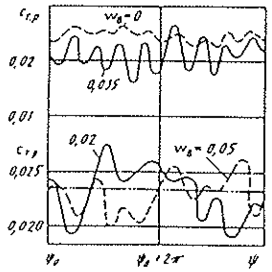


Fig. 10



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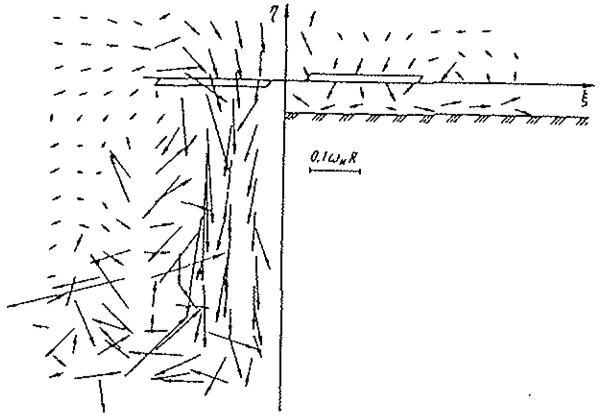

Fig. 12

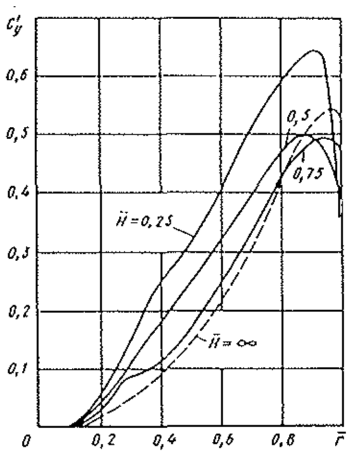

Fig. 13

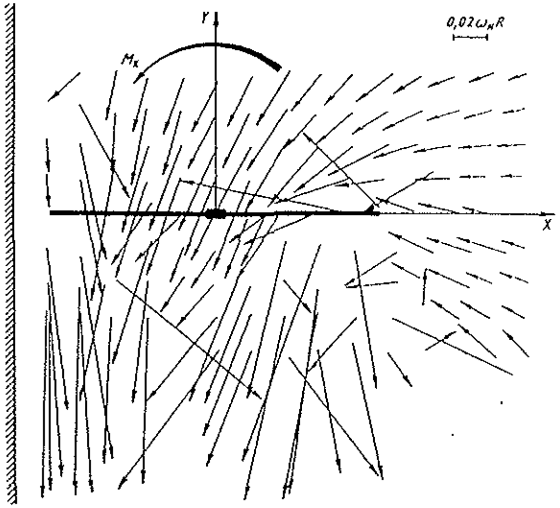

Fig. 14

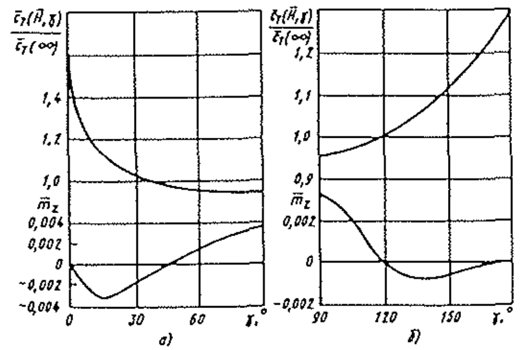

Fig. 15

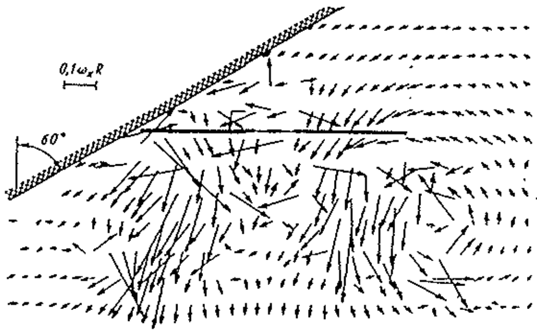

Fig. 16

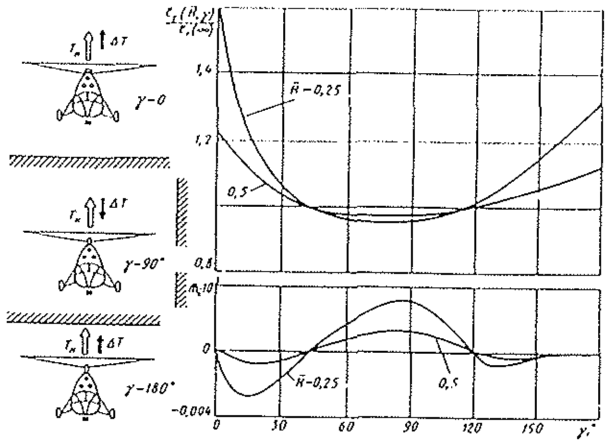

Fig. 17

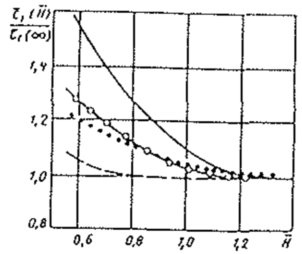

Fig. 18

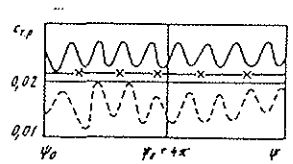

Fig. 19

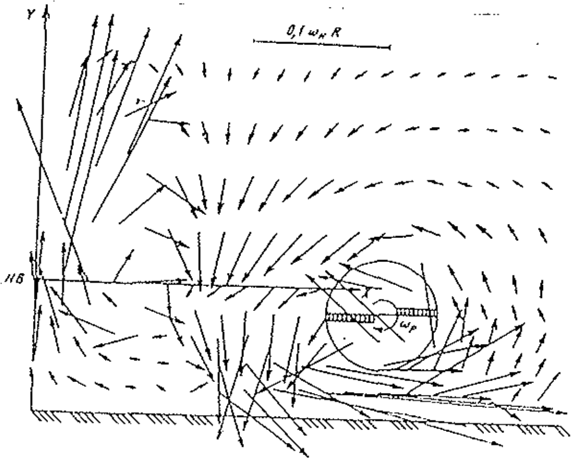

Fig. 20