Module – 3

STABILITY AND CONTROL – LONGITUDINAL AND MANEUVERING

Syllabus:

Static & dynamic longitudinal stability: - methods of flight testing and data reduction techniques. Stick free stability methods. Maneuvering stability methods & data reduction.

3.1 Static Longitudinal Stability Flight Test Methods

From the pilot's standpoint, the static longitudinal stability of an aircraft may be divided into several characteristics. These characteristics include gust stability, speed stability, and flight path stability.

Both gust stability and speed stability are related to the classical stick-fixed and stick-free static longitudinal stability and are dependent on stability margins. They are also affected by friction in the longitudinal control system and by control system gimmicks such as downsprings, bobweights, or artificial stick-force systems.

Flight path stability is related to the pilot's opinion of the aircraft in the approach configuration.

Since gust stability and speed stability are dependent on stability margins, it is worthwhile to determine the neutral point locations in order to fix the aft c.g. limit. We would want this limit to provide us with a useable c.g. travel, while at the same time giving us adequate stability margins. Both of these items are airplane mission dependent.

3.1.1 Federal Aviation Administration Regulations

The FARs have had requirements for static longitudinal stability since their inception. However, their requirements are only for stick-free longitudinal static stability as demonstrated by longitudinal control force when the airplane is displaced from trim. There are no requirements for stick-fixed longitudinal static stability or flight path stability.

3.1.2 Stick-Fixed Neutral Point Determination

As was discussed in the section on stick-fixed stability theory, the stick-fixed stability $(dC_m/dC_L)_{\text{fixed}}$ can be related to the elevator position δ_e through the relation:[4,7]

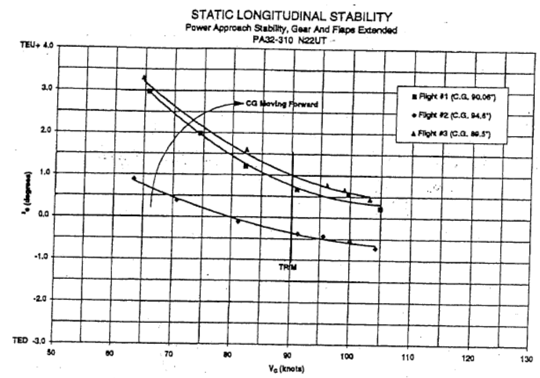
$$\frac{d\delta_e}{dC_L} = \frac{(dC_m/dC_L)_{\text{fixed}}}{C_{m_{\delta_e}}} \tag{21.1}$$

Since $d\delta_e/dC_L$ will be zero when $(dC_m/dC_L)_{\text{fixed}}$ is zero, the stick-fixed neutral point can be found by moving the aircraft c.g. aft until the plot of δ_e vs C_L

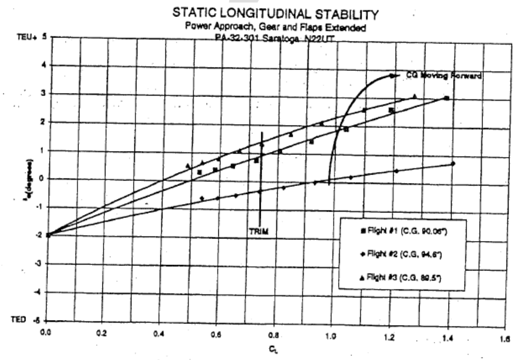
has a zero slope. Although it is possible to determine the stick-fixed neutral point by this method, it is not a safe way to approach the problem.

A safer way to approach the problem is to measure the elevator position δ_e vs equivalent airspeed V_e, both above and below some specified trim airspeed, for a number of c.g. positions safely ahead of the neutral point. This should be accomplished for the configurations specified in the FAA Regulations at the trim airspeeds and power settings specified. Once these data have been taken they are plotted and reduced using the sequence shown in Fig. 21.1 (Refs. 4, 8).

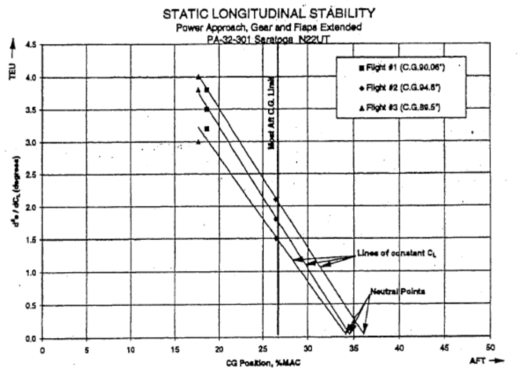
Positive stick-fixed, or elevator position, longitudinal stability is not required by the federal air regulations, but is important in determining if the stick-free longitudinal stability can be improved through gimmicks like down-springs or bobweights.



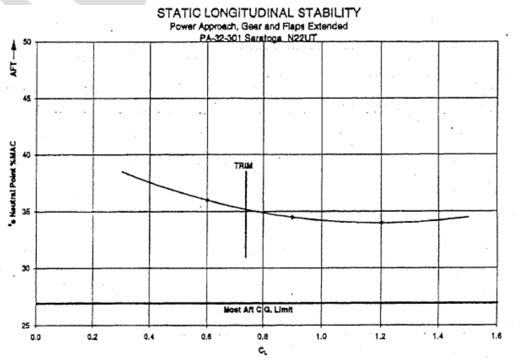
Step 1. Plot data of elevator position (δ_e) vs calibrated airspeed (V_C) for each flight at different c.g. positions and fair a smooth curve through the data. Mark the trim airspeed on the plot.



Step 2. From the smooth curves of Step 1 plot elevator position δ_e vs lift coefficient C_L. Select airspeed at which the flight test data were obtained to calculate C_L but obtain the δ_e from the faired lines. Note that these curves all ray from the δ_e for $C_L = 0$.



Step 3. Take slopes $d\delta_e/dC_L$ at even increments of C_L from each of the curves and plot c.g. position. Fair curves through the points for each respective C_L and extrapolate to zero. This is the c.g. position of the neutral point for that lift coefficient.



Step 4. Plot the locus of neutral points for each C_L vs C_L and compare with the desired most aft c.g. position. Mark trim C_L neutral point since this is most important neutral point.

