THE EXPLOSIVE WELDING PROCESS

EXPLOSIVE WELDING

The process of explosive welding has been understood for decades. Although academia has acknowledged explosive welding as a novel and fascinating process, with several specific exceptions, industry has been slow to realize its potential and the possible composites that it makes available. More recently, explosive welding manufacturers have characterized and defined many aspects of the process and have made efforts to inform design engineers of the many composite possibilities that explosive bonding allows. A composite can be designed and fabricated to combine desirable properties of very different metals. This process allows the designers to optimize the performance of the composite for high temperature, cryogenic, high strength, thermal or electrical conductivity, enhanced mechanical properties, corrosion resistance, or any other application.

Explosive bonding is considered to be a solid-state welding process that uses controlled explosive energy to force two or more metals together at high pressures (Figure 1). The resultant composite system is joined with a high-quality metallurgical bond. The time duration involved in the explosive welding event is so short, that the reaction zone between the constituent metals is microscopic. During the bonding process, several atomic layers on the surface of each metal become plasma. The collision angle between the two surfaces (typically less than 30°) forces the plasma to jet ahead of the collision front, effectively scrubbing both surfaces and leaving virgin metal. The remaining thickness remains near ambient temperature and acts as a huge heat sink. Therefore, the bond line is an abrupt transition from the clad metal to the base metal with virtually no degradation of their initial physical or mechanical properties.

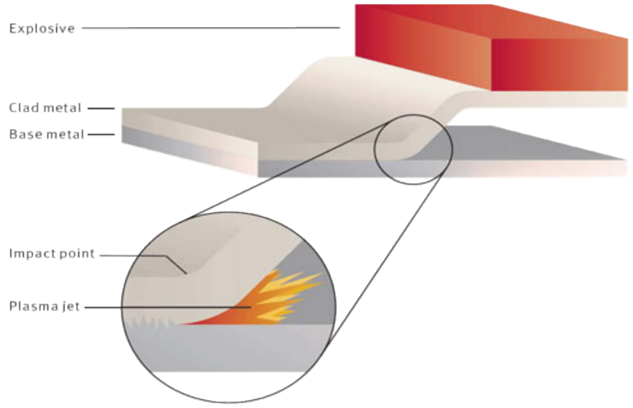

Figure 1 - *The Explosive Welding Event*

The obvious benefit from this process is the joining of metallurgically incompatible systems. Any conventional joining method, which uses heat, may cause brittle intermetallic compounds to form.

PROCESS CONTROL

The fabrication of multilaminates by explosive welding involves a working knowledge of the process phenomena and the ability to utilize them efficiently to create quality composites. In order to produce a quality weld, the variables affecting the weld formation must be tightly controlled. The amplitude and periodicity of the wave pattern formed during explosive welding can be controlled by adjusting three major parameters: detonation velocity (Vd), explosive load, and the interface spacing. The wave pattern formed at the bond line is most often described as resulting from a fluid-flow collision. The two constituent metals can be considered to act as viscous fluids in the reaction zone and, just as in describing laminar or turbulent flow, a Reynolds number can be determined for the system. In a fluid-flow collision, the interface turbulence is controlled by the detonation velocity and the collision angle (Figure 2).

Figure 2. *Wave Morphology Variation.*

The interface morphology is important for some specific applications. For example: it may be desirable to attain a wavy interface to increase transition joint's shear strength. It also may be desirable to attain a flat interface in a system, where a reaction zone must be minimized for thermal reasons, or where it is necessary to know the depth of a bond line on a microscopic level.
It is also important to know the metallurgy involved in a particular system when selecting bonding parameters. In very turbulent wave patterns, localized melt pockets can occur at the "crests" of the waves. These melt pockets can contain a variety of binary alloys, rapidly-solidified microstructures and intermetallic compounds. Some systems that form a very stable intermetallic compound may form a continuous layer of that compound at high bonding pressures. Such a bond, with a continuous intermetallic layer, usually shows very high tensile strength, but low ductility and impact resistance. It will also react poorly to thermal cycling.

INTERLAYERS

The problems of extreme metallurgical incompatibility may be overcome with the addition of an interlayer. The interlayer is chosen for improved compatibility with both of the constituent metals or because it allows thermal excursions which otherwise may lead to service problems. High melting temperature interlayers allow transition joints to be conventionally welded to their respective parent metals without the concern of diffusion related failures or bond degradation.

SUMMARY

Explosively welded multilaminates come very close to achieving ideal composite conditions i.e. a sharp transition between layers; physical and mechanical properties which are constant or enhanced throughout individual layer thickness'; and a metallurgical bond between layers. These composites are available for a wide variety of industrial and strategic applications. The high integrity of the bond allows design engineers to utilize the specific desirable properties of metals more efficiently.

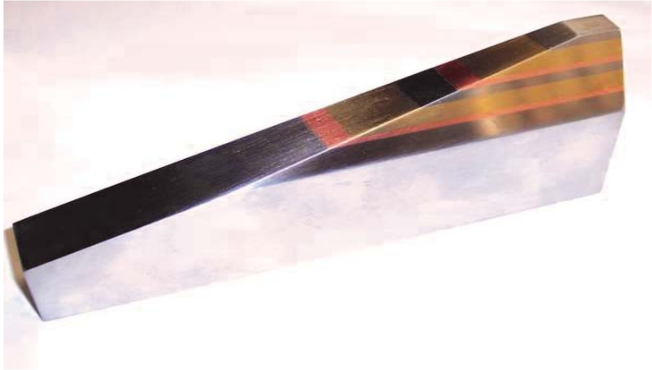

Figure 3. *Bonded Metal Stack*

Transition joints between metals with widely differing melting temperatures can be produced with the appropriate diffusion barrier interlayer. Thin, exotic metals with unique desirable properties can be metallurgically incorporated externally or within a metal matrix. This process allows the economical use of strategic metals, while mitigating design constraints common with mechanical joining methods.

Explosive bonding is used in several different geometries. Flat sheets can be bonded as shown in Figure 1 or as tubes and rods. The geometry used for any given product depends on the end requirements for the material.

Explosive cladding offers advantages over other coating technologies, because after sheets of material are bonded together, they retain essentially 100% of their theoretical density. Other coating techniques, which employ spray or vapor deposition, have much higher porosity and, as a result, do not protect the substrate as well.

Explosive welding is a proven process that has gained Navy approval for joining aluminum to steel (MIL-J-24445). Further explosion bonded multilaminates are certified for manned space flight and both civilian and military aerospace applications.