Spring-Energized, Metallic, Gasket-Sealed Windows Versus Diffusion Bonded Windows Diffusion Bonded Windows

Diffusion bonding operates on the principle of solid-state diffusion. Given enough time at an elevated temperature, atoms of two solid surfaces become comingled. Diffusion bonding typically applies high pressure as well as high temperature to the materials to be joined.

This type of joining almost always joins only two surfaces, with no intermediate material. It begins by abutting two pieces to be joined, often arranged to generate a clamping force. Prior to joining, the bonding surfaces must be prepared to provide a very regular, smooth finish; and, any chemical or physical debris must be eliminated. Any foreign material at the joining interface may prevent adequate diffusion of material. The presence of loose particulate at the interface is a common failure mode. Once assembled, clamping pressure and heat are applied to the components, usually for many hours.

The diffusion bonding process may be described in stages. In the earliest stage, very small surface irregularities (high spots) on the two surfaces make contact and plastically deform. As the irregularities deform, they allow relative movement of the two surfaces toward each other, ultimately such that atomically-intimate contact is made and inter-penetration of the two surfaces occurs. With the application of elevated temperature and pressure, an intermediate stage of creep is accelerated in the materials (strongly material dependent). In this stage of plastic deformation, material continues to migrate between the gaps in the two surfaces until they are reduced to isolated voids. In the final stage, material begins to diffuse across the interface mixing this boundary and creating a bond.

The materials joined by diffusion bonding may have widely differing thermal coefficients of expansion. Due to a lack of available plasticity or elasticity at the interface, cyclical thermal stresses cause fatigue of this rigid structure. Further, thermal shock can cause an abrupt rise in stress at the interface that exceeds the strength of the bond.

The weaknesses of the diffusion bond are: 1. High process sensitivity to cleanliness, particulates and oxidation; 2. Abrupt, microscopic joint extent, made fragile by the lack of ductility at the interface and stress concentration at the edges; 3. Extreme sensitivity to thermal stresses (cyclic – fatigue, shock – catastrophic failure). (Continued pg. 2)

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Spring-Energized, Metallic, Gasket-Sealed Windows Versus Diffusion Bonded Windows
Diffusion Bonded Windows (continued)

Diffusion bonded windows are mechanically prone to failure, especially under conditions requiring elevated temperature. One commercial manufacturer states the maximum allowable temperature is 120o C and maximum rate of heating/cooling at 3o C/min. Violation of either high temperature limit or thermal heating rate will invalidate any warranty. Additionally, flange assembly instructions for this product cautions that one must

"…always use annealed copper gaskets and washers on both sides with each nut and bolt. Use all bolt holes. Tighten opposing mounting bolts equally over several passes. Use a torque wrench to ensure equal sealing torque. Do not over tighten. Failure to follow this procedure will invalidate any warranty."

Spring-Energized, Metallic Gasket Sealed Windows

Metallic gaskets are thin metal foil rings that are interposed between two bonded surfaces. The mechanics of bonding are similar to diffusion bonding in the early stages. High spots on the two surfaces that are to be joined are filled in by a malleable, ductile metal layer. The addition of this malleable layer locks plasticity and ductility into the interfacial joint. As atoms from the metallic gasket plastically flow to fill gaps between both mating surfaces, the substrate materials themselves need not have the ability to flow; and, the elevation of creep, promoted by high temperature, is unnecessary to achieve atomically intimate contact. Because the gasket sealing system is macroscopic in extent, the sensitivity to contaminants and particulates is not as great. Part-to-part reproducibility is good, and high-quality seals are likely. Restated, the process window is larger than that of diffusion bonding, having minimal sensitivity to cleanliness or complex process variables.

With spring-energized gasket joints, sealing stresses are always compressive. This is in contrast to those stresses created in the diffusion bonding process. In that high temperature process, the clamping force is either removed entirely upon bond completion or is designed such that a lower expansion outer member creates residual hoop strain upon cooling. MPF uses a proprietary spring energized design which maintains a compressive load regardless of the direction of change in temperature. (Continued pg. 3)

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Spring-Energized, Metallic Gasket Sealed Windows (continued)

The advantages of spring-energized, metallic gasket seals are greatly improved mechanical and thermal stability. The maximum bake-out temperature for MPF's extended range windows is 200oC with a maximum rate of heating/cooling of 25oC/min. The mechanical stability has been independently tested for shock and vibration and passed the following testing where bonded and other O-ring sealed windows failed:

Shock: [23G's vertical] [18 G's lateral] [18 G's longitudinal] and acoustic noise [165 dB, 12.5 hours].

No special care is required for installing Conflat™ mounted MPF extended range windows. The window assemblies are stable to shock, vibration, thermal cycling and thermal shock as well as significant differential pressure [>10 atm].

Conclusions

There is a significant difference between the mechanical robustness exhibited by windows sealed with spring-energized, metallic gaskets and the fragility found in diffusion bonded windows. Unequal thermal coefficients of expansion (TCE's) give rise to thermal stresses at bonding interfaces. With diffusion bonding, the residual stress is unidirectional (hoop) or non-existent. The interface between two dissimilar materials is rigid and thus unforgiving to rapid or cyclical temperature changes. The thermal failure of the diffusion bonds most commonly occur due to fatigue and usually at sites of impurities or highly strained seal edges. By contrast, spring-energized gasket seals employ a third, interposed material that is ductile (malleable) and has residual spring energy in either thermal direction. MPF window seals are much less sensitive to rapid heating or cooling, thermal cycling, mechanical shock or vibration.

Spring-Energized **Thermal and Mechanical Characteristics Diffusion Bonded Metallic Gasket**		
Maximum Service Temperature (Deg C) 120 200		
Maximum Heating/Co oling Rate (Deg C/min) 3 25		
Shock and Vibration (G) Vertical - 25		
Lateral - 18		
Longitudinal - 18		
Pressure Differential (atm) 4x Safety factor - > 9		

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