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Modal Testing of Vertical Tail of F/A-18 Hornet

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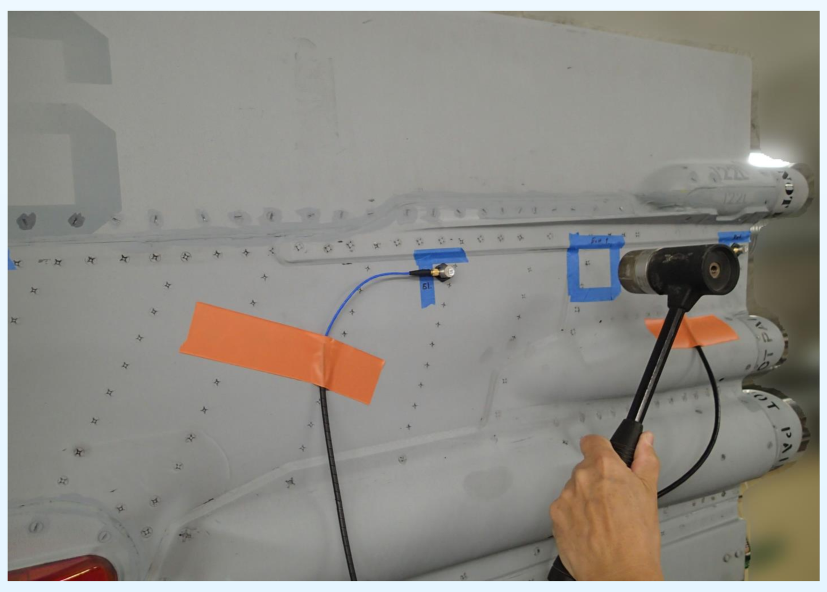
Introduction

The goal of the study was to identify experimentally dynamic vibration characteristics of the aft fuselage and especially the Vertical Tail (VT) of a F/A-18 Hornet. The broadband dynamic loads, i.e., buffet loads, together with the static manoeuvring loads, contribute to the fatigue of the Vertical Tails (VT) of the aircraft. The Vertical Tail lowest elastic modes (bending and torsion) has dominant impact on the fatigue life of the lower aft root region.

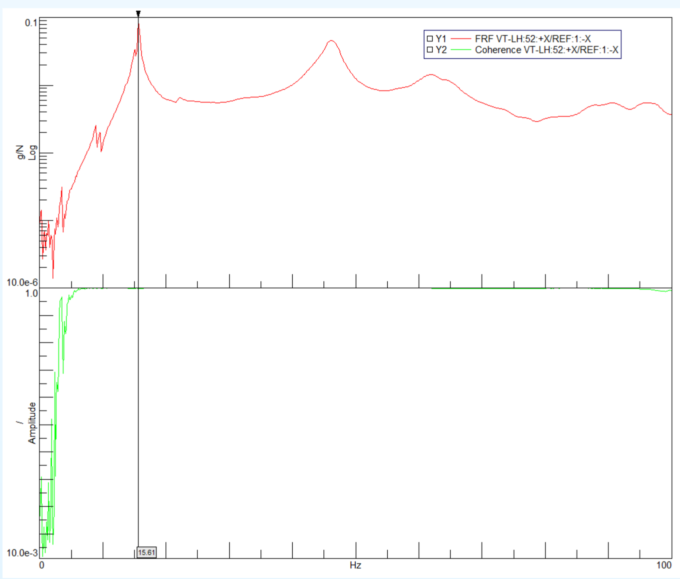
Main Research Questions

i. Applicability of impact testing method for modal parameter identification of certain component of the aircraft (in this case Vertical Tail) instead of traditionally used extensive MIMO multi-shaker testing.

