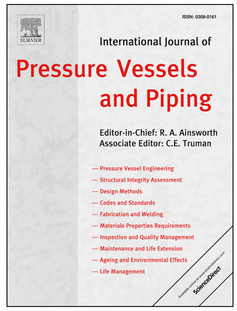
Accepted Manuscript



Creep-fatigue behavior of aluminum alloy-based metal matrix composite

Daniele Barbera, Hao Feng Chen, Ying Hua Liu

PII: S0308-0161(16)30042-4

DOI: 10.1016/j.ijpvp.2016.02.004

Reference: IPVP 3488

To appear in: *International Journal of Pressure Vessels and Piping*

Creep-fatigue behavior of aluminum alloy-based metal matrix composite

Daniele Barbera[a], Hao Feng Chen[a,]*, Ying Hua Liu[b]

[a]*Department of Mechanical & Aerospace Enginnering, University of Strathclyde,Montrose Street 76, Glasgow, G1 1XJ, UK*
[b]*Department of Engineering Mechanics, Tsinghua University, Beijing, 100084, China*

Abstract

Metal Matrix Composite (MMC) represents a valuable option as structural material for different type of structures and components. Despite this they struggle to become widely adopted due to expensive manufacturing process and complex microstructural behaviour. When subjected to cyclic load conditions the structural response of MMC is not trivial, and becomes even more difficult when high temperature load is involved. Different failure mechanisms would happen and they are originated by the different material properties between the fibre and surrounding matrix. Among all, the mismatch of thermal expansion coefficient is recognized to be the dominant one. The significantly differing coefficients of thermal expansion between ceramic and metal give rise to micro thermal stresses, which enhance the initiation of matrix micro cracks. Their performance under varying load and high temperature is complex, and hence it is difficult to have a clear understanding of the structural responses, especially when fatigue and creep damages become the main failures of MMCs. To improve current understanding of the relationship between creep fatigue interaction of MMCs, the history of thermal and mechanical loading, and the creep dwell period, a highly accurate but robust direct simulation technique on the basis of the Linear Matching Method (LMM) framework has been proposed in this paper, and been applied to model the fatigue and creep behaviour of MMCs. A homogenised FE model is considered in all analyses, which consist of continuous silicon carbide fibres embedded in a square 2024T3 aluminium alloy matrix array. Various factors that affect creep and fatigue behaviours of composites are analysed and discussed, including effects of the applied load level, dwell period and temperature on the MMC's performance. The effects of reversed plasticity on stress relaxation and creep deformation of MMC are investigated, and the behaviours of cyclically enhanced creep and elastic follow-up are presented. A detailed study of the creep ratchetting mechanism is also performed with the concentration on the impact of temperature and different loading conditions. The accuracy of the proposed method has been verified by detailed incremental finite element analyses using the commercial finite element solver Abaqus. Such verifications further improve the understanding of the failure mechanisms identified and discussed in this work.

Keywords: Linear Matching Method (LMM); Creep; Fatigue; Cyclic Plasticity; Metal Matrix Composite (MMC)

1. Introduction

The increasing demand of machines operating at high level of efficiency requires high operating temperatures, and for particular application also a light weight design. Metal Matrix Composites (MMCs) are composite materials which are capable of delivering the aforementioned requirements. Different types of reinforcement can be introduced in the metal matrix, including randomly dispersed particles, short fibres and homogenously aligned long fibres. This work is concentrated on the latter type of reinforcement, which has a high strength on the fibre direction and low weight ratio as well. However these advantages are seriously downsized by creep behaviour, thermal fatigue, manufacturing processes and environment problems like oxidation [1]. Especially creep fatigue behaviour becomes an area of research interest, due to the lack of a unified and universal method to asses it, although different standard codes were developed for the assessment of creep fatigue life of high temperature component, including ASME BPV code and UK R5 [2, 3].

When creep is present, the structure's response to a cyclic loading condition changes dramatically [4-6], with respect to the low temperature case. Due to the induced residual stresses by creep and plasticity, a closed stress

* Corresponding author. Tel.: +44-141-548- 2036.
E-mail address: haofeng.chen@strath.ac.uk (Hao Feng Chen)