# Technical Development of the VS-300 Helicopter During 1941

## By I. I. Sikorksy in Journal of the Aeronautical Sciences

Even a brief glance at the history of direct lift aircraft reveals that the primary problems that were encountered in this field were those of (1) stability, (2) control, and (3) the smoothness of operation of rotors and of transmission mechanisms.

During the nineteen twenties, however, extensive research and experimentation was carried on by Juan de la Cierva and his associates on the autogyro which made possible for the first time a practical understanding of many principles of rotating wings, including the famous articulated blades, rotor balance, rotor control, etc. The impulse given by the successful work of de la Cierva, as well as the general progress in aeronautical engineering, finally permitted the successful solution of all main problems connected with the design of a helicopter.

The object of this paper is to describe briefly the general characteristics of the VS-300 helicopter which was constructed in 1939 and successfully flown during the last two years.

### Description of the VS-300

The VS-300 helicopter is equipped with a three-bladed main rotor of 14 ft. radius and has a welded tubular steel fuselage and an auxiliary propeller for torque compensation and directional control, rotating in a vertical plane at the tail of the fuselage. During the early part of 1941, a 90-h.p. Franklin air-cooled engine replaced the previous 75-h.p. engine in the aircraft and has supplied the power ever since.

In addition to the torque-compensating propeller, various control propellers have been installed at the tail of the fuselage at various stages of development. During 1941 the tail propellers, including the one for torque compensation, were generally two-bladed with 46 in. radii. The main rotor in hovering flight turns about 260 r.p.m., and the tail propeller or propellers turn about five times that speed. A free-wheeling unit is installed between the engine and the rotor drive shafts so that the main rotor and tail rotors may continue to turn in an autorotative condition in the event of engine failure. Power is transmitted by means of a multiple-V-belt drive and bevel gears. The angle of incidence of the main rotor blades is controllable with a range from +2 to +13 deg., and the incidence of the tail rotor blades is controllable and reversible. It is obvious that if the incidence of the main lifting rotor is increased more power will be required for it. Therefore, a means of synchronization is provided between the main pitch control and the throttle arm of the carburetor so that an increase in incidence will be accompanied by an automatic increase in throttle opening and vice versa.

### Flights of the VS-300

The practical results of 1941 are best demonstrated by a brief resume of the flights made.

During the year several pilots flew the aircraft extensively, and satisfactory flight and control characteristics were demonstrated. The aircraft, without exception, always took off and landed with no ground run whatsoever, regardless of the wind velocity. It could rise and descend vertically or on an inclined plane varying from 0 to 90 deg.; it could hover over one spot for any desired length of time and could be flown backward or sideways as well as forward. In forward flight, speeds upward of 60 miles per hour were reached, although the aircraft did not at any time approach its maximum. Precision control was repeatedly demonstrated by approaching persons or objects on the ground and hovering within inches of a given point, followed either by backing away or by proceeding sideways or forward in a routine manner. One example of this was the changing of a tire while the aircraft hung motionless just above the ground.

During the late summer and fall, the aircraft was mounted on pneumatic rubber floats and extensive water operations were carried on within a range from 0 to 60 miles per hour, and fast forward flights, sometimes low over the surface of the water, were repeatedly made to demonstrate the accuracy of control. On the surface of the water the aircraft was found to be more easily handled than any other surface vessel. It not only taxied forward and turned as do other surface craft, but it could also be brought to a complete stop without disengaging a clutch or stopping the engine and be taxied backward without using a reverse gear. It could taxi sideways even against a strong current or wind and turn complete circles precisely on one spot. Because of the aircraft's ability to land and take off vertically, there was no problem of spray from the pontoons and no step was required.

During 1941, three important recorded flights were made by the writer as follows:

On April 15 the VS-300 established the official national helicopter endurance record by remaining in the air 1 hour, 5 min., 14.5 sec.

On April 17 the helicopter, mounted on rubber floats, was repeatedly taken off from the water and landed on water and then landed on the ground, demonstrating for the first time a direct lift aircraft with excellent amphibian characteristics on which no adjustments whatsoever are needed when going from water to land and vice versa.

On May 6 the VS-300 brought to the United States the official international record for helicopter endurance by remaining in the air 1 hour, 32 min., 26.1 sec.

### Control With Two Horizontal Tail Outriggers

During the first half of 1941, control of the VS-300 helicopter was secured from two auxiliary tail rotors turning in a horizontal plane; these were in addition to the previously mentioned torque-compensating rotor that turns in the vertical plane.

The two horizontal rotors were mounted on welded steel tube outriggers, one on either side of the tail of the fuselage. Each of these outriggers was approximately 10 ft. long, and various angles were given to them in order to investigate the advantages to be secured from changing the plane of rotation of the tail propellers in relation to the main rotor disc. These horizontal propellers provided lateral and longitudinal control as follows: (1) lateral control was secured by increasing the incidence of the blades of one propeller while decreasing the incidence of the blades of the other propeller (this was accomplished by moving the conventional pilot's control stick to one side or the other); (2) longitudinal control was secured by increasing or decreasing the incidence of the blades of both horizontal tail propellers simultaneously (this was done by forward and backward movement of the conventional pilot's control stick). This type of control was found to be extremely sensitive and positive under all circumstances and provided almost instant change of attitude of the airship. The inherent stability, however, was not so marked as in more recent control revisions and, obviously, the structure and transmission arrangements were more complex than in the later designs. It was with this control that the record flights previously mentioned were made.



