HELIICOPTER GROUND RESONANCE

Undercarriage Design Problems Discussed at Helicopter Association Meeting

T
his season's fourth meeting of the Helicopter Association of Great Britain took place—as we briefly recorded last week—on Friday, December 4th, in the library of the Royal Aeronautical Society. A technical paper entitled Ground Resonance of the Helicopter, by R. M. Howarth, M.A., and C. H. Jones, B.Sc.(Eng.), was read by Mr. Howarth and afterwards discussed. We give here a résumé of the proceedings.

The chairman of the meeting, Mr. C. F. Uwins, O.B.E., introduced the joint authors. Mr. Jones, he said, had been a student apprentice at Bristol in 1940, and was now technical assistant in the structural-design department. Mr. Howarth, who would be presenting the paper, had been awarded the mathematical Tripos at Cambridge, and, before joining the Bristol Company, had spent a period with Flight Refuelling Ltd. He was now assistant chief designer (helicopters) at Bristol.

Mr. Howarth began by defining the term "ground resonance." It was, he said, a divergent oscillation of the helicopter on its undercarriage, in which the rotor hubs moved cyclically in the plane of rotation; it might occur when the helicopter rested on the ground with its rotors turning, or, more probably, when taxing, landing, or taking-off. A coupling existed between the rotor freedom and one or more degrees of freedom of the helicopter. If this coupling allowed energy to be transferred from the stored kinetic energy of rotation to the helicopter oscillation at a greater rate than energy was dissipated at the undercarriage and at the drag-hinge dampers, then self-excited or divergent oscillations would occur. The problem was analogous to the flutter of a wing.

Self-excitation could occur only at rotor speeds near a natural frequency of the helicopter. It was general practice in design to ensure that the lowest natural frequencies of the aircraft, when airborne, should be well above the maximum rotor speed. This confined the phenomenon of self-excitation to modes of vibration of the helicopter on its undercarriage (i.e., on the ground).

Using Coleman's theory as a basis, the lecturer then went on to discuss mathematically the theory of drag-hinge oscillations, showing the effect of damping, and the influence on vibration frequency of coupling between lateral and rolling modes. His conclusions showed that, where an unstable range did exist in which self-excited oscillations were a possibility, it was unlikely that sufficient damping could be provided to eliminate them. Within that range the designer had to rely for stability on a suitable selection of the frequencies of coupled modes.

Three schemes of undercarriage design were considered by the lecturer, representing some of the alternatives a designer could adopt to avoid ground resonance. Scheme 1 was typified by the landing gear of the Bristol 173 Mk 1. Each telescopic leg was partly filled with oil, and connected by a large-bore pipe to the chamber. The two chambers were connected by a small-bore pipe. The piston in the chamber was pre-loaded by air pressure in the space below. Where a simultaneous load was applied to the wheels in a normal landing the system worked as though normal oleos were fitted. In a one-wheel landing oil passed through the cross-pipe and the opposite wheel was moved downwards towards the ground, thereby reducing the time before both wheels loaded the shock absorber struts and tyres. The system was designed to ensure high mechanical stiffness in roll. As a result, the rolling frequency was well above the maximum rotor frequency. In a one-wheel landing both oleos operated on the one wheel. Such an undercarriage tended to become less stable with increase of taxing speed, but was safe in the event of a burst tyre. Scheme 3 relied on the lateral stiffness of the tyre and the vertical stiffness of the oleo to provide stability. It was in common use, and the Bristol 171 landing gear was a typical example. Although this method had been the most successful for smaller machines, care had to be taken to see that the pressures of the tyre and oleo were correctly matched, and the system was likely to give trouble if a puncture or tyre burst occurred.

Generally, the problem of ground resonance was likely to assume greater importance with the advent of larger helicopters, and the designer's difficulties would be eased by the availability of more comprehensive data on the dynamic properties of shock-absorber struts and tyres.

The Discussion

Mr. Kenneth Reed (Saunders-Roe) thought it was essential that a series of ground tests be made on the actual machine to determine that it was free from any tendencies to resonance. Models were not a satisfactory substitute. If a burst tyre could cause resonance, then pneumatic tyres should be excluded from the design. Why not solid tyres? He, also, thought that the characteristics of hydraulic dampers were superior to those of friction dampers.

Mr. A. E. Fowle (Fairley Aviation) wondered to what extent Coleman's theory could be used for accurate predictions on this question.

Mr. D. J. Mead (Southampton University) made a plea for an electronic simulator to reproduce the effects of ground resonance for research purposes, as with the flutter simulator.

Mr. J. S. Shapiro (consultant) thought that the call for a simulator was misguided. Coleman's theory would give a satisfactory degree of perfection if it was appropriately applied. Too much reliance should not be placed on damping, because of its erratic qualities.

Mr. A. L. Buchanan (Saunders-Roe) said that technical research had not produced any resonance-cure other than damping. He suggested that the chassis natural frequency should be kept as low as possible, and the maximum damping be applied to it in order to reduce blade damping which, he thought, should increase in amplitude with momento.

Mr. T. L. Ciastula (Saunders-Roe) felt he had had a full share of trouble in this respect, and that it was necessary to carry out full-scale resonance tests on the ground by introducing excitations into the fuselage with the rotor running.

Dr. G. S. Hilsop (Fairley Aviation) suggested that a rotor head without drag hinges was one solution to the problem.

Mr. C. T. D. Hosegood (Bristol) had confidence in Mr. Howarth's theories, as he had found them justified in practice. He said that the 173 in its early days was short of the landing gears, but it was likely that the Bristol 173 would shortly be leaving the Bristol stable, when other pilots would have an opportunity of confirming that it no longer had the slightest tendency to resonance.

Mr. J. Wotton (Percival Aircraft) also considered that the tip-driven rotor without drag hinges should be free from resonance.

Mr. G. H. Tidbury (Saunders-Roe) described the ground-running tests, carried out on the Skeeter, and suggested that solid-rimmed wheels with sprung spokes, or some form of track undercarriage, might be better than the pneumatic-tyred wheel.

Mr. Howarth, replying to the questions, agreed that certain assumptions had to be made when applying Coleman's theory. But they had worked out in practice, and if one had faith in the theory no ground-running tests should be needed. The time to eliminate ground resonance was in the design stage, before the machine was built. He welcomed the possibility of an electronic simulator. He agreed that damping could be dispensed with by using coupled frequencies, but thought that dampers provided a good safety factor. He concluded by paying a tribute to the work put into the paper by his co-author Mr. Jones, without which, he said, it would never have been written.