EXPERIMENTAL INVESTIGATIONS IN THE FIELD OF AN AIR JET NOZZLE CONTROLLED HELICOPTER AERODYNAMICS

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An air jet nozzle controlled helicopter has been attracting much interest of late. The most prominent achievements in this area were demonstrated by the MacDonnell Douglas Helicopter Company when developping and testing such helicopters. Some theoretical and experimental work has been carried out in the field of investigating the air jet nozzle control system and its functioning on the helicopter [1].

The subject of this paper is the description of some experimental investigation carried out in the same field by the Kamov Helicopter Scientific and Technology Company. Under the term "an air jet nozzle controlled helicopter" we mean the system which is very near to the NOTAR, with a nozzle allowing for a 3-dimentional thrust vector control.

An air jet nozzle controlled helicopter has a number of particular features which make it more advantageous in operation.

The energetics of the air jet nozzle controlled helicopter to a great extend depend upon the efficiency of the jet nozzle system namely upon the losses in the gas dynamical path (air intakes, nozzles, channels), fan efficiency ration and efficiency of the tail boom circulation flow.

To develop the jet nozzle system in general and its components in particular an experimental base was created (fig. 1). It included stands for investigation of the system elements operation, the influence of various factors like ground effect (screen effect); engine exhaust jets, shape and geometry of the gas dynamical path etc. To investigate the operation of the jet nozzle system in an oblique flow mechanised models were developed for wind tunnel testing and to investigate the system operation in flight conditions a flying test bed on the base of the Ka-26 helicopter was prepared.

Some results of the investigations carried out are presented below.

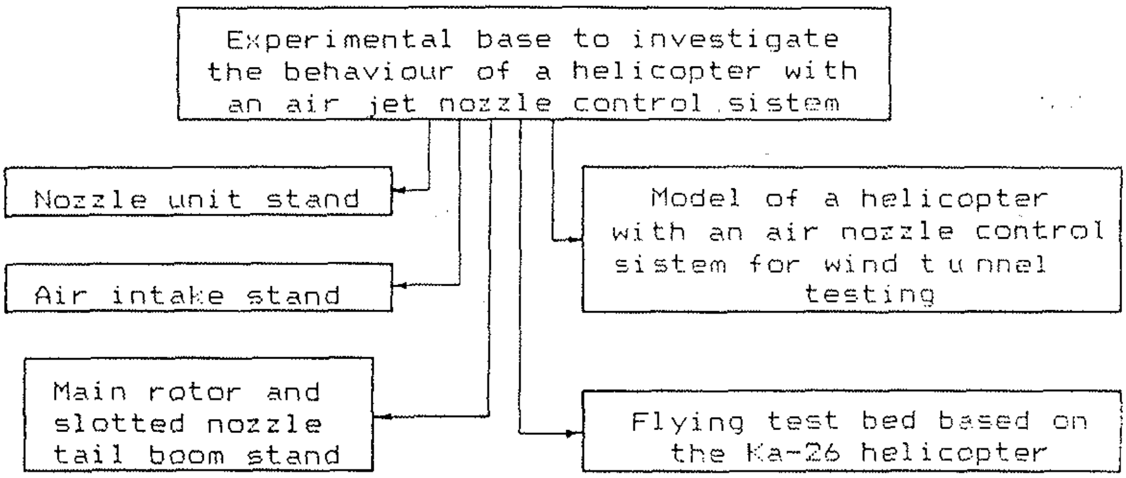

Fig. 1

The side force is created on the boom when it is streamed by the rotor flow due to the air exhaust to the surface of the tail boom along the tangent throuth a slot nozzle due to Coanda effect the flow around the boom is reorganized, becomes circulational, a depression and a corresponding force are created at one side of the boom. A large volume of experimental investigations was carried out to determine the value of this force with dependence to design and kinematics of the system parameters.

