Study of the Explosive Welding Process and Applications

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ABSTRACT

Explosive welding is a process used for large surface area joining of dissimilar material with metallurgical bonding. Over the last few decades, a lot of work has been done in this field. This paper briefly present the basic mechanism and detailed review of research work carried in different parts of the world. Review of applications in the field of defense, space and industries is also presented. These would enable researchers in the field to have a quick overview of work done in this field and its application.

***Keywords**:Explosive welding process, joining of dissimilar materials.*

1. INTRODUCTION

Explosive Welding is one of the finest welding processes known for its capability of joining the two metal plates with similar or dissimilar metallurgical properties which cannot be joined by any other conventional manufacture process. It is the solid state welding process in which controlled detonation of an explosive is used to produce a weld surface. This process is capable of joining the large surface area as due to the distributing ability of high energy density available in the explosive over the welding area. The metal plates are joined at an internal point causing considerable local plastic deformation at the interface in which metallurgical bonding occurs in nature and even stronger than the parent metals[1]. The bond is formed due to the high- velocity oblique impact, and this impact helps in jetting action. Jetting is the process which plays a very vital role in joining of the metals plate, in jetting action the top surface of both the metals which contain non-metallic films such as oxide which create obstacle for the formation of the metallurgical bond are clean up and help in smooth welding process. Conservation of momentum is used to describe the bonding mechanisium [25]. The pressure has to be sufficient high and for a sufficient length of time to achieve inter-atomic bonds. The velocity of the collision point V_c govern the time available for bonding, The quality of the bond depends on careful control of the process parameters. These include material surface preparation, plate separation, the explosive load, detonation energy and detonation velocity V_d [2]. During the explosive welding the collision happen for a very short period of time i.e with in micro sec, due to which diffusion process cannot occur with in such a short period of time, which is why this method is widely applied in the production of metal laminated composite materials composed of dissimilar material [3].The first publication to recognize the potential for generating metallic welding by using explosively driven plates appeared in 1944 [4]. The first explosive bonding patent associated with the commercial application of the technique was issued in 1962 [5]. Over 260 various similar and dis-similar metal and alloy combinations can be welded by using explosive welding techniques [9]. The two parameters i.e. plate velocity Vp and collision velocity Vc should be less than that of the velocity of sound in either material to be welded [10]. It is generally recognized that for the flyer plate selection material with lowest density and tensile yield strength should be taken [13].The explosive with detonation velocities greater than 120% of the sonic velocity of the metal should not be used [14]. The pressure impact at the collision point is typically between 0.5 and 6 GPA [15]. The thickness of the explosive had a very small effect on the bond strength while that of the stand-off distance was more influential although the effect is small [16].

1.2 Explosive welding process.

Explosive welding is of two types. The oblique and parallel configuration, the oblique configuration is shown in figure 1, this method come into play when the size of plate is thin and small, but when the plate is large then parallel method is taken as shown in figure 2.

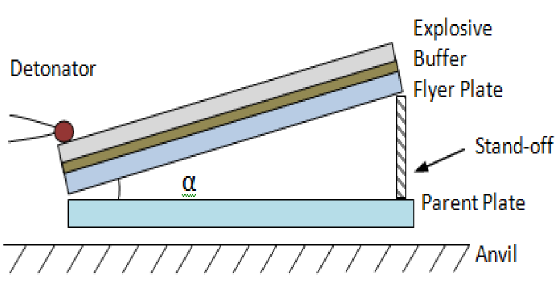

Fig.1

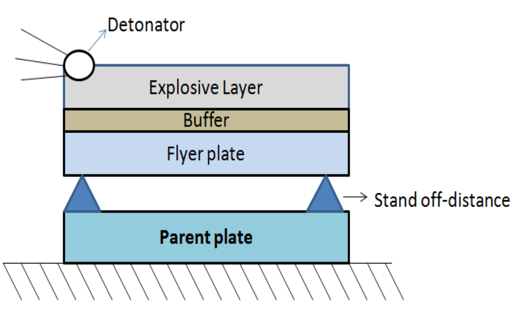

Fig.2

In parallel method the plates to be welded are clean and polish very gently so as to form the good welding, in this process the base plate are keep at the ground in which the flyer plate is placed at top of it by the predefine distance called stand-off distance, the design of the stand-off should be able to bear and handle the load of flyer plate and explosive, above this buffer sheet is kept at the surface of flyer plate ,so as to protect the top surface from damage due to the shock impact of the explosive. Now the prepared explosive placed in a box structure design at the perimeter of the flyer plate is placed at the top of the flyer plate.

1.3 SET UP FOR EXPLOSIVE WELDING.

In this aluminum is acting as flyer plate and stainless steel as parent plate is taken, the two plate are placed at a predefine distance, as due to which it can accelerate and obtain so called jetting action, which is very important for successful welding to occur. The welding phenomenon occurs in a fraction of micro sec.

