iments performed in a test cell with aspect ratio $L/H = 16$ have shown that steady thermal distortions arise in the presence of relatively large g-jitter at relatively high frequencies. These distortions depend on the value of the vibrational Rayleigh number (proportional to the temperature difference and to the velocity of the g-jitter oscillations).

An experimental proposal is being considered for the International Space Station, where the steady residual gravity is reduced by several orders of magnitude, compared with Earth conditions, so that a fluid cell with unitary aspect ratio could be used and relatively small g-jitter will be sufficient to induce measurable thermofluiddynamic distortions.

References

[1]Gershuni, G. Z., and Zhukhovitskii, E. M., *Convective Stability of Incompressible Fluids*, Keterpress Enterprises, Jerusalem, Israel, 1976.

[2]Zavarykin, M. P., Zorin, S. V., and Putin, G. F., "Experimental Study of Vibrational Convection," *Fluid Mechanics—Translation of Soviet Physics Doklady*, Vol. 37, No. 4, 1985, pp. 267, 268.

[3]Zavarykin, M. P., Zorin, S. V., and Putin, G. F., "Convective Instabilities in a Vibrational Field," *Fluid Mechanics—Translation of Soviet Physics Doklady*, Vol. 33, No. 3, 1988, pp. 174–176.

[4]Monti, R., and Savino, R., "A New Approach to g-Level Tolerability for Fluid and Material Science Experiments," *Acta Astronautica*, Vol. 37, No. 4, 1994, pp. 313–331.

[5]Monti, R., and Savino, R., "The Basis and Recent Developments of Napolitano's Scaling and Order of Magnitude Analysis," *Microgravity Quarterly*, Vol. 5, No. 1, 1995, pp. 13–17.

[6]Monti, R., and Savino, R., "Microgravity Experiments Acceleration Tolerability on Space Orbiting Laboratories," *Journal of Spacecraft and Rockets*, Vol. 33, No. 5, 1996, pp. 707–716.

[7]Fletcher, C. A. J., *Computational Techniques for Fluid-Dynamics*," Springer–Verlag, Berlin, 1991.

[8]Monti, R., Savino, R., Alterio, G., and Fortezza, R., "Experimental Study of Thermovibrational Convection," AIAA Paper 98-0736, Jan. 1998.

[9]Gershuni, G. Z., Zhukhovitskii, E. M., and Yurkov, Y. S., "Vibrational Thermal Convection in a Rectangular Cavity," *Fluid Dynamics—Translation of Izvestiya Akademii Nauk SSSR, Mekhanika Zhidkosti i Gaza.*, Vol. 17, No. 4, 1982, pp. 565–569.

[10]Kondos, P. A., and Subramanian, R. S., "Buoyant Flow in a Two-Dimensional Cavity Due to a Sinusoidal Gravitational Field," *Microgravity Science and Technology*, Vol. 9, No. 3, 1996, pp. 143–151.

Satellite Mesh Reflector Temperature Measured by Using Fine Thermocouples

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Nomenclature

A_1 = solar power absorption area, m^2
A_2 = heat radiation area, m^2
c_2 = Planck's constant, m K
F = solar flux, W/m^2
S = luminance temperature, K
T = temperature, K
T_m = mesh temperature, K
T_s = boundary temperature, K
α = solar absorptivity
ε = infrared emissivity
λ_e = effective wavelength, m
σ = Stefan–Boltzmann constant, W m^{-2} K^{-4}
τ = transmissivity

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Introduction

THE weight of large-aperture space antenna reflectors can be effectively reduced by using mesh as the reflector surface.[1] The mesh is made of gold-plated metal filaments, and the woven configuration is determined by the radio frequency. The mesh shape is controlled by a cable network, which consists of surface cables, back cables, and tie cables.[2] The antenna reflector itself consists of a mesh surface, a cable network, and truss structure.[3] In the case of solar energy incident on the mesh, the estimated mesh temperature exceeds 473 K (200°C), when it is calculated from the surface properties of gold. At this temperature, the stiffness of surface cables attached to the mesh surface can change or the cables can become fused, and as a result, cable quality is an important design factor. The thermal deformation of a reflector can be evaluated by considering the temperature of the cables and the truss pipes. However, the mesh temperature affects the temperature of the cables and truss pipes, and no studies have been done to determine the mesh temperature; therefore, the extent of the problem is not known. In a conventional method, the temperature measured by ordinary thermocouples attached to the mesh is influenced by the surface properties of the thermocouples. Because the diameter of a thermocouple is 10 times greater than that of a mesh filament, the radiative and conductive heat transfer between a thermocouple and filaments is substantial. Therefore, it is difficult to measure an accurate mesh temperature using ordinary thermocouples. Thus, the correct mesh temperature has not yet been experimentally obtained. In this Note, we report experimental mesh temperature measurements that were done using fine thermocouples with diameters nearly equal to those of the mesh filaments. The experimental results were obtained by irradiating pseudosolar radiation on the mesh in a space environment simulation chamber. In addition, we compared the temperature measured by radiation thermometers and ordinary thermocouples with the measeuements done using the fine thermocouples.

Experiment

Mesh and Thermocouple Combination

The meshes we tested are shown in Fig. 1. The magnified photographs reveal two texture sizes of mesh with fine thermocouples attached. The meshes were fixed on a frame with 500 kg/m of tension. Both meshes were composed of gold-plated filaments 3.0×10^{-5} m in diameter. The fine thermocouples were Chromel–Alumel-type thermocouples and measured 5.0×10^{-5} m in diameter. We also measured the mesh temperature using ordinary thermocouples and radiation thermometers. The ordinary and thermocouples were sewn through the mesh. The mesh was irradiated in a vacuum chamber, and the mesh temperature was measured. The solar power was varied from 600 to 1400 W/m^2. The temperature of each mesh was determined from the average values measured by the two fine thermocouples.

Measurement by Radiation Thermometers

When measuring the temperature with a radiation thermometer, the correct emissivity must be set to measure an accurate temperature. However, it is difficult to determine the mesh emissivity when the effects of porous or gathered fine filaments are included. The emissivity is different for polished or sandblasted surface conditions. Moreover, ordinary radiation thermometers do not work for emissivities less than 0.1. Radiation thermometers measure the radiance of a body to determine its

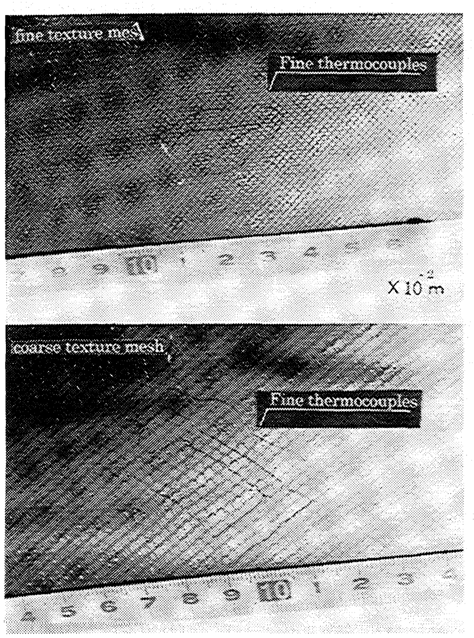

Fig. 1 Experimental meshes.

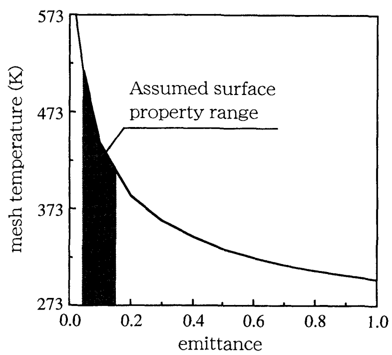

Fig. 2 Temperature estimation using a radiation thermometer.

temperature. The relationship between luminance temperature and absolute temperature is given by Wien's formula

$$T = \frac{c_2}{(c_2/S) + \lambda_e \cdot \ell n\, \varepsilon} \tag{1}$$

The temperature of the mesh measured by the radiation thermometer varies, depending on the emissivity, which can be set from 0.1 to 1.0. Thus, the mesh temperatures were obtained by the radiation thermometer at various emissivity values to determine the value S and λ_e in Eq. (1). The value of T substituted into Eq. (1) was measured at 1400 W/m^2 solar flux. The relationship between the temperature and emissivity is shown in Fig. 2. Using gold surface emissivity values found in Ref. 4, e.g., sandblasted gold is 0.14 and polished gold is 0.05, we estimated the mesh temperature to be between 523 K (250°C) and 433 K (160°C). Therefore, a precise mesh temperature estimate by this method requires one to know the exact mesh emissivity.

Measurement by Fine Thermocouples

The mesh temperature obtained by the ordinary thermocouples and the fine thermocouples is shown in Fig. 3. The measured temperature deviation was within 10 K. This deviation was caused by variations in the irradiating solar power. Figure 3 also shows the mean temperature measured by each type of thermocouple. Although the mesh temperature measured by

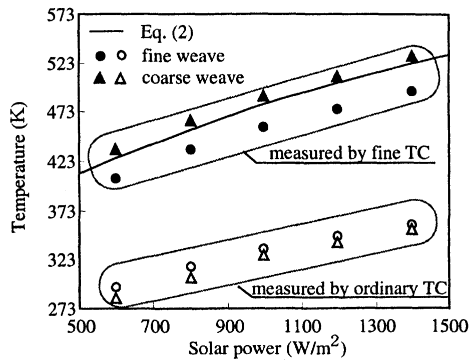

Fig. 3 Temperatures measured by fine and ordinary thermocouples.

the fine thermocouples was about 513 K (240°C), the temperature measured by the ordinary thermocouples was 333 K (60°C) at 1400 W/m^2 solar power. The temperatures obtained by the fine thermocouples were within the range evaluated by the radiation thermometers and, thus, constituted acceptable data. At 1400 W/m^2 solar power, the temperature of the coarser texture mesh was 20 K greater than that of the finer mesh. The mesh filaments for each mesh were identical. The cause of the temperature difference in two types of meshes has not been determined. However, it is clear that the mesh temperature exceeded 473 K (200°C) in this experiment. Based on these experimental results, we considered a method for the simple estimation of the mesh temperature. The thermal balance on the mesh was evaluated using a rectangular model, in which solar power could be absorbed on one face of the rectangle and heat could be radiated from both sides. The heat balance of the rectangular model is given by

$$\alpha \cdot (1 - \tau) \cdot A_1 \cdot F = \varepsilon \cdot \sigma \cdot A_2 \cdot (T_m^4 - T_s^4) \tag{2}$$

In this model, $A_2/A_1 = 2$.

The values of α and ε were for a polished gold surface ($\alpha/\varepsilon = 0.3/0.05$). The result of this calculation was compared with the measured temperatures and is shown in Fig. 3. The calculated values agree fairly well with the experimental data. Therefore, a simple calculation that uses the surface properties of gold is adequate to give a rough estimate of the mesh temperature in a rectangular model.

Conclusions

The mesh temperature was able to be measured by fine thermocouples that were close to the mesh filaments' diameter. The measured temperature exceeded 473 K (200°C) in the experiment. This value was within the temperature range that was obtained using radiation thermometers. However, the temperature measured by the ordinary thermocouples was considerably lower than those of either the radiation thermometers or the fine thermocouples. A simple calculation was accurate enough to give a rough estimate of the temperature and was in fairly good agreement with the experimental data obtained by the fine thermocouples.

References

[1]Russell, R., Campbell, T. G., and Freeland, R. E., "A Technology Development Program for Large Space Antennas," 31st International Astronautical Congress, IAF-80-A33, Sept. 1980.

[2]Mitsugi, J., Yasaka, T., and Miura, K., "Shape Control of the Tension Truss Antenna," *AIAA Journal*, Vol. 28, No. 2, 1990, pp. 316–322.

[3]Meguro, A., Mitsugi, J., Miyasaka, A., and Watanabe, M., "Development of a 15 m Class Modular Mesh Deployable Antenna," 48th International Astronautical Congress, IAF-97-I.1.09, Oct. 1997.

[4]Gilmore, D. G., "Thermal Finish α and ε data," *Satellite Thermal Control Handbook*, 1st ed., The Aerospace Corp. Press, CA, 1995.