3.1.3 Stick-Free Neutral Point Determination

As was discussed earlier, the stick-free longitudinal stability $(dC_m/dC_L)_{free}$ can be related to the elevator control force by the relation:[4]

$$\frac{dF_s}{dV_e} = 2K\frac{W}{S_W}\frac{C_{h_{\delta_e}}}{C_{m_{\delta_e}}}\left(\frac{dC_m}{dC_L}\right)_{free}\frac{V_e}{V^2_{e_{trim}}} \tag{21.2}$$

From this relation we can see that when we are at the stick-free neutral point $(dC_m/dC_L)_{free} = 0$ then the derivative dF_s/dV_e is also equal to zero. Again, we would prefer not to test at the actual neutral point. Therefore, while we are collecting the data for stick-fixed stability, we also record elevator control force. We then plot elevator control force F_s vs equivalent airspeed V_e as is shown in the first plot of Fig. 21.2 (Refs. 4, 8).

For FAA certification it is not necessary to determine the stick-free, or control force, neutral point. For FAA testing one only needs to plot elevator control force at the control wheel, or control stick, and plot it vs calibrated airspeed as is shown in the first plot of Fig. 21.2. This plot must have a stable slope, as shown, to satisfy the regulations.

As can be seen in Eq. (21.2), the derivative dF_s/dV_s is a function of aircraft trim as well as stability. This fact reduces the value of a neutral point extracted from this derivative. If we divide stick force by dynamic pressure, the derivative of this quantity $d(F_s/q)/dC_L$, is a function of stability only.[7]

$$\frac{d(F_s/q)}{dC_L} = -A\frac{C_{h_{\delta_e}}}{C_{m_{\delta_e}}}\left(\frac{dC_m}{dC_L}\right)_{free} \tag{21.3}$$

where

$A = -KS_eC_e$

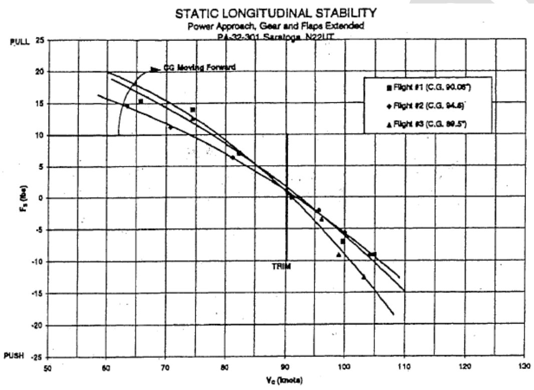
S_e = elevator area

C_e = elevator MAC

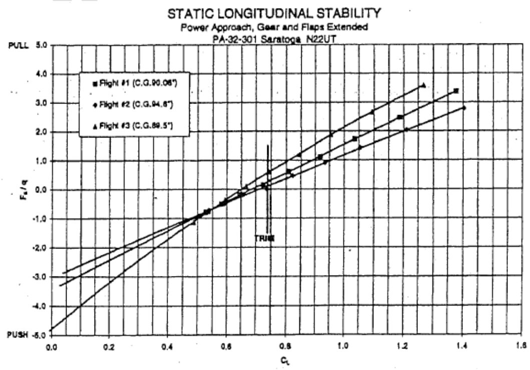
K = control system gearing constant

The next step in the data reduction process is to divide the stick force by dynamic pressure and plot this vs lift coefficient (see second plot of Fig. 21.2.). In order to extract the neutral point, the sequence of Fig. 21.2 is continued.

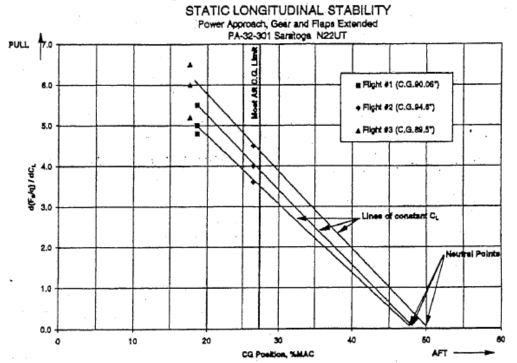
Again, it should be cautioned that this method will not give the stick-free neutral point if there are springs or other "force feel" systems in the longitudinal control system. In such a case, you will only have an apparent or stick-force neutral point.



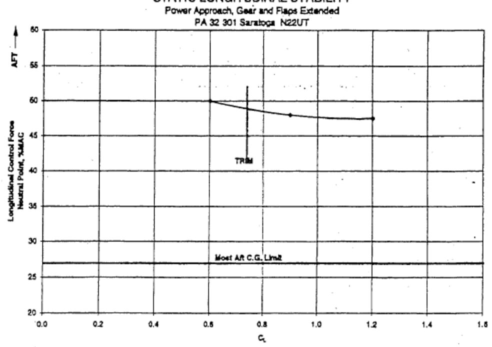
Step 1. Plot elevator control force F_S vs calibrated airspeed V_C for each c.g. position tested and fair a smooth curve through the data points. Mark the trim airspeed on the plot. For FAA testing this is all that is required by the regulations.



Step 2. Using even increments of airspeed obtain the F_S from the previous plot using the faired lines and not the data points and plot F_s/q vs C_L for each c.g. position tested. These lines should cross at or near the trim C_L.



Step 3. At even increments of C_L take slopes $dF_s/q/dC_L$ for each c.g. position tested and plot these slopes vs c.g. as shown. Fair straight lines connecting the slopes for each C_L and extrapolate to a zero slope. This point is the control force neutral point for that C_L.



Step 4. Plot the locus of neutral points vs C_L and mark the trim C_L. This is the most important control force neutral point since the pilot spends most of his time flying at or near trim.