The parameters of the rotor flow circulation around the tail boom are presented at fig. 2-4. Adopting C_z side force and C_μ exhausted jet impulse coefficients using the product (L D P) where L- slot length, D- tail boom diameter, P - rotor disc load, kg/m^2, ensures small scatter and stability of the $C_z(C_\mu)$ dependence in a wide range of changing the jet nozzle system kinematic parameters (fig. 2, shaded area). At the same figure $C_z(C_\mu)$ dependence for the boom with a plate is shown. It

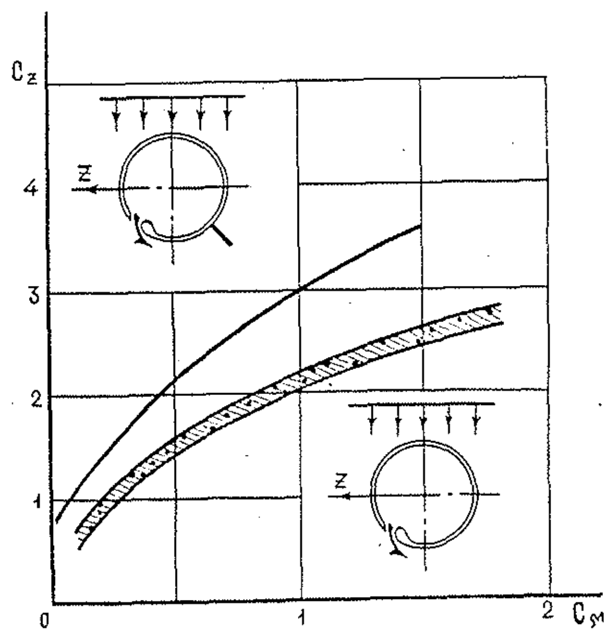

Fig.2

is also possible to raise the effectiveness of the circulation flow by changing the boom cross section configuration, optimizing its geometry, changing the number of slots and their location and some other design features.

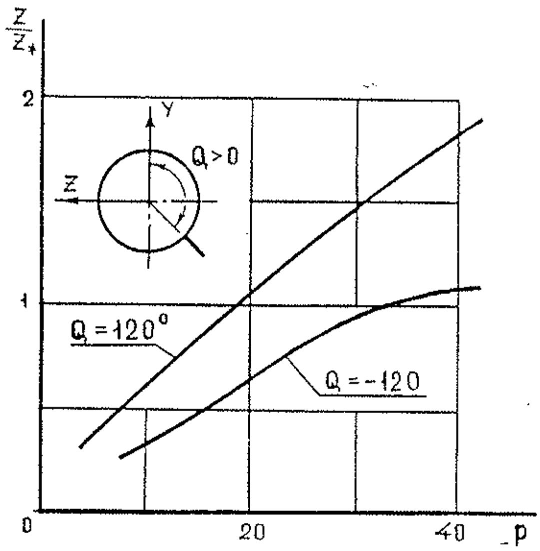

Fig.3

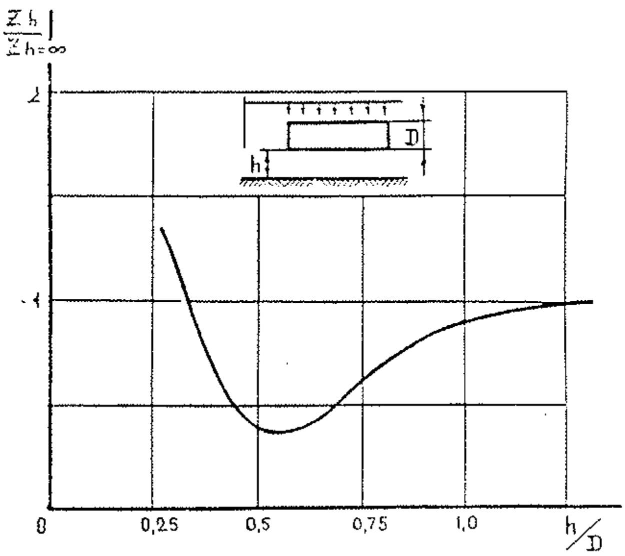

Fig.4

The circulation streaming of the boom by a complex flow comming from the rotor is of a 3-dimentional nature and differes from that of the round cylinder by a flat parallel flow (fig.3) the ground the nature of the aerodynamic force change should be taken into account when working out the helicopter general arrangement (fig.4).

The power consumed to create a unit of a side force at a tail boom circulation flow is rather small and its engergetics depend largely upon the helicopter general arrangement. Since with the increase of the boom geometrical size and reduction of flow speed, specific power consumption values required to create the side force diminish.

The fan air intake is a very important component of the jet nozzle system. The output losses of the low pressure fans may influence greatly the general power consumption level of the whole system. In the course of testing various intake variants were tried out.

At fig. 5 the total pressure losses ν in a two phase (two channel) fan intake depending upon the relative consumption Q are presented.