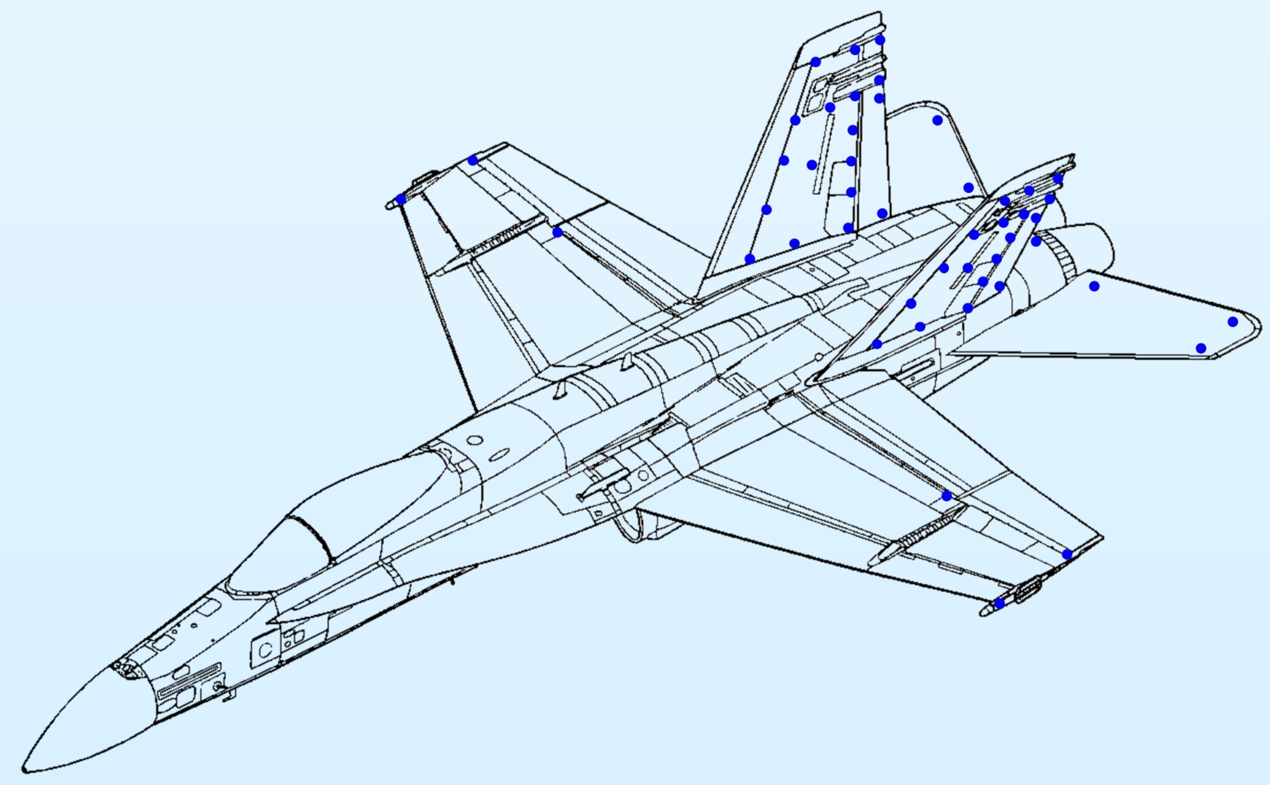
ii. Suitability of random multi-impact excitation technique for Operational Modal Analysis to identify closely spaced double modes. Mono-reference analysis technique deteriorates in cases of closely coupled modes or repeated roots.



Excitation location of impact testing for LH VT



Measured FRF and corresponding coherence



Measurement points in the experimental modal analysis. A total of 50 response points were measured by triaxial accelerometers

Measurements

The plane was standing on the landing gears during the measurements. The left and right Vertical Tails were excited by an instrumented impact hammer having a soft plastic tip. Both VTs were excited separately and responses from both VTs and all other locations were measured during all tests.

Impact testing:

Frequency Response Functions (FRFs) were calculated between measured input excitation force and acceleration responses in traditional impact testing.

