Comparison of Conventional Pneumatically-Controlled Ultrasonic Metal Welding to Advanced Servomotor Controlled Ultrasonic Metal Welding Processes

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Background

In the ultrasonics industry, most of the batteries made use ultrasonic welding to weld the foils together. The industry standard is to use an analog pneumatic ultrasonic welder when creating lithium-ion batteries. Ultrasonic welding of wires is also commonly used in the automotive industry for wire harness applications. There are numerous other applications in other industries, including: EV, battery, appliance, HVAC, solar, medical, and military. Currently, pneumatic ultrasonic welding machines are the industry standard for these applications. Tech-Sonic created a Servo controlled ultrasonic welding machine for improved process control.

Motivation

The data collected in this project will allow Tech-Sonic, who created the first digital servo-motor driven ultrasonic welder, to show that a servo welder can work just as well as a analog pneumatic ultrasonic welder, and maybe even try to set a new standard for the industry

Objectives

- Compare the pneumatic and servo ultrasonic welding machines using wire-to wire splicing, foil-to foil welding, and foil-to-tab welding
- Compare the cross-sectional analysis of the servo and pneumatic samples to find which machine created a better weld

Approach

- Conduct test welds on pneumatic and servo controlled ultrasonic welding machines for wire splicing and spot welded foil applications.
- Conduct mechanical testing on test welds to compare servo to pneumatic and compare both to industry standards that exist.
- Conduct cross-sectional analysis on all welded applications to compare compaction and weld integrity.

Conclusions

- Wire consistency results were inconclusive in terms of start height and weld height deviations
- Pneumatic has better compaction for wire applications
- Servo provides more consistency for using ultrasonic welding on foils
- Wire results for the pull and Cpk values were inconclusive when comparing pneumatic to servo values
- Compaction analysis of foil applications

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Results & Discussion

	Compaction	
Wire Size mm^2	Pneumatic	Servo
1.05	98.25%	96.56%
2.7	93.11%	91.54%
5.75	93.50%	92.40%
12.25	90.60%	87.99%

This table shows the compaction percentage of the cross sectional views for all the wire combinations for both servo controlled and pneumatic controlled ultrasonic welding. The compaction was higher for the pneumatic based welding process for every wire combination.

Cross sectional view of 1.05 mm² welded bundle. The Pneumatic weld is on the left side, and the servo weld is on the right. The Pneumatic weld had a higher compaction compared to the Servo weld.

For the compaction analysis of the wire splice applications wire samples were cut, ground, and polished. Image J software was then used to complete the analysis of empty space between wire strands to determine compaction percentage. The values that were found for both the pneumatic and servo applications were recorded and compared. From the data shown in the table to the left, the pneumatic had a better compaction rate. The pnuematic had a better compaction rate due to the process differences between pneumatic driven and servo driven forces. The pneumatic driven process maintain the forces throughout the duration of the welding process. As the weld compresses, the follow up forces further compressed the welded wires. Good compaction is important because the better compaction there is, the better the electrical conductivity of the wire.

Looking at the standard deviation for the start and weld height, it can be seen that servo machine for both start and weld height is the better in terms of deviation, which translates into better consistency. Smaller standard deviation allows tighter tolerances to be made for the start height and weld height. Tighter tolerances and more consistency opens the possibility of catching missing foils or extra foils in the stack prior to welding.

