Strong-Al Welding

Improved Joint Efficiencies in Aluminum Alloys

Presented By

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- **Background information on present methods of welding**
  - **Issues with resistance, arc and friction-stir welding**
  - **Desirable features of a good welding process for aluminum alloys**
- **Examples of *Strong-Al* Focused Current Resistance Welds (FCRW) made**
- **Present work on hand**
- **Summary of *Strong-Al* weld features**
- **Opportunities for cooperative work?**

Present Methods of Welding Aluminum Alloys: Some Issues

- **Resistance spot/seam welding**
  - **Significant loss of strength in the weld/HAZ**
  - **Electrode Indentation/electrode-metal sticking**
  - **Porosity/cracks in weld metal**
  - **Extreme sensitivity to surface condition and cleaning**
  - **Thick sections and thick-thin combinations difficult to weld**
  - **Welded surface/HAZ microstructures may be prone to corrosion in marine and other environments**
  - **Some high strength aluminum alloys are considered non-weldable**

Present Methods of Welding Aluminum Alloys: Some Issues

- **Arc welding**
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Present Methods of Welding Aluminum Alloys: Some Issues

- **Friction-Stir welding**
  - Expensive equipment and fixturing/tooling
  - Complicated and high-precision tool geometry
  - Potential cracks at weld starts/stops and thermal profile change locations
  - Inability to pass liquid penetrant tests consistently even after weld surface machining
  - Loss of strength in the weld/HAZ
  - Thick-thin combinations difficult to weld
  - Welded surface/HAZ microstructures may be prone to corrosion/stress corrosion cracking in marine and other environments

We need a method of welding that:

- **Uses commonly available large-volume process equipment**
- **Is easy to set up in production**
- **Minimizes/eliminates electrode-metal metallurgical reactions**
- **Results in welds free from porosity and cracks**
- **Yields relatively high strength weld metal and HAZ areas**
- **Enables localized heat-treatment in the weld machine**
- **Results in no loss of thickness at or near the weld**
- **Retains non-melted microstructures on the outer surfaces that are no more prone to corrosion than parent metals welded**
- **Enables obtaining large nuggets not limited in size by sheet thickness, without melting outer surfaces welded**

Focused Current Resistance (*Strong-Al*) Welds

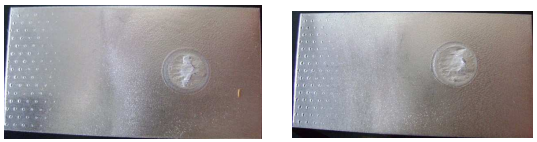
- **Made in commonly used resistance weld machines with improved controller software**
  - **Temperature control at a location in the weld electrode possible during the post-weld heat treatment stage**
- **Large electrode contact areas on both mating parts enable minimizing heat generated and indentation at the electrode-metal interfaces**
- **Weld current is focused at the weld interface to an order-of-magnitude higher current density using patent-pending technology**
- **Features that enable the focusing of weld current also enable effective forging of the weld nugget at the appropriate time to generate a defect-free solidified weld nugget**
- **Many different weld shapes are possible, including seam welds**

Focused Current Resistance (*Strong-Al*) Welds

- **Detailed know-how sharing can be done with a commercial agreement**
- **This presentation will demonstrate improved features of the process and the welded structures**
  - **Work in progress will be detailed to explore opportunities to work together**

Conventional and *Strong-Al* Resistance Welds: 6061 T6 Aluminum alloy sheets(1.5” * 0.060”)

Conventional RSW

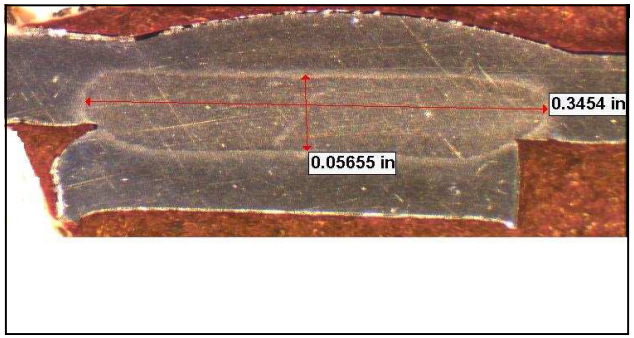


- **Very sensitive to surface cleaning prior to welding**
- **Weld strength 700-1300 pounds in a tensile-shear test**
- **Failure through weld metal in tensile-shear test**
- **Nugget size limited by expulsion, electrode indentation, electrode sticking and weld defects**
- **Little or no part stretching prior to failure**

