Shakedown analysis of structures with temperature-dependent properties

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Abstract

Shakedown theorems were originally stated for structures subjected to mechanical loads and made of elastic-perfectly plastic materials with constant properties. Furthermore, shakedown theorems have been extended to consider thermal loading conditions with temperature-independent properties (e.g. Simon and Weichert, 2011).

Actually, it is reasonable to perform shakedown analysis of structures with temperature-independent properties if we consider thermal loading of low amplitude (e.g. Hasbroucq et al., 2010). On the other hand, however, the extensions to consider thermal loads of high amplitude have made it necessary to account for the dependence of elastic and plastic properties on the temperature (e.g. Li et al., 2016).

Melan's static theorem and Koiter's kinematic theorem were initially extended to consider thermal loads and temperature-dependent yield stress by Prager (1956) and König (1979, 1982), respectively. Further, much effort was made to consider temperature-dependent yield stress (e.g. Vu and Staat, 2007). Moreover, the influence of temperature dependence of elastic modulus cannot be neglected if thermal loading concerned is of large amplitude (e.g. Cazzani et al., 1992).

The paper is to contribute to confirm the duality relationship between static and kinematic theorems with temperature-dependent properties. Following that, it is to establish static and kinematic formulations for shakedown analysis of structures with temperature-dependent properties by duality theorems. Numerical effort will be also made to develop algorithms based on the computing tool MATLAB for static and kinematic shakedown analyses involving temperature-dependent properties. Accordingly, the static analysis and the kinematic analysis are validated by converging to the shakedown limit efficiently. Finally, the step-by-step finite-element analysis by using ABAQUS is also performed to verify the analytical formulation and numerical implementation.

Keywords: Shakedown analysis, Temperature dependence, Finite-element method.

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