Development of Measurement Equipment of Membrane Stress Using White Noise Sound Wave

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Abstract

One of the most important matters in keeping membrane structures in healthy condition is to maintain the proper tension distribution over the membrane. However, it is not easy to know the real stress level in the membrane quantitatively after completion of the structures. Authors suggested measurement method that can measure membrane stress using sound wave, and have been holding experimental tests of membrane stress measurement that used the sound external excitation with sine wave and white noise. The concept of the method is the fact that measurement of resonance frequency by vibrating membrane having rectangular boundary by audible frequency can measure membrane stress indirectly. In this paper, through the experimental tests it is proved that the equipment can be used for not only the membrane material of type A but also for types B and C. In addition, it is proved that the developed measurement equipment is available to stably measure the membrane stress which exists in the membrane material of the actual membrane structures.

Keywords : Measurement of membrane stress, Sound excitation, White noise, Practical measurement

1. Introduction

Membrane structure is a structure that used membrane materials which cannot afford compression or bending, but is stabilized by maintaining appropriate tensile status, and thus able to endure load like snow or wind, etc. These membrane structures need accurate maintenance

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been changed until recent days, and we do not have the measurement tools yet on which we can actually depend. Moreover, due to the different properties in biaxial directions for material of membrane, the stress in the warp direction is generally different from that in the fill one. We have not yet had such practicable device by which membrane stress in both directions can be measured even roughly.

Authors suggested measurement method that can measure membrane stress using sound wave, and have been holding experimental tests of membrane stress measurement that used sine wave and white noise as external excitation. As shown in Fig. 1, the concept of the method is the fact that measurement of resonance frequency by vibrating membrane with rectangular boundaries as shown Fig. 2 by audible frequency can measure membrane stress indirectly. This is a basic concept, but from the research we realized that natural frequency of membrane is affected by air. That is because the vibrating membrane is as light as air. For estimation of theoretical natural frequency, the effect of added mass of air has to be considered. Thus by replacing vibrating surface of membrane to the circular plate having the same area, we estimated added mass by air theoretically.

In experimental test conducted by using white noise which has frequency field of 0 to 500Hz as an external excitation to measure membrane stress, verification experiments are held such as weighting upper part of equipment, improving power of speaker, sticking rubber to the base of the equipment and sharpened boundary of acrylic box. In addition, for practical use of equipment, we have held experimental tests to verify the effectiveness of improved equipment for high accuracy.

In this paper, it is proved that the equipment can be used not only the membrane material of type A for membrane structure but also types B and C through the experimental tests. Moreover, result of the measurement of existing frame supported membrane structure covered with the membrane material of type A is reported.

2. Fundamental Theory

The equation of motion of the membrane can be expressed as the following equation,

\[ -\rho_k \frac{\partial^2 \omega}{\partial t^2} + \left( \frac{\partial^2 \omega}{\partial x^2} T_x + \frac{\partial^2 \omega}{\partial y^2} T_y \right) = p \]  \( (1) \)

where \( \omega = \omega(x, y, t) \) is the deflection of membrane over the surface, \( t \) is the time, \( p \) is the external pressure, \( \rho_k \) is the mass of membrane per unit area and \( T_x \) and \( T_y \) represent the existing tension per a unit length in \( x \) and \( y \) directions, respectively. Let us assume that...