Main Rotor Torque Band-edging on Flight 85

Summary

The measured main rotor torque is band-edged or clipped for counters 8533 and 8534 on Flight 85. The engine output torques are unaffected by the band-edge problem. An estimate of the main rotor torque for these counters is obtained from a regression of all torque values for the flight.

Discussion

The main rotor torque for the UH–60A Airloads Program was measured with a torsion strain-gauge bridge installed on the main rotor mast. This is a rotating system measurement and, as with all such measurements, signal conditioning and amplification were done in the rotating system with the Rotating Data Acquisition System (RDAS). The conditioned range of signals was established with precision resistors on cards in the RDAS and there was a tradeoff between opening the range too much, which would result in larger quantization errors for the 10-bit PCM system, or reducing the range for improved quantization errors, and encountering amplifier band-edging or clipping.

The main rotor torque measurement on Flight 85 has been found to be band-edged at the two highest speed points, counters 8533 and 8534. Figure 1 shows the measured main rotor torque for the four highest speed points for this flight, counters 8531 to 8534. The measured torque is shown for the first 0.25 sec. of the data record. The time history shown is a little bit longer than one revolution (1 revolution = 0.233 sec.). Counters 8531 and 8532, $\mu = 0.340$ and 0.351 respectively, show the normal 4/rev oscillation for this four-bladed helicopter and are not band-edged. Counter 8533, however, is band-edged and its mean value appears to be close to the range limit. Counter 8534 is severely band-edged and appears unusable.

Power (or torque) measurements are important as one step in the evaluation of comprehensive methods. From the previous discussion, it is clear that the main rotor torque measurement is in error for Counter 8534. However, the measured engine output torques are not similarly affected. These torques are measured in the fixed-system and, as shown in Fig. 2 for Counter 8534, there is no indication of a band-edge problem. The engine output power, therefore, can be used as one measure of the helicopter's performance.

Although the main rotor torque measurement is corrupted for Counter 8534, it is possible to make an estimate of the torque. Consider the power balance equation for this aircraft, where the power balance is defined at the input to the main gearbox

$$SHP_{e1} + SHP_{e1} + SHP_a = \frac{1}{\eta}(SHP_{mr} + SHP_{tr}) \qquad (1)$$

SHP_{e1} and SHP_{e2} are the powers measured at the engine output shafts, SHP_a is the accessory power, η is the gearbox efficiency, SHP_{mr} is the main rotor power, and SHP_{tr} is the tail rotor power. Eq. (1) can be rewritten as

$$SHP_{mr} = \eta(SHP_{e1} + SHP_{e1} + SHP_a) - SHP_{tr} \quad (2)$$

As the accessory power is roughly constant, the main rotor power (or torque) should be linearly dependent on the difference of the combined engine powers and the tail rotor power. The main rotor torque is shown in Fig. 3 as a function of the power difference. A linear regression of these variables is also shown in Fig. 3 and provides a very good fit ($r^2 = 0.9962$). The standard error of estimate of the main rotor torque is ±475 ft-lb. Table 1 shows the measured torques for counters 8533 and 8534 and estimates of corrected values.

The standard error of estimate for the corrected torques in Table 1 are within ±1% of the maximum torque. However, there are other uncertainties having to do with these power measurements the inaccuracy may be as high as ±5% (Bousman 2002). Caution should be use when comparing calculated results with these values.

References

William G. Bousman, "Power Measurement Errors on a Utility Aircraft," American Helicopter Society Aerodynamics, Acoustics, Test and Evaluation Technical Specialists' Meeting, San Francisco, January 23-25, 2002.

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Table 1. – Measured main rotor torque for Counters 8533 and 8534 and estimates of corrected values.

Counter	Measured Torque, ft-lb	Estimated Torque, ft-lb
8533	48,559	48,853
8534	49,641	51,238

