Flushmate Vessel Welding Process Improvements

Chuck Eden
Sloan Flushmate
Bryan Agosto and Joon Park
Emabond Solutions, LLC

Abstract

The Emabond® process is used for the assembly of Sloan's FLUSHMATE® pressure-assist technology to deliver the best possible quality solution for a product that offers the only true high-performance, low consumption alternative. The FLUSHMATE Pressure-Assist system (Figure 1) is a component inside of a specially designed toilet that harnesses the pressure from the water supply line to provide the energy needed to complete the flush.

Figure 1
Pressure Assist Toilet Operating System

The benefits of using the Emabond process allows Sloan Flushmate, to offer a standard ten year conditional warranty on all new Flushmate systems. This innovative high reliable Polypropylene pressure vessel is done through business without borders. Emabond Solutions and Sloan are partners who are connected, forward-looking and have customer focus.

The Emabond process offers a high performance welding solution in a turnkey package for the most demanding thermoplastic product assembly applications. Emabond uses induction energy and electromagnetic materials to deliver heat precisely to the bond line to provide superior welding of thermoplastics. The process joins certain dissimilar materials, highly-filled materials and flexible to rigid substrates and can meet the most demanding temperature, leak-proof and pressure-tight and aesthetic requirements. The Emabond process uses Induction Heating to create the interaction of High Frequency Electromagnetic Field Strength and Susceptors to generate Heat on Command to weld the base plastic composites.

The implementation for the assembly of the Flushmate low pressure toilet tanks resulted in a marked increase in product reliability for a pressure tank when compared to the previous assembly method of vibration welding. The Flushmate product requires a hermetic seal and an aggressive hydrostatic burst pressure. This is achieved through a tongue and groove joint design which puts the weld line under a shear load. The Emabond process yielded higher weld strengths for hydrostatic burst tests while retaining the desired failure mode. The process also increased the long term reliability of the part through its capability to handle part variability. The process is now being used to weld additional components on the Flushmate tank with the same level of robustness and repeatability.

Introduction

Figure 2
Flushmate Polypropylene Pressure Tank

The vessel of the Flushmate (Figure 2) is comprised of two injection molded, glass reinforced polypropylene halves. The halves were initially welded together by the vibration welding process to form a pressure-tight assembly.

A percentage of vibration welded assemblies produced on a limited number of manufacturing days had experienced failures of the weld line joint during service. All products manufactured during or close to the periods in question were actively sought out and replaced. Replacement product was provided at no cost to the consumer and covered by a lifetime warranty on the vessel, and the current ten-year warranty on all other components.

Vibration welding was selected as the bonding method during Flushmate development in 1995. The process moves the vessel halves relative to each other under a clamping pressure to generate sufficient heat to melt the thermoplastic resin. The motion is stopped and the halves are held under the clamping pressure until the resin has cooled and returned to a solid polymer. A polymer weld is established between the two components. The consistency of the weld joint is dependent on flange width, flatness and the uniform intimate contact of the two welding surfaces of the vessel halves during welding, duration of the welding cycle and holding pressures. The welding parameters are fixed and continuously monitored to assure consistent processing.

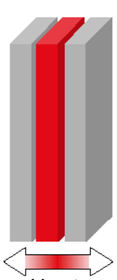
Rigid Production Testing

Sloan's samples are selected during the course of the day from the output of each welder. These samples are subjected to destructive testing and evaluation. The pressure at which the vessel fails and the manner in which it fails are monitored. Each completed vessel is subjected to a minimum of three leak checks during the course of final product acceptance testing: A water immersion test at nominal operating pressure, and two functional cycles at the extremes of the specified operating pressures.

Sloan's Flushmate is High Performance

Figure 3
Supercharged Toilet Operating System

The current welding operation is the Emabond electromagnetic welding process. This process uses a filler material of a ferromagnetic powder in a polypropylene resin matrix and induction heating to melt the filler and establish a polymer bond between the components (Figure 4). The Flushmate Hydrostatic burst testing using Emabond resulted in increased values for weld strength (Figure 3) while maintaining the desired mode and positioning of the vessel wall failure.