Fig. 21.2 Graphical method for determining control force neutral point (continued).[3,8]

3.1.4 Flight Test Method for Determination of Neutral Points

Both the stick-fixed and stick-free neutral point data are collected at the same time. First, the pilot trims the aircraft to the trim airspeed and power setting required by the regulation for the flight condition (climb, cruise, or power approach). The following data are then recorded:

1) observed trim airspeed
2) elevator position (Note: It will not be zero.)
3) longitudinal control force (It should be zero.)
4) fuel consumed (for test weight calculation)
5) power setting
6) altitude
7) ambient air temperature

Once the trim data are obtained the airspeed is either increased or decreased by use of the longitudinal control without retrimming the aircraft and the new value of airspeed is held constant by exerting a force upon the longitudinal control. Items 1 through 4 of the above data set are read again at this new speed. Whether one uses a speed above or below the trim airspeed for the first point depends upon the flight condition being measured. If it is a climb condition then the first point should be above trim, if power approach it should be below trim, if cruise it makes no difference. The reason for doing this is to reduce the altitude gain or loss during the measurement. This procedure is then repeated at an airspeed on the opposite side of the trim airspeed. Once that data is obtained, the airspeed is then again moved to the opposite side of the trim speed to some value that is at least 5 kn higher or lower than the previous measurement. This alternating procedure with data points 5–10 kn apart is continued until the required stable range is covered. Data items 1 through 4 are collected at each airspeed.

After completing the last point above and below the trim airspeed, the longitudinal control is gradually released toward trim until the pilot's hands can be removed without any further airspeed change. This airspeed is then recorded as the "free return airspeed." It is an indication of control system friction and the FARs require that it not be more than + or − 10% of the trim airspeed.

Once the data have been collected, the instrument corrections are applied and the data plotted as shown in Figs. 21.1 and 21.2.

(Need to plot graphs mentioned in section 3.1.3 and 3.1.4)

3.1.5 Speed Stability

The military specifications require that aircraft have a stable stick force throughout its speed range. This requirement addresses itself to the irreversible control system since these systems do not have classical stick-free stability.

The test for speed stability is quite simple. A series of overlapping stick force vs equivalent airspeed plots are obtained across the operating envelope as shown in Fig. 21.3 (Ref. 7).

The military specifications do allow for some instability in the transonic range. This instability may not be of such nature as to be objectionable to the pilot.

In measuring speed stability, one must be careful to take into account the control system friction and breakout forces. The normal procedure is to measure the force on the back side, or low force side, of the friction band for speeds below trim, and on the high side (low force side) at speeds above trim.

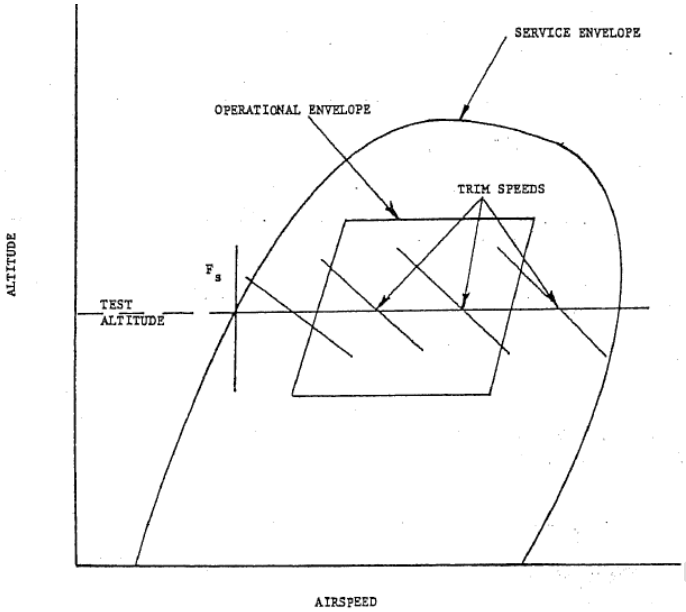


Fig. 21.3 Speed stability measurement.[7]

3.1.6 Flight Path Stability

An airplane is said to exhibit positive flight path stability if an increase in airspeed by elevator alone decreases the flight path angle, while a decrease in airspeed by this method increases the flight path angle. Flight path stability is directly related to the speed at which an airplane flies its approach and the relationship of this speed to the thrust required curve. For instance, an airplane

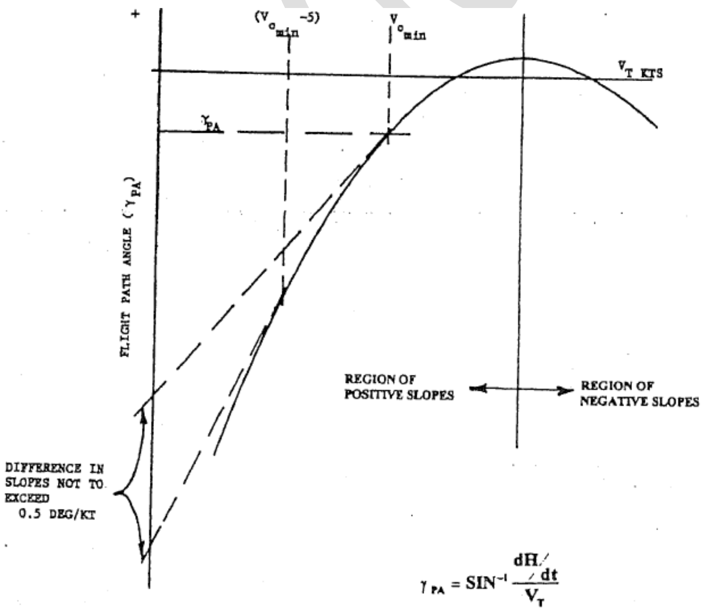


Fig. 21.4 Flight path stability measurement.[5]

that flies its approach at an airspeed that is in the flat portion of the thrust required curve generally has better flight path stability than one with its approach speed on the back side of the thrust required curve. Therefore, flight path stability may sometimes be improved by increasing the approach speed.

Although the items that affect flight path stability are more nearly related to airplane performance than to airplane stability, they do affect the pilot's opinion of the airplane's handling qualities and affect workload during an approach. It is for this reason that flight path stability is included as a longitudinal stability test.

To analyze flight path stability in the power approach configuration, we need a plot of flight path angle vs true airspeed, such as is shown in Fig. 21.4 (Ref. 5). To obtain this plot we need to measure the rate of descent in the power approach configuration through a range of −10 to +10 kn of the approach speed. The airplane should be trimmed at the approach speed and the speed variations made with elevator only. In certain cases it may be possible to conduct this test at the same time data is being gathered for the power approach longitudinal stability test since pilot techniques for the two tests are nearly the same.

