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THE CONTROL OF HELICOPTER NOISE BY THE USE OF A QUIET TAIL ROTOR

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1. INTRODUCTION

The importance of tail rotor noise to the overall helicopter noise is often underrated yet it is fairly clear that, in addition to often controlling the level and/or subjective character of the noise on approach, it can have a marked effect on the 'peak' or maximum noise level generated during overflight. This lack of appreciation of the contribution of tail rotor noise has arisen partly as a result of the deficiencies in predicting tail rotor noise and partly since it is difficult to measure and isolate the tail rotor noise sources. The position is further complicated by the fact that in addition to the basic tail rotor noise, "interaction noise" resulting from the interaction of the main rotor wake by the tail rotor blades is often the dominant source. It was established during a research programme on the Lynx during the period 1974-75 that the noise on the approach on this helicopter was characterised by 'burble noise'. This work was reported in reference 1 together with the preliminary results of an experiment which confirmed that considerable noise reductions could be obtained by modifying the operating parameters of the tail rotor.

The outcome of these research studies lead to the design and subsequent manufacture of a Quiet Tail Rotor (Q.T/R) which in due course was flight tested on a Lynx. In parallel with this activity further investigations into the noise generated by a helicopter in flight were conducted, which lead to the detection of another interaction noise source which manifested itself during overflight. This source has again been attributed to an interaction between the tail rotor and the tip vortices shed by the main rotor, but unlike 'burble' which is a function of the direction of rotation of the tail rotor, this source is essentially dependent on the speed of the tail rotor only. The Q.T/R on the Lynx was configured to reduce this source as well as that associated with 'burble'. The concept has also been applied to the tail rotor for the Westland WG.30.

2. TAIL ROTOR NOISE - BASIC CHARACTERISTICS

Tail rotor noise is impulsive in character with the impulses occurring at the blade passing interval which is typically in the range 60Hz to 130Hz. Due to this relative high repetition rate and the short duration of the individual pulses, it is classified subjectively as a 'whine' very much akin to propeller noise. A narrow band analysis of such a signal contains 'discrete frequencies' at the blade passing frequency and its harmonics and since it is impulsive it will be rich in higher harmonics.

When interaction with the wake shed by the main rotor occurs the pressure amplitude-time history is further complicated since the tip vortices are "spaced" at a period corresponding to the main rotor interval which typically corresponds to a frequency in the range 15 to 20Hz. As a consequence a complex impulsive character (waveform) which contains both components of main rotor and tail rotor is generated. The resulting narrowband analysis therefore contains both tail rotor harmonics and 'side bands' of these with frequencies corresponding to combination frequencies of the main and tail rotors.

Due to its impulsive character tail rotor noise, like other impulsive type signals, is underestimated by conventional rating methods based on dB(A) or EPNL analysis. Detailed studies at Westland Helicopters Limited have suggested that subjective corrections in the order of 5dB(A) are required and recently some studies have suggested even higher corrections. It is important, therefore, that this aspect is taken into account when evaluating helicopter noise, particularly when it is remembered that tail rotor noise often dominates the helicopter noise heard on approach. In the studies relating to selecting parameters for the Q.T/R a 5dB(A) allowance was assumed.

3. INTERACTION NOISE SOURCES

The two interaction noise sources of main interest are illustrated diagramatically in Figure 1, which shows the effect of change in direction of tail rotor rotation. As shown the sources are associated with the intersection of the tail rotor blades with tip vortices shed by the main rotor. The figure shows 'burble noise' which is radiated in the direction of flight and hence heard on approach and 'overhead interaction' noise which is "beamed" in a vertical plane. These two sources give rise to a time history plot of the type indicated in Figure 2 where the 'dashed line' represents the time history resulting from a flyover of a helicopter where these two sources have been reduced or eliminated.

4. Q. T/R DESIGN

The design and final selection of operating parameters was, of course, an iterative process and hence somewhat difficult to summarise. An estimation of the minimum tip speed for a tail rotor with an 'advanced technology' aerofoil to give a yaw performance compatible with the standard Lynx indicates that tip speeds as low as 625 ft./s would be possible. Since, however, from the acoustic study the minimum tip speed required was 650 ft./s this was selected for the Q.T/R.

5. NOISE REDUCTION

The impact of the Q. T/R on the dB(A) analysis for a 150 knots flyover can be seen from Figure 2 where the reduction in the maximum level is in the order of 5 dB(A).

The 'burble' noise detected on approach is similarly reduced by the Q.T/R, this can be seen in terms of dB(A) on Figure 2 where at distance the reduction is up to 15dB(A). This reduction, combined with the subjective change in the character of the noise, explains why the Q.T/R Lynx could not be heard whilst at the same distance the standard Lynx was very audible.

The reduction in the level of the tail rotor noise, and the 'burble', can be readily seen from Figure 3 which shows for a 130 Knot flyover the narrowband analysis for the two helicopters together with the corresponding pressure amplitude time history. It will be observed that the 'burble' noise has been eliminated and the level of the basic tail rotor noise reduced well below that of the main rotor, which although subjectively less important, now dominates the unweighted signal.

