Thermoelastic stress analysis using visible-infrared synchronous measurement for resin materials

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Abstract. Resin materials have excellent corrosion resistance and electrical insulation properties, so they are used in products in a variety of fields, from electronics to mechanical structures. Resin materials exhibit viscoelastic behaviour. Strain and temperature fluctuations of resin materials were measured using visible and infrared synchronous measurement, and the applicability of thermoelastic stress measurement was investigated. As a result of measuring the phase difference of temperature and strain fluctuations with respect to stress fluctuations, it was found that temperature fluctuations are also affected by viscosity.

Possible Sessions

10. Infrared & Thermal Methods

Introduction

Epoxy resin has excellent corrosion resistance and electrical insulation properties, so it is used in products in a variety of fields, from electronics to mechanical structures. The fatigue strength of resin adhesives is important for improving the safety of structures. However, there are still many unknowns regarding the fatigue crack initiation process in resin materials. In metal materials, the actual stress is measured by thermoelastic stress measurement [1]. In addition, it has been reported that the temperature component with a double harmonic frequency reflects energy dissipation due to plastic deformation, and that it is possible to estimate fatigue limits and fatigue crack initiation locations based on the double harmonic temperature component [2]-[5]. Since resin materials have viscosity, it is thought that the influence of viscosity appears on thermoelastic temperature changes and energy dissipation. In this study, a visible-infrared synchronous measurement was used to compare thermoelastic temperature changes, harmonic components of temperature change, and viscoelastic properties for resin material.

Visible-infrared synchronous measurement

In order to improve the accuracy of the stress distribution measurement for resin material, motion compensation using a visible-infrared synchronous measurement system was applied (Fig. 1) [6]. In this system, the infrared thermography and the visible camera are synchronized with the same shutter pulse to take infrared and visible images. Also, the visible image is corrected to the field of view of the infrared image using homography transformation based on the four markers detectable from both cameras. Infrared thermography and visible camera are thus spatially and temporally synchronized. The motion vectors is detected by DIC, and then the infrared image of the specimen is transformed into its pre-deformation state by reflecting the motion vector of the optical camera on the infrared image. Visible cameras can also measure the strain behavior of materials. At the same time, the load signal is recorded from the fatigue testing control device.

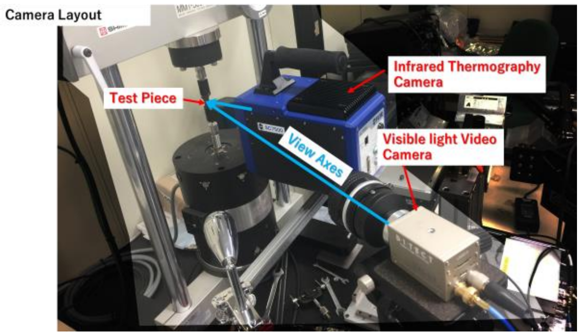

Fig. 1 visible-infrared synchronous measurement set-up

Results and disscutions

As test pieces, commercially available epoxy adhesive was cured onto a board and then cut out from the board. Figures 2 and 3 show the time series changes in stress, temperature, and strain when f=3Hz and σ_a=12.15MPa. Fig. 2 shows that the phase of the strain waveform lags behind the stress waveform. From Fig. 3, the temperature waveform is progressing in the opposite phase of the stress waveform. In metal materials, temperature changes are measured that lag behind the opposite phase of the stress waveform due to thermal diffusion. However, in the case of resin material, the phase of the temperature waveform is ahead of the stress waveform. In order to investigate the cause of the phase behavior, measurements were performed while varying the load frequency. Table 1 shows the results of examining the phase difference between the load frequency and the strain/temperature stress waveform. It can be seen that the phase difference between stress and strain increases as the load signal increases, and the phase difference between stress and temperature waveforms also changes as the viscous property increases. Changes in thermoelastic temperature fluctuations associated with changes in viscoelastic properties are thought to be caused by temperature fluctuations due to entropy changes in the resin material.

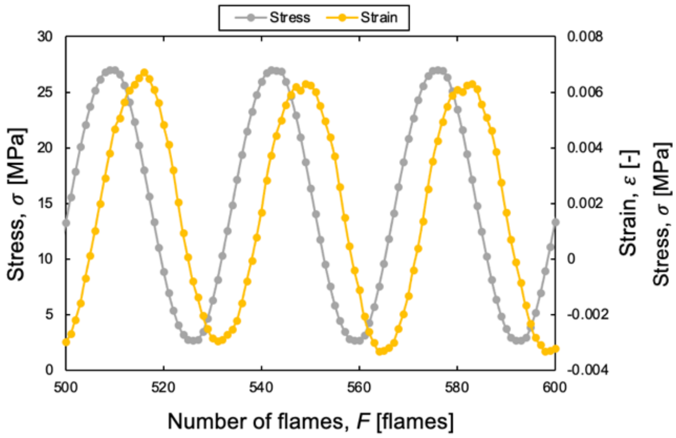

Fig. 2 Relationship between stress and strain changes change

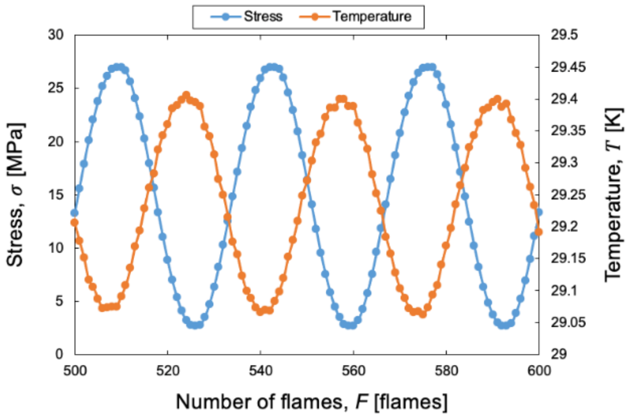

Fig. 3 Relationship between stress and temperature

Conclusion

Thermoelastic temperature changes and harmonic components of temperature fluctuations was measured when cyclic loading was applied to resin material. As a result, it was found that thermoelastic temperature fluctuations may include temperature fluctuations due to entropy changes in addition to temperature fluctuations due to thermoelastic effects.

References

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