Strong-Al Welds

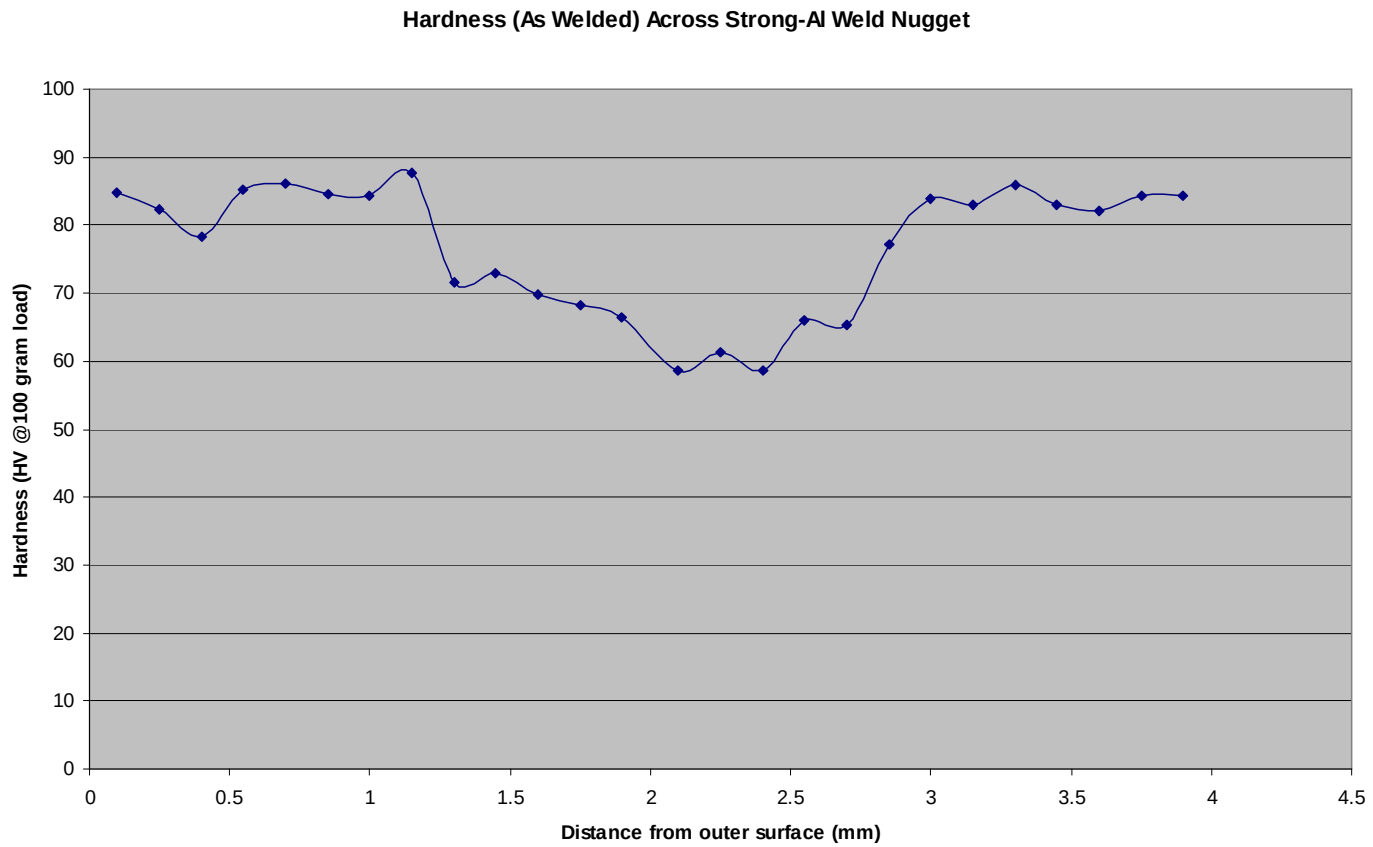
- **Weld quality and strength not sensitive to cleaning prior to welding**
- **Weld strength >2300 pounds and can be increased by increasing spot size**
- **Failure through HAZ of relatively high hardness**
- **Nugget size independent of sheet thickness**
- **Considerable stretching prior to failure**

Strong-Al weld appearance and geometry: Sheets of thickness 0.060” and width 1.5”



