Accepted Manuscript

Characterization of seawater hygrothermal conditioning effects on the properties of titanium-based fiber-metal laminates for marine applications

Ali Aamir, Pan Lei, Duan Lixiang, Zheng Zengmin, Sapkota Bhuwan

PII: S0263-8223(16)30966-7
DOI: http://dx.doi.org/10.1016/j.compstruct.2016.09.037
Reference: COST 7763

To appear in: *Composite Structures*

Received Date: 18 June 2016
Revised Date: 30 July 2016
Accepted Date: 15 September 2016

Characterization of seawater hygrothermal conditioning effects on the properties of titanium-based fiber-metal laminates for marine applications

Ali Aamir, Pan Lei*, Duan Lixiang, Zheng Zengmin, Sapkota Bhuwan

College of Material Science & Technology
Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China
*bettypan@nuaa.edu.cn

Abstract

The mechanical properties and corrosion behavior of the pure titanium TA2, carbon fiber/epoxy composite (CF/E composite), and titanium-carbon fiber/epoxy fiber-metal laminate (Ti FML) have been investigated after hygrothermal conditioning in seawater at 70^{o}C for marine applications. The results showed that the percentage reduction in the mechanical properties of the Ti FML was lower, compared to the CF/E composite, due to the shielding effect of outer TA2 layers against the water absorption. Unconditioned Ti FML specimens showed composite prepreg failure, whereas conditioned specimens exhibited delamination at the metal/composite prepreg interface as the primary failure mode. Plasticizing and swelling of the epoxy resin due to the combined effect of elevated temperature and water absorption, caused the generation of residual stresses that resulted in delamination at the metal/composite prepreg and fiber/resin interfaces. The TA2 foil showed negligible crevice corrosion on the surface because of the formation of the stable oxide film.

Keywords: Fracture mechanisms; Mechanical properties and corrosion behavior; Metal/composite prepreg interface; Seawater hygrothermal conditioning; Titanium-carbon fiber/epoxy fiber-metal laminate (FML).

1. Introduction

Conventional polymer matrix composites (PMCs) are common materials used in the marine environment [1]. Unfortunately, PMCs, especially epoxy based, absorb water when exposed to water/moisture containing environments [2–8]. Due to the higher water absorption, reduction in the mechanical properties of the resin matrix occurs because of the plasticization and hydrolysis of polymer chains. On the contrary, in fiber-metal laminates (FML), because of their lay-up pattern, the outer surface of metallic layers act a primary role against the diffusion of water inside the laminate, thereby increasing FML's resistance to absorbing water [9,10]. As a result, water can only be ingress inside the laminate through free edges or riveted holes [2].

FMLs consist of alternate layers of metal and fiber-reinforced polymer matrix composites. These laminates, other than having lower water absorption capabilities, have many other superior properties than conventional PMCs, such as high fracture toughness and excellent impact resistance [11]. FMLs are preferred over metals due to their high fatigue resistance, excellent corrosion resistance, diverse failure modes, and specific stiffness and strength [12]. Titanium (Ti)-based FMLs have been developed with the aim of enhancing fatigue resistance of pure Ti-alloys [13]. Therefore, the use of Ti-based FMLs in marine and offshore applications has been increasing, due to their excellent physical and specific mechanical properties [14,15]. In offshore industries, deepwater steel risers are being replaced by Ti-based FMLs because of their excellent corrosion resistance, specific weight, and high specific strength and ductility at low temperature [14].

Ti alloys, in the marine environment, are being widely used in shipbuilding, military applications and off-shore industries due to their excellent corrosion resistance [16]. An adherent, continuous and stable oxide film is formed on Ti alloys when exposed to oxygen in air or water. The natural oxide film on the Ti alloys surface is much more durable and thinner than those of aluminum alloys [15]. Moreover, carbon fibers (CF)