Counter 8534 Steadiness

Summary

The steadiness of measurements obtained for Counter 8534 in the UH–60A Airloads Program are examined to determine their suitability for correlation purposes, with a particular focus on measurements important for the specification of trim. It is demonstrated that unsteadiness in the measurements is substantially less than the accuracy level desired for correlation of analyses with measurements and, hence, these data are suitably steady. It is recommended that the first revolution of data obtained on the flight counter be used for correlation.

Purpose

The purpose of this note is to examine unsteadiness in the measurements obtained on Counter 8534 and consider, first, whether the data are suitably steady for correlation purposes and, second, whether a single revolution of data or averaged data should be used for correlation purposes.

Discussion

For data to be used as a basis for correlation with analysis, it is necessary that the data meet a number of tests of accuracy. One of these tests is that unsteadiness in the data should be significantly less than the desired level of accuracy required of the analysis. If unsteadiness is too great, then the correlation effort will fail, as the data uncertainty will confound the assessment of accuracy.

The data from Counter 8534 were obtained on Flight 85 of the Airloads Program and this was the highest airspeed tested at a nominal weight coefficient of 0.08. The length of the record in the data base is 5.0 seconds, and this provides 19 complete revolutions of data.

Pressure measurements were obtained at nine radial stations and these were integrated to provide the normal and chord forces and the pitching moment. The normal forces at four radial stations outboard on the blade are shown in Fig. 1. The steadiness over the 19 revolutions of record is shown on this plot by mean + 1σ and mean – 1σ curves. Qualitatively, the normal force appears quite steady.

The trim solution for the helicopter is a balance of steady trim forces in the fixed system and steady and 1st harmonic forces in the rotating system. The steadiness of the magnitude of the first harmonic of the normal force at three radial stations is examined in Fig. 2. The standard deviation of the normal force is between 0.11 and 0.14 lb/in for the six outboard stations. The standard deviation/mean (coefficient of variation) is between 0.63 and 0.90% for the three radial stations in Fig. 2. Quantitatively, these first harmonic loads are quite steady and variation in the normal forces of this size are slight in comparison to the accuracy requirements of comprehensive analyses.

A different kind of unsteadiness is observed in the shaft angle of attack as shown in Fig. 3. The shaft angle of attack is based on the fuselage pitch attitude that is measured by a gyro mounted near the center of the aircraft. Over the length of the record, the shaft angle of attack varies from about –7.3 deg to –7.8 deg. This variation is larger than observed for the normal forces, with a coefficient of variation of –2.1%. Compared to the normal forces, the power spectral density of this variation appears to be reduced in frequency.

Aircraft moment trim can be specified using the first harmonics of measured hub moments or blade flap angles. Figure 4 shows the variation over the length of the data record of the measured shaft bending moment, M_{Hs}, mnemonic RQ12, and a moment estimate based on blade flapping

$$M_{H\beta} \cong 2e_\beta CF \sin\beta$$

where e_β is the offset of the elastomeric bearing focal point, CF is the centrifugal force at the bearing focal point, and β is the blade first harmonic flap angle. Measurements taken for an on-ground test with the rotor at flat pitch on Flight 83 have shown very good agreement between these two sets of measurements, suggesting that in that case first harmonic hub shears were negligible. The offset seen in Fig. 4, however, may be a consequence of non-zero first harmonic hub shears for this high-speed condition. The coefficient of variation for the shaft bending moment measurement is 1.7%. For the moments derived from the blade 1 and 2 flap angles, the coefficients of variation are 1.7 and 2.1% respectively. This variation is about twice what was observed for the normal forces measured on the blade. Most of the unsteadiness that is observed in the blade flap angle magnitudes is in the cosine flapping rather than the sine flapping. The cosine flap angle combined with the shaft angle of attack defines the tip-path-plane angle of attack. The coefficient of variation for the tip-path-plane angle of attack is –1.6%.

Based on the examination of measurements for Counter 8534 reported here, it is concluded that the flight data are quite steady over the length of the data record, that is, 19 revolutions of data. The coefficient of variation for first harmonic loads varies from less than 1% for the normal force at the outer blade stations to slightly over 2% for blade flapping. This amount of variation is substantially less than the desired level of accuracy for current comprehensive analyses.

It is recommended that the first cycle or revolution of Counter 8534 be used for correlation purposes. The use of averaged data is most beneficial when it is necessary to reduce excessive noise in the data, which is not the case for the present data.

