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Study on interface of aircraft external stores

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ABSTRACT

Among aircraft external stores, there are external stores mounted on aircrafts by lug and sway-brace mechanism. This mounting boundary condition is not a perfect constraint. Lateral and vertical directions are constrained by pushing by sway-brace and pulling by lug. The longitudinal direction is constrained by the friction of sway-brace and the portion where the lug is not allowed to deviate from the specified range. So, it is difficult to set the boundary conditions for the FEM analysis in the design process of aircraft external stores. Since the normal mode according to the boundary condition can be changed, it is difficult to design the frequency avoidance.

In this article, characteristic of the boundary condition by dynamic characteristic analysis is described on the aircraft external store

Keywords: External Store, Frequency Avoidance, Dynamic Characteristic
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1. INTRODUCTION

Aircraft external stores are mounted on aircraft wings and fuselages, and types of aircraft external store include fuel tanks, armament, electronic warfare equipment and others. Among load conditions generated during aircraft operation, vibration has the greatest influence on the durability of aircraft external store. In MIL-STD-810, the vibration of helicopters in aircrafts is described as follows. First, there is sinusoidal vibration by rotation of rotor. The sinusoidal vibration is rotation frequency and its harmonic frequencies. Second, there is broadband random vibration by aerodynamic phenomena. The vibration of the helicopter appears as sine on random vibration in which these two types of vibrations are combined. When an aircraft external store is mounted on a helicopter, it is good if all frequencies of the helicopter can be avoided. However, since the random vibration of the helicopter has a wide frequency range, frequency avoidance is impossible. The sinusoidal vibration generated by roter of helicopter is higher than the broadband random vibration. The sinusoidal vibration shows the peak value at specific frequencies. Therefore, the frequency of sinusoidal vibration should be avoided in the desing of aircraft external stores. Among the aircraft external stores, there are external stores mounted on the aircraft by lug and swaybrace mechanism. This mounting boundary condition is not a perfect constraint. Lateral and vertical directions are constrained by pushing by swaybrace and pulling by lug.

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The longitudinal direction is constrained by the friction of swaybrace and the portion where the lug is not allowed to deviate from the specified range. So, it is difficult to set the boundary conditions for the FEM analysis in the design process of aircraft external stores. Also, since the normal mode according to the boundary condition can be changed, it is difficult to design the frequency avoidance. In this study, the change of the normal mode according to change of weight is analyzed by the ODS test to verify the characteristic of boundary condition.

2. VIBRATION OF HELICOPTERS

2.1. MIL-STD-810

In MIL-STD-810, it is recommended that the vibration test specification for the durability verification of the device mounted on the helicopter be set through vibration measurement. When vibration measurement is impossible, a method for calculating the specification is proposed. The vibration test specification can be calculated by reflecting mounting position, the number of rotors and rotational RPM of the helicopter. The vibration test specification calculated by reflecting the condition of an actual helicopter equipped with an aircraft external store is shown in Figure 1.