Once we have obtained the data it should be corrected for weight and other nonstandard performance factors and plotted as shown in Fig. 21.4.

We then need to take slopes at points along the curve, including a slope at the approach speed for reference. We then may compare these slopes with applicable requirements to determine if they comply.

3.2 Dynamic Longitudinal Stability Flight Test Methods and Data Reduction

The longitudinal quartic equation can be factored into a pair of second order differential equations. One of these second order differential equations describes the longitudinal short period motion which on most airplanes is a well-damped motion of fairly high frequency, normally with a period of under three seconds.

The other second order differential equation factored from the longitudinal quartic equation describes a motion called the phugoid or long period motion. It is a lightly damped motion of low frequency with a period on the order of 30 s or more.

A third set of motion called the short period elevator motion may exist for airplanes with reversible control systems. It resembles the longitudinal short period but is driven by the elevator.

Since dynamic longitudinal stability involves evaluating the response of the airplane over a period of time, the flight test methods must, by necessity, differ from those required for static stability. In addition, we must also consider more sophisticated methods of data collection since the aircraft responses may be oscillatory and of short duration. Let us, again, separate the discussion into methods to evaluate the phugoid and methods to evaluate the short period.

3.2.1 Federal Aviation Administration Regulations

The FARs only address the short period mode of dynamic longitudinal stability. They do not address the long period longitudinal dynamic stability—or phugoid—mode of motion. The reason behind this is that the long period mode of motion can be easily damped by the pilot under visual flight conditions. However, some more recent research has shown that an undamped phugoid may create problems during instrument flight. The FAA has in recent amendments revised the regulation to reflect the change in thinking on the phugoid. In any case, an airplane will possess better flying qualities if the phugoid motion is damped, so it should not be ignored just because there is no regulation to cover it.

3.2.2 Flight Test Methods for Evaluating the Phugoid (Long Period Motion)

The flight test method for measuring the phugoid motion is quite simple. First, the aircraft is trimmed to the test trim speed and the test configuration of power, gear, and flaps established. Once in configuration and trim, the airspeed is displaced 10–15 kn from trim by use of the elevator control. The elevator is then returned to the trim elevator position using control movement near the aircraft's long period frequency and the resultant airplane oscillation recorded.

The airspeed may be displaced either above or below the trim speed. Normal procedure is to observe phugoid motions from displacements both above and below trim.

Also, once returned to the trim position the control stick may be either held fixed or released. Again, both approaches should be tested since differences between the stick-fixed and stick-free cases normally exist.

Data may be recorded by a data collection system or, since the frequency is low, by hand.

Phugoid Data Reduction

To reduce the data, first make a plot of equivalent airspeed vs time, as is shown in Fig. 23.1, for all cases tested. On top of this plot, plot a subsistence envelope (also shown in Fig. 23.1).

From the plot in Fig. 23.1 determine the amplitude ratio X_n/X_{n+1}. With the resultant amplitude ratio, enter Fig. 23.2 (Ref. 4) and determine the damping ratio ζ. If the phugoid is erratic it may be necessary to measure several subsistence ratios and determine resulting damping ratios. The damping ratios may then be averaged to come up with an average damping ratio for the motion.

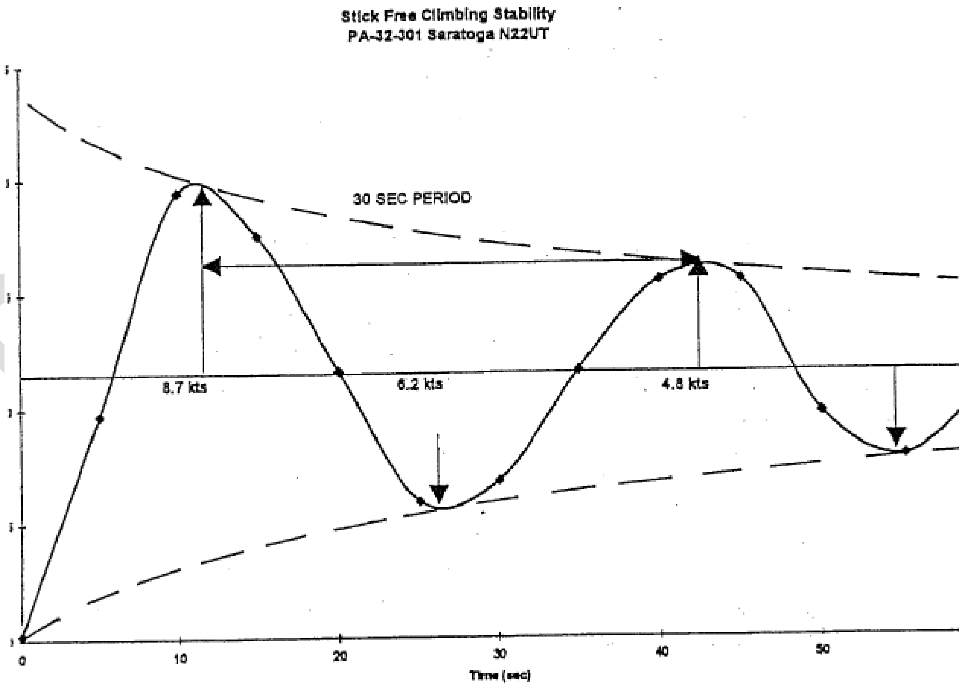


Fig. 23.1 Plot of climb phugoid airspeed vs time.

Once we have damping ratio we may determine the undamped natural frequency ω_p from the equation:[7]

$$\omega_p = \frac{2\pi f}{\sqrt{1-\zeta^2}} \tag{23.1}$$

where
$f = \Delta cycles/\Delta time$

We may then wish to make plots of phugoid frequency vs airspeed and damping ratio vs airspeed for comparison with applicable specifications or regulations. We may also make plots of the phugoid roots using the natural frequency and damping and by knowing that:

$$\zeta = \cos\theta \tag{23.2}$$

and using Fig. 23.3. Knowing the value and location of these roots may be useful in tailoring autopilots or in later modifications to the airplane.