### Control With One Horizontal Tail Propeller

During the summer of 1941, experiments were carried on with sectional pitch control in the main lifting rotor. In this plan the horizontal tail outriggers were removed and each main rotor blade changed its angle of incidence progressively throughout its cycle of rotation. Thus, for instance, with the control stick moved toward the right, all blades would progress to a certain minimum incidence as they passed the right-hand side of the airship, while at the left-hand side, all of them would be at a certain maximum incidence. Such an arrangement resulted in inclining the lift vector of the main lifting rotor to the right, thus causing a resultant horizontal force to act.

During the following five months, extensive flights were made with sectional control used on the lateral axis only, and with longitudinal control secured through a tail propeller mounted on a skeleton tower above the tail of the fuselage. The incidence of the blades of this propeller could be increased or decreased at the will of the pilot. This arrangement was found to have many advantages, primarily a certain pendular lateral stability and positive longitudinal control. It also had a more simplified structure with its obvious advantages of storage, etc.

### Full Sectional Control

During December, 1941, the control arrangements were again revised in order to provide control by sectional change of the incidence of the main rotor blades longitudinally as well as laterally. Thus, the former lateral sectional control was broadened to be effective throughout the entire 360 deg. of the disc of rotation. The horizontal tail propeller, which had previously been used for longitudinal control, was entirely removed, leaving only the torque-compensating propeller at the tail. Sectional change of pitch in the main lifting rotor was secured by inclining the conventional pilot's control stick in the desired direction. The first flights with this control were made just before the end of the year and during January, 1942, the new control arrangement was proved to be satisfactory in extensive flights. Various modifications have been investigated, including the installation of a horizontal fin surface at the tail. This is now being tried alternately as a movable surface co-ordinated with the fore-and-aft inclination of the main rotor disc and as a fixed surface to act as a stabilizer and a dampener. However, the amount of flying to date with this supplementary surface is not yet sufficient to evaluate fully its worth. Flights with the full sectional control have so far been entirely satisfactory, and the aircraft seems to have reasonable inherent pendular stability, laterally and longitudinally. The obvious advantages of this arrangement are the further simplification of structure and transmission problems.

### Directional Control

It has been stated above that the torque-compensating propeller, turning in the vertical plane at the tail of the aircraft, also provides directional control. This is secured through action of the pilot's rudder pedals which change the angle of incidence of the torque-compensating propeller blades, thus increasing or decreasing their thrust. With the rudder pedals in neutral, a few degrees positive incidence is always carried on the blades of this propeller to compensate for the torque of the main lifting rotor.

### Action of Main Rotor Blades

By reviewing briefly the action of the main rotor blades, therefore, it is found that in the present full sectional control arrangement their incidence may be varied in two different ways: (1) simultaneous increase or decrease through action of the pitch control lever at the pilot's left hand, which results in increasing or decreasing the thrust of the main rotor and thus controlling the rate of ascent or descent of the craft; synchronized with this is the action of the throttle so as to provide a change in horsepower as required by the change of incidence and maintain a substantially constant number of revolutions per minute without the need of manually adjusting the throttle; and (2) progressively throughout the cycle of rotation so that each blade will follow a varying path in relation to normal; this is controlled by the conventional control stick which not only determines the direction of inclination of the main rotor disc but also the degree of this inclination. Thus it is possible in a given condition of flight to have, for example, 9 deg. of incidence on the main rotor blades through action of the main pitch control and then to add or subtract a few degrees at any point in the cycle through action of the sectional control. The sectional control, of course, always works so that the lowest point of the blades in their cycle of rotation is at 180 deg. to the highest point.

### Fuselage Covering

In conjunction with the investigation of the three fundamental controls outlined herein, the effect of fuselage covering in various degrees was also studied. Vertical fin area toward the tail of the fuselage was first applied; thereafter, the entire side of the fuselage was covered, and finally, a nose covering was installed which provided an open cockpit for the pilot. As a general rule it was found that a certain amount of fin area made the controls considerably more effective and pleasant but that an excess tended to give too much damping to the action of the controls. The nose covering did not appear to change materially the flying characteristics, and the aircraft is being flown at present with this covering constantly installed.

### Conclusion

On the basis of the results achieved with the VS-300 helicopter during the year 1941 in which fundamental problems of control and stability appear to have been solved, the writer looks forward with confidence to the future of direct lift aircraft. The future work that remains to be done will include the refinement of controls already investigated, as well as research along many other lines of thought. This will doubtless produce further improvement in the handling qualities of the aircraft, but it is certain that 1941 has seen the VS-300 grow from an experimental laboratory model to an aircraft that embodies practical flying qualities.

Hey! Drop that—The new "Wings Over Borden" is out.