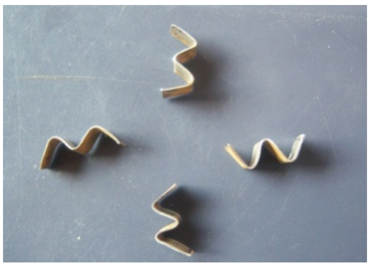

Fig.3 (a)

Fig.3 (b)

Fig.3 (c)

Fig.3 (d)

Fig.4

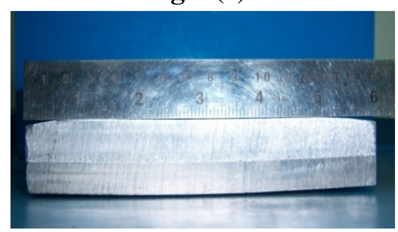

Fig.5

Fig3 (a) Capital letter (M) Stand-off made up of aluminum.
Fig3(b) Two plate Al-SS being placed at a predetermine distance with the help of stand-off, Fig3(c) Explosive welding trial set up(top view), Fig3.(d) Explosive welding trial set up(side view).

The Impact on the area around the plate can be seen in the figure 4 after explosion welding, and after the trial the plate is been clean properly as shown in the figure 5.

2. THE MOST CRITICAL FACTOR AFFECTING EXPLOSIVE WELDING PHENOMENON.

2.1 Jet Formation.

It is one of the phenomenon that occurs during the weld formation, the collision angle determine the formation of the jet. For the waves formation jet is responsible, in theory velocity of collision point remains subsonic, jetting occurs, in practice the pressure magnitude should be sufficient to exceed the dynamic elastic limit of the material for weld to occur. If from both plate jet occurs the jetting formation is symmetric and else from one it is asymmetric [2]. Due to the presence of higher yield strength of the flyer plate low amplitude wave was observed and the plate was not able to deform properly. The jetting materials get entrapped when the velocity of explosion is more, and produce a lack of bond area [19].

2.2 Stand-off distance.

It plays an important role as it is the one which helps in metal acceleration and obtain the desire angle for weld. Stand-off distance that is twice the flyer plate thickness is used for thin component (up to 6.5mm or 0.26in.) and for the thicker components (up to 13mm, or 0.5in) the stand-off distance is equal to the flyer plate thickness [7]. The reduction of the melted area fraction in the bond was due to increase in the stand-off distance [8]. Shear strength (Rs) and Peel strength (Ro) is directly depended on the stand-off distance. Melt area fraction in the bond reduce with the increase of the stand-off distance. After exceeding the distance of 2h between the plate the hardening of the steel grows extensively [8].

2.3 The collision angle (β)

It determines the formation of the jet. The change in the interface morphology in the welded front from wavy to smooth is directly due to the change in the collision angle [6]. It depends upon the controlled Guidelines velocity of detonation and the stand-off distance, usually range from 5 to 25^0 [16]

2.4 Velocity of detonation (V.O.D)

The detonation velocity of the explosive must be less than about 120% of the sonic velocity of the material [15]. Explosive with Broad range of low- detonation velocities are more appropriate as due the deleterious effect of shock rarefaction, it is desirable to use the explosive with detonation velocities ranges from 2000 to 6000 m/s [13]. High detonation velocity can give rise to a relatively high collision angle β, due to which high turbulence is created at the interface [18]. Detonation velocity is a characteristic of the type of the explosive and is directly proportional to the explosive density derive from empirically for nitro guanidine explosive [24].

TABLE 1. Explosive welding trial data.

Trail No.	Plate Material	Plate Size, (mm)	Explosive thickness (mm)	Explosive loading ratio (C/M)	Flyer velocity (m/s)
01	Flyer: Al-6061 Base : SS304	300x150x5 300x150x19	17	1.0	400
02	Flyer: Al-6061 Base : SS304	300x150x5 300x150x19	15	0.9	325

3.1 TABLE 2. Testing standards.

Sr.no.	Test	Standard
1	Ultra sonic inspection	ASTM A 578
2	Bond shear strength	ASTM A 265
3	Ram tensile test	MIL-J-24445
4	Drop weight test	ASTM E20S-66T

3. APPLICATIONS.

Explosive welding is been used in many different organization and industries, some of the important applications of explosive welding process include:

- Used by the marine for the various applications for the structurally sound corrosion resistant of aluminum and steel [27].
- Cylindrical components such as tubular transition joints, tube to tubeplate and concentric cylinders [28].
- Heat exchanger with a clad tube sheet and sheel [29].
- To produce high strength weld between niobium and 6061- T651 Aluminum [30].
- Feedwater heater tubes [31].
- Joining of dissimilar metals, e.g. steel to aluminum [23].
- Joining of similar metals, e.g. Aluminum to aluminum [6].
- Light weight metal sheets [32].

4. CONCLUSIONS

Limitation was the metal must be ductile enough to undergo the deformation without cracking, Limits accepted for the elongation are minimum 15%, A notch toughness of value above 30 J at bonding temperature [16]. Advantages were no heat affected zone (HAZ), No diffusion, retain the properties of the parent material, only minor melting, Material melting temperature and Co-efficient of thermal. Expansion differences do not affect the final product, Can join large plate in very less time, High uniform mechanical bond strength [15]. High degree of plastic deformation occurred at the interface, which was shown when grain of the cladded materials at the interface was elongated in the explosion direction for both untreated and treated materials. Due to the cold plastic deformation, higher microhardness values were observed at the interface [18]. The transition from straight to a wavy interface appears to be due to an increase in the plastic strain and shear stress [2]. The nature of deformation in the surface layers of the welded materials is determined by the presence of a jet formation [23].

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