Technical Note

Relationships between flying qualities and flight tests parameters for the F/A-18 aircraft

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In this Technical Note, is shown that relationships exist between flying qualities levels 1, 2 and 3 and flight conditions expressed in terms of Mach numbers, altitudes and angles-of-attack for the F/A-18 SRA (System Research Aircraft). These relationships are helpful in detecting if derivatives are well calculated for flight tests intermediate conditions.

The stability and control derivatives were calculated at NASA Dryden Flight Research Center DFRC laboratories for a number of 52 flight test conditions for the longitudinal and lateral aircraft motion. Flight tests were considered at Mach numbers between 0·3 and 1·3, at altitudes between 1,000ft and 40,000ft and at angles-of- attack vary between 1º and 10º. Following two methods were used to calculate the characteristic system eigenvalues: the approximate method and the exact method.

From these eigenvalues, by use of the classic vibration equation, the natural frequencies and damping were determined for the longitudinal and for the lateral aircraft motion[1]. In case of the longitudinal aircraft motion, the flying qualities were evaluated for the long and short period of motion, while for the lateral aircraft motion, the flying qualities were evaluated for the roll, Dutch roll and spiral motions. In the following paragraphs, results are presented.

The longitudinal motion damping rates are the long period and the short period damping rates, while the lateral motion damping rates is the Dutch roll damping rate. The long period damping rates reduce with the altitude augmentation and with the reduction of Mach number. The short period damping rates reduce with the altitude augmentation and remain constant with the Mach number variation for different flight conditions as seen on Fig. 1. Dutch roll damping rates increase with the Mach number augmentation and with the reduction of the altitude. Figure 2 shows the increase of the Dutch roll natural frequency ω_{nDR} with the Mach number augmentation and with the altitude decrease for a number of 17 flight test cases where $n = 1$ denotes uniform flight at zero angle-of-attack.

Relative errors were calculated for frequencies and damping with the approximate method versus the frequencies and damping calculated with the exact method for the F/A-18 aircraft. Then, maximum relative errors were calculated for the longitudinal motion and (short and long period of motion) and for the lateral motion (Dutch roll, roll and spiral).

Maximum relative errors calculated for the natural frequencies and damping for the short and long period motions appear for the same angle-of-attack α = 10º. Maximum relative errors calculated for the natural frequencies ξ_{DR} and damping ω_{nDR} of the Dutch roll mode, such as the roll time constant τ_{roll}, and the time to double the spiral mode amplitude $T_{2spiral}$ appear for the same angle-of-attack α = 10º and for the Mach number M = 0·3.

Maximum relative errors were found to be much smaller for the short period motion than for the long period motion, which is equivalent to say that the frequencies and damping values calculated with the approximate method are closer to the natural frequencies and damping calculated with the exact method for the short period motion. Frequencies and damping calculated with the approximate method are far from the frequencies and damping calculated with the exact method for the long period of motion, with the exception of flight cases with small angles-of-attack and high Mach numbers.

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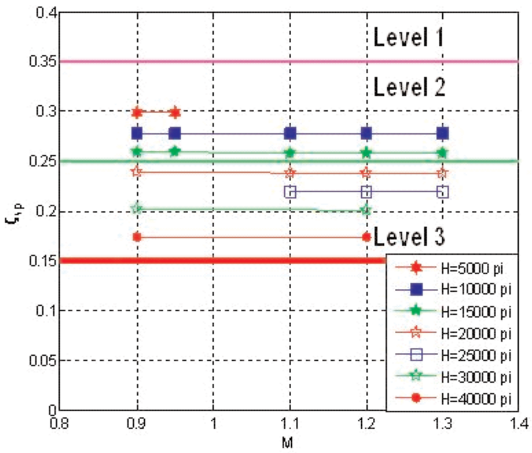

Figure 1. Short period damping rate ξ_{sp} variation with Mach number and altitude.

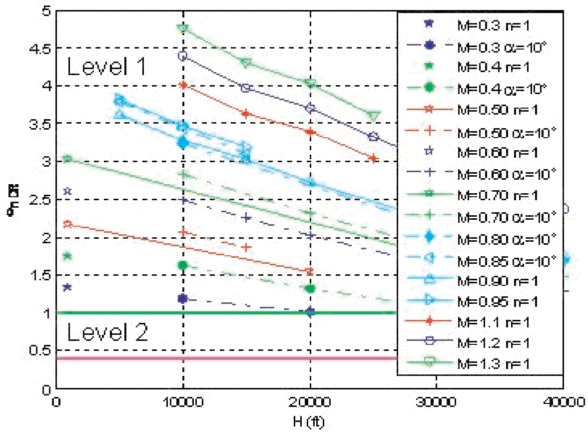

Figure 2. Variation of the Dutch roll natural frequency damping with altitude and Mach number.