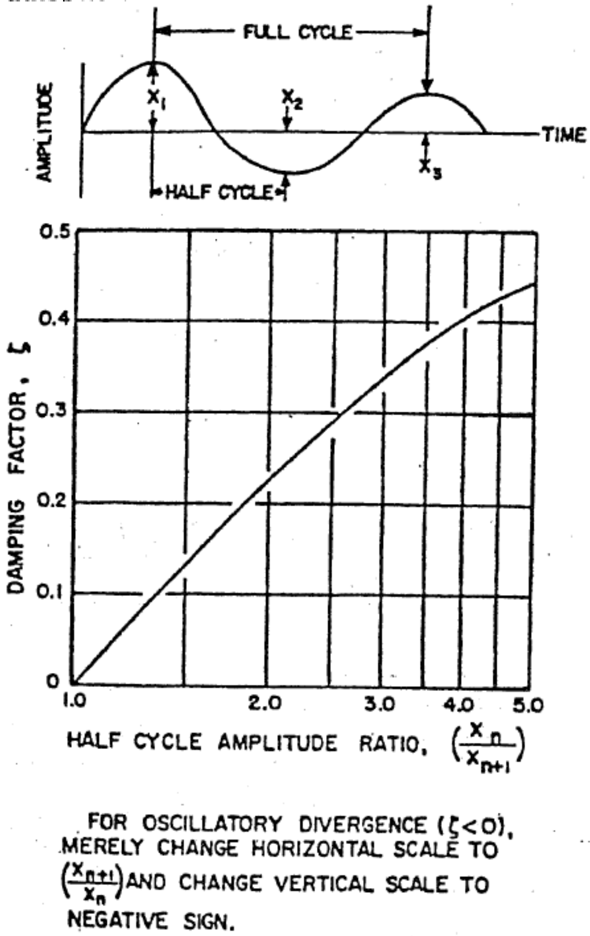


Fig. 23.2 **Determination of damping ratio for lightly damped system.**[4]

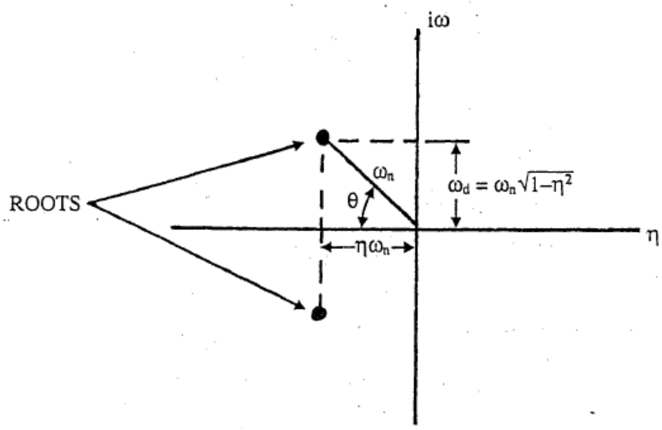


Fig. 23.3 **Root locus plot.**

3.2.2 Short Period Flight Test Methods

As might be expected, different techniques are used to test the airplane and elevator short periods.

3.2.2.1 Airplane Short Period

First, let us discuss the methods to evaluate the airplane short period. There are three methods used to excite the short period. They are 1) doublet input; 2) pulse input; and 3) 2-*g* pull-up.

The doublet input is a very good method for evaluating the short period, because in addition to exciting the short period motion it tends to suppress the phugoid. To perform the doublet input, the pilot first trims the aircraft to the test condition. The test instrumentation is started, and the pilot rapidly moves the control nose down, then nose up, then back to trim. Once the control is returned to trim, it may be either held in the trim position or released, depending upon the type of short period (stick-fixed or stick-free) to be evaluated. Data recording should continue until all short period motion has subsided. In testing the short period, the pilot should try several different doublets, in which the frequency of the input is varied, until the frequency that best excites the aircraft's short period frequency is found. Due to the shortness of the motion, data recording will need to be done using an automatic recording device, unless only the number of overshoots is recorded.

The pulse input might be described as one half of a doublet input. In performing the pulse input, the control is only moved forward, or aft, of trim, but not both as in the doublet. The pulse input is not as good a method for evaluating the airplane short period as is the doublet input, because it tends to also excite the phugoid. This makes it difficult to reduce the data since it may be hard to separate the short period motion from the phugoid motion. However, it may be necessary to use the pulse method for airplanes that have a very high short period frequency.

The 2-*g* pull-up method is also a good method for evaluating the short period, since it too suppresses the phugoid. It is a very good method for airplanes that have a low short period frequency. To perform the 2-*g* pull-up method the pilot first trims the aircraft to the test condition, records the trim data, and then starts a pull-up decreasing airspeed and increasing altitude. The pilot then pushes the nose over and enters a dive in a fairly steep nose down attitude. As trim airspeed and altitude are approached the aircraft is smoothly rotated so as to achieve trim airspeed and attitude at the same time. When this occurs the control stick is rapidly returned to trim and released or held fixed depending upon the short period to be evaluated. The 2-*g* pull-up method provides a large amplitude input for testing short periods with heavy damping. However, it does require considerable pilot skill and proficiency in performing the maneuver.

3.2.2.2 Elevator Short Period

To evaluate the elevator short period the pulse method described in the preceding section is used. As might be expected the elevator short period is always evaluated stick free and should normally be heavily damped. Also, as mentioned in the theory, it only has meaning for a reversible control system.

3.2.2.3 Short Period Data Reduction

The airplane short period natural frequency and damping ratio may be found using the procedure shown in Fig. 23.4 (Ref. 4). Once these values have been obtained they may be plotted on the short period thumbprint for evaluation as is shown in Fig. 22.6. Short period roots may also be plotted using the methods shown for the phugoid.

For well-damped systems, the elevator short period is evaluated by counting the number of overshoots of the trim position. A more detailed investigation of the elevator short period is not warranted unless low damping exists or data are needed for handling qualities improvements.