A special random multi-impact excitation for Operational Modal Analysis (OMA):

To identify potentially closely spaced double modes, separate measurements were conducted for OMA where both VTs were excited simultaneously randomly at random locations of the VT surfaces by two impact hammers having soft plastic tips (MIMO analysis). OMA is response-only methodology having basic assumption that the unknown broadband excitation force is randomly distributed both in time and space.

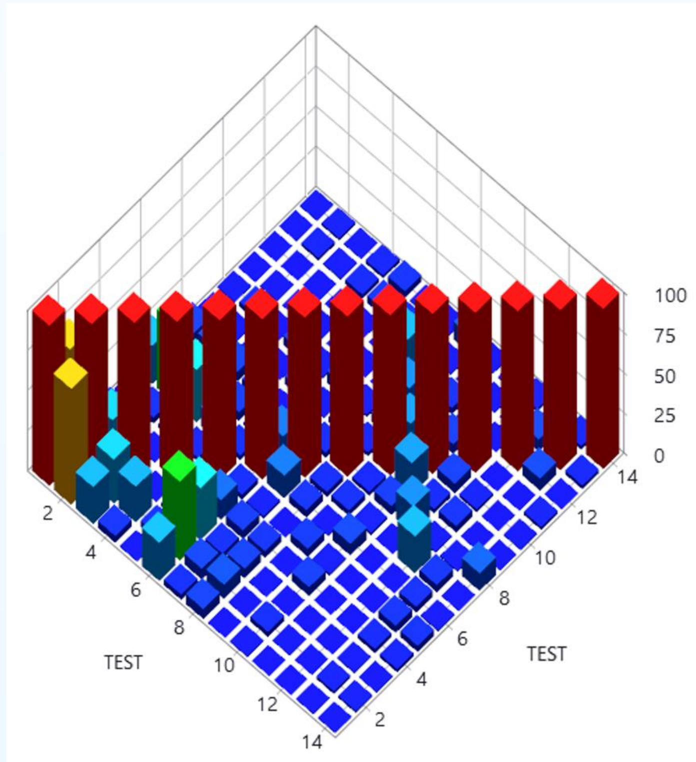
Modal Parameter Estimation

Traditional impact testing: Poly-reference least squares complex frequency domain estimation method (PolyMAX).

