Friction Stir Welding of Aluminum Using a Tapered Shoulder Tool

TMS 2005

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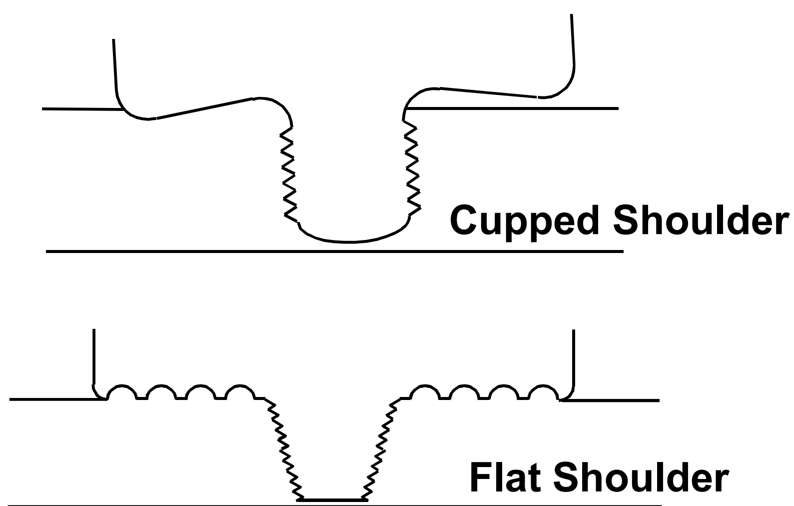
Agenda

- **Background**
- **Case Studies**
  - **Variable depth welding**
  - **Fixed-geometry bobbin welding**
  - **Pipe welding**
- **Conclusions**

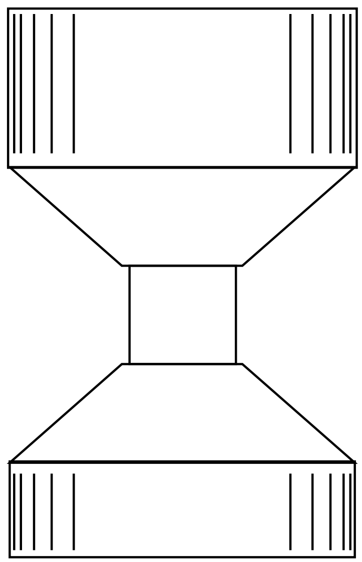
Background

- **Evolution of shoulder design features**
  - **"cupped" shoulder for tilted-axis welding**
  - **flat, scrolled (spiral groove) shoulder for normal-to-the-plate welding**
- **Flat, scrolled shoulder is a major advancement, but challenges still exist:**
  - **mismatch**
  - **variation in workpiece thickness**



Background

- **Tapered shoulder design was introduced by TWI in the original FSW patent**
  - **bobbin tool concept (fixed or variable gap)**
  - **smooth shoulder surfaces - no scroll**
- **This design is impractical**
  - **excessive flash**
  - **pin breakage**



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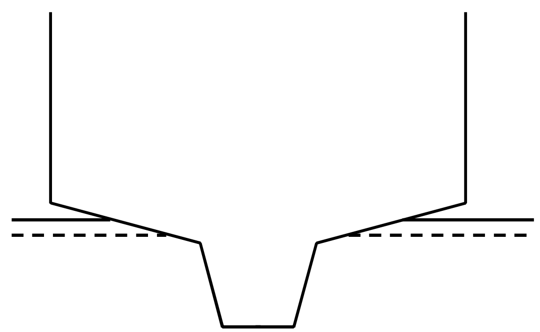