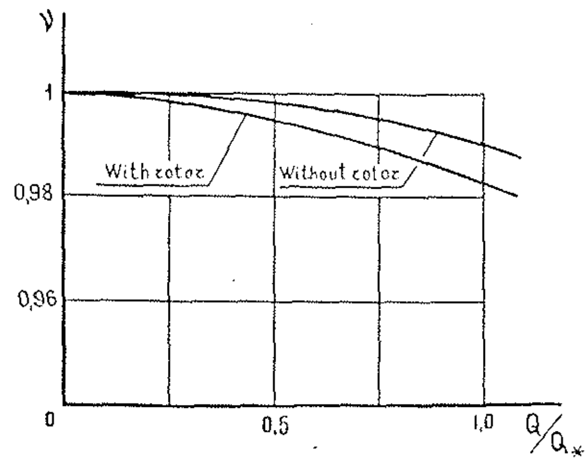

Fig.5

At a nozzle unit stand a large volume of experimental testing was done on various nozzle variants. Flat and 3-dimentional nozzles with various thrust vector control arrangements were tested in a low pressure ($\pi_c \sim 1,1$) zone. The nozzle efficiency was evaluated by one jet turn losses as a ratio between measured Z and ideal Z* forces. If the nozzle is made to turn the flow in only one plane the nozzle losses may be reduced by practically two times as compared that of a more general configuration nozzle (fig. 6).

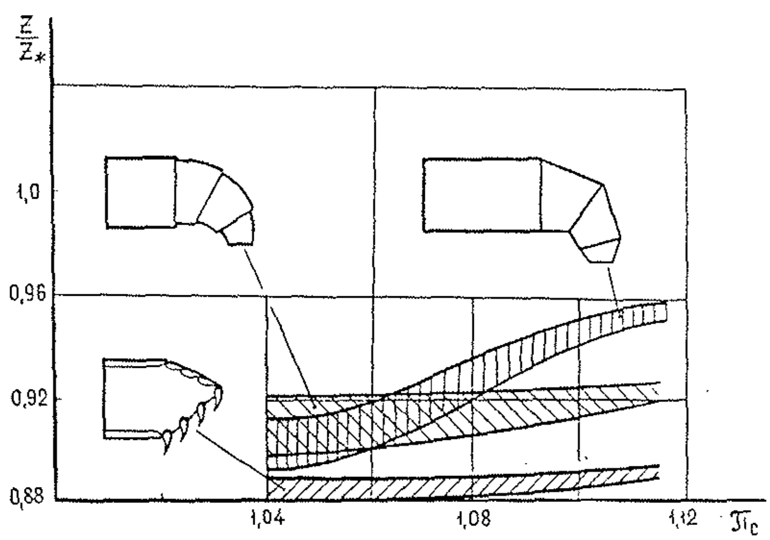

Fig.6

The investigation carried out show that optimization of geometry and flow pattern may help to reach a low level of losses in the gas dynamical path components, and the total power consumption to compensate for the main rotor torque with an air jet nozzle system may be brought nearer to that of the tail rotor.

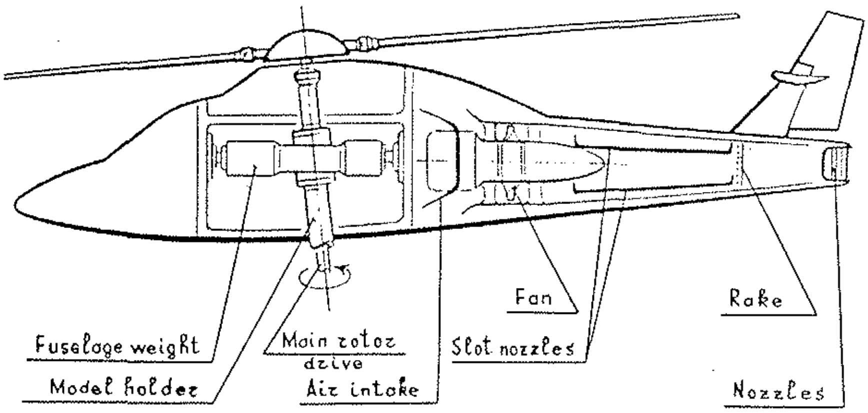

Fig.7

To investigate the behaviour of an air jet nozzle controlled helicopter in the oblique flow conditions a mechanized model was prepared for wind tunnel testing (fig. 7). The air jet nozzle system with two slots ensures the stable circular flow and required helicopter balancing and control margin parameters in a wide range of attack and slip angles, (fig. 8).

