Using Modeling and Simulation Data to Analyze Complex Aircraft

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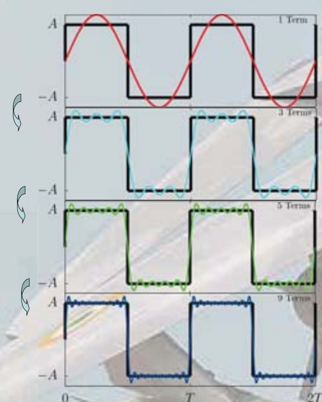
Introduction

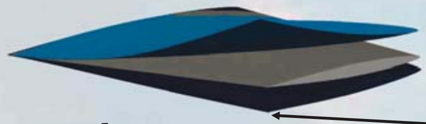
Wing tip flutter is the up and down motion of the wing on an aircraft caused by aerodynamic forces such as pressure change and wind resistance. Too much flutter on a wing could lead to catastrophic failures during flight. Through math based Modeling and Simulation (M&S), tests can be performed on a wing of the aircraft to reduce cost for repairs and modifications to the aircraft and reduce risk for the pilot.

Materials and Methods

Fast Fourier Transforms (FFTs) take sinusoidal type graphs (i.e. a saw tooth graph) and use the sum of a combination of sine and cosine functions to approximate the graph. The formula is quite complicated. Thus, using the data analysis function of excel is much more efficient than calculating the sum by hand.

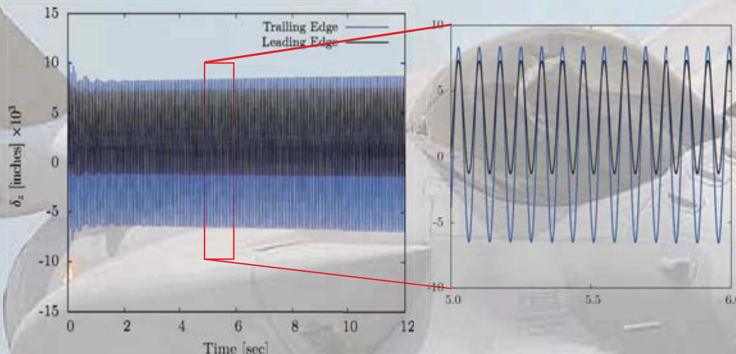
Right: The top graph is the first step to the Fourier Series where there is only one term. It demonstrates the general sinusoidal nature of this square graph. The subsequent steps show how the process is carried on to accurately approximate the graph in 3, 5, and 9 terms. The algorithm continues infinitely for a more accurate representation.





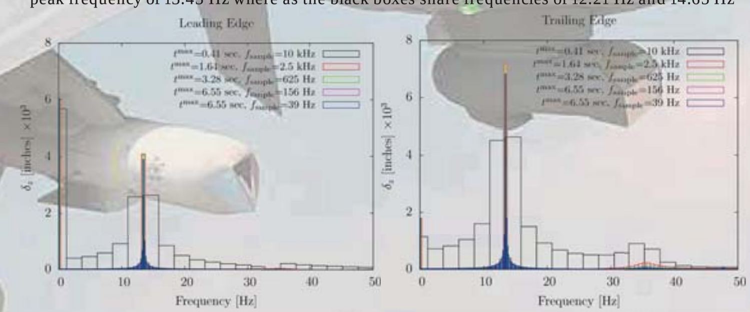
Left: Wing tip flutter is caused by aerodynamic forces exerted the wing. The motion can either converge to equilibrium or diverge to cause catastrophic results.

Results



Above: The time plots demonstrate the sinusoidal nature of the deflection of the wing. This pattern is necessary to performing an FFT on a set of data.

Below: The black boxes versus the color boxes show how inaccurate sampling a shorter time period with more data per period can be. These graphs demonstrate an inaccurate dual peak frequency and a more accurate single peak frequency. The color boxes of both graphs share a peak frequency of 13.43 Hz where as the black boxes share frequencies of 12.21 Hz and 14.65 Hz



Analysis

•The data obtained from the wing has a sinusoidal pattern with several amplitudes when plotted in a time versus deflection chart.

•FFTs are performed on the Z coordinates of the data to calculate the frequency of these amplitudes over a period of time.

•The peak frequency determined by generating the FFT chart is representative of the amplitude that occurs most within the data.

•There is an accepted “norm” frequency associated with each Mach number which the data should be reflect.

•It is important to be as accurate as possible when observing the peak frequency of each test.

•The shape of the graph is more accurate when a shorter time interval and more data per period is used.

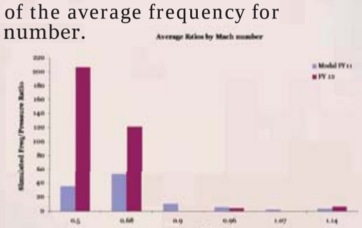
•The perceived peak frequencies from the graph would vary considerably or show multiple peaks.

•When a longer time interval and less data per period is used, the peak frequency is more accurate (much like Gibb's Phenomenon).

•Analyzing the longer time interval demonstrated a single, consistent peak frequency across all filters tested.

•The peak frequencies steadily increases as PSI increases.

•They are within 2 Hz of the average frequency for their respective Mach number.



Right: As the Mach number increases, the frequency to pressure ratio converges around 5. At lower Mach numbers, the frequency is extremely sensitive to pressure while at higher Mach numbers, the frequency is hardly sensitive to pressure.

(Ref 1)

References

Ref 1: Ramirez, Robert W. *The FFT, Fundamentals and Concepts*. Englewood Cliffs, N.J.: Prentice-Hall, 1985. Print.

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Conclusion

While it would be ideal to analyze all the data obtained, it is necessary to meet the requirements of the FFT program being used. By truncating the data obtained from flight simulation to utilize a longer time period, it is possible to obtain a more accurate understanding of the behavior of the wing. Ensuring the peak frequency of the wingtip flutter is close to the accepted value for each Mach number allows for more confidence when flying the tested aircraft in regards to cost to repair or modify the plane or risk to the life of the pilot. These methods of testing will be used to characterize the behavior of an F-16 wing.

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