

The Modal Characteristics of the Post Buckled Plate

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Abstract. Flight vehicles that fly at hypersonic speeds are subjected to seriously aerodynamic heating, which leads to high surface temperatures and large temperature gradients, which are several hundred or even over 1000°C. Thermal load will affect the dynamic stiffness and influence the modal characteristics. A series of the thermal modal tests were carried out for the panel structures to investigate the effect of thermal loads on modal parameters, especially the effect of the critical buckled temperature. The evolutions of modal parameters were obtained with the increase of structure temperature.

Introduction

With the rapid developments in space technology and high speed atmospheric flights, the effect of seriously transient and steady aerodynamic heating on mechanical characteristics has been an active research recently. Aerodynamic heating will leads to high surface temperatures and large temperature gradients of the flight. The temperature will affect the material properties, and thermal stresses resulting from the temperature distributions will change the effective stiffness of the structure. Therefore, the modal characteristics of the structure at elevated temperatures will be different from that at room temperature[1-2].

In the 1950s, NASA Langley[3-4] had carried out a series of the tests to investigate the dynamic behavior of the structure exposed to the thermal load. In the 1990s, NASA Dryden[5-6] gave analytical and experimental modal test results from uniform, non-uniform, and transient thermoelastic vibration tests of several plates in the oven. And in the 2000s, NASA Dryden[7] performed the modal test of the carbon-silicon carbide Ruddervator Subcomponent Test Article at the room and the elevated temperature.

Although several high temperature modal surveys had already carried out for the free-free boundary condition, the modal characteristics for the clamped plate have rarely investigated. For the clamped plate, it will be buckled, with the rise of the temperature. In this paper, the modal test for thermal post-buckled composite plate is carried out. The critical buckled temperature is obtained by DIC. The modal survey shows that the modal characteristics changes dramatically at the critical buckled temperature. Meanwhile, the numerical simulation is also carried out.

Experimental Description

The testing sample was heated using a quartz lamp radiated heating system. The heating zone was one side of the test specimens. The plate was instrumented with thermocouples to measure the temperature. The rear side of the plate had one thermocouple to achieve the closed-loop temperature control.

Thermal buckling test.

The plate was heated the rate of 0.1°C/s. A 3D digital image correlation system (PMLAB DIC) was employed to measure the in-plane and out-of-plane displacements. The relationship between displacements and temperature was used to obtain the critical buckled temperature.

Modal test at elevated temperature.

The random vibration was conducted to the plate by a small exciter. The ceramic rod was used to connect the shaker to the structures. This rod can transfer the excitation and insulate the plates from the thermal load. The force transducer was incorporated between the shaker and the rod to avoid the high temperature. A Polytech Laser Scanning Vibrometer(LSV) was used to measure the dynamic responses in a hostile environment. The modal characteristics were acquired at every steady temperature. Once the data acquisition was completed, modal parameters the first three plate modes were estimated. The modal parameter estimates were carried out by PolyMAX using LMS Test Lab.

Experimental Results

Out-of-plane displacement of the central part of the panel was obtained. The relationship between the temperature and the displacement was presented in Fig 1. The critical buckled temperature was about 176°C.

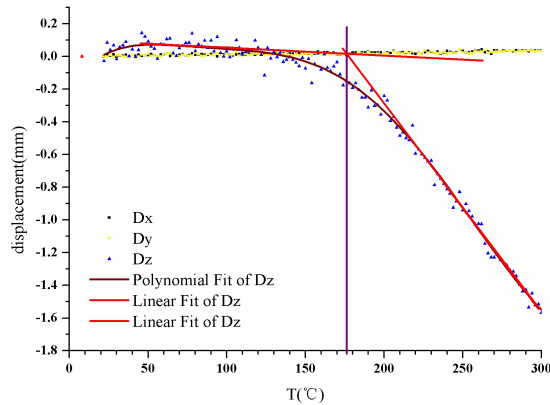


Figure 1 The relationship between the temperature and the displacement

The changes of the modal frequencies were shown in Fig 2. It can be shown that the modal frequencies reduced firstly as the temperature increased. Around the critical buckled temperature, the trends were different. After the critical buckled temperature, the modal frequencies increased with the increase of the temperature. The modal frequencies did not reduce to zero as the theory states. It is because the panel is not perfectly flat, and with some imperfections. Meanwhile, the heated panel is distorted. All these factor leads to the results that the modal frequency did not reduce to zero.

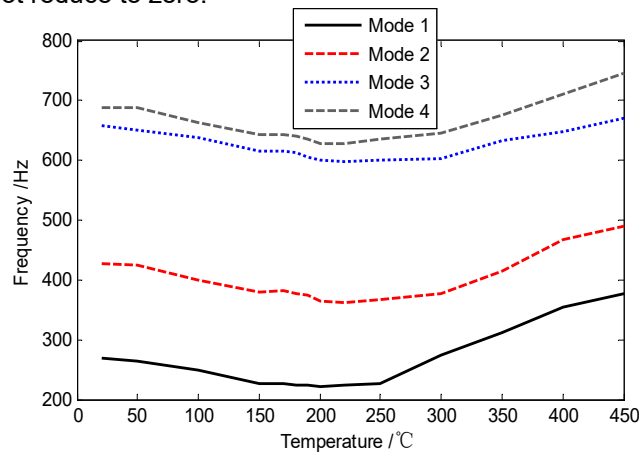


Figure 2 the results of modal test

Conclusion

The thermal buckling test was carried out to obtain the critical buckled temperature. And the modal survey was used to investigate the modal characteristics before and after the critical buckled temperature. The trends of the changes of modal frequencies were similar to the theory. However, because of imperfections and distortions, the first modal frequency was not zero at the critical buckled temperature.

Acknowledgments

This work is supported by the National Natural Science Foundation of China (Grant No. 11502024).

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