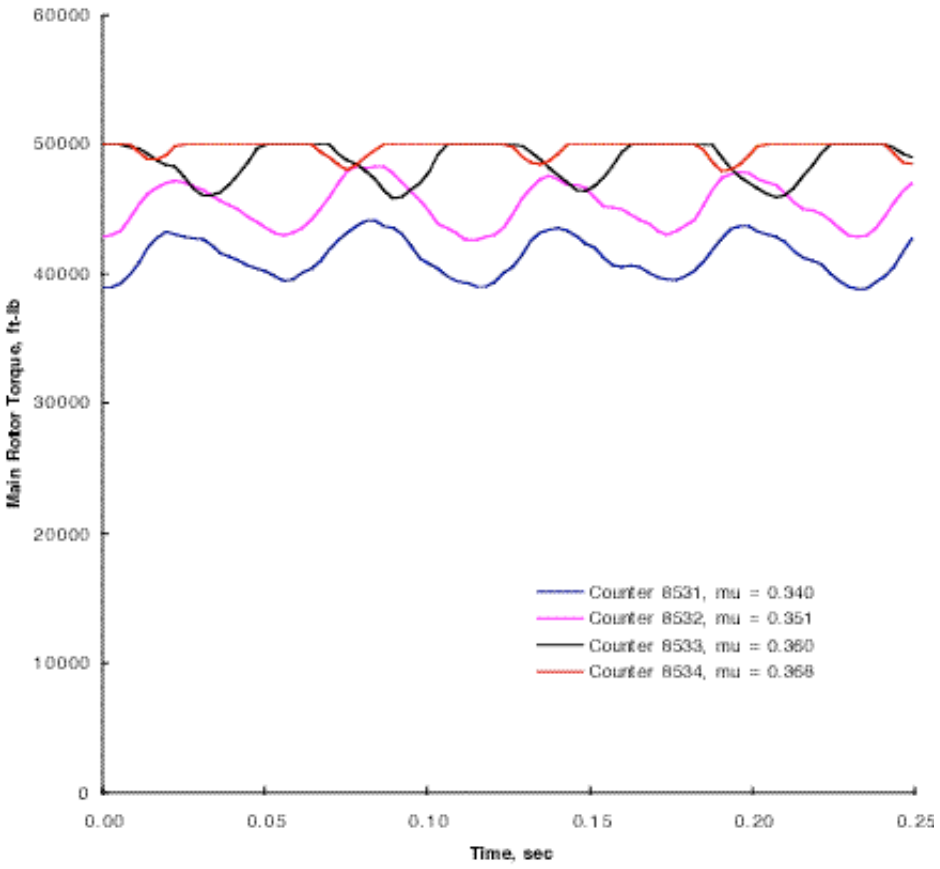

Figure 1. – Measured main rotor torque for four highest speed points on Flight 85.

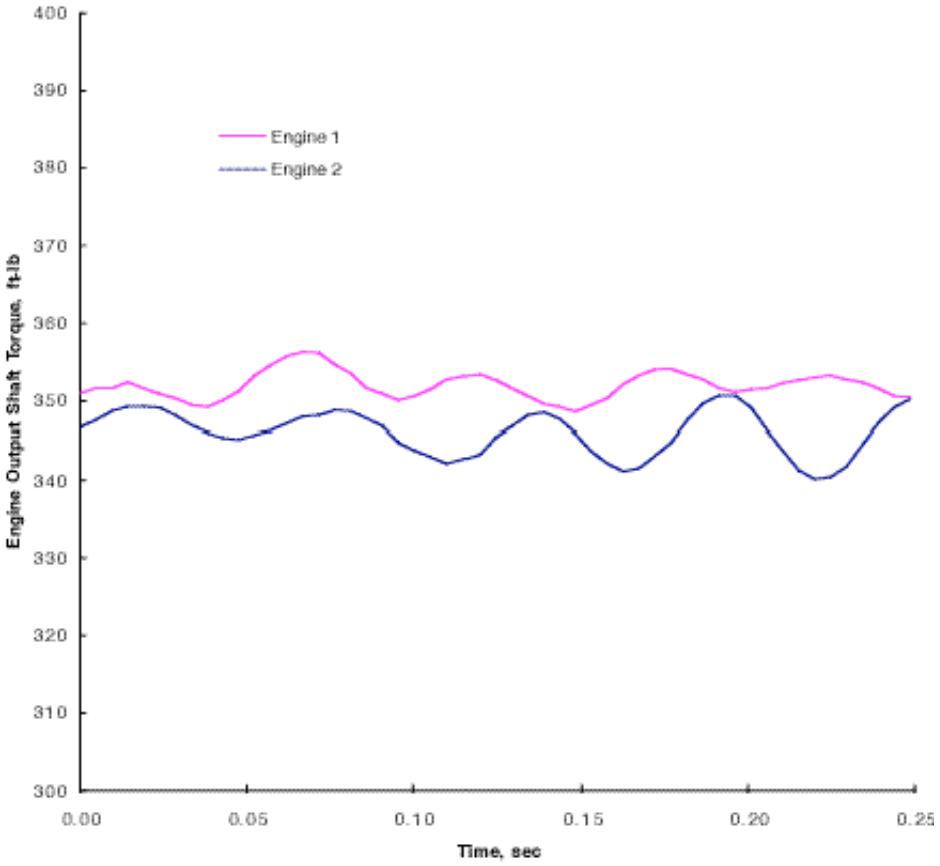

Figure 2. – Measured engine output shaft torques for Counter 8534.

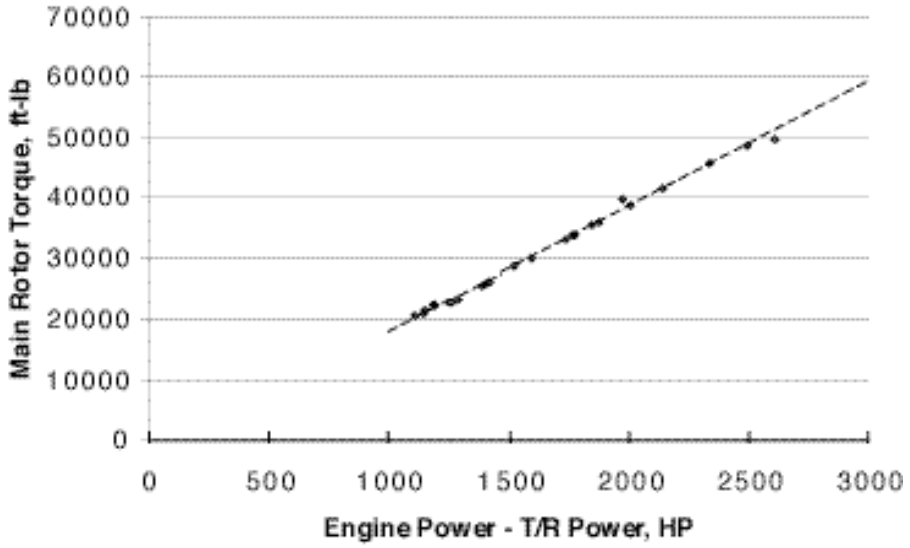

Figure 3. – Linear regression of main rotor torque on difference of engine and tail rotor powers for all level flight conditions from Flight 85.