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CASE STUDIES ON MANUFACTURING OF AEROSPACE COMPONENTS WITH SOLID STATE WELDING TECHNOLOGIES

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ABSTRACT

This work presents several case studies to manufacture lightweight aerospace parts with solid state welding technologies. Friction stir welding and diffusion bonding process are used for aluminum alloys and titanium alloys in the aerospace industry to produce complex and inaccessible joints without localized distortion. Pressure bonding of superalloy alloy was successful without any foreign materials. Diffusion bonding of dissimilar alloys of copper alloy and stainless steel was demonstrated to fabricate complex shape of combustion chamber for liquid rocket engine. The optical and scanning electron micrographs show that there is no notable distinction or foreign phase at the interface and the strength of the bonded interface is evaluated. Manufacturing of aerospace components with complex shape is successfully demonstrated with solid state welding processes.

Keywords: solid state joining, titanium, aluminium, diffusion bonding, friction stir welding.

INTRODUCTION

Solid state welding is an attractive method to join materials without melting where mechanical properties and microstructurally homogeneous joining are important. Welding at solid state is obtained by applying heat, below the melting temperature of the materials and a microscopic force or pressure. Since solid state welding is formed from continuous mixing of microstructure across an interface without a liquid phase, the interface is homogeneous and hence mechanical properties and microstructure at the bonded region show better properties than fusion welding. In diffusion bonding, enough time is required to allow atomic diffusion at elevated temperature. In friction welding (FSW), high temperature can be obtained from the frictional heat induced from mechanical sliding or rotating motion between two materials.

Diffusion bonding consisted of vacancy diffusion to allow for complete void closure and homogeneous bonding at the interface [1]. The whole mechanism is governed by surface diffusion, volume diffusion, grain boundary diffusion, and power-law creep. The bonding is formed from atomic migration across an interface in a solid state, and there is no metallurgical discontinuity at the interface and therefore mechanical properties and microstructure at the bonded interface are not different from those of the parent metal. This is different from a brazing process in which a foreign metal with a lower melting point is used to weld together. In brazing, a thin film of liquid filler metal is penetrated into the bond interface and hence, the bonding can be weak. Selection of adequate joining process depends on the type of materials, design, and producibility of the component. In all of the solid state joining processes, time, temperature, and pressure are involved. In this study, most popular solid state joining processes, like diffusion bonding and friction welding, are presented for typical aerospace materials and the optimum process condition is obtained.

CASE-1 DIFFUSION BONDED TANK

The photographs of diffusion bonding press and bonded article are shown in Fig. 1(a). The microstructure and hydraulic pressurization test reveals the structural integrity of bonded region of the titanium tank [1].

(a) (b)

Fig. 1 - Diffusion bonded titanium tank(a) and combustion chamber(b)

CASE-2 DIFFUSION BONDED STEEL/COPPER FOR COMBUSTION CHAMBER

In liquid rocket engine, regenerative cooling method is one of the widely applied technologies for a combustion chamber. The combustion chamber is composed of dual phase steel for outer jacket and copper alloy for inner wall with cooling channels. Diffusion bonding of copper alloy and steel was successfully performed to manufacture the combustion chamber in Fig. 1(a) [2].

CASE-3 FRICTION STIR WELDING FOR ALUMINUM CYLINDER

Since the commercial size of the aluminum plate cannot accommodate the large tank size of the launcher, welding several pieces is necessary. However, lithium is highly reactive and its compounds can decompose with heat from conventional fusion welding and form gases which result in formation of defects. Therefore, friction stir welding (FSW) is an attractive joining method for this alloy. FSW is a solid-state joining process, in which avoiding hot cracking and distortion without melting, and produces a mechanically mixed and softened zone of material.

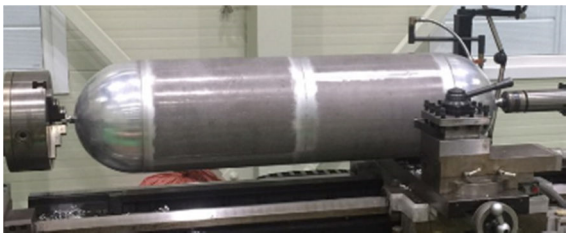

Fig. 2 - Cylindrical tank welded with FSW [3]

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