Side flight mode seems to be the most difficult for the air jet nozzle system energetics (fig. 9). Here the moment is created by the boom and the nozzle forces. In the course of testing some cases of stalled circulation flow on the boom were observed when the aerodymanics characteristics demonstrated considerable nonlinearity.

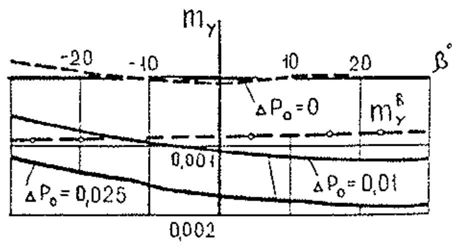

Fig.8

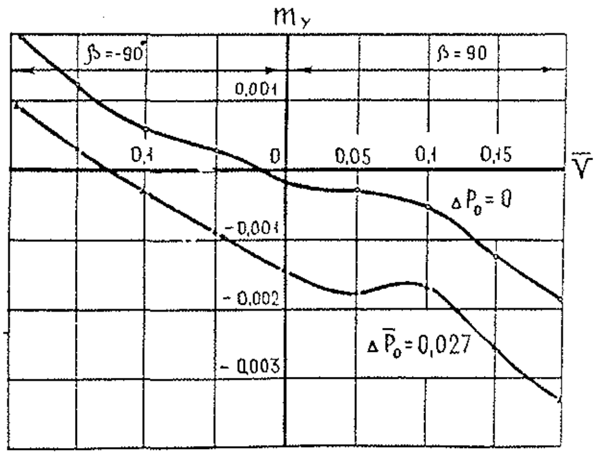

Fig.9

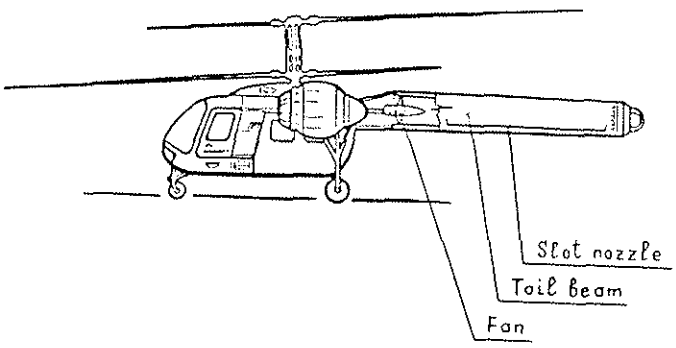

Fig.10

To investigate the jet nozzle controlled helicopter dynamics in the turbulent air a flying test bed was created. A coaxial helicopter Ka-26 (fig. 10) was selected for safety reasons. Coaxial rotors torque disbalance was compensated by the moment of the forces appearing on the tail boom.

The level of tail boom "loading" was controlled by the second pilot. In case some piloting difficulties were met the boom moment was brought to zero and the helicopter started to operate as an ordinary coaxial helicopter. At testing of a single slot tail boom some modes demonstrating sharp nature of the balancing dependencies behaviour were detected and negatively evaluated by the pilots. Filming the silk particles glued to the boom with a mobil camera permitted to determine the reason for such dependencies presence which was a stalled flow (fig. 11).

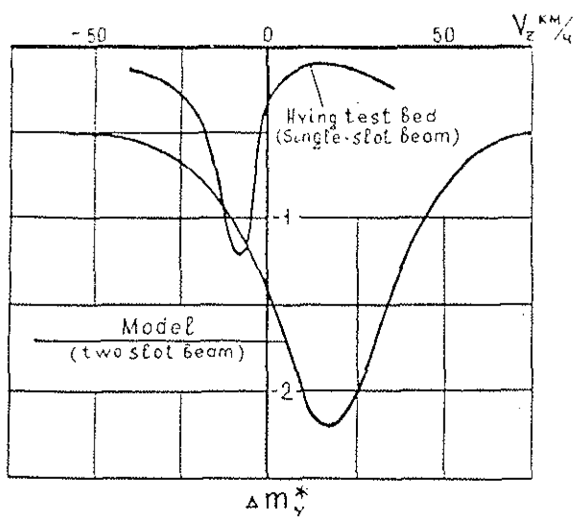

Fig.11

A tail boom configuration and nozzle system kinematic parameters change permits to eliminate undesirable effects.

R e f e f e n c e :

1. Andrew H. Logan, Rancho Palos Verdes and Richard E. Moore, Helicopter antitorque system using circulation control. 4.200.252. Los Angeles, both of Calif., assignors to Summa Corp., Las Vegas, Nev.