Aluminum and Robotic Welding

Five years ago, robotic welding of aluminum automotive structures like windshield frames or aluminum engine cradles was a risky proposition. This recently completed project for a large automotive tier supplier specializing in aluminum windshield and cradle structures required the latest technology and teamwork to make it happen.

High production automotive welding requires continuous defect free welding and system uptimes of 95% plus if the Tier component provider is going to make a living in the hyper competitive automotive component supply business. Margins are thin and there is no room for downtime. Like anything new and difficult, robotic aluminum welding is hard work, especially five years ago. Even today, it's not easy and successful automotive aluminum welding projects require cooperation of the suppliers as well as the customer. I do mean the plural version of suppliers. A partnership of companies and a good team is necessary for a program like this.

Success comes more easily when you have a good team. A range of technologies, welding equipment and wire, robots, controls, systems, fixtures and engineering are equally important disciplines that go into a successful program. It's interesting to note that not one of these items on its own typically accounts for more than 30% of the cost of the program. The point is you need a Team. Many hands make the work easier. The hands in this case were Genesis Systems Group, Fanuc Robotics and Lincoln Electric. The three companies have worked closely together for years. The skills of each compliment the skills and know-how of the other. Mature, strong management-to-management commitments among the three partners keep the focus on project success. This partnership is not a partnership of convenience pulled together by a project opportunity. It is a long term complimentary Partnership.

Welding aluminum automotive structures requires an understanding of the unique issues associated with aluminum. Key issues are:

1. Project Planning, including a thorough understanding of optimization of designs for automation
2. Carrying this knowledge through to weld Fixture Design and Build
3. Selection and implementation of appropriate Weld Process Technology for high production aluminum automotive structures

There are other critical issues such as overall automation processing, system selection, runoff, training and support that are not covered in this article. The intent of this article is discussion of important robotic aluminum welding issues best addressed early in the project.

1. Project Planning - Pay attention to the part!

Understand what needs to be welded first. Aluminum weldments are less forgiving than steel to automate and having a well thought part design helps tremendously. To help with this, Genesis purchased Dimensional Tooling Solutions (DTS) of Detroit several years ago. The intent was the assimilation of DTS's Design For Manufacturability (DFM) and Variation Simulation Analysis (VSA) know-how into Genesis Project Management, weld process development and weld fixture design and build. Along with this know-how the Program Team learned customer goals for production quantities, cost targets and quality expectations. Questions like - What are you making? How is it made? What are the subtle but meaningful *variations* of the part and processes? (Some variation is OK if you know what it is and have a way to deal with it.) Assuming the part to be welded is fit for its purpose, critical review of the design must occur to assure you can do two things - weld with consistent quality and hold the required dimensions.

You can be sure the parts to be assembled as the final weldment aren't perfect. How much time do your engineers spend understanding the variance introduced by each step of your manufacturing process? Probably not as much as they should. Automation works when variation is quantified. In fact, it gets less expensive too.

The part print rarely addresses the issues of interest to make a good weld. When welding aluminum it's especially important to remember.

- Designers establish Critical Print Dimensions at attachment and engagement points
- Mating surfaces such as weld locations are reference dimensions on most part prints
- Joining surfaces and conditions, interference points and gaps are critical when automated

Automation thrives on consistency. It can thrive with variation when it's identified in advance and accommodated. The planning process is the time to identify variation

in your parts and processes and either eliminate variation or account for it in your planning.

2. Fixture Design and Build

High production automotive fixtures typically include 3D design. Fixture design reviews should be held early and often to assure thorough communication among the designers, project engineers, and customer.

When welding aluminum, fixture designers need to pay particular attention to weld gun clearances. Aluminum welding works best with optimum gun angles. Robotic simulation/offline programming software can help you spot opportunities to improve fixture designs for gun clearance.

Some do's & don'ts for fixture design include:

- Don't use spring plungers to hold parts to datums.
- Do use cylinders that clamp in a sequence.
- Do check design – all piece parts should have a design clearance.
- Do use shimmable, fixed clamp locators, not bolts.
- Do pay attention to components used in the fixture to minimize deflections during clamping and operation.

