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Single and double plate impact welding: Experimental and numerical simulation

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ABSTRACT

This paper presents an experimental study and a numerical simulation of impact welding of single and double aluminium plates using a gas gun. The study shows the differences in the bonding quality of the two impacting flyer plates. In general the bonded area between the two flyer plates is less than that between the leading flyer and the target. The simulations show that the back surface of the leading plate flyer exhibits an increase in roughness after impacting onto the target. The numerical modelling in agreement with the experiment shows that the contact surface between two flyers at the time of the contact is not flat.

1. Introduction

High energy rate welding methods are capable of producing good quality and large area bonding between metal plates, including plates with grossly different mechanical properties [1].

Two main methods have been developed, gas gun impact welding and explosive welding. The techniques are essentially a metal joining process in which the impact between the flyer(s) and target being welded creates clean surfaces and forces them together under a pressure high enough to cause atomic bonding over the interface [2]. Localized melting and alloy formation occurs with most of the bond interface being practically diffusionless despite the high temperatures that are generated at the collision front [3].

The unique mechanical, electrical and chemical properties of cladded plate create considerable demand for it in various industries. The most commonly used industrial method for impact welding uses explosives to drive plates together. A typical arrangement is shown in Fig. 1a. The explosive reaction is triggered near one end of the plates and the progressive oblique collision along the length of the plates causes welding to occur. However the method is expensive, time consuming and requires the use of a licensed site to perform. Whilst the process is generally successful failures do occur and often the cause is unknown. Attempts have also been made to weld several plates together in a single shot, but these have not always been successful and have resulted in expensive failures [4]. As an alternative to explosives for creating and studying the impact conditions several workers [5–7] have used pneumatic guns to drive plates onto a fixed target. Here small plates are fixed at an angle to the front of a cylindrical sabot and fired along the barrel of a gun to make oblique contact with a fixed target.

This paper presents the data from experimental tests with single and double plate projectiles using a 63 mm bore gas gun and the numerical results obtained from simulation of the impacts. The main objective of this paper is to improve the understanding of the mechanical behaviour of double plate projectile impacts in order to improve the efficiency and success of impact welding.

2. Material and methods

2.1. Gas gun

The experimental study was performed using a 63 mm bore gas gun to fire small obliquely mounted aluminium plate(s) at an aluminium target block. The gun consists of four main components, a pressure chamber, a 63 mm bore, 2 m long barrel, a bursting disc

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Fig. 1. The 63 mm bore gas gun used in the experiments. The test was carried out in a vacuum chamber to avoid compressed air between the target and impact face of the projectile.

Fig. 3. Plastic bursting discs with wire heating loop mounted between them. The disc was held by two flanges which were attaching the barrel to the gas reservoir.

mechanism and a target holder [8]. The projectile, which is placed close to the bursting disc, is propelled down the barrel when the disc is ruptured by electrical means, and impacts on a target fixed a few centimetres away from the end of the barrel. A photograph of the gun used in the experiments is shown in Fig. 1.

The targets were mounted in a target holder which was either bolted tightly to the end of the barrel to make an airtight seal or clamped in a standoff position to leave the barrel open. In the former case the barrel was usually evacuated of air which enabled the maximum projectile velocity to be realised and silent firing (because of the absence of a shock wave in the barrel). Fig. 2 shows a schematic diagram of the arrangement.

The projectile consisting of either one or two flat flyer plate(s) mounted on a light weight sabot, such that the plates were off normal to the axis of the gun barrel, was fitted into the breech of the barrel close to the bursting disc.

2.2. Pressurising system and bursting discs

The pressure chamber was pressurised from compressed gas bottles. For maximum projectile velocity the pressurising gas has to be light [9] and hence helium was used in most tests. A few shots were performed using compressed air.

The gas stored in the pressure chamber is suddenly released into the barrel by the bursting of approximately 0.25 mm thick plastic discs. The discs were located in a recess at the end of the pressure chamber and held in place by the two flanges which attached and sealed the barrel to the gas reservoir.

The rupture of the discs is initiated by passing an electrical current through a loop of wire placed between the discs (see Fig. 3). This causes those adjacent to the wire to melt and the weakened assembly to burst. For relative low pressures, up to 7 MPa, the arrangement worked reasonably well but at higher pressures with more than about four discs, the discs tended to tear rather than rupture quickly resulting in inconsistent and in some cases very low projectile velocity. Fig. 4 shows the disc in position after bursting.

The projectile velocity as a function of bursting pressure obtained from experiment is shown in Fig. 5. The bursting time is

Fig. 4. Two examples of burst discs. The rupture of the discs with maximum four discs (pressure up to 7 MPa) was generally sharp cut but for more discs the rupture was not regular.

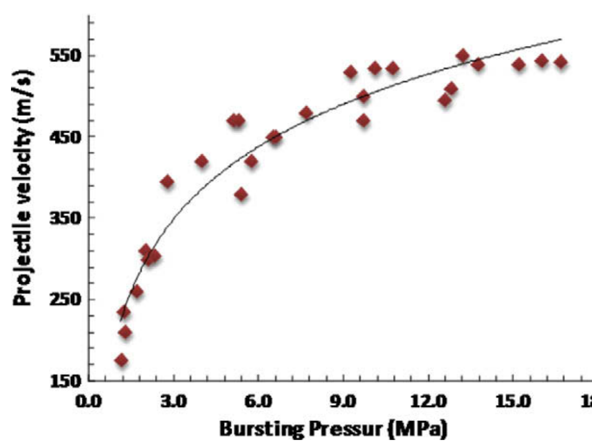

Fig. 5. Bursting pressure versus the projectile velocity from experiment. Same thickness and material was used for the bursting discs.

dependent on the material and thickness of the bursting disc and the driving pressure [10].

Some bursting discs were made from 0.7 mm thick brass. The bursting pressure being controlled by the depth of grooves cut along radial lines in the surface of the disc. As these discs were very

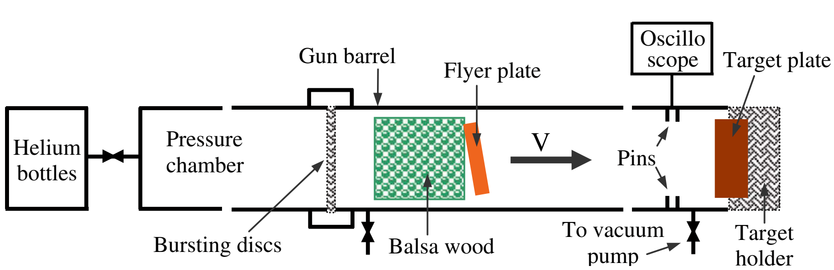

Fig. 2. Schematic of impact welding with a gas gun. The impact velocity of the projectile was evaluated by measuring the time to pass a fixed distance using a pin method.