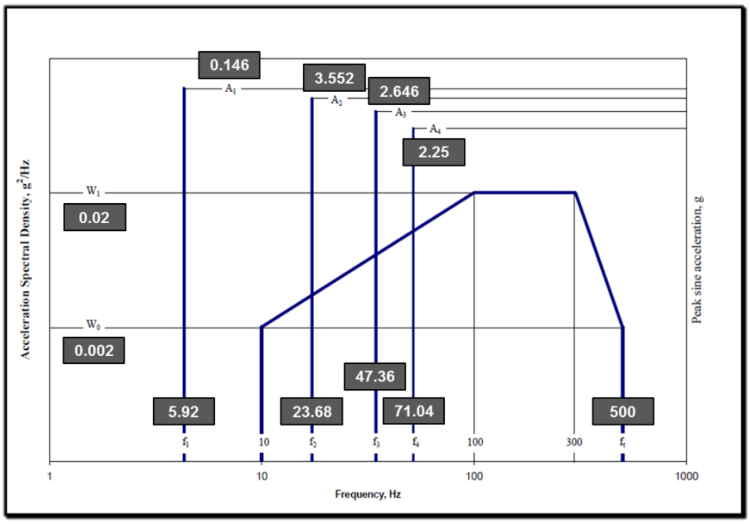

Figure 1: The vibration test specification calculated by MIL-STD-810

2.2. Actual Helicopter

The real flight vibration was measured by mounting an external store to an actual helicopter. The tri-axis acceleration sensor was attached to the most rigid position of the external store. The helicopter flew a total of 7 sorties for the measurement. One sortie was approximately one hour from take-off to landing. The measured data of 21-channels were obtained. The kurtosis was analyzed by extracting 200 seconds(Samples 500,000) of the measured data. A kurtosis is a factor representing the probability distribution. The closer the kurtosis is to 3, the closer to the normal distribution. As a result of calculating the kurtosis of 21-channels, the average value is 2.885, and it was judged that the measured data was close to the normal distribution and reliable as signals of random vibration. The maximum PSD was obtained by superimposing the results of 21-Channels PSD. The maximum PSD of an actual helicopter is shown in Figure 2.

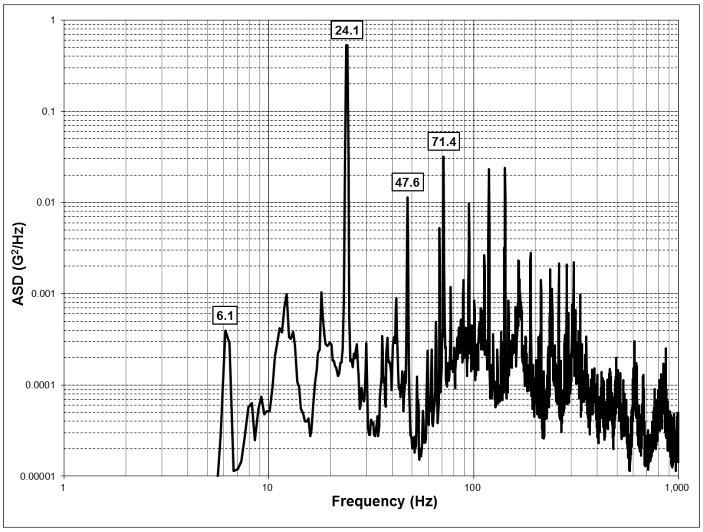

Figure 2: The maximum PSD of an actual helicopter

2.3. Comparison the Results

The vibration test specification by MIL-STD-810 and the maximum PSD of an actual helicopter is compared. The sinusoidal vibration by rotor of an helicopter is confirmed in same frequencies. When an aircraft external store is designed, if it can not measure an actual vibration of a helicopter, it is judged that frequency avoidance based on the vibration specification calculated by MIL-STD-810 is vaild.

3. CHARACTERISTIC ANALYSIS OF BOUNDARY CONDITION

3.1. Operation Deflection Shape Test

The mounting boundary condition of aircraft external stores is not a perfect constraint. Lateral and vertical directions are constrained by pushing by swaybrace and pulling by lug. The longitudinal direction is constrained by the friction of swaybrace and the portion where the lug is not allowed to deviate from the specified range. So, it is difficult to set the boundary conditions for the FEM analysis in the design process of aircraft external stores. Also, since the normal mode according to the boundary condition can be changed, it is difficult to design the frequency avoidance. The change of normal mode according to weight is analyzed by the ODS test to verify the characteristic of boundary condition. Because of the geometric characteristic of the aircraft external store, the magnitude of the vibration in the X direction, which is the direction of travel of aircraft, is less than the magnitude of the vibration in the Y and Z direction. The Y direction is the lateral direction of the aircraft, and the Z direction is the vertical direction. And the vibration in the Y and Z direction generates a sufficient amount of the vibration in the X direction. In MIL-STD-810, it is described that X-Axis vibration test can be excluded when the length of the external store is 4 times or more the height or width. In this study, the length of the external store is 4 times or more the height or width. So, the dynamic characteristics analysis for the X-Axis is excluded. The ODS test was performed by mounting the external store to a test fixture. An exciter of B&K company was used, and input acceleration PSD is the maximum PSD and White-noise Random Vibration PSD (5~2,000Hz, 0.01g2/Hz). DAQ was LAN-XI of B&K company. And Reflex S/W of B&K company was used to confirm the modal characteristics. An 1-Axis acceleration sensor was attached to the measurement points.