Once in production the weld fixtures need to be easy to maintain - solve this by building maintainability into the design. Weld spatter cannot build up on locating surfaces, inhibit clamp opening and closing or stick to exposed cylinder rods on the fixture. Likewise, cables, hoses and tubing on the fixture must be protected and easy to maintain.

Poke/Yoke/Error Proofing reduces dependency on operator finesse for loading and unloading the fixture. An example is including a designed clearance to nest parts repeatability in the fixture when loading or building features into the fixture that prevent the operator from improperly loading the fixture.

After the fixture is built, datum's and locating surfaces should be measured with a capable gage such as a CMM, laser tracker or theatolite to verify design position. All design position requirements should be documented as well as the actual measured position. At this time also note shim pack, or grind spacer information pertinent to each design position. This document is critical - it becomes the log that keeps you in control if and when adjustments to the fixture are required. This is called a Shim Log. The Shim Log should be updated anytime a change is made to the fixture.

Shim Log Example

GENESIS DIMENSIONAL & TOOLING SOLUTIONS- SHIM RECORD

JOB #	93102
Tool #	500933

DIM/ DATUM	Description	AS VALIDATED	VALIDATED SHIM PACK	DATE	SHIM PACK	Initial	DATE	SHIM PACK	Initial	DATE
A		0.458	0.115							
B		19.631	0.135							
C		17.404	0.150							
D		16.572	0.115							

It's beneficial to tie the knowledge gained at the Planning & Fixture design steps with design and build of check fixtures. The three activities should be closely linked to assure that your check fixtures are measuring the same features your fixture holds.

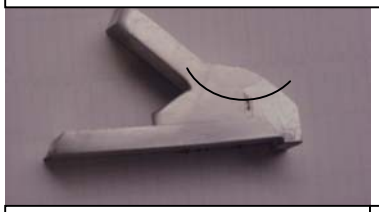
3. Weld Process Selection

There are many elements to address when welding aluminum. This is especially true when dealing with complex aluminum welded automotive structures with many material thicknesses and weld joint types. Variable weld joint positions and gaps you will see in day-to-day production further complicate the task. In other words seeing an amazing aluminum weld demo comes no where near the challenge you face dealing with high production welding.

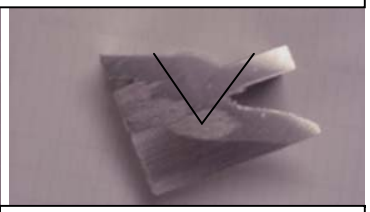
During weld development Lincoln Electric engineers and the customer reviewed the broad range of weld joints of the various aluminum structures. Since the components to be welded are structures, the welds have to be strong which usually implies significant penetration. That sounds good but anyone who has welded aluminum quickly learns how fast aluminum can turn from a soft molten liquid to a disappearing act as it drops through the hole of a burn through. Control of the arc and penetration profile were critical to making good welds while avoiding production stopping quality problems associated with burn through.

Working with the Program Team Lincoln & Fanuc Weld Group Engineers developed weld parameters using Powerwave 455 wave-form sets that moved seamlessly between penetrating weld profiles to broader less penetrating pulse on pulse wave forms for thin material joints or areas where gaps are common.

Examples of Aluminum Weld Penetration



Process 100: Lincoln's pulse-on-pulse: Better cleaning action, reduces interference with two arcs, better arc control, broader penetration



Process 74: Lincoln's OEM Schedule: General purpose, Voltage start, good penetration

Enabled by high speed digital communication between the Fanuc RJ3 Robot Control & Powerwave 455, developed by Lincoln and Fanuc's welding software groups, specialized Process Types were put to use (see the example Process 100 & 74). The Genesis, Lincoln, Fanuc partnership is able to learn, develop and implement improved weld processes quickly thanks to this North American based welding software development group. Fanuc is the only welding robot manufacturer that develops its welding software in North America. Once again, application specific documentation of developed and proven weld processes is the key to sustainable high quality production. Working together the Project Team identified and documented each joint type. Weld number, work angle, travel angle and weld parameters were associated with each weld. This is a sample of the Process Development Documentation.