- Welded parts possible (as-welded)
  - Both sides smooth
  - Both sides with outward projections to increase thickness and strength
  - one side smooth-one side with outward projections
- Failure in the parent metal in a peel test
- Microstructure shows
  - No defects/cracks in the weld nugget
  - Steep temperature gradient from the surface to the nugget as a result of the focused current

Microhardness Traverses Without Post-Weld Heat Treatment



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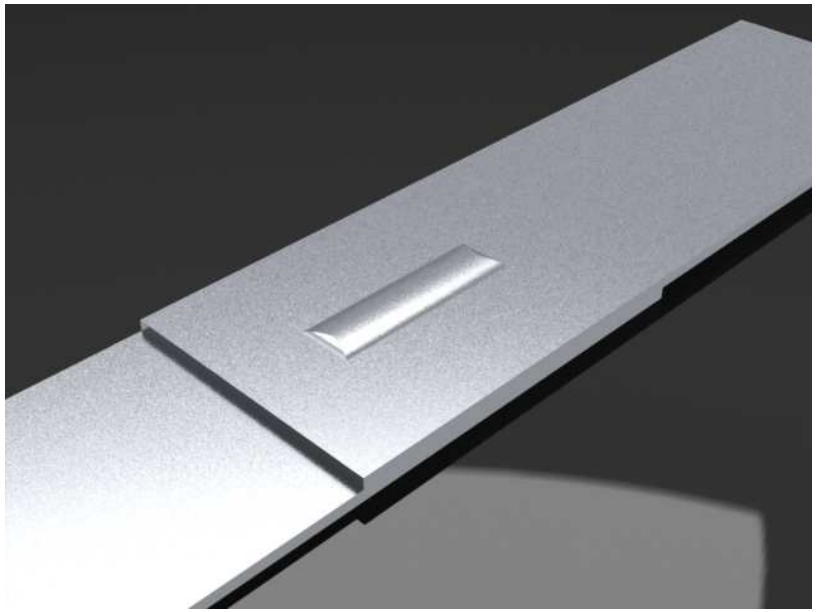
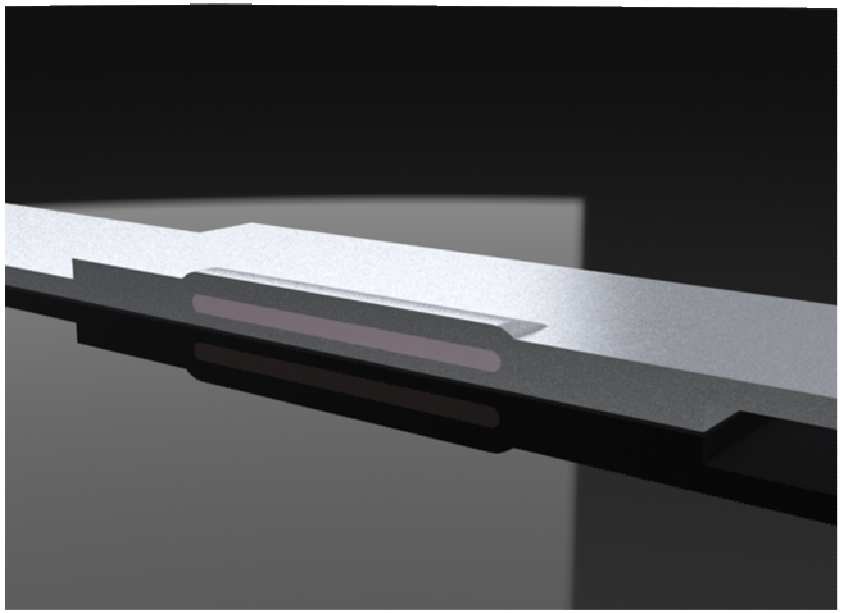
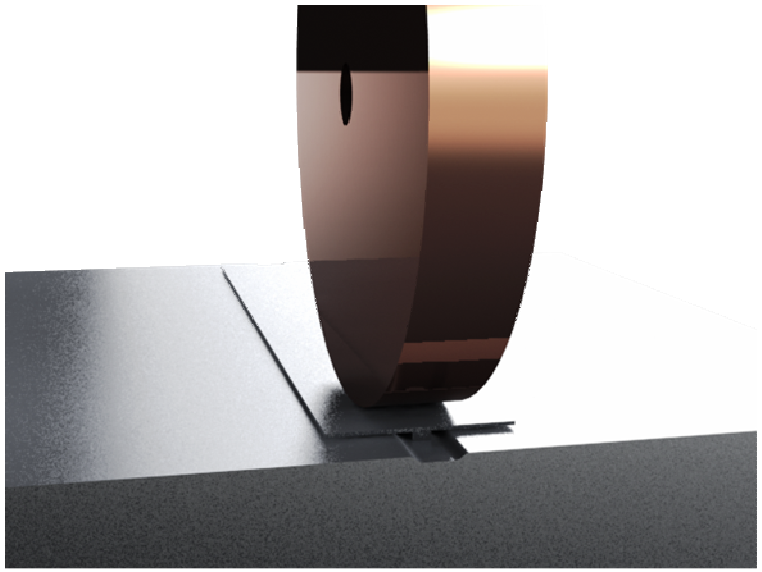
Strong-Al Welding: Work on hand





