THE HELICOPTER . . .

A typical hub is that of the Sikorsky S-51, built in this country under licence by the Westland Aircraft Co. The hub is illustrated in Fig. 1, which shows the swashplate (1), linked by the push-pull rods (2) and torsion-bar assembly (3), to the blade-control horns (4). The blade-root attachment (5) is rotatably mounted on the drag-hinge spindle (6), which in turn is carried on a vertical hinge-pin in the flapping link (7). The latter is rotatably mounted on the hub arms (8) for flapping. Collective-pitch control is obtained by moving the swashplate axially up and down the rotor shaft, so as to change the angle of all blades equally, whatever may be the tilt of the swashplate for cyclic control. The drag-hinge hydraulic dampers are seen at (9).

A very neat hub using a different method of blade control is that of the Bristol Type 171, shown in Fig. 2. Instead of a swashplate, an overhead spider (1) is linked to the blade-control arms (2). The spider is carried on a ball-joint inside the hub, and can be raised or lowered by movement of the pilots' collective-pitch lever, or tilted in any azimuth by movement of the control column. An interesting feature of this hub is the method of mounting the blades. Instead of the normal method of carrying them in the drag-hinge link by thrust bearings and retaining nuts, they are carried by a segmentally divided tie-bar, one end of which is anchored to the drag-link sleeve (3) and the other to an outer sleeve (4) carrying fork ends which register with, and are pinned to, the blade-end fittings. All loads are thus

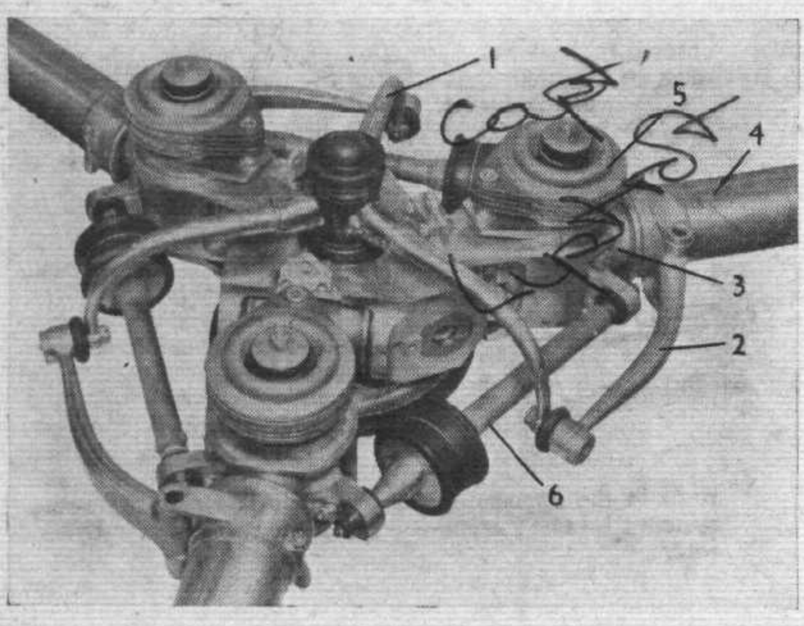

Fig. 2. The Bristol 171 hub, in which a spider takes the place of a swashplate.

transmitted from blade to hub through this torsion bar, which not only takes the centrifugal loads but also acts as a torsion bearing to permit the necessary angular movement of the blade. The drag-hinge dampers (5) consist of interleaved packs of Ferodo and steel plates, and in addition there are drag struts (6) with rubber compression/tension buffers; fitted between the blades they ensure that the latter remain correctly in pattern at 120 deg to one another.

Special Hubs.—Mention has been made of governor devices to relieve the pilot of the need continually to coordinate collective-pitch and throttle settings. In some hubs this is achieved automatically. In one design the blade collective pitch is linked to the movement of the blades about the flapping hinge. Quite independently of flapping due to forward motion, the blades rise all together on the flapping hinges, due to the lift and centrifugal forces, and it is the oscillation of the blades about this mean "coning angle" which is flapping properly so-called. The coning angle is obviously associated with the rotational speed and blade lift, and so with the throttle opening; thus, with a proper linkage the coning can be made to give the correct relation between throttle setting and collective pitch. Such a linkage was used on the Cierva W.9 helicopter.

Another hub of great interest, in which two simplifications are seen, is that which was designed for the Fairey Gyrodyne, where not only is the blade collective pitch automatically set by the throttle opening, but, also, the usual pitch-changing hinge is eliminated. In this hub (illustrated in Fig. 3) the drag hinge is given a small downward and outward inclination, an arrangement which makes the blade angle change as it is displaced about the hinge by changes in torque. As the throttle is opened, for instance, the blade lags behind the direction of rotation and increases its pitch angle, and *vice versa*. There is thus an immediate increase in manifold pressure, and therefore in power output, whenever the throttle is opened and without any appreciable change in rotational speed.

As there are no torsional bearings for pitch change, cyclic-pitch control cannot be used, and instead of a separate swashplate to transmit control movements from the stick to each individual blade through levers, etc., the rotor head

Fig. 3. Fairey Gyrodyne hub, with blade collective-pitch automatically set by throttle opening and the usual pitch-changing hinge eliminated.

virtually becomes the swashplate. This is not the usual practice with the tilting-hub form of control, in that the hub axis does not tilt. In the Gyrodyne, the hub axis remains fixed, and it is only the rotor head, which is universally mounted on the hub axis, which tilts with respect to the axis. In this way, the tip-path plane of the blades is made to remain substantially at right angles to the hub in any steady flight condition, and one of the causes of rotor vibration is eliminated.

Stabilized Rotors.—The single-rotor helicopter is not altogether satisfactory from the point of view of stability, and several interesting rotors have been designed to improve its behaviour in this respect. Two which are used on helicopters at present in production are worthy of brief reference.

In the Bell rotor (seen schematically in Fig. 4 and in detail in Fig. 5) only two blades are used, which do not have individual flapping hinges, nor is cyclic-pitch control applied through the collective-pitch mounting of the blades. Instead, the hub is mounted on the drive shaft by a Cardan universal joint, the axis of the outer gimbal ring, which carries the blades, being in line with the blade axis, while the axis of the inner ring is at right angles. The former acts as a pitch-changing hinge for cyclic-pitch control, since any rotation of the outer ring causes one blade to increase pitch and the other to decrease it. The inner-ring axis is the equivalent of flapping hinges, since it permits the rotor as a whole to see-saw, so tilting the disc in response to cyclic control applied by a normal swashplate arrangement. In addition to this, however, below the hub and mounted on the shaft by a pivot bearing allowing a see-saw motion (see Fig. 4), is a weighted bar at right angles to the blades and rotating with the shaft. As the sketch shows, this bar is linked to the outer pitch-changing ring. In flight it acts