William G. Bousman
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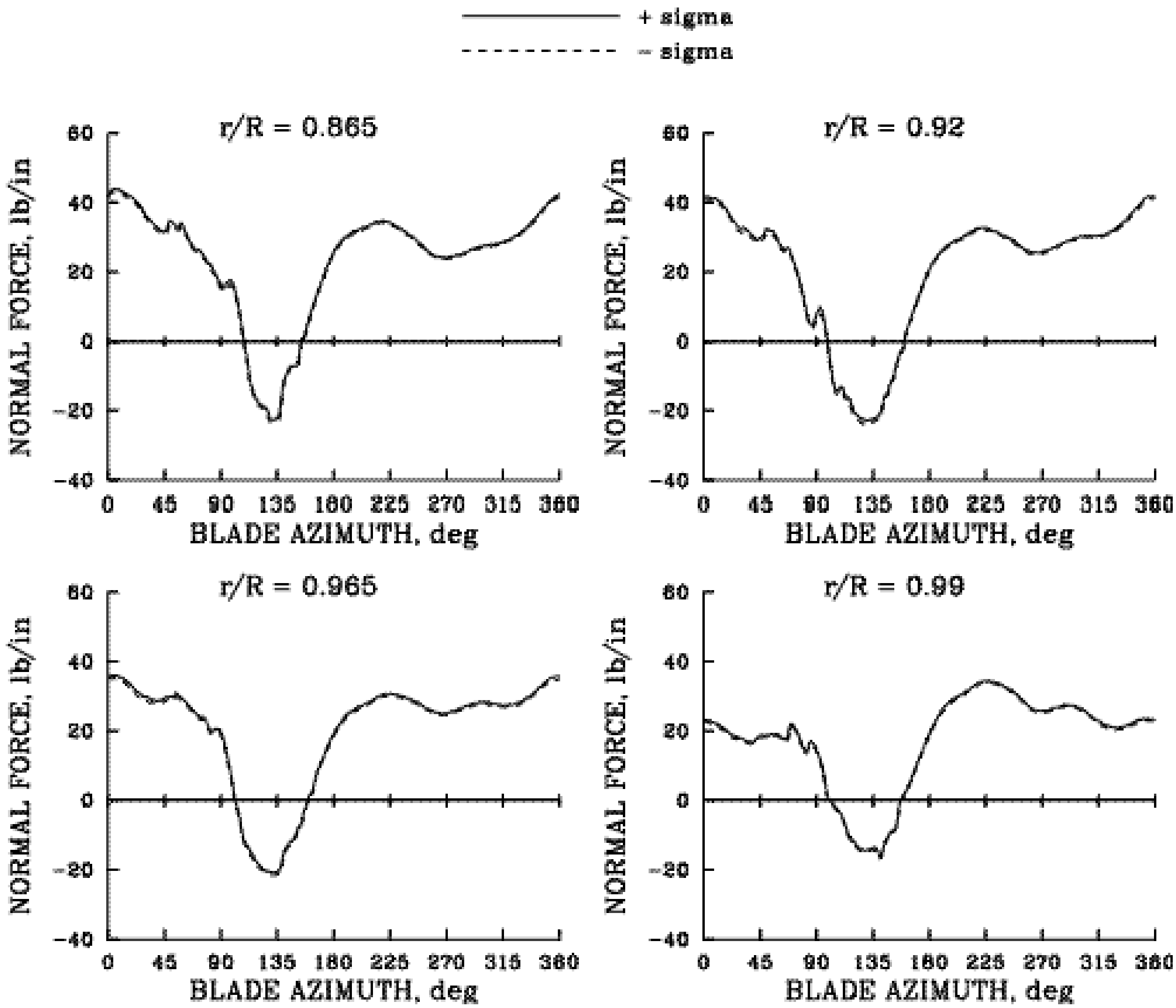

Figure 1. – Normal force at four radial stations on the UH–60A; μ = 0.368, C_W/σ = 0.0783. Mean + one standard deviation and mean – one standard deviation are shown (n = 19).

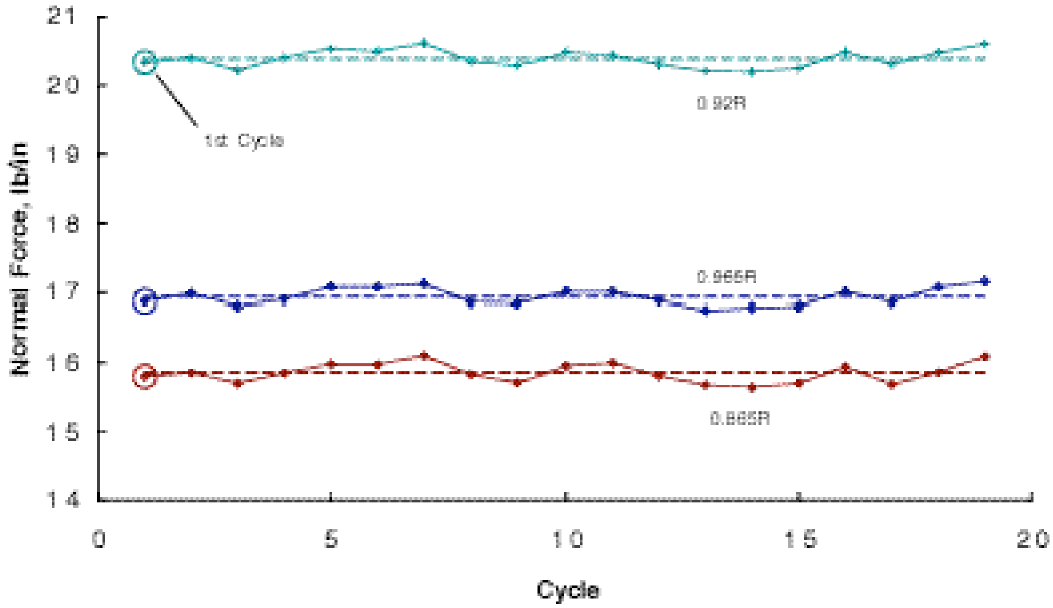

Figure 2. – Magnitude of the first harmonic of normal force at three radial stations as a function of cycle or revolution number for Counter 8534.