The Emabond Process generates the uniform heat inside a thin layer of Plastic Welding Material, which will reduce adverse effects on the substrates like

- thermal degradation
- thermally induced residual stress

And will offer advantages in regard of

- compact shear joint design
- speed
- energy efficiency

Figure 4
Emabond Technology

Sloan's engineering and quality requirements for the Glass filled Polypropylene tank are measured at the consumer level for performance and reliability with attention to detail in aesthetics. They are as follows:

- ✓ Effective hermetical sealing assembly technique requiring high pressure and endurance
- ✓ Excellent welding method for Olefins with higher content of reinforcement fillers
- ✓ Manufacturable shear & tongue-in-grove joint for structural part assembly and integrity
- ✓ Provides flexible part design considerations
- ✓ Eliminates particulate & contamination
- ✓ Results in very clean distortion free weld line
- ✓ Excellent weld flash control
- ✓ Molded Part Flexibility and Gap Filling

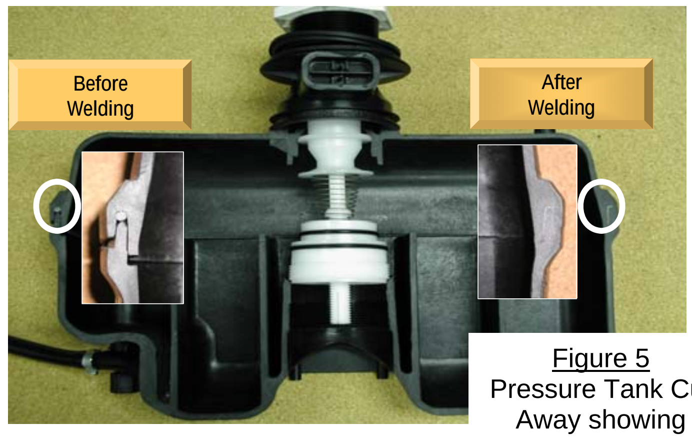


Figure 5
Pressure Tank Cut Away showing Welding process

Process Quality Procedures

Machine Parameters: The preset parameters of the process are: initial and holding clamp loads, maximum weld time and hold duration. Typical values for the Flushmate are initial clamp load of 2000 pounds and a maximum weld time of 24 seconds; typical weld times are 18 to 21 seconds. The hold clamp load is 2250 pounds and is typically applied for 9 to 11 seconds. Deviation from preset control limits for these parameters results in a machine fault (Figure 6).

Machine Fault: The cycle interrupt assemblies associated with a machine fault are functionally and/or destructively evaluated; none are allowed to proceed into deliverable product.

Machine Process Control: The total weld depth, or the vertical travel of the weld fixture from the clamp load set point to the final hold clamp point, is a resultant parameter and subject to preset control limits. The weld depth must be achieved within the above time limits or a machine fault will result.

Design of Experiments (DOE): The joint is subject to cleavage loading during the flush and fill cycle. Hydrostatic burst testing of daily vibration welded production samples of Flushmate is consistently well beyond four times the operating pressure. Failure modes during destructive testing have consistently been tensile failures of the sidewall in the upper half, initiating in the area of the innermost stiffening ribs. This location corresponds with FEA designations of maximum stress.

Weld and hold intervals were optimized during process development and verified during production system validation. Typical weld time is 18 seconds followed by an 8 second hold and cool period. Provisions have been made in the design of the vessel halves to incorporate an attribute check of the welded assembly to assure full seating.

The joint is primarily subject to shear loads with a minor peel component. Hydrostatic burst testing of production tank vessels welded with the induction work coil assembly cell below, has resulted in part geometry failures only, and at a greater burst pressure than with vibration welding. Over 1.2 million Flushmate tanks have been welded and there has been no failures at the weld line (Shear Joint).

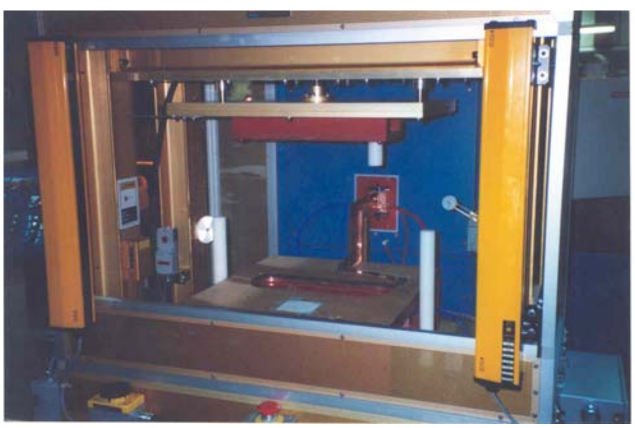


Figure 6 Emabond Welding Machine

Test Results

Test Specimen Tensile Testing: Specimens including approximately 1.5 linear inches of weld joint were removed from vibration and electromagnetic welded vessels, and subjected to testing to determine the ultimate tensile strength of the joints. *The electromagnetic weld specimens demonstrated an increase in ultimate tensile strength of greater than five percent over the vibration-welded specimens.*

Hydrostatic Burst Testing: Samples of electromagnetic welded vessels were subjected to hydrostatic burst testing in the same manner as vibration welded assemblies. In each series of tests, *the electromagnetic welded vessels burst at levels at least ten percent greater than those for production vibration welded assemblies for the same time period.*

Vessel Assembly Tensile Testing: Samples of vibration and electromagnetic welded vessels were subjected to testing to determine the ultimate tensile strength of the joints. Adapters were fabricated to pick up on the threads in the top cap bore and on the discharge extension boss. The initial series of tests resulted in no weld line failures, and ultimate tensile values greater than 2500 pounds. All the failure modes were rupture of the vessel flange at the point where it joins the discharge boss.

