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Explosion Bonding Engineering and Design Basics

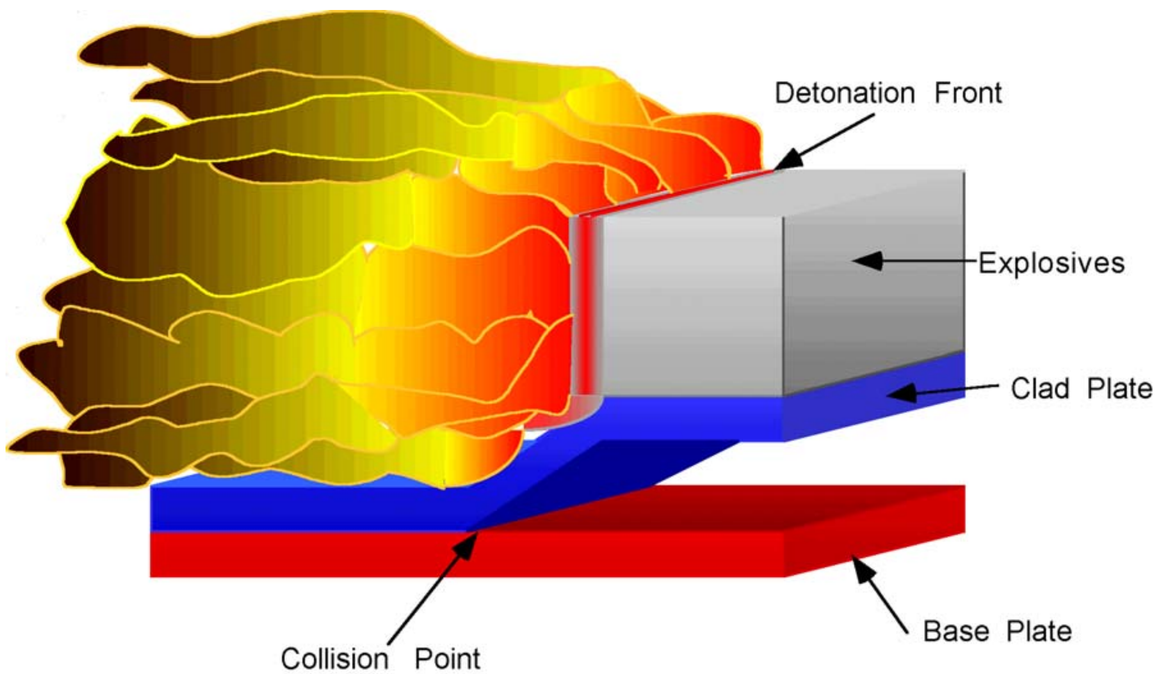

***Figure 1**. Explosion weld in mid-event.*

Introduction

Explosion welding, or bonding, is a solid state welding process that is used for the metallurgical joining of metals. Explosion welding can be used to join a wide variety of dissimilar or similar metals. Simply stated, explosion bonding uses the controlled detonation of explosives to accelerate one or both of the constituent metals into each other in such a manner as to cause the collision to fuse them together.

As shown in Figure 1, the metallurgical joining occurs when the clad metal is driven down into the base metal by the explosive energy. The force of the explosion sets up an angular collision which produces an ejected plasma. The plasma jet acts to remove impurities from both metals' surfaces in front of the collision point, leaving behind clean metal for joining. The pressures at the collision point, which can be from 100,000 – 600,000 psi, are enough to squeeze the metals into behaving like viscous fluids. The fluid-like behavior is responsible for creating the wave pattern bond line in an explosive weld.