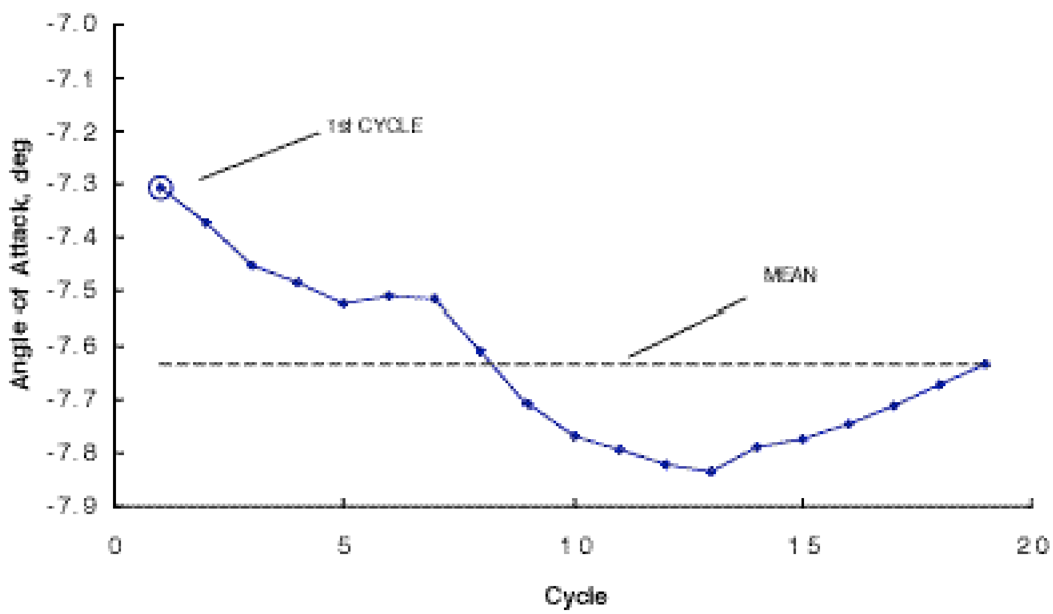

Figure 3. – Variation in shaft angle of attack over the length of Counter 8534.

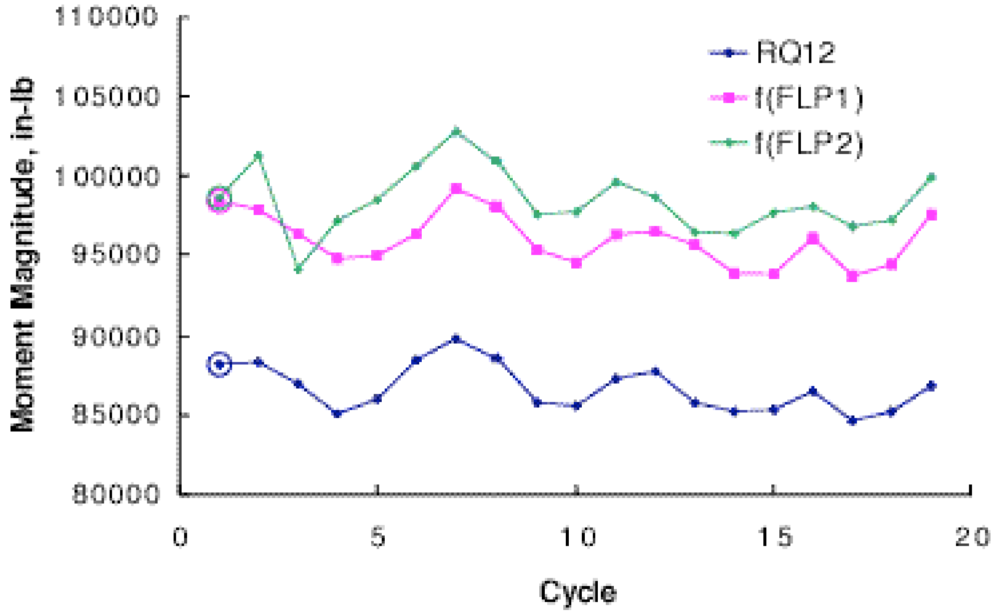

Figure 4. – Variation of first harmonic shaft bending moment as measured on the shaft and as derived from flap angle measurements on blades 1 and 2 for Counter 8534.