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Atmospheric vs Vacuum Clad: What Matters?

History

The explosion cladding technology (EXW) was discovered and patented by DuPont in 1959. The DuPont DetaClad® team built the world's first industrial explosion cladding facility in the mid 1960's at Pompton Lakes, NJ, USA. The cladding operations for this facility were performed in an underground blast chamber two hundred meters from the clad production factory. The chamber was isolated by heavy steel doors to provide noise and air-pollution management. After evaluation of cladding atmosphere options, including vacuum, DetaClad chose to work with the natural air atmosphere in their underground chamber. The DuPont cladding production technology was fully developed and codified at this site, culminating in the creation of the DetaClad Technical Cladding Manual. In the late 1960's DuPont proceeded to license their DetaClad EXW technology globally to licensors in several European countries as well as India and Japan.

In the early years many of the licensor companies chose to operate open air (atmospheric) cladding production sites to minimize startup costs. Today, all the major explosion cladding facilities globally, except for India and China, have moved their cladding operations in to blasting chambers, similar to the original DetaClad chamber in Pompton Lakes. These chambers provide protection from natural weather events and temperature variances as well as the ability to manage the natural environmental noise, shock, and visual effects of the explosion cladding event. Cladding chambers around the world vary from tunnels originally created by mining operations to highly engineered blast control structures. Almost all explosion clad manufactured globally today is produced in an atmospheric environment.

Wave Size is Driven by Collision Energy

The basic explosion cladding technology of all explosion clad manufacturing companies globally traces back to the original DetaClad Technical Cladding manual. Figure 1 is a typical presentation of the Explosive Cladding Window, as developed by DetaClad. It defines the allowable range of explosion cladding parameters which result in a high-quality clad product. Over the years many of the companies have modified the precise explosion cladding process and parameters to reflect their unique operating techniques and to utilize the specific explosives types which are allowed by local regulations. This includes the vacuum cladding variant of the process.

The early DetaClad technology research demonstrated that explosion clad could be produced over a broad range of cladding parameters. At very low cladding energy (gray area in Figure 1), a flat waveless bond would be achieved (Figure 3). As the cladding energy was increased the bond transitioned to the traditional wavy interface (red area in Figure 1). When cladding energy was excessive a highly turbulent wave resulted (orange area in Figure 1). It was clearly shown that optimum bond quality and reliability was achieved in the middle energy regime (Figure 2).

