Numerical and experimental study of the stressed skin effect of radome structures

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Abstract

Radome is used to protect the cover of the radar antenna, and is a structure that combines structural functionality with electromagnetic transparency. In electromagnetic design, the structural members of the radome are required to be as thin as possible to minimize the influence on the electromagnetic characteristics; on the other hand, the slender members may result in insufficient structural stability. Therefore, how to balance the use of functional and structural safety is a key issue in the design of radome structures. The metal space frame cover is in the ascendant and has great development potential. The current structural design has a problem of being conservative because it bases on the elastic theory to ensure structural safety by a large safety factor. Therefore, this paper proposes a new metal space frame radome, which is composed of an aluminum alloy spherical grid skeleton with skins covered. The material used is light, and the application of stressed skin effect theory is put to innovate.

Considering that the previous studies did not deeply grasp the stability performance of such structures, a static loading test was carried out for a radome which has a span of 5.24 m and a height of 3.66 m. A self-designed multi-stage distribution beam loading system was applied to the structure. Therefore, simultaneous multi-stage loading was realized on multi-point of the structure. Three load cases- completely covering skin, partially covering skin and framework- were considered respectively.

Besides, a numerical simulation method for this new structural system is established, which is verified by the test results that this method is effective to reflect the influence of the stressed skin effect on the overall stability of the radome structure. Different from the previous structural analysis that the role of the envelope structure is not considered, the refined finite element model combines beam elements and shell elements to work together, which is a difficulty in the previous research. Determined by the method of energy error, the mesh size guarantees both accuracy of results and computational convergence. Considering geometric nonlinearity and material nonlinearity, the whole process stability analysis is carried out by the arc length method, and initial defects are introduced based on the consistent mode imperfection method. The influence on structure stability due to geometry and physics parameters changing is confirmed. Finally, the design method of such structures is proposed. At the same time, both the numerical and experimental study show that due to the lateral bracing of the stressed skin on the aluminum alloy members, the prematurely elastic instability of the members around the weak axis is avoided. The global stability bearing capacity of the structure is significantly improved, even up to 5 times. As a result, in the design of such radomes, the stressed skin effect should be considered to solve the problem of structural safety and electromagnetic transparency.

Keywords: Radome, Aluminum Alloy Structure, Membrane Structure, Stressed Skin effect, Static Loading Test