Process Development Worksheet

						Arc Start Parameters							Arc End Parameters					
Weld Number	Joint Type	Joint Position	Size (mm)	Work Angle (degrees)	Travel Angle (degrees)	Schedule	Weld Process	Wave Control	Trim	WFS (ipm)	Travel Speed (ipm)	Time (sec)	Schedule	Weld Process	Wave Control	Trim	WFS (ipm)	Travel Speed (ipm)
107	Lap	1F		45	10	1	1	0.1	1.00	185	45	0.00	17	2	10	1.00	115	n/a
111	Lap	1F		45	15	2	1	0.1	1.00	230	25	0.20	18	2	10	1.00	125	n/a
103	Lap	1F		45	15	3	2	10	1.10	195	35	0.20	19	2	10	1.00	125	n/a
109	Lap	1F		45	15	4	2	10	1.10	195	35	0.20	20	2	10	1.00	125	n/a
110	Lap	1F		45	15	5	1	0.1	1.00	195	38	0.20	21	2	10	1.00	115	n/a
104	Lap	1F		45	15	6	1	0.1	1.05	195	38	0.25	22	2	10	1.00	115	n/a
108	Lap	1F		45	15	7	1	0.1	1.00	180	45	0.10	23	2	10	1.00	115	n/a
106	Lap	1F		45	15	8	1	0.1	1.00	180	45	0.10	24	2	10	1.00	115	n/a
114	T-Joint	1F		45	15	9	2	10	0.95	200	26	0.25	25	2	10	1.00	110	n/a
113	Lap	1F		45	15	10	2	10	1.05	205	28	0.30	26	2	10	1.05	120	n/a
112	T-Joint	1F		45	15	11	2	10	0.90	190	31	0.25	27	2	10	1.05	100	n/a
103	Lap	1F		45	10	12	2	10	1.00	220	38	0.10	28	2	10	1.00	125	n/a
101	Lap	1F		45	10	13	2	10	1.00	220	40	0.20	29	2	10	1.00	125	n/a
102	Lap	1F		45	10	14	2	10	1.00	220	45	0.20	30	2	10	1.00	125	n/a

Cleanliness:
Aluminum welding is more reliable when the parts are clean. During development be sure to clean prototype parts with alcohol before welding. Once in production, clean parts prior to welding in a hot chemical bath and rinse. It's very important to remove burrs from part edges. Burrs cause piece parts to strike together during fixture loading and result in dimensional flyers. Weld wire should be container fed to improve weld wire cleanliness as well.

Once you have good understanding of weld process issues and problems that occur in production documenting the defects and causes will help resolve problems quickly.

Defect	Potential Cause(s)
Porosity	Part Cleanliness, Gas Coverage (low or high)
Cracks	Wire alloy, joint type, blisters, parameters
Blisters	Torch Angle or Position, Travel Speed (be ahead of puddle) Joint Design, Part Variability, Fixture Repeatability
Under Size Weld	Wire Feed Problem, Part Fitup or Gaps, Blistering
Weld Out of Joint	Arc Blow (favors heavier part), Arc Length, Torch/Robot Crash, Wire Cast, Part Variability, Fixture Repeatability
Lack of Fusion	Process Schedule Change, Parameter, Arc Length, Torch Angle or Grounding
Undercutting	Parameters, Torch Angle
Burnback at Start	Dressed Wire Length, Wire Feeding, Cleanliness, Parameter Schedule Change, Grounding Torch Angle
Burnback during Welding	Wire Feed Problems or Cleanliness
Birdnest in Feeder	Guides, Drag on Barrel, Burnback at Tip

In conclusion keep in mind:

- Select an experienced Team that is used to working together. Good relationships and available support is important. Look for a Team player to avoid finger pointing. Despite good planning there will times when proactive support is needed. Don't forget the customer's responsibility to the Team. The Program can be improved with openness to design improvements & operator training.
- Pay attention to base metal aluminum alloy & thickness. Select appropriate weld wire - this is very important - feeding aluminum wire can be a challenge
- Account for weld joint configuration and torch angles
- Simulate production gaps and joint repeatability - test the weld process against these conditions
- Understand quality requirements
- Cycle time estimates should match production requirements
- Document what you learn and communicate across the project Team