Relative errors calculated for the time to double the spiral mode $T_{2spiral}$ reduce with the altitude augmentation and with the Mach number reduction. The relative errors for the roll constant time increase with the increase of the altitude and with the reduction of the Mach number. The relative errors calculated for the natural frequency of the Dutch roll mode ξ_{DR} are found to be smaller for cases with Mach numbers greater than 0·9 than the relative errors for ξ_{DR} for the cases with Mach numbers smaller than 0·85, but remain always higher than 30%. Relative error calculated for the natural frequency of the Dutch roll mode ω_{nDR} is much smaller than 4% for all Mach numbers, which means that the natural frequency of the Dutch roll calculated with the exact method is close to ω_{nDR} calculated with the approximate method.

The aircraft had, for the long period and for the roll motions, the best flying qualities 1 for most of the flight cases (45 cases from 52 cases), while for the short period motion, the flying qualities were worse than for the long period motion. Figure 3 shows that the long period damping ξ_p increases with Mach number and decreases with the altitude. Flying level is equal to 1 for this case. Figure 4 shows the variation of the roll time constant troll with the altitude and with the Mach number, actually τ_{roll} increases with the altitude augmentation and decreases with Mach number augmentation.

For the spiral mode, the aircraft has the best flying qualities 1 and 2 when the time to double the amplitude $T_{2spiral}$ was calculated with the exact method and has the level flight 3 when $T_{2spiral}$ is calculated with the approximate method.

For the Dutch roll mode, the aircraft had the flying qualities 2 for most flight cases for Mach numbers higher than 0·5 while the aircraft has the best flying qualities 1 for Mach numbers between 0·3 and 0·4. The aircraft had the best flying qualities for all cases analysed with the frequency criteria for the Dutch roll mode.

Relationships were found between flying qualities levels and following flight test parameters: Mach number, altitudes and angles of attack. These relationships expressed in terms of augmentation and decrease of flying qualities levels with Mach number, altitude and angle-of-attack are useful in the determination of stability and control derivatives dependent on these flight test conditions.

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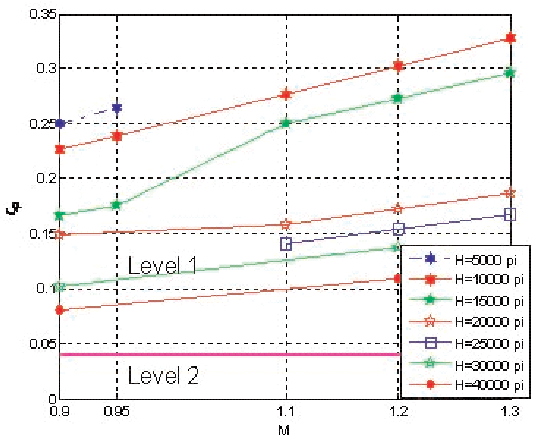

Figure 3. Variation of the long period damping ξ_p with Mach number and altitude.

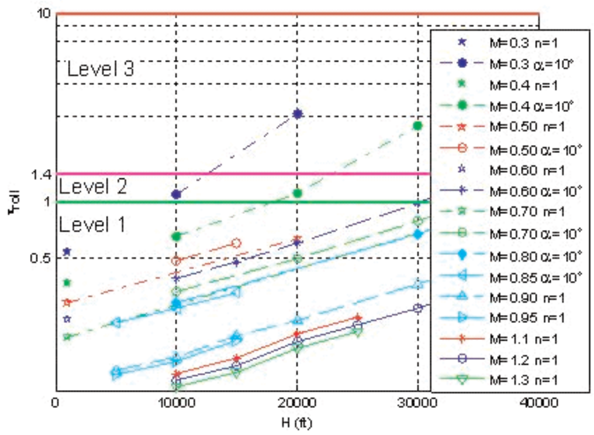

Figure 4. Variation of the roll time constant τ_{roll} with altitude and Mach number.

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