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Fatigue crack growth analysis in Al/Ti layered material in ambient and cryogenic conditions

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Abstract

The paper deals with the process of crack growth in a layered material made by explosive welding from AA2519 aluminum alloy and Ti6Al4V titanium alloy. The tests involved loading CT type specimens parallel to the weld surface so as to cause simultaneous fatigue crack growth in both layers. Independent optical measurement of the crack growth lengths enabled comparison of the crack growth behavior for both layers and relating them to the results of a crack growth analysis performed by the compliance method with the use of a COD extensometer and FEA crack length analysis. Tests of crack growth lengths by the compliance and FEA methods were also performed in a liquid nitrogen which made it possible to compare the crack growth behavior in ambient temperature and cryogenic temperature.

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Keywords: explosive welding; layered material; AA2519; Ti6Al4V; fatigue; crack growth; cryogenic conditions

1. Introduction

Metal layered materials find a very wide range of applications. There is a variety of technologies used to manufacture them including the explosive welding method (EXW). This method involves using the energy of high-energetic materials explosion for welding particular layers. Figure 1 shows a scheme of the explosion welding process where flayer layer is welded with the base layer. This method of building layered materials provides the possibility of welding alloys with very different physical and mechanical properties. In literature we can find examples of Al/Al [1], Al/Cu [2,3], Al/Mg [4,5], Al/Fe [6,7], Al/steel [8,9], Al/Ni [10], Ti/Mg [11], Ti/Ni [12,13],

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Ti/Cu [14] or Ti/steel [15,16] alloys welding. One of the application areas where joining different materials is beneficial is aviation and aerospace industry as the environment where technical objects operate imposes numerous requirements on construction materials which include very high strength properties in relations to the density as well as low radiation permeability, high ballistic resistance [17] and high heat resistance.

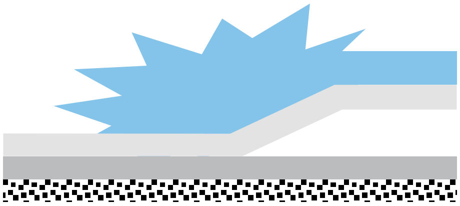

Fig. 1. Scheme of explosive welding with longitudinal layer configuration.

This study presents results of crack growth behavior tests for a new layered material AA2519-AA1050-Ti6Al4V to be used for spacecraft structures, which was developed in cooperation with Military University of Technology in Warsaw, Warsaw University of Technology, Institute of Non-Ferrous Metals, Space Research Centre of the Polish Academy of Sciences, UTP University of Science and Technology in Bydgoszcz and Explomet company.

Many available works deal with explosive welding of aluminum and titanium alloys. They usually present analyses of the transition zone properties including its impact on the crack growth rate for cracks perpendicular to the surface of weld. There are also tests connected with fatigue life of layered materials, whose example is work [18]. However, there are not many studies of fatigue crack growth behavior of layered materials made of high strength aluminum and titanium alloys with the cracks propagating simultaneously in particular layers of the laminates.

Tests of metal construction materials indicate that generally, cryogenic temperatures improve and stabilize the structure of a crystal grid in alloys of metal materials which results in their strengthening [19]. Taking into account the range of application of developed material, it is important to have knowledge of the influence of cryogenic temperature on a layered material crack growth behavior.

2. Experimental procedure

Base materials used in AA2519-AA1050-Ti6Al4V construction are AA2519 alloy aluminum and Ti6Al4V titanium alloy. Their chemical compositions are given in Table 1. Nominal mechanical properties of both alloys are presented, among others, in [20]. A detailed analysis of static properties of a base material and a layered material determined in ambient temperature and under cryogenic conditions is subject to another test and will be presented in a different work of the authors of this paper.

Table 1. Chemical composition of AA2519, Ti6Al4V and AA1050 [20,21]

Chemical composition of AA2519, wt %									
Si	Fe	Cu	Mg	Zn	Ti	Sc	Zr	V	Al
0.06	0.08	5.77	0.18	0.01	0.04	0.36	0.12	0.12	balance
Chemical composition of Ti6Al4V, wt %									
O	V	Al	Fe	H	C	N	Ti		
<0.2	3.5	5.5	<0.3	<0.0015	<0.08	<0.05	balance		
Chemical composition of AA1050, wt %									
Si	Fe	Cu	Mg	Mn	Ti	Zn	Al		
0.25	0.4	0.06	0.05	0.05	0.05	0.07	balance		