Advanced Actuation System and “Dynamic Follow-Through” Deliver Improved Ultrasonic Weld Quality

By Tom Hoover, Sr. Medical Business Development Manager – Americas, Assembly Technologies at Emerson

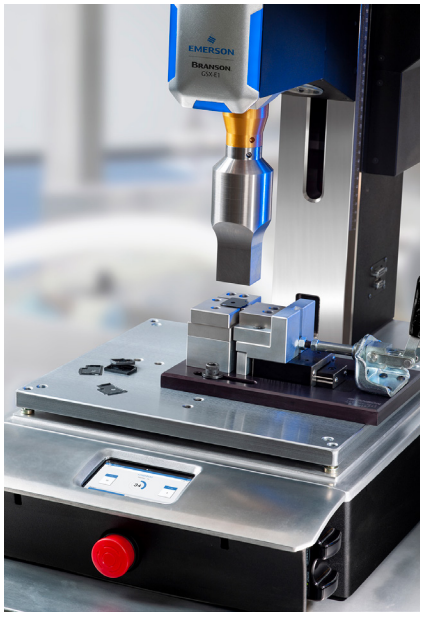
As devices miniaturize, there is an increased need to weld plastic parts that are smaller, lighter, thinner-walled and often more complex in shape or contour than in the past. The challenge is multiplied by the growing presence of parts that contain embedded electronics and sensors that require special care in the ultrasonic welding process.

Meeting industry demand for strong and consistent welds in ever smaller and more delicate plastic components has required major new developments in ultrasonic welding technology. Among the most important is the development of new and more precise methods of force control. There are two kinds of force control applied to mating parts during the weld process. The first, clamp force, is the initial pressure applied by the actuator to the mating parts to hold them together and initiate the weld process. But then, after ultrasonic energy has initiated molecular friction and the glass-transition temperature (Tg) of the polymer is reached, plastic begins to flow. At this point, clamp force drops and is replaced by dynamic weld force control that controls force variations throughout the rest of the weld process. It is this dynamic force control that results in a weld force profile that delivers the strongest welds. For decades, actuators have relied on pneumatics to deliver force control and regulate the speed with which it is applied. Pneumatic actuators continue to be an industry standard today.

However, to meet the force control challenges posed by welding newer, smaller and delicate parts, the developers of Emerson’s Branson™ ultrasonic welding technology had to reconsider the capabilities of pneumatic actuators in light of the rapidly advancing capabilities of servo-control technology. They ultimately found an optimal solution: an advanced electromechanical actuation system that delivers precise levels of clamp force with greater responsiveness throughout the ultrasonic welding process. This advanced actuation system is now available in the Branson GSX-E1 ultrasonic welder from Emerson (See Figure 1).

Extensive testing of the Branson GSX-E1 and its new actuation system revealed that, by more rapidly and precisely adjusting downforce during the weld process, the GSX-E1 welder offers users a higher likelihood of achieving 100% good parts or zero scrap. In a number of cases, the new GSX-E1 welder actually makes it possible to complete good welds on plastic parts that could not be reliably ultrasonically welded before.

Figure 1: **Advanced Actuator System on Branson GSX-E1 Ultrasonic Welder**



The advanced electromechanical actuation system on the Branson GSX-E1 ultrasonic welder from Emerson enables it to exercise substantially more precise and responsive force control through the entire weld process. Better force control is critical to ensuring maximum consistency and strength in welds of small, delicate or thin-walled parts.

Precise Force Control

The Difference: "Dynamic Follow-Through"

The control and consistency with which force is applied and measured through the actuator have enormous implications for weld quality. For any given set of weld parameters, variations in clamp force that result in applying too little force reduce compression of the mating surfaces, reduce the heat generation needed for plastic melt and result in "cold" or weakened welds. Similarly, force variations that result in applying too much force during the weld process can cause part joints or energy directors to deform, deflect or even break, all of which prevent proper melt flow and polymer entanglement.

