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Study on Mechanism and Process of Explosive Welding

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Abstract. Introducing the mechanism of explosive welding, this paper made a brief review of the development of explosive welding and summarized recent development of explosive welding, including parallel explosive welding , multi-layer explosive welding, underwater explosive welding, composite technology of explosive welding and rolling and explosive welding process structural component. Finally, the paper points out components with complex structure are the important development direction of explosive welding.

Introduction

Explosive welding, also called explosive cladding, is a high-energy process, in which solid surfaces of two metal components of dissimilar or similar materials are cladded by detonation energy from oblique high velocity impact [1]. The flyer plate hits the base plate quickly driven by the impact force, and the high speed jet cleans the oxide film and adsorption layer on the metal surfaces, then the two clean metal surfaces contact with each other close under high pressure, so the metallurgical bonding is formed. With the development of society and the progress of modern technology, there is a higher quality request for function and structure of composite. Explosive welding has been the hot spot in the composite field. Explosive welding has been widely used in petrochemical industry, salt and alkali production, transportation, aerospace industry, and nuclear industry etc.

Explosive welding involves materials science, explosion mechanics, fluid mechanics, and some other subjects. Since American L.R.Carl[2] first put forward the idea of explosive welding, a lot of theoretical and experimental studies on explosive welding have been done both home and abroad and many progress and results have been made in mechanism analysis, characterization test, and new process. But a unified conclusion and understanding have not been formed yet in interface bonding mechanism, interface wave mechanism, and flyer plate movement model.

Mechanism of explosive welding

Currently, there are three theoretical hypotheses of interface bonding mechanism of explosive welding: fusion welding, pressure welding, shear welding. Philipchuk and Hammers believe that the essence of explosive welding is fusion welding. It is the direct cause that the impact of flyer plate and base plate makes the metal in the interface melt and cool quickly, but this theory can't explain the direct bonding of interface without melted layer. Crossland[3] and co-workers proposed pressure welding mechanism. They thought that if the explosion pressure keeps a enough long time, the metal interface will have a severe plasticity deformation. And because of the metal jet the whole metal will have a diffusion motion, so metallurgical bonding is realized. However, peak explosion pressure can only continue a few seconds and diffusion coefficient of solids is small, which is not consistent with the actually observed diffusion in the interface. Otto and co-workers proposed shear welding mechanism, which is during the explosive welding the heat gave out by shearing in the interface bonding area, and a wavy bonding interface is formed. These theories above have analyzed and studies bonding mechanism of explosive welding to a certain extent, but there are still many things needed to perfect. Recently, Yao-hua Wang and Chang-gen Shi proposed a special

pressure welding mechanism of explosive welding, in which high temperature of the interface, high pressure and jet are considered to provide condition for the solid-state bonding of the two surfaces.

It can be known from the above analysis that a lot of deep researches about interface bonding have been done by scholars both home and abroad, and many scientific theoretical hypotheses in bonding mechanism, wave mechanism, and jet formation mechanism have been proposed, laying the theoretical foundation for the optimization of the charge parameter and quality control of explosive welding.

Development of explosive welding process and its existing problems

In recent years, with the fast maturity of explosive welding process, its application fields expand constantly. Explosive welding technique for materials that are hard to melt like rare metals, such as zirconium and titanium, and amorphous alloy has been improved. New processes came out constantly, such as explosive welding under water, thermal explosion, and explosive welding and rolling. All these enrich and develop explosive welding process greatly.

Parallel explosive welding process. Common parallel explosive welding equipment is shown in Fig.1, in which the base plate is placed on sand stone, and a certain gap is left between the two plates with a spacer supporting the flyer plate. The flyer plate and the base plate are parallel to each other. Explosive and detonator are set on the flyer plate.

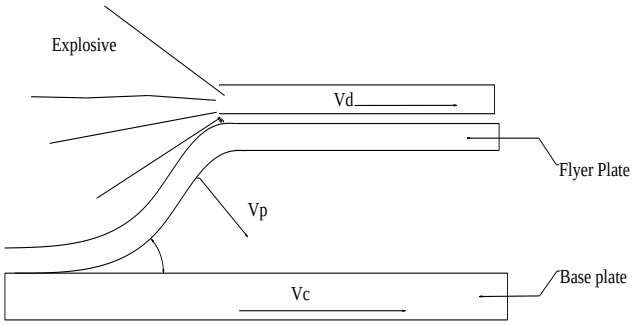

Fig.1 Explosive welding parameters

Multi-layer explosive welding process. The equipment in multi-layer explosive welding is similar to that of common parallel explosive welding. Their only difference is it has two flyer plates, not one. After the detonation of the explosive, the two flyer plates hit the base plate at the same time and the three plates then are cladded together. Usually, multi-layer explosive welding is used to weld rare metal materials, so it is widely used in high-tech field. Brittle intermediate compounds will be formed in the bonding interface of rare metal, which will affect the service performance. Brittle intermediate compounds will be reduced by using layered composite method or middle layer (tantalum), so an ideal rare metal composite plate will be got.