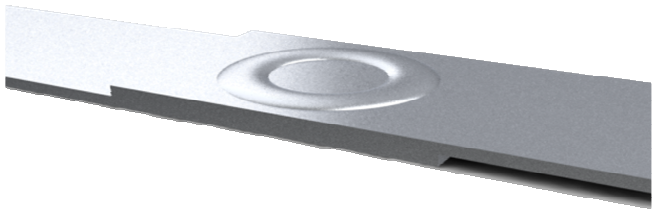
1” long and 0.25” to 0.4” wide welds in 0.25” thick 6061-T6 sheets

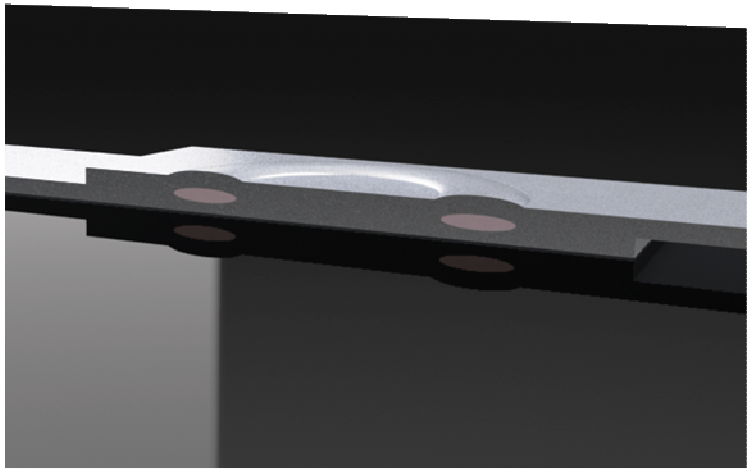
Strong-Al Welding: Other geometries



- FCRSEW Seam welds of thick-thin and equal thickness combinations without outer surfaces being melted or indented are being planned
  - Temperature gradients from the outer surfaces to the weld nuggets will be steep
- Weld nugget width will be large enough to force HAZ failure in tensile-shear test
- Looking for partners to work with

Strong-Al Welding: Other geometries possible





- FCRW Ring welds of thick-thin and equal thickness combinations without outer surfaces being melted or indented
- Weld nugget width to be large enough to force HAZ failure in tensile-shear test
- Suggestions of other industrially relevant geometries welcome
- Again, outer surfaces can be designed to have outward projections to increase thickness and strength or be smooth

Strong-Al Welding: Localized Heat-Treatment in the Weld Machine

- **New combination of hardware and control software successfully generated**
  - **European infrared sensors for the relevant temperature ranges with small focal spot sizes used**
  - **New control software written to control temperature at a given location in a molybdenum tipped electrode**
  - **Localized Solutionizing and precipitation treatments helped increase joint efficiencies to values between 85 and 90% of parent metals welded**

Strong-Al Welding: Summary

- Improved joint efficiencies in heat treatable and non-heat treatable aluminum alloys have been demonstrated
- Ability to focus the weld current at the weld interface with low current densities at the electrode-metal interfaces enables:
  - Increasing nugget sizes without overheating part surfaces or generating weld defects
    - Little or no indentation on the outer surface
    - Better corrosion resistance
    - Geometries with outward projections to increase thickness and strength
  - Ensuring failure in a relatively hard HAZ in a tensile-shear test
  - Obtaining outer surfaces of parts welded that are not melted
  - A variety of joint geometries, including thick-thin seam welds
  - Weld geometry that is effectively heat-treatable in the weld machine

Strong-Al Welding: Contact Information

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