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A NEW, DIRECT APPROACH TOWARD MODELING THERMO-COUPLED FATIGUE FAILURE BEHAVIOR OF METALS AND ALLOYS

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ABSTRACT The objective of this study is two-fold. Firstly, new finite strain elastoplasticity models are proposed from a fresh standpoint to achieve a comprehensive representation of thermomechanical behavior of metals and alloys over the whole deformation range up to failure. As contrasted with the usual elastoplasticity models, such new models of much simpler structure are totally free, in the sense that both the yield condition and the loading-unloading conditions need not be introduced as extrinsic coercive conditions but are automatically incorporated as inherent constitutive features into the models. Furthermore, the new models are shown to be thermodynamically consistent, in a further sense that both the specific entropy function and the Helmholtz free energy function may be presented in explicit forms, such that the thermodynamic restriction stipulated by Clausius-Duhem inequality for the intrinsic dissipation may be identically satisfied. Secondly, it is then demonstrated that the thermo-coupled fatigue failure behavior under combined cyclic changes of stress and temperature may be derived as direct consequences from the new models. This novel result implies that the new model can directly characterize the thermo-coupled fatigue failure behavior of metals and alloys, without involving any usual damage-like variables as well as any ad hoc additional criteria for failure. In particular, numerical examples show that, under cyclic changes of temperature, the fatigue characteristic curve of fatigue life versus temperature amplitude may be obtained for the first time from model prediction both in the absence and in the presence of stress. Results are in agreement with the salient features of metal fatigue failure.

KEY WORDS Metals, Thermo-coupled behavior, Fatigue failure, Finite deformations, New elastoplasticity models, Direct simulation

I. INTRODUCTION

It is known[1] that metal fatigue is the leading factor that gives rise to fracture and failure of various metal components and parts in engineering structures. This fact becomes even more outstanding for hot sections of aircraft engines and gas turbines under extreme service conditions with combined changes of temperature and stress. The study of metal fatigue behavior plays an essential role in evaluating the safety and reliability of metal components and parts by predicting the service life under prescribed service conditions. In the past decades, considerable efforts and resources