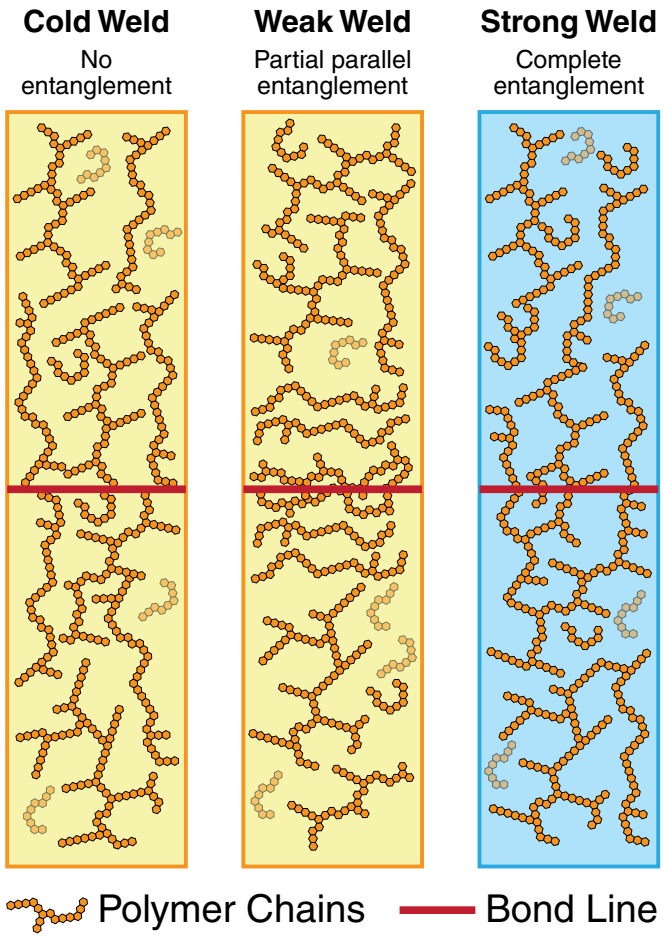
Applying just the right amount of force control at just the right time results in quality welds with highly consistent characteristics and strength. To achieve such ideal control, the actuator must be capable of *"dynamic follow-through"* — extremely rapid, dynamic adjustments in force and downspeed in the millisecond timescale as plastic melts at the part interface, then dynamically following the melt flow index of the specific polymers through to the end of the weld.

The more sensitive and precise its dynamic follow-through capability, the greater the strength, consistency and quality of the output that an ultrasonic welder can produce. For example, the strongest "pull force" for a part weld results from a controlled force profile that allows for complete and random polymer chain entanglement. This makes the weld as strong as the parent material (See Figure 2).

By eliminating even small force variations, the advanced actuation system in the Branson GSX-E1 welder maintains more consistent horn-to-part contact and enables weld parameters to be executed far more accurately and gently.

So, for even hard-to-weld shapes and small or delicate parts, it can provide superior weld quality and improved yields, characterized by uniform and consistent weld collapse depths and minimal flash or part marking.

Figure 2: **Polymer Chains in Cold, Weak and Strong Welds**



As seen in the right-most illustration in Figure 2, ideal force control adjusts downforce milliseconds after the melt, allowing polymer chains to extend vertically across the part interface and entangle with each other across the bond line as melt and compression occur before cooling. By contrast, weaker welds, characterized by partial or no polymer chain entanglement, show polymer chains that reassemble parallel to the bond line without entangling across the part interface. The center weld shows the impact of inadequate force control, while the "cold" weld at left could be caused by too little or too much downforce in too short a weld time.

Precise Force Control

Benefits of Improved Force Control

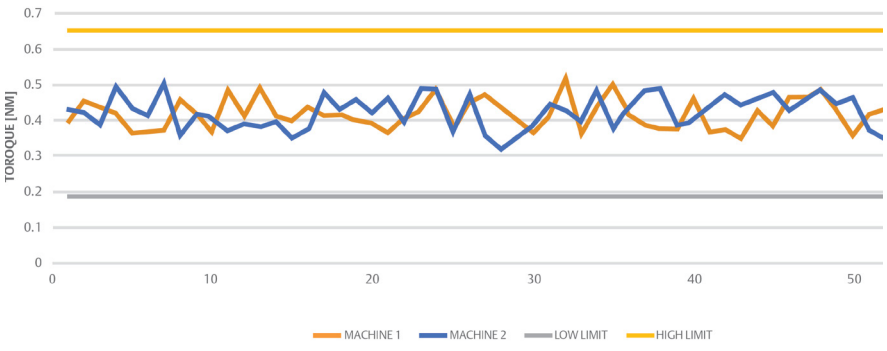
The dynamic follow-through capability of the advanced electromechanical actuator in the Branson GSX-E1 welder enabled it to outperform both pneumatically actuated welders and competitive servo-actuated welders. When compared to these welders in laboratory and customer tests, the Branson GSX-E1:

- **Produced welded parts with more consistent and repeatable levels of strength.** In a head-to-head comparison of welding performance on identical parts, a GSX-E1 was matched against an excellent pneumatically actuated welder. Results showed that while both welders produced strong welds, the GSX-E1 was able to produce parts with higher average pull strength and more consistent and repeatable levels of break force (e.g., lower standard deviation in results), as well as physical characteristics that more closely matched those of parent material.
- **Exerted more precise control over heat generation and dissipation, weld-collapse depth and weld quality**. In another example, a customer evaluated the performance of the GSX-E1 welder when its legacy welder, a pneumatically actuated welder, was unable to change weld downforce quickly enough to avoid bubble formation in the weld zone between two polycarbonate parts. The result was an unacceptable level of scrap parts. The customer found that the more rapid, precise action of the electromechanical actuator and control on the Branson GSX-E1 eliminated the bubbles, producing consistently high-quality welds while reducing weld cycle time, peak power input and total weld energy consumption.
- **Delivered exceptional welder-to-welder consistency.** A customer application required that welds be successfully completed across multiple welders using a low and consistent level of weld clamp force. The specific requirement was to maintain a torque value test range between 0.2 Nm and 0.65 Nm across multiple welders. Their trial with GSX-E1 welders far exceeded this requirement, holding torque values to within a nominal range of approximately 0.2 Nm (See Figure 3) over a run of 50 production-quality welds — a feat impossible with the customer's pneumatically actuated ultrasonic welder.

Welder	Avg. Pull Strength Newtons (N)	Std. Deviation	# of Tests
Branson GSX-E1-E1	7,812	3.80%	40+
Pneumatically actuated welder	7,166	7.52%	20

Attribute	GSX-E1	Pneumatically Actuated Welder	Result
Speed of Force Change	Faster	Slower	No Bubbles
Weld Time (seconds)	0.123	0.162	Greater Throughput
Hold Time (seconds)	0.02	0.05	
Energy (joules)	19	30.7	Greater Energy Efficiency
Peak Power (watts)	230	316	

Figure 3:



Precise Force Control

- **Eliminated part marking and flashing, while strengthening far-field welds.** In another example, this time involving far-field welds of a long, thin (0.070-inch wall thickness) tube with a shear joint into a molded base, a customer was able to produce strong welds with its legacy welder but sometimes had quality problems including part marking and inconsistent weld depth, resulting in flashing. A weld trial set up in less than 15 minutes with the new intuitive Branson GSX-E1 quickly resolved the problems. Its more responsive process control and electromechanical actuator delivered weld amplitude more consistently and smoothly, resulting in parts free of markings and flash with higher average pull strength.
- **Performed challenging, low-force part welds with high volume and zero scrap.** The force control capabilities of the GSX-E1 were also proven in applications involving long, delicate and thin-walled parts. In one application, a customer using a competitive, servo-actuated ultrasonic welder struggled to consistently produce welds with high break-push strength (>80 pounds) on parts with a very thin (~0.5 millimeter) plastic shear joint. An extended production trial with the GSX-E1, working at 500 parts per hour, delivered 3,000 perfect parts with an average break force of 152 lbs., nearly double the customer requirement. In addition, the GSX-E1 produced 100% good parts — zero scrap — a yield that the customer could not achieve with either the competitive servo-actuated ultrasonic welder or their own pneumatically actuated ultrasonic welder.

The improved force control capabilities built into the new Branson GSX-E1 ultrasonic welding platform from Emerson typically enable it to produce these and similar results while reducing weld cycle time, peak power input and total weld energy consumption compared to welders equipped with less-responsive and precise actuation systems.

Not every customer or application needs the additional and advanced force control capabilities that the Branson GSX-E1 ultrasonic welding platform offers. But when they do, Emerson has the solution.

To learn more, contact your Emerson Assembly Technologies representative or visit www.Emerson.com/Branson.

Emerson
41 Eagle Road
Danbury, CT 06810, USA
T +1 203 796 0400
Emerson.com/Branson