And natural frequencies were confirmed. The measurement points are shown in Figure 3.

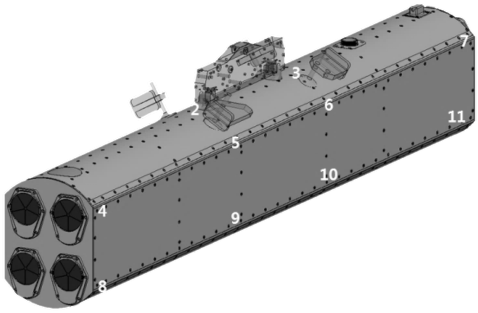

Figure 3: Measurement/monitoring points

3.2. FEM Analysis

The change of the normal mode according to weight is analyzed by the mode analysis were performed by FEM analysis. The modal characteristic of the external store was confirmed. The monitoring points are shown in Figure 3.

3.3. Comparison the Results of ODS Test with the Result of FEM Analysis

The results of ODS test and the result of FEM analysis were compared. The comparison results are shown in Table 1. The mode shape was matched, and the frequency inversion did not occur.

Table 1. Comparison the result of ODS test with the results of FEM analysis

Mode	Shape	Weight(29.8kg)			Weight(33.1kg)			Weight(38.3kg)		
		EMA (Hz)	FEA (Hz)	Effective Mass Ratio (%)	EMA (Hz)	FEA (Hz)	Effective Mass Ratio (%)	EMA (Hz)	FEA (Hz)	Effective Mass Ratio (%)
1	Y-Axis Rotation	14.5	16.0	5.5	12.5	14.4	6.2	-	12.6	6.2
2	Z-Axis Rotation	23.5	25.9	2.6	19.5	23.5	2.7	-	20.3	6.6
3	Z-Axis Bending	25.0	30.0	57.0	21.5	27.1	60.0	19	23.7	64.6
4	Y-Axis Bending	32.0	34.7	49.1	28.5	31.7	54.5	25.5	28.4	56.7
5	X-Axis Rotation	65.5	70.9	6.4	60	69.7	19.0	58.5	68.5	16.8
6	Y-Axis Bending	96.0	105	20.6	99.5	105	4.5	100	104	3.2

4. CONCLUSIONS

The vibration condition of the helicopter was analyzed. First, the vibration test specification of the helicopter described in MIL-STD-810 was confirmed, and vibration test specification of an actual helicopter was calculated by the vibration test specification calculation method. Second, the vibration of the actual helicopter was measured and vibration test specification was calculated by PSD analysis. By comparing the two specifications, it is confirmed that frequency avoidance for sinusoidal vibration generated by the rotor of the helicopter is necessary. There are aircraft external stores mounted on aircrafts by lug and sway-brace mechanism. This mounting boundary condition is not a perfect constraint. The boundary condition of imperfect constraint is difficult to predict at the design of aircraft external stores. Accordingly, the characteristic of the boundary condition according to change of weight of an aircraft external store were analyzed by ODS test. In addition, the normal mode was analyed by FEM. The normal mode by ODS test and the normal mode by FEM. In the case of a large weight, the normal mode appeared in the FEM analysis, but the normal mode did not apper in experimental test. I analyzed whether this phenomenon occurred because the effitive mass was small. However, even though the effitiveness mass ratio in the FEM analysis was rather higher than the effitiveness mass ratio in experimental test, the normal mode did not appear in the case of a large weight. From the results, it can be assumed that the boundary condition of the aircraft external store show different characteristics depending on the external force. Therefore, it may not be necessary to avoid some normal modes when the external force is weak.

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6. REFERENCES

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