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Durability of orbital riveted steel/aluminium joints in salt spray environment

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ABSTRACT

In this work, aluminium alloy/steel joints were realised with an orbital riveting process. Two series of joints were made; i.e. in the first, the head of rivet touches with the aluminium sheet; in the second, it touches with the steel one. After their manufacturing, during tests were carried out by exposing the joints to a salt spray fog up to 10 weeks into a climatic chamber. Finally, mechanical tests were performed with the aim to know the effect of corrosion on performance and failure.

1. Introduction

Nowadays, industries develop innovative leading technologies to respond to market requirements [1]. In joining technology, riveting is significant in various industries (i.e. especially in aeronautical industry and, particularly, in the connection among the sheets in aircraft). Therefore, many progresses have been done for its improvement in terms of performances (i.e. resistance and durability of the joint). The process of riveting presents different procedures; i.e. pop riveting, press riveting, explosion and radial frictional riveting [2].

The main critical issue is the resistance and the sensitivity to failure. In particular, this depends directly on tension status of the joint. Various parameters (i.e. riveting load, friction ratio and tolerance) affect directly on the stress and the fatigue life of the riveted joint.

To increase the joint properties, in pressing operations, Collette et al applied non-uniform-impact force [3]. In such methods, study on rivet microstructure [4], evidenced the starting of numerous cracks and the dissolution of rivets' structure. Moreover, after applying desired forces, it much needed to consider tension [5], torsion tolerance [6] and residual stress in work pieces. According to experiments conducted on sheets connected by changing the type of riveting, sheets riveted by pressing operations [7] respect to modern methods, are characterised by a less dissolution of rivets' particle structure.

A new vision in manufacturing, including just-in-time (JIT) manufacturing and measurable process control and the requirement of a joint with less residual stress, increased the use of a new technology: the orbital forming.

This is a cold forming process, alternative to conventional fastening operations (i.e. staking, peening, crimping, pressing, swaging, spinning, rolling, riveting, welding, upsetting) [8].

It is comparable to impact and compression forming, where is applied with a tool a compressive axial load to deform the piece. The difference with the previous processes is that, in orbital forming, the tool rotates at a fixed angle (i.e. typically 3° to 6°) and applies axial and radial forces to progressively deform material until the specific shape is reached (see Fig. 1 [9]). Moreover, the process requires more tool revolutions and typically takes 1.5–3.0 s to complete.

During the process, the deformation work interests only the tool/rivet line of contact, not the whole tool surface.

This fact reduces axial loads of about 80% by inducing several advantages; i.e.:

- lower level of stress on the parts that have to be fastened or mated;
- smooth surface finish;
- elimination of cracks caused by impact riveting;
- cold-head forming by avoiding bending or swelling of the fastener shank;
- use of smaller presses in terms of sizes and costs;
- less rigid fixturing and longer lasting tools.

The process is employed with different materials; i.e. metals (ferrous and nonferrous) and plastics [10].

However, the industrial applicability of this joining technology is strongly limited by highly aggressive environmental conditions that can induce localised corrosion mechanisms [11]: i.e. the junction between dissimilar substrates (i.e. steel/aluminium) can induce corrosion

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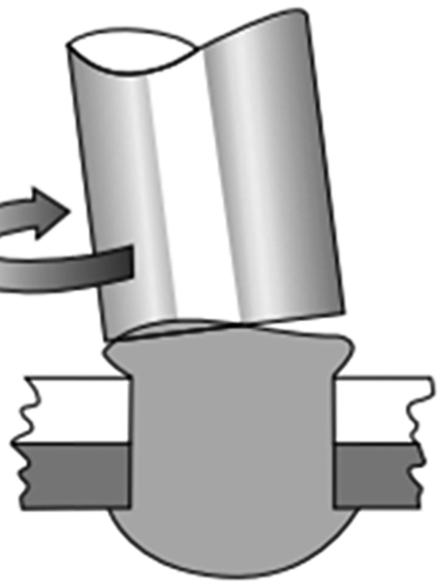

Fig. 1. Orbital forming.

phenomena for galvanic effects. In fact, these metals have a quite different electrochemical behaviour [12]. This phenomenon can be intensified by crevices (i.e. crevice corrosion attack) or irregularities. For this fact, in joining design, the metal sheets have to be chosen by evaluating also electrochemical and corrosion properties [13]. Moreover, internal stresses can influence the durability. This can induce starting and diffusion of local cracks (i.e. effect of stress corrosion cracking - SCC), by reducing the joint resistance by increasing the ageing times [14].

Porcaro et al. [15] shown that the mechanical strength of aluminium riveted joints is stable after 3 days of natural ageing. Moroni et al. [16] investigated the behaviour of hybrid adhesive-mechanical joints after thermal cyclic ageing.

Calabrese el al. [14] showed that, after long durability time (i.e. 60 days), the mechanical performance of aluminium self-riveting joints decreases significantly, by evidencing that the corrosion phenomena influence performance and failure.

Although the durability of dissimilar joints in a corrosion fog is well known, few works operate on the ratio between joint durability and electrochemical characteristics of the metal [13,14].

In particular, the goal of this research is to study the performance of a hybrid joint between an aluminium sheet and a steel one, realised with an orbital forming process by focusing the attention not only on the mechanical resistance but mainly on the durability in salt spray fog.

This work follows other studies performed by the Authors that in recent years have investigated several joining techniques between dissimilar materials: i.e. self-piercing riveting [17,14], clinching and [18], clinch-bonding [19].

2. Experimental setup

2.1. Materials

The substrates of the joint were realised using, respectively, a 6082 aluminium alloy, subjected to a heat treatment process (i.e. T6), and a steel alloy A570.

6082 aluminium alloy is characterised by a good strength and a really good corrosion strength. It is the better of the 6000 series alloys and, for this fact, is used mainly in structural applications.

In plate form, the alloy is used for machining.

Carbon steel A570 is widely used in production. It has good corrosion strength, high harness, toughness and strength.

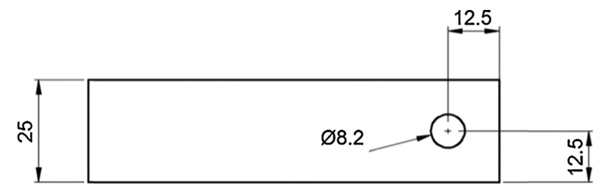

Fig. 2. Geometry of substrate [mm].

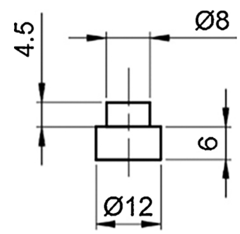

Fig. 3. Geometry of rivet [mm].

The rivet was realised with a S11aluminium alloy.

2.2. Geometry

In Figs. 2 and 3 are reported, respectively, the geometry of the substrate and the rivet.

The thickness of the substrate is 1 mm for steel alloy and 2 mm for aluminium one.

Two configurations of joints have been made: in the first, the rivet part subjected to orbital forming touches with the aluminium sheet (in the next, series A); in the second, it touches with the steel (in the next, series F).

2.3. Joining process

Orbital forming was performed using a BK-TAUMEL "BK80" machine (Fig. 4). Its characteristics are reported in Table 1.

Table 2 reports the setup parameters; i.e. F is the punch force that deforms the rivet, t is the working time and Δx is the displacement of the punch.

Fig. 4. BK-TAUMEL "BK80" machine.