6. WG.30 TAIL ROTOR

The Q.T/R concept has also been incorporated in the Westland WG.30 and as a result this helicopter is very quiet on approach during high speed flight. The tip speed chosen for the tail rotor was 690 ft./s with the value being somewhat higher than on the Q.T/R for the Lynx due to relative differences between the levels of main rotor noise on the two helicopters. Prior to the installation of the 'quiet tail rotor', some preliminary flight tests were conducted on the WG.30 fitted with a standard Lynx tail rotor (tip speed 717.5 ft./s). Noise measurements were performed in both configurations and the results obtained were for all practical purposes identical to those for the experimental Q.T/R Lynx.

7. CONCLUDING REMARKS

It has been shown that marked reductions in noise on approach (up to 15 dB(A)) and significant reductions in overhead noise (by typically 5 dB(A)) can be obtained by use of a tail rotor whose operating parameters are chosen to minimise noise. It has also been shown that much of the noise initially considered to be associated with the main rotor during overflight is due to main rotor wake/tail rotor interaction. With the use of Q.T/R the noise level on approach is very low and providing no other impulsive source, such as blade slap, is present the helicopter would be acceptable from the community point of view. This, however, does not automatically imply it would meet the proposed noise certification since this is concentrated mainly on the level of noise as the helicopter flies directly overhead at 500 ft. (150 m) altitude.

The design and manufacture of Quiet Tail Rotor does not appear to present any major problem with the advanced aerofoil sections available and weight penalties are negligible. There is no erosion of performance and hence in the future tail rotor noise should become of secondary importance from the point of view of helicopter noise.

Acknowledgements

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NOTE: This paper is based on a more detailed paper entitled 'Reduction of Helicopter Noise by use of a Quiet Tail Rotor' presented at the Sixth European Rotorcraft and Powered Lift Aircraft Forum, Bristol 16 - 19 September 1980.

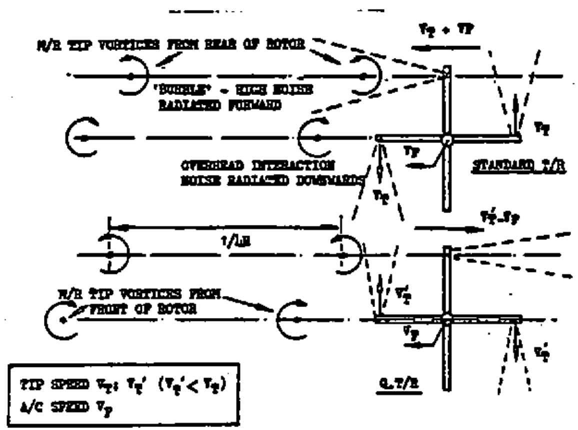

FIGURE 1 INTERACTION NOISE MODEL

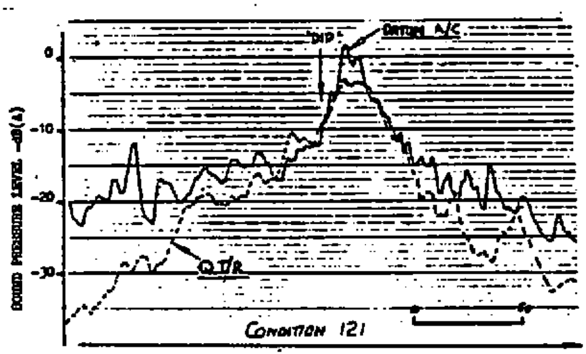

FIGURE 2 dB(A) TIME HISTORY

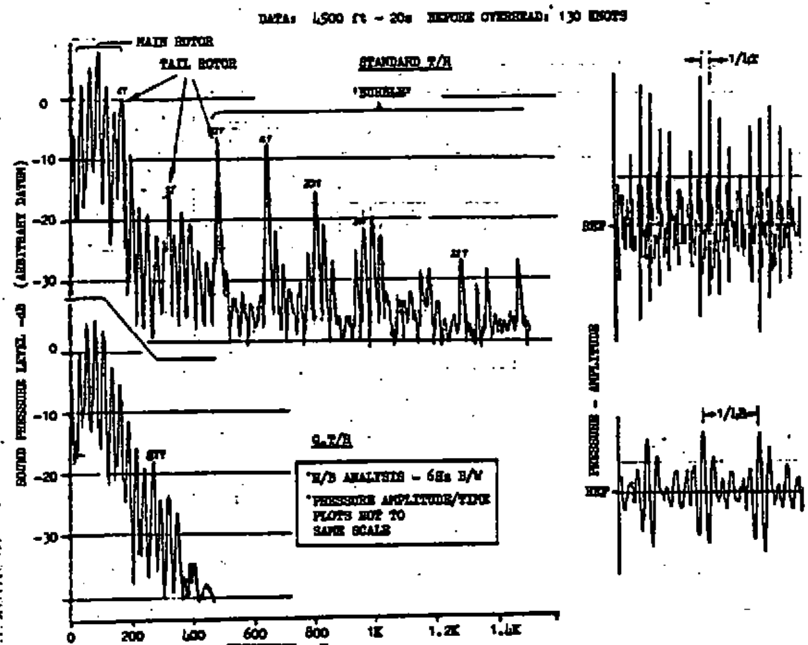

FIGURE 3 NARROWBAND ANALYSES & PRESSURE AMPLITUDE TIME PLOT