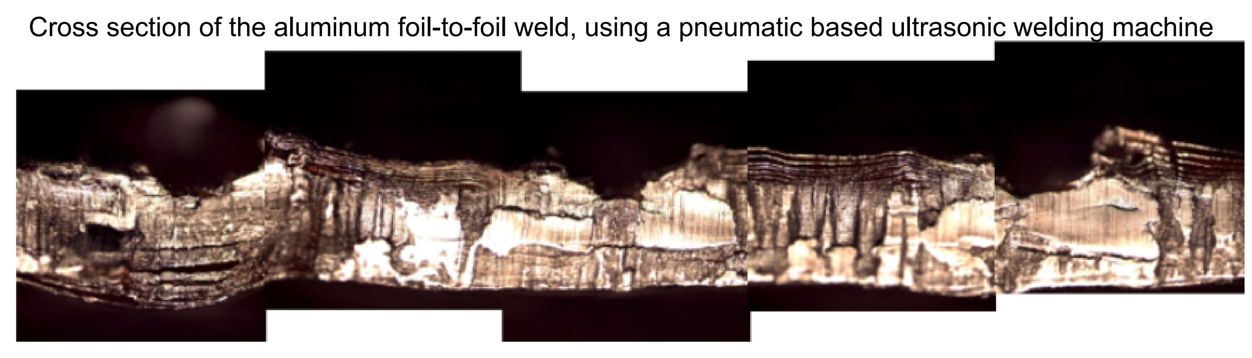
	Start Height Deviation (mm)	
Wire Size mm^2	Pneumatic	Servo
Al: F-F	0.0668	0.0025
Cu: F-F	0.0216	0.0017

Table showing the standard deviation for the start height of the foil to foil welds. Both the Servo applications had a smaller standard deviation than the pneumatic deviations.

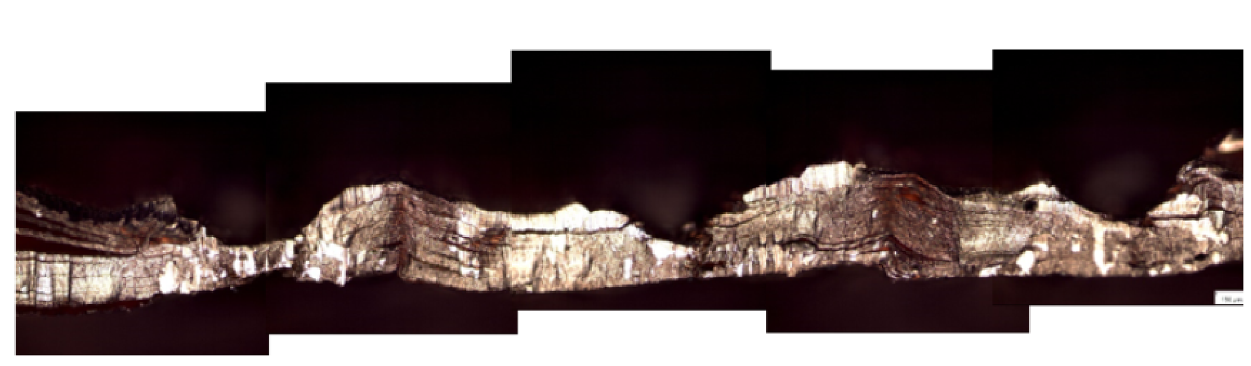
	Weld Height Deviation (mm)	
Wire Size mm^2	Pneumatic	Servo
Al: F-F	0.0237	0.0056
Cu: F-F	0.017	0.0169

Table showing the standard deviation of the weld height after the welding process was complete. The servo driven welding had a smaller standard deviation compared to the pneumatic driven process.

Cross section of the aluminum foil-to-foil weld, using a pneumatic based ultrasonic welding machine



Cross section of the Copper foil-to-foil weld, using a pneumatic based ultrasonic welding machine



Cross section of the Copper foil-to-foil weld, using a servo based ultrasonic welding machine

One of the larger issues in this project can be turned into an area of future development. Mounting of the foil samples was substantially harder than mounting the wire samples. Each foil weld had 60 layers of foils, making it difficult to polish to a point where all 60 foils were visible. This made compaction analysis for foils impossible to complete in the manner the wire compaction analysis was completed. With a better mounting, grinding, and polishing procedure, compaction analysis can be completed for the foils as well, allowing for a better understanding of servo machines vs pneumatic machines for foil applications.