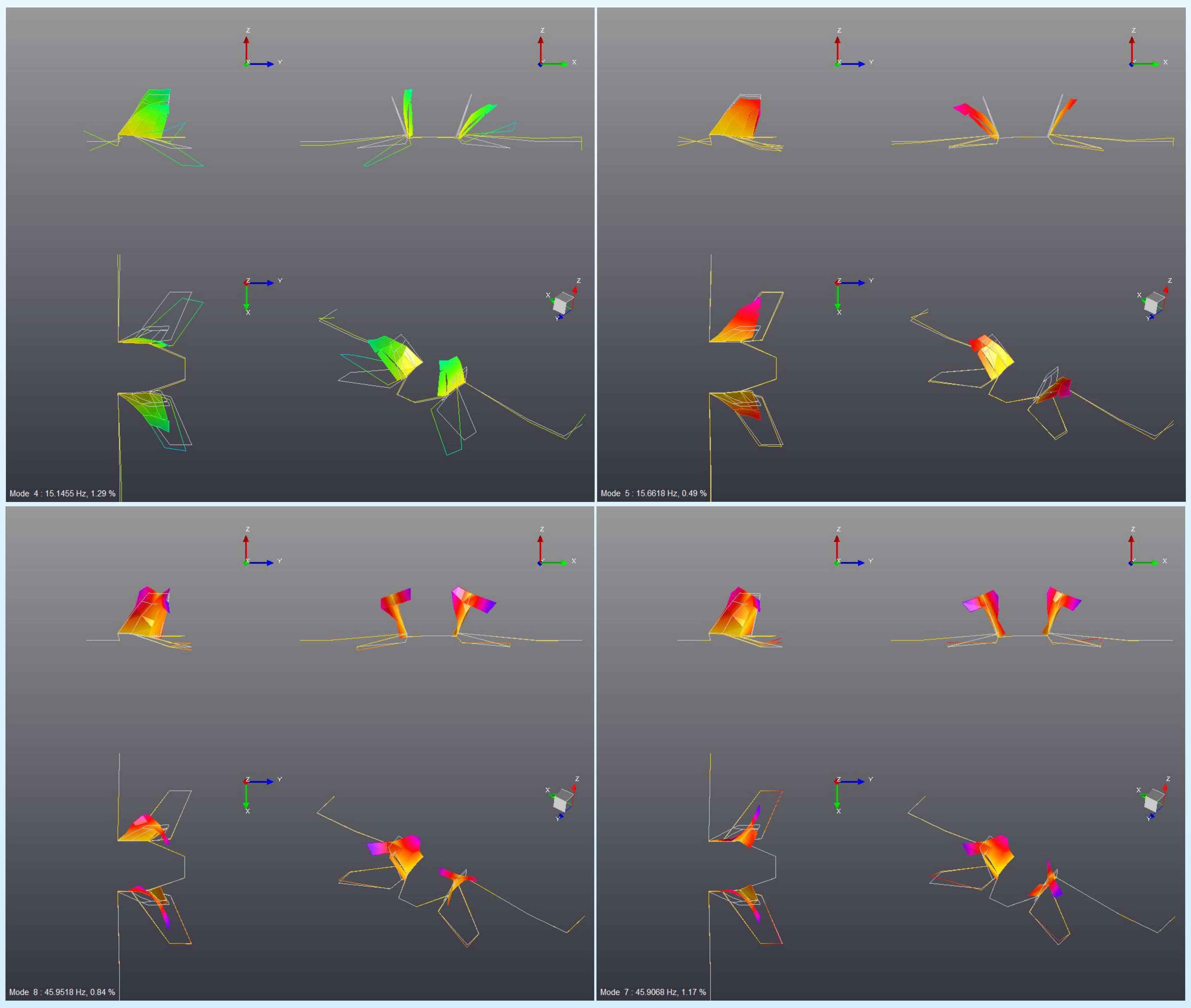
In addition, maximum likelihood modal model-based (MLMM) estimator was used to improve the initial modal parameter estimates, i.e., for improving modal model fit to measured FRFs.

Operational Modal Analysis: Poly-reference least squares complex frequency domain method (PolyMAX) and Least-Squares Frequency-Domain method.

Mode no	Freq [Hz]	Damp [%]	Description
1	8.96	1.0	Global torsional
2	9.65	2.4	Global torsional+roll
3	13.75	1.9	HT bending, out of phase
4	**15.15**	**1.3**	**First VT+HT bending, antimetric, VTs in phase**
5	**15.66**	**0.5**	**First VT bending, symmetric, VTs out of phase**
6	22.13	3.1	Tail twisting
7	23.80	17.2	RH Rudder rotation
8	30.93	8.1	LH Rudder rotation
9	**45.91**	**1.2**	**VT torsion, symmetric**
10	**45.95**	**0.8**	**VT torsion, antimetric**
11	62.15	4.1	LH VT 2. bending
12	62.92	4.9	RH VT 2. bending
13	84.41	2.9	RH Rudder torsion
14	86.24	2.5	LH Rudder torsion



Experimentally identified modes (natural frequencies, modal damping factors and mode shapes) and AutoMAC matrix of the identified mode shapes, which is a measure of orthogonality or independency of modal vectors.



Identified antimetric (left) and symmetric (right) mode shapes; lowest bending (upper) and torsional (lower) modes of the VT

Conclusion

- **Dominant elastic natural modes of the VT of the F/A-18 Hornet were identified experimentally successfully by impact testing.**
- **Main dominant VT modes of interest are divided into two modes having close natural frequencies.**
- **Random multi-impact excitation technique for Operational Modal Analysis was demonstrated to be applicable for identification of very closely spaced modes.**

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