An additional adapter was fabricated to pick up on the full surface of the flush valve seat in an attempt to reduce the localized stress at the discharge boss thread and prompt a failure at the bond line itself. Again the testing resulted in failures of the vessel wall, but no failures of the weld line for either technology.

Accelerated Life Cycle Testing: The test stand cycling of welded Flushmate tanks were with 80 PSIG supply pressure applied. *Electromagnetic welded assemblies have completed over 150,000 cycles with no anomalies*.

Fatigue Testing: *Electromagnetic welded assemblies have completed over 500,000 fatigue cycles with no anomalies*. Each cycle consists of applying 50 PSIG compressed air for five seconds, and then bringing the vessel to ambient pressure for five seconds.

Conclusions

The Emabond process is a value added assembly solution. The advantage of the electromagnetic welding process is the use of the compact shear joint. The tongue and groove configuration results in a lap joint rather than the vibration welded butt joint. The lap joint is inherently a stronger joint. The bond line is loaded in shear across the entire width of the joint. The configuration of the joint provides a nesting of the opposing elements and brings the two vessel halves into a consistent relationship during the course of the welding cycle. The clamping loads involved are only necessary to move the components into the seated position.

- Electromagnetic welding requires approximately 15 pounds of force per linear inch of joint preload. Vibration welding clamp forces are in the range of 50 pounds per inch. While the loading is applied through the flange specifically designed for the purpose, the bending forces developed during the weld phase, and the residual stresses induced may be considerable in the vibration welding process.

- The vibration welding process of filled thermoplastics has the potential of developing an apparent resin depleted area at the interface of the joint. Electromagnetic welding does not produce such an area. The addition of the filler material also provides a source of resin at the joint interface to facilitate a full weld between components and to insure there are no voids.

- In the vibration welding process, there are two distinct areas of the bond line, those with the relative motion in line with the length of the joint, and those at right angles to it. The bonding surfaces in the areas with inline motion are in full contact during the full range of the cycle. The energy input will be consistent along the bond line. Those areas at right angles to the relative motion will have an interrupted energy input. This discontinuity in input energy can not be eliminated and must be compensated for by adjustments in the weld duration and clamp loads. The uniformity of the weld joint is likely to vary as a result.

- An additional consideration is flexure of the right angle surfaces during relative motion. Again this concern is addressed during design of the components, but the probability of flexure, or scuffing, during the weld cycle must be considered.

- Electromagnetic welding is not as sensitive to process variables as vibration welding. There are essentially two key parameters: filling the joint pocket with filler material and duration of the electromagnetic field. The joint pocket volume is governed by the configuration of the mating components. The designs establish the size and relationship of the joint components in a manner that facilitates consistency during the molding process. The fit up of the two components is such that there is a centering of the halves as they come to a seated position, and the variation in gap is biased to the joint interface where it will be filled. The filler material is applied in the form of a uniform cross section cylindrical strand and provides sufficient material to accommodate worst case joint pocket volume. The duration of the application of the electromagnetic field is essentially a minimum value set to provide complete melt of the filler. The time is established with sufficient margin to ensure this is accomplished. Continued application of the energy will provide added bonding to the component surfaces.

Testimony

Customer satisfaction and acceptance are critical to the Sloan Flushmate success. Read them at http://www.flushmate.com/Testimonials/default.asp

Acknowledgements

The authors wish to thank those at Sloan Flushmate and Emabond Solutions that were involved in the successful transition to the electromagnetic welding process

References

1. Branson Corporation, Vibration Welding Manual, version 3.02.

2. Emabond Systems, Ashland Chemical Co, Technical Literature, Bulletin2237, entitled EMAWELD.

3. Steven Chookazian, Ashland Chemical Co, "Electromagnetic Welding of Thermoplastics and specific Design Criteria with Emphasis on Polypropylene", Technical Paper.

4. Steven Chookazian, Ashland Chemical Co, "The Emabond Process for Thermoplastic Assembly", SME Technical Paper AD99-214.

5. Emabond Process Presentation, Emabond Systems, Ashland Chemical Co.,

6. Handbook of Plastic Joining, Copyright 1997, Plastics Design Library