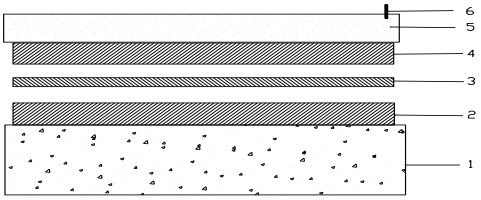

Fig.3 Schematic diagram of Multi-layer explosive welding set-up

1 basement, 2 steel plate, 3 titanium plate, 4 Zr-2 alloy plate, 5 explosive, 6 detonator

Underwater explosive welding process. Because of its special working environment and distinctive features, underwater explosive welding has become a new research field. In foreign countries, underwater explosive welding has been used successfully in the repair and connection of underwater pipelines. Japanese K.Hokamoto and co-workers[4] successfully welded Al/Zirconia ceramic, tungsten/Cu, amorphous alloy/steel and other composite materials, meeting the requirement for bonding strength and comprehensive properties by parameter optimization. In China, Ke-qiang Chen and co-workers have done a lot of research on underwater explosive welding

and they have successfully made a underwater explosive welding of a steel pipe with the external diameter of 80mm and the wall thickness of 8mm.

At present, there are three kinds of successful underwater explosive welding in research and practice at home and abroad: local drainage method, gapless method, and regulated underwater shockwave method, and their assemblies are shown in the Fig. 4. Local drainage method can get the best effect and gapless method the worst. It is worth to point out that Hokamato and co-workers proved by numerical simulation and experiment study that even distribution of underwater impact load and interface wave can be got if using explosive of high strength and placing the explosive in a linearly increasing way in regulated underwater shockwave method.

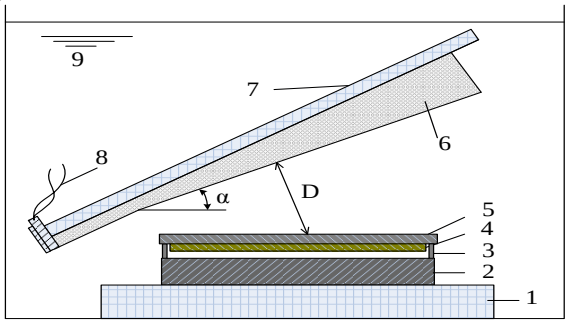

Fig.4 The method of regulated underwater shockwave
1 foundation, 2 base plate, 3 gap, 4 flyer plate, 5 cover plate,
6 explosive, 7 reflection thick plate, 8 detonation, 9 water

Explosive welding and rolling process. Composite plate production process of explosive welding and rolling can conquer shortage of explosive welding and produce ultrathin metal composite materials of large size and with low cost, meeting requite for a composite plate and avoiding adverse effect of placing explosive in a large scale, so it has a promotion effect on scale production of explosive welding in low harm condition.

According to characteristics of material and processing requirement, rolling of explosive composite plate can be divided as: cold rolling, hot rolling, and hot rolling and cold rolling. Chang-gen Shi and co-workers studied on the explosive welding and rolling of 304/A36 and other materials. They got a stainless steel composite plate, $0.1mm \leq \delta \geq 2mm$ in the complex layer thickness, 2m in width, 20m in length. Yuan-mou Zheng[5] and co-workers found that a layer of white or black zonal material appeared on Ni/stainless steel interface, which components was solid solution that did not affect binding performance, and hard brittle intermetallic compound that affected interface quality appeared on the Ni/Ti composite plate.

Structure component explosive welding process. At present, research on explosive welding application both home and abroad mainly concentrate on layered metal composite plate and metal composite pipe, and member, and few research are on component of complicated structure [6]. In the world, American Denver Research Institute made a Ti-6V-4V rib strengthen panel in 1980's, but they didn't disclose their specific process and parameters. Compared with common metal layer plate welding, a lot of problems need to solve in explosive welding of large area rib strengthen component, which is one of technical problems in academic circle of explosive welding. Especially for protection of thin panel and the demould of filling mould, there is still no good solution.

Conclusion

From the development status of explosive welding talked above, it can be known that application fields of explosive welding expand constantly. Welding process for rare metal like Ti and Zr and amorphous alloy that were hard to weld becomes more and more perfect. Underwater explosive welding process and explosive welding and rolling process has advantages on reducing secondary effect and avoiding work in a large area.

References

[1] J. Amos Robert Jayachandran and N. Murugan Investigations on the Influence of Surfacing Process Parameters Over Bead Properties During Stainless Steel Cladding [J]. Materials and Manufacturing Processes, 2011:01-27: 69.

[2] SUN Xian-Jun, TAO Jie, GUO Xun-zhong. Bonding properties of interface in Fe/Al clad tube prepared by explosive welding. Trans Nonferrous Met soc. China 21(2011)2175-2180

[3] Fehim Findik. Recent developments in explosive welding. Mater Des 32 (2011) 1081–1093

[4] K. Hokamoto, M.Fujita, H. Shimokawa, ect., A new method for explosive welding of Al/ZrO2 joint using regulated underwater shock wave, Mater Proce Techn. 85 (1999) 175-179.

[5] S. Saravanan and K. Raghukandan. Influence of Interlayer in Explosive Cladding of Dissimilar Metals [J]. Materials and Manufacturing Processes, 2013, 05-28:589.

[6] S. Tanaka, K. Hokamoto, S. Itoh, Analysis of particle penetraion into Aluminum plate using underwater shock wave, AIP Conference Proceedings. 1 (2007) 053-1058.