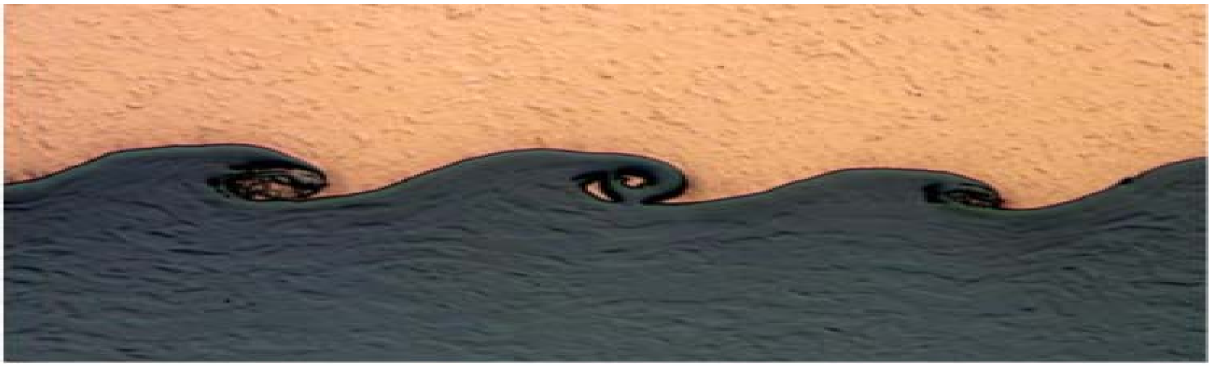

***Figure 2**. Typical explosion weld bondline. Note wavy fluid-like behavior.*

The object of HEMI's Engineering and Design Basics is to assist potential users in understanding the strengths and limitations of the process in order for the most reliable and cost effective parts to be designed.

1.) ***Explosive Deformation.*** Explosion bonding creates forces that bend the metals during the event with localized pressures of up to 600,000 psi. This deformation creates two aftereffects.

Metal Thinning. During the explosive collision the forces tend to squish the thickness of the metals. This thinning is a function of the metals' initial hardness and thickness. For example, when bonding copper to stainless, a .250" x 12" x 24" copper plate might end up .220" x 12.25" x 24.25". Since the stainless is harder, it might go from .250" x 12" x 24" to .240" x 12.12" x 24.2". Soft and thick materials tend to thin more than hard and thin. Therefore, starting with thicker material and machining after bonding is strongly recommended.

Flatness. The standard flatness of explosion clad material is summarized in Table I below. Bonded material usually requires mechanical flattening. On systems where one or more of the constituent metals are crack sensitive, i.e., titanium, molybdenum or tungsten, flattening may be done at elevated temperature or after a thermal stress relief treatment.

Flatness Tolerances of Explosion Bonded Sheet and Plate

	Dimensions				
Thickness	**up to 6" x 12"**	**up to 12" x 36"**	**up to 12" x 72"**	**up to 24" x 72"**	**up to 48" x 96"**
	Flatness in inches overall				
.005" - .050"	0.020	0.125	0.500	1.000	2.000
.051" - .100"	0.020	0.125	0.250	1.000	2.000
.101" - .250"	0.020	0.080	0.125	0.750	2.000
.251" - .375"	0.020	0.080	0.125	0.500	2.000
0.376" - .750"	0.020	0.200	0.250	0.250	2.000
.751" - 1.50"	0.020	0.250	0.375	0.500	2.000
1.51" - 3.00"	0.020	0.250	0.500	0.750	2.000
>3.01"	0.020	0.250	0.500	1.000	2.000

2.) ***Joint Integrity.*** Explosion welded joints are outstanding for ultra-high vacuum (UHV) applications. Transition joints designed for electron-beam weld installation with wall thicknesses of 0.020" are regularly fabricated that perform leak-tight (10^{-10}). HEMI recommends for rugged designs, the leak path be designed at a .125" minimum. Thermal excursion limits should be discussed with HEMI but are typically in excess of 400'C.

3.) ***Testing.*** HEMI performs ultrasonic inspections per ASTM A-578, mechanical bend tests per MIL-J-24445A Paragraph 4.5.3 and dye-penetrant inspections for all materials. Ultrasonic C-Scan recordings, bond strength test data and Helium leak test results can be included for a nominal fee.

4.) ***Bondline Linearity.*** The behavior of the constituent metals under the pressures of explosion bonding is similar to a viscous fluid. This behavior leads to a naturally occurring wavy bondline (see figure 2). The wavy bond can be controlled and is typically in the range of. .020"-.040" peak to peak. The wavy nature of the bond makes it difficult to hold precise tolerances of the bondline. Bondline linearity is dependent on particular systems and thicknesses but HEMI can generally hold a bondline to ±.020 on flat composites and ±0.025" on cylindrical composites. HEMI has significant experience in controlling bondline dimensions and can hold tighter tolerances on request.