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Finite – Element analysis for optimization of Explosion welding Process

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ABSTRACT

Explosion welding (EXW) is a solid state (solid-phase) process where welding is accomplished by accelerating one of the components at extremely high velocity through the use of chemical explosives. This process is most commonly utilized to clad carbon steel plate with a thin layer of corrosion resistant material (stainless steel, nickel alloy, titanium, or zirconium). Due to the nature of this process, producible geometries are very limited. They must be simple. Typical geometries produced include plates, tubing and tube sheets. Explosion welding or bonding is a solid-state welding process that is used for the metallurgical joining of dissimilar metals. The process uses the forces of controlled detonations to accelerate one metal plate into another creating an atomic bond. Explosion bonding can introduce thin, diffusion inhibiting interlayer such as tantalum and titanium, which allow conventional weld-up installation. In addition, explosive welding is considered a cold-welding process, which allows metals to be joined without losing their pre-bonded properties.

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Introduction

Explosion welding can produce a bond between two metals that cannot necessarily be welded by conventional means. The process does not melt either metal, instead it plasticizes the surfaces of both metals, causing them to come into intimate contact sufficient to create a weld. This is a similar principle to other non-fusion welding techniques, such as friction welding. Large areas can be bonded extremely quickly and the weld itself is very clean, due to the fact that the surface material of both metals is violently expelled during the reaction.

A major disadvantage of this method is that an expansive knowledge of explosives is needed before the procedure may be attempted. Explosion welding is therefore far less commonly used than fusion welding alternatives. Fig.1. shows Explosion welding process.

To form an explosive weld the following conditions need to occur:

- Two surfaces that need to be joined are initially spaced at a small distance (standoff distance).
- An explosive force brings these two surfaces together progressively at a collision front. The collision front's velocity must be lower than the speed of sound in the materials, so that the shock wave precedes the bond being formed. If not, the shockwave would interfere with the contacted surfaces preventing a bond occurring.
- The interfacial pressure at the collision front must exceed the yield strength of the materials, so that plastic deformation will occur.

A jet of metal is formed just ahead of the collision front, comprising of the two component surfaces, which is finally ejected from the interface. The surfaces and any surface contaminants are removed in the jet. Behind the collision front, the now clean surfaces bond, under extreme pressure, in the solid state. This dynamic welding situation is shown in Fig.2. In cross section, the materials usually bond together in an undulating wave form and the process can weld a parent plate of thickness 0.025mm to over 1m (the maximum flyer plate thickness is one third that of the parent plate).

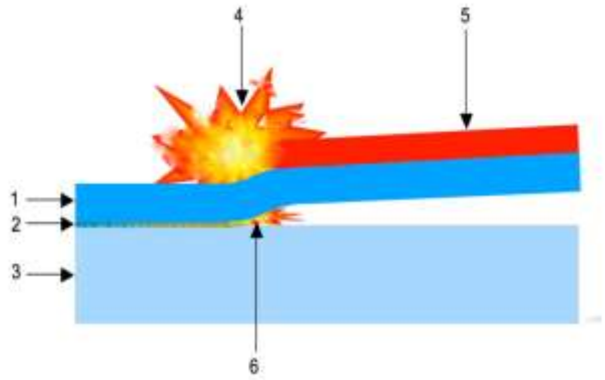

Fig.1.Explosion welding

1Flyer (cladding). 2 Resolidified zone (needs to be minimized for welding of dissimilar materials).3 Target (substrate). 4 Explosion. 5 Explosive powder. 6 Plasma jet.

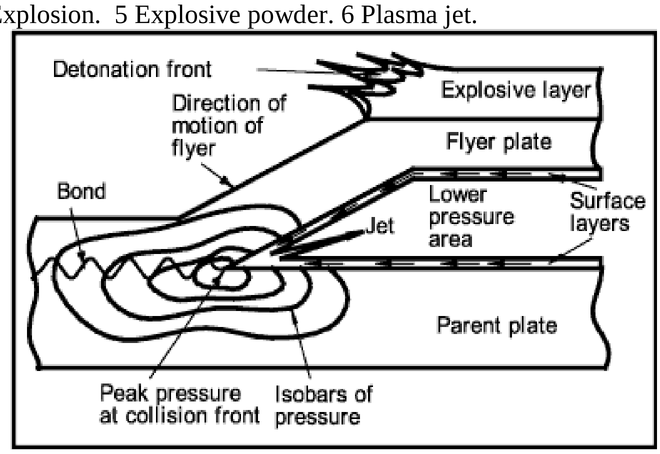

Fig.1. Dynamic situation at thecollision front showing the jetting mechanism

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Experimental tests and procedures

Some welding trials were performed with two PETN based explosives in inclined and parallel arrangements, but most welding experiments were carried out using ANFO mixtures with the plates mounted in parallel. Preliminary experiments were undertaken to determine the flyer plate and collision velocities and the detonation velocity of the explosives using a pin contact test method. All the welding tests performed were simulated.

The test program was designed to determine the effect of changes in the operational parameters of the process (contact velocity, flyer plate velocity and dynamic angle) on the physical parameters such as effective stress, strain and contact pressure. Loading is due to detonation of the low explosive, which is in the form of 80 mm and 235 mm high powder mixtures covering the upper surface of the flyer plate for the different cases considered.

Most of the low explosives cannot generally be initiated by a detonator alone. A booster made of about 50–500 g of high explosive such as Composition C4, which can be initiated by a detonator, is used to start the detonation.

Following the tests two samples were cut from the central region of each welded plate, one sample parallel to the longitudinal axis of the plate, (i.e. in the direction of detonation), the other sample perpendicular to the direction of detonation. Each sample was polished and metallography of the region around the bond lines performed.

It was found that using an inclined plate arrangement with high explosive (PETN) the plates only partially bonded, whereas with the parallel arrangement and ANFO, bonding was almost 100% complete. In the case of the inclined plate set up bonding did not occur until approximately half way along the plate i.e. about 12 cm from the booster charge.

Results of model

The simulations showing 3D maps and profiles of a number of physical parameters, such as contact pressure, shear stress, normal stress, plastic strain, effective strain, strain rate, internal energy, kinetic energy, temperature and velocity of the flyer plate at the point of contact and the angle of contact. Plots of mesh and material boundaries, and quantities as a function of time and distance for given co-ordinate were also available.

For the sake of clarity, only a representative sample of the simulations of the experimental tests is presented here. The results are presented in the following order (they are also listed in Fig 3).

The overall movement of the flyer plate; Vertical and horizontal velocities of flyer and base plates; Maximum pressure (P); Maximum shear stresses (S12); Maximum strains; The maximum base plate velocity (assuming the base plate moves after impact); The maximum impact angle. These variables are discussed later and finally the collision velocities calculated by dividing the length of the material by the total timing of the simulation process.

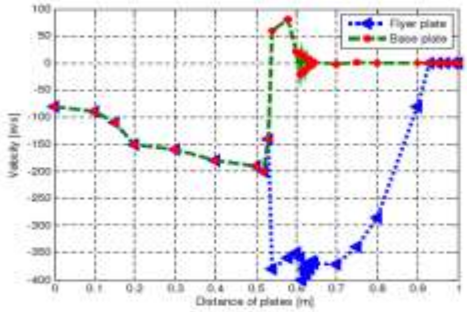

Fig.3. Results of model

Conclusions

The present study has made it possible to model the main features of the explosive welding process.

Relationships between operational conditions and physical parameters, such as local stresses, strains and particle velocities which determine the success or failure of the weld were identified .

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