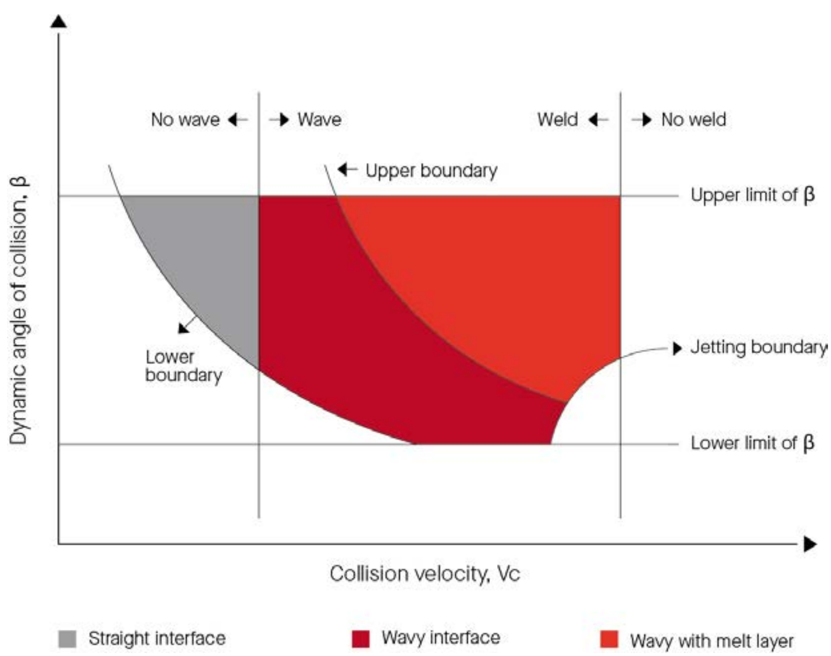

Figure 1: Typical presentation of the Explosive Cladding Window

Low Energy Parameters Address Cost Issues with Vacuum

A variation of the explosive cladding process is performed under vacuum conditions in a chamber. The process modifications for explosive cladding in a vacuum were initially implemented in Germany around 1970. The vacuum environment allowed a reduction in the amount of explosive required. However, the major drawback of the vacuum operations was the high capital expense of the chambers as well as high ongoing maintenance costs. Consequently, the vacuum cladding companies tended to seek a further reduction in explosive pressure by choosing to produce clad using parameters in the lowest energy regime of the cladding window Figure 3. These conditions result in a waveless interface. They also exhibited less consistent bond quality due to a much more limited process control window.

Surmet in Aachen was one of the early leaders in development of vacuum chambers for cladding. Several other companies followed in this effort including GVM, also in Germany, and SMT in the Netherlands. With the exception of SMT, all of the vacuum cladding companies had gone out of business by the mid 1990's. The primary cause was the high expense of maintaining their explosive chambers under conditions necessary for production of high-quality explosion clad.

As shown in the gray area of Figure 1, the production window for making high quality flat bond clad is much smaller and more difficult to control than for higher-energy wavy bond clad. There are rarely technical benefits of cladding in the flat bond regime, the product is typically lower strength and less consistent. Consequently, most explosion cladding companies produce the higher quality wavy-bond products. On the other hand, the vacuum cladding companies have chosen to produce flat bond products, primarily to increase the performance life of their chambers. Low energy flat interfaces are close to the low limit of the cladding window, and they may generate layers of intermetallics spread on large portions of the surface. NobelClad's choice has been to increase the impact energy and increase the interface deformations, grouping the intermetallic into the vortex and achieving a stronger and more reliable wavy pattern. This pattern is also an indirect proof that enough energy has been put into the interface to generate a true metallurgical bond (metallic bond at an atomic scale).

Figure 2: Interfaces at middle energy regime

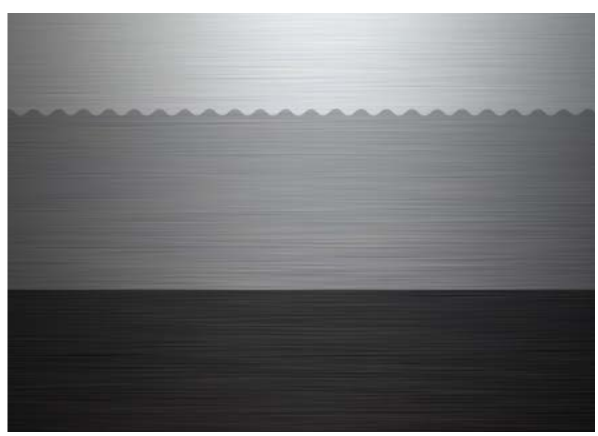

Figure 3: Flat interface at low energy regime

Conclusion

Both atmospheric and vacuum conditions can produce either good, but also poor quality bonds; the critical component being to maintaining collision parameters within appropriate range in the cladding window, Figure 1.

It has further been clearly shown that it is more difficult to maintain these reliable cladding conditions while working in the flat bond regime. The marine and shipbuilding market in Europe has become quite competitive over the years. NobelClad would like to address some misinformation about atmospheric EXW that has been distributed over the years by competitors. For instance, it has been stated that a superior bond can be achieved if the bonding operation takes place under vacuum. There is no evidence that supports this, and in fact the mechanical properties of TriClad is superior to that of vacuum explosion bonded products. In vacuum explosion cladding, the ejection of oxide particles is not always effective because of the lower energy available in the explosion process. Statements like "smoother wave bonds…barely visible" are not representative of a better product, in fact most customers are interested in the stronger bond.

In conclusion, both atmospheric and vacuum explosion welding have their pros and cons. What is important however to customers, is that the bond strength be reliable and repetitive. For 50 years, NobelClad has demonstrated unparalleled expertise and design ingenuity in atmospheric explosion welding to create custom clad solutions for marine applications.

To learn why bi-metallic strips are good for marine business visit www.triclad.com or email us today.

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