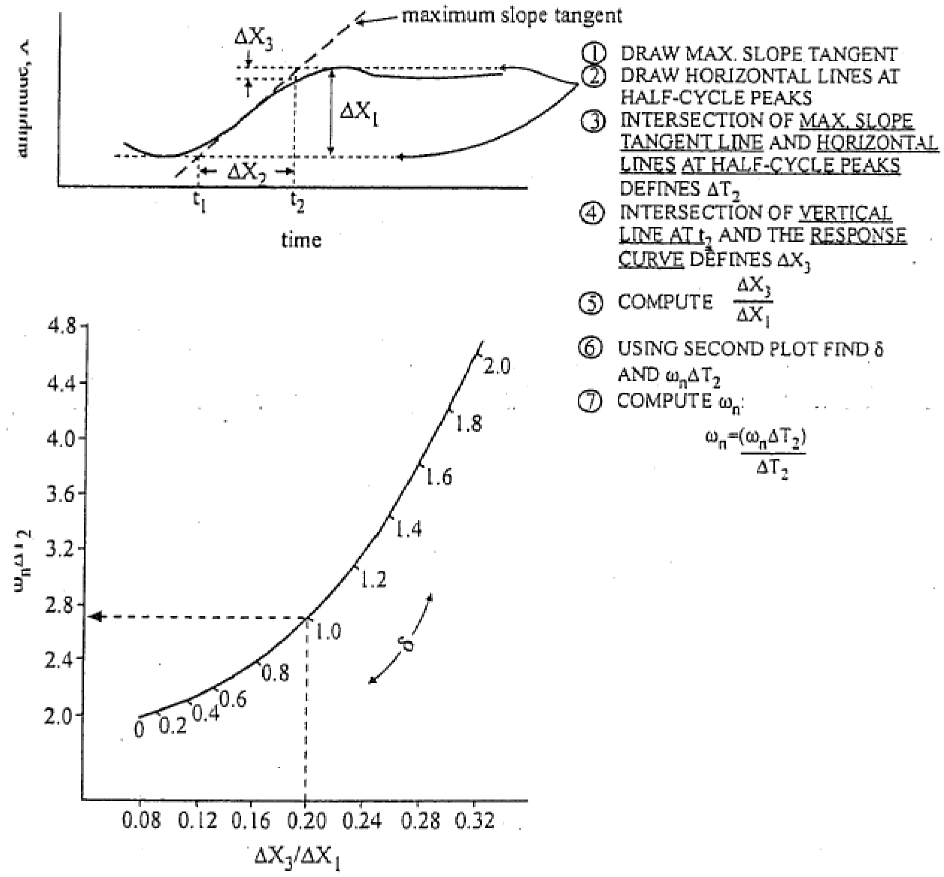


Fig. 23.4 Determination of second order response characteristics for a heavily damped system.[4]

3.3 Maneuvering Stability Methods and Data Reduction

Like other areas of stability and control flight testing, evaluation of maneuvering stability requires significant inputs from the test pilot on the suitability of the aircraft to perform the maneuvering task of its mission. These inputs should be in addition to the qualitative evaluation of the airplane's ability to meet applicable regulations or specifications. The test pilot may form an opinion of the aircraft's suitability to perform the maneuvering task of its mission from flights other than the quantitative maneuvering flight test. Because of this we will discuss the factors making up pilot opinion and the quantitative evaluation separately.

3.3.1 Federal Aviation Administration Regulations

FAA regulations prior to FAR Part 23, Amendment 14, did not contain any requirements for maneuvering stability. This lack of requirements led to a number of accidents with airplanes that had low values of maneuvering stability and a requirement was added to the later versions of FAR Part 23.

3.3.2 Evaluation by Pilot Openion

A number of factors contribute to the pilot's opinion of the airplane during maneuvering tasks. Two items that help to form the pilot's opinion of the aircraft during maneuvering flight are longitudinal control system breakout force and friction. Friction in a control system is always undesirable. High friction will cause poor control feel during maneuvering, and may mask the airplane's actual stick force per *g* gradient at low values of normal acceleration. A reasonable amount of breakout force is desirable during maneuvering since it can reduce sensitivity in control feel about trim, and prevent pilot induced oscillations. However, excessive breakout force may cause the pilot to feel a lag in the control system and cause overcontrolling.[3]

Another control system item that may affect the pilot's opinion of the airplane during maneuvering is free-play. Free-play in the control system makes precise tracking task at low values of normal acceleration difficult. This causes the pilot to fly slightly out of trim so that the plane is always on one side or the other of the free-play dead-band. Attempts should be made to keep control system free-play to a minimum.[3]

Residual control system oscillations after a longitudinal control input are undesirable. During rapid maneuvering they produce an objectionable control feedback.[3]

Positive stick centering is a desirable feature during maneuvering since it allows the pilot to return to trim by releasing control pressure.[3]

The primary factor in the pilot's opinion of the airplane during maneuvering is the variation in stick force with normal acceleration called stick force per *g*. The gradient of the stick force per *g* curve should be a function of the airplane's mission, its design load factor, and the type of longitudinal control in the cockpit.[3,4]

First if the airplane's mission is such that it requires extensive maneuvering then the stick force per *g* gradient should not be so high as to tire the pilot. It should be high enough, however, to prevent inadvertent over-stressing of the airplane.[4]

If the airplane is designed with a low load factor such as a bomber or transport aircraft, then the stick force per *g* gradient should be large. Such aircraft will not be maneuvered extensively, and will normally have a control wheel that allows for the pilot to accept larger stick force per *g* gradients. The control wheel gives the pilot more leverage than does a stick control, and also allows him to use both hands.[3]

An airplane with a side stick controller, such as is appearing on more recent fighter designs, would require a very low stick force per *g* gradient since the pilot cannot exert great force on such devices.

Stick force per *g* is normally measured in a steady state condition. However, the transient stick force per *g* gradient should also be sufficient to prevent overstress of the airplane due to a rapid longitudinal control input. Since these transient forces are difficult to measure, pilot opinion is normally relied on for this information.[3]

Elevator position per *g* is also an important parameter in the pilot's opinion of the airplane. The criteria for this parameter is that trailing edge up elevator should increase with increasing load factor. Although elevator position per *g* is an important parameter to the pilot, it is not as important as stick force per *g* (Ref. 3).

It has also been found that some stick motion with increasing load factor is important to the pilot's opinion of the airplane.[3] This control motion improves control feel for the pilot and allows him to determine when he has reached control stops.

What has just been described are some of the factors that affect the pilot's opinion of the airplane during maneuvering. It is important to seek out the pilot's opinion on the maneuvering mission effectiveness, since not all of the above factors are measurable. We would hope, however, that the factors that are measurable would verify the pilot's opinion.

3.3.3 Flight Test Methods for Quantitative Evalutaion

Now let us turn our attention to the measurable quantities of maneuvering stability and the methods we use to measure them. The most common parameters measured are stick force per g and elevator position per g, stick position per g and n/α. The data obtained from these tests may be used for comparison with regulatory requirements or for extrapolating neutral points. There are five methods that may be used to obtain maneuvering stability data. They are:

1) steady pull-ups
2) steady pushovers
3) wind-up turns (slowly varying g method)
4) steady turns (stabilized g method)
5) constant g

3.3.3.1 Steady Pull-Ups

This method involves obtaining maneuvering stability data by varying normal acceleration with pitch rate during wings level pull-ups. To perform this method one first establishes the trim condition at the test altitude and records the trim data. Once this is accomplished a zoom climb should be entered, without changing trim or power settings, followed by a push-over to enter a shallow dive toward the trim altitude. When the airspeed approaches the trim airspeed up elevator is applied to establish a pitch rate that will place the aircraft back on the trim airspeed at the desired load factor. During the short period of time that the aircraft is stabilized in this condition data should be recorded. The magnitude of the zoom climb, push-over, and pull-up will depend upon the desired load factor, with larger maneuvers being required for larger load factors.

Airspeed control is critical on this maneuver, and any data on which the airspeed was more than ± 5 kn from the trim airspeed should be discarded. Altitude should be within ± 200 ft of the trim altitude, and pitch attitude should be within $\pm 15°$ of the trim attitude.

The normal acceleration should be increased in even steps up to the maximum acceleration desired, or the onset of stall buffet.

3.3.3.2 Steady Pushovers

This maneuver is used to obtain maneuvering stability data at less than one g. It is essentially the reverse of the steady pull-up and is performed in that manner. The minimum normal acceleration obtainable by this maneuver is limited by the design negative load factor and the amount of down elevator available. In most cases the down elevator limit will be reached prior to achieving the maximum negative load factor.

3.3.3.3 Wind-Up Turns (Slowly Varying g Method)

The wind-up turn is an easy method to obtain a large amount of data in a single test maneuver. To perform the wind-up turn one must first trim the aircraft to the desired conditions at the test altitude and record the trim data. The aircraft is then climbed 500–1000 ft above the trim altitude, trim power reset, and trim airspeed reobtained. The aircraft is then smoothly and slowly rolled into the windup turn while maintaining trim airspeed. If an automatic data recording device is installed, data may be recorded from the initiation of the turn. If not, data should be collected in even increments up to maximum acceleration or stall buffet. Airspeed and altitude limitations for this method are the same as those for the steady pull-ups method. Wind-up turns would be performed to the left and right to check for any turn direction effects on the aircraft maneuvering stability.

3.3.3.4 Steady Turns (Stabilized g Method)

This method is used primarily for testing transport and bomber aircraft, and for fighters in the power approach configuration. The method is performed by first trimming the aircraft at the test altitude, and recording the trim data. The next step is to climb the aircraft above the test altitude and reset the trim power. The aircraft is then rolled into a 15 deg bank, and the nose is lowered to obtain and maintain the trim airspeed. Once the airspeed and bank angle are stabilized the data should be recorded. The bank angle is increased another 15 deg and the procedure repeated. Data points are obtained every 15 deg up to 60 deg, and at 0.5 g increments up to the limit load factor or stall buffet after 60 deg has been reached. Airspeed and altitude limitations are the same for this method as for the other methods.

3.3.3.5 Constant g Method

This method may also be used to determine the buffet or stall envelope of the airplane. To perform the method the aircraft is trimmed at the test altitude and the maximum airspeed for the test. The aircraft is then placed in a constant g turn, data recording started, and the aircraft is climbed or descended to obtain a 2–5 kn/s airspeed bleed rate. The primary parameter to maintain during the test is the constant load factor. The airspeed bleed rate is a secondary parameter. The test altitude should be maintained within ± 200 ft. Should the aircraft go outside this band the test should be discontinued, and started again within the band at an airspeed slightly above where it was discontinued. Due to the rapidly changing airspeed, this method requires the use of an automatic data recording device.

3.3.3.6 Data Reduction Techniques

Once the data has been obtained by use of one of the methods just described, we must present it in some meaningful form.

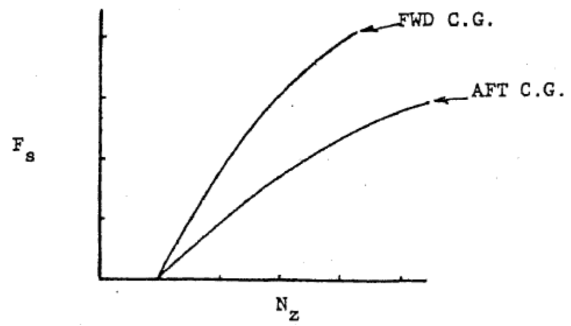
The first step in any data reduction sequence is to correct the observed data for instrument and other errors from the calibration curves.

Next we plot stick force F_s, and elevator position δ_e vs load factor N_Z; see Fig. 25.1 (Ref. 4). Then plot load factor vs angle of attack α; see Fig. 25.2 (Ref. 4). If all we are concerned about is comparison with specifications or regulations, then this may be as far as we need to go. However, if we wish to determine maneuvering stability margin, maneuver points, and other aerodynamic data then we must perform other steps.

To determine the stick-fixed maneuver point N_M we need to take slopes of the δ_e vs N_Z curve at several values of N_Z for each c.g. tested. We then plot the values of $d\delta_e/dN_Z$ vs c.g. positions as is shown in Fig. 25.3 (Ref. 4) and extrapolate the values of $d\delta_e/dN_Z = 0$ to determine stick-fixed maneuver points at each value of N_Z. We may then obtain plots of how maneuver point varies with load factor as is shown in Fig. 25.4 (Ref. 4).

The stick-free maneuver point may also be determined in a similar manner as is shown in Figs. 25.5 and 25.6 (Ref. 4).

If we need to know if the local stick force per g gradient meets the requirements of MIL-F-8785B, then we may wish to construct a log-log plot of F_s/N_Z vs N_Z/α such as is shown in Fig. 25.7 (Ref. 5).



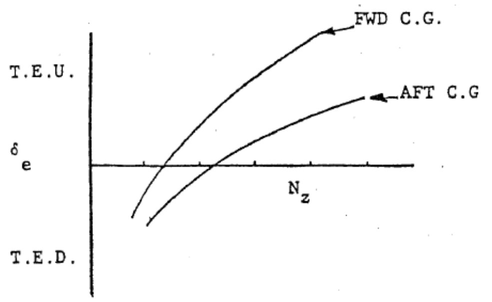


Fig. 25.1 Maneuvering stability data plots.[4]

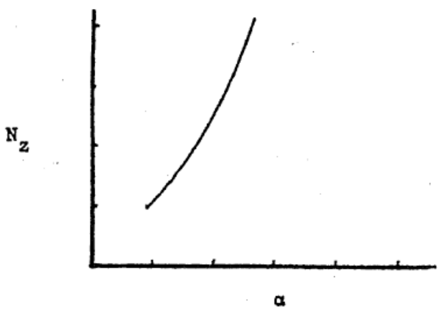


Fig. 25.2 Load factor vs angle of attack.[4]

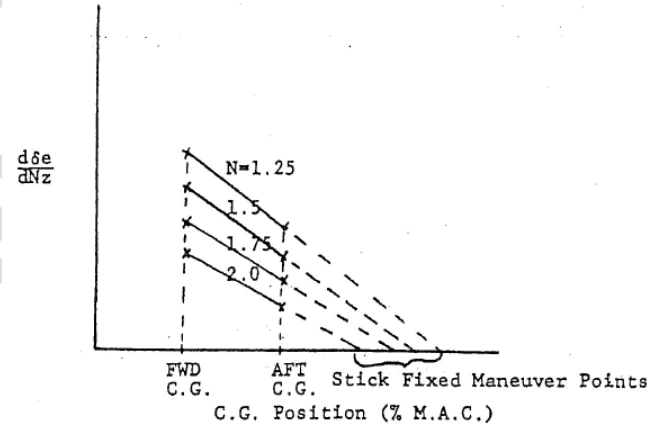


Fig. 25.3 Maneuver point extrapolation.[4]

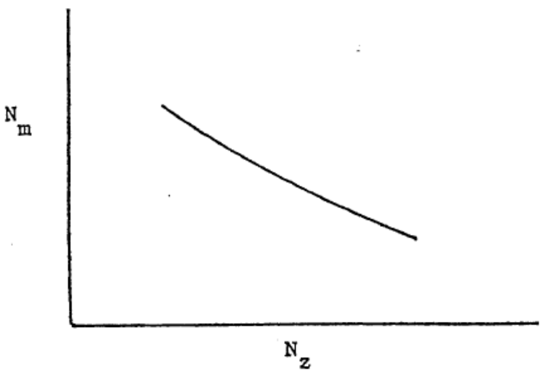


Fig. 25.4 Stick-fixed maneuver points vs load factor.[4]

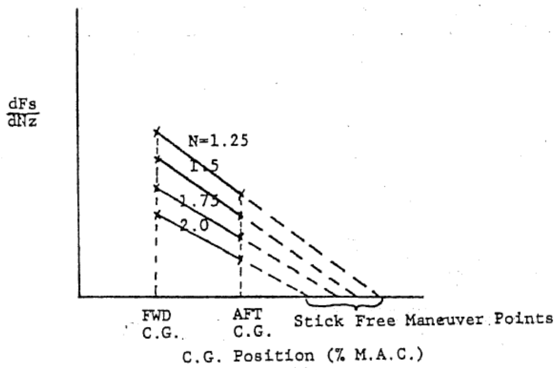


Fig. 25.5 Stick-free maneuver point extrapolation.[4]

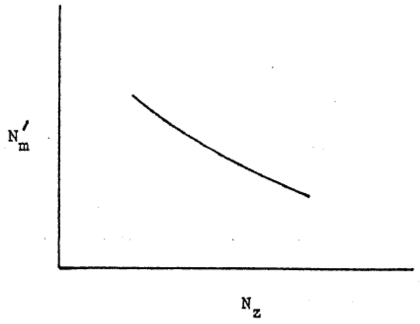


Fig. 25.6 Stick-free maneuver point vs load factor.[6]

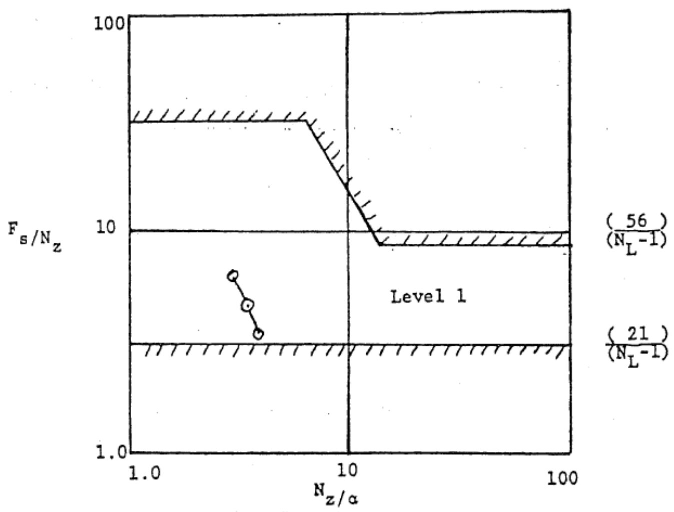


Fig. 25.7 Stick-force per g vs N_Z/α (Ref. 5).

Previous exam questions:

1. (10AE831 – June/July 2018)

a. Define neutral point and describe the flight test methods for determining the stick-fixed and stick-free neutral points. (10M)

b. What is the importance the short-period mode for aircraft stability and control? Explain the flight test method and data reduction for evaluating short-period modal parameters. (10M)

2. (10AE831 – June/July 2017)

a. Explain flight test methods determining neutral point. (10M)

b. Explain flight test methods for qualitative evaluation. (10M)

3. (06AE831 – June/July 2011)

a. What are flight test methods for evaluation maneuvering stability? (20M)

3. (06AE831 – May/June 2010)

a. Explain flight test method for determining neutral point. (10M)

b. What are flight path stability and speed stability. (10M)