Thermal Fatigue Life Prediction of Glidcop Al-15 Using Nonlinear FEA

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Photon absorbers, masks, and shutters of the third-generation light sources are subjected to intense thermal stress cycles from the x-ray beam. A collaborative research study is underway at APS and ESRF to establish thermal fatigue design criteria for Glidcop Al-15, which is commonly used for high-heat-load components.

A nonlinear finite-element methodology is used for modeling the nonlinear response of a Glidcop test specimen under a multi-axial stress state caused by nonuniform exposure to high-intensity x-ray beam. The methodology consists of transient thermal analyses followed by elastic-rate independent plastic analyses and elastic-rate dependent plastic analyses. The following scenarios are investigated for the stress-strain response corresponding to: (a) a peak test temperature of 600°C with no hold time, (b) a peak test temperature of 500°C with no hold time, and (c) a peak test temperature of 600°C with 20 hours of hold time.

The Socie-modified Smith-Watson-Topper model is used for thermal fatigue life prediction. This model postulates that a crack would grow perpendicular to the maximum tensile stress, and the parameters that control damage are the maximum principal strain amplitude and the maximum principal stress on the maximum principal strain plane. The important features of this model are that it considers the plane for crack nucleation and has the capability to model hold-time effects. A good correlation is observed between predicted thermal fatigue life and experimental observations from thermal cyclic tests at ESRF, which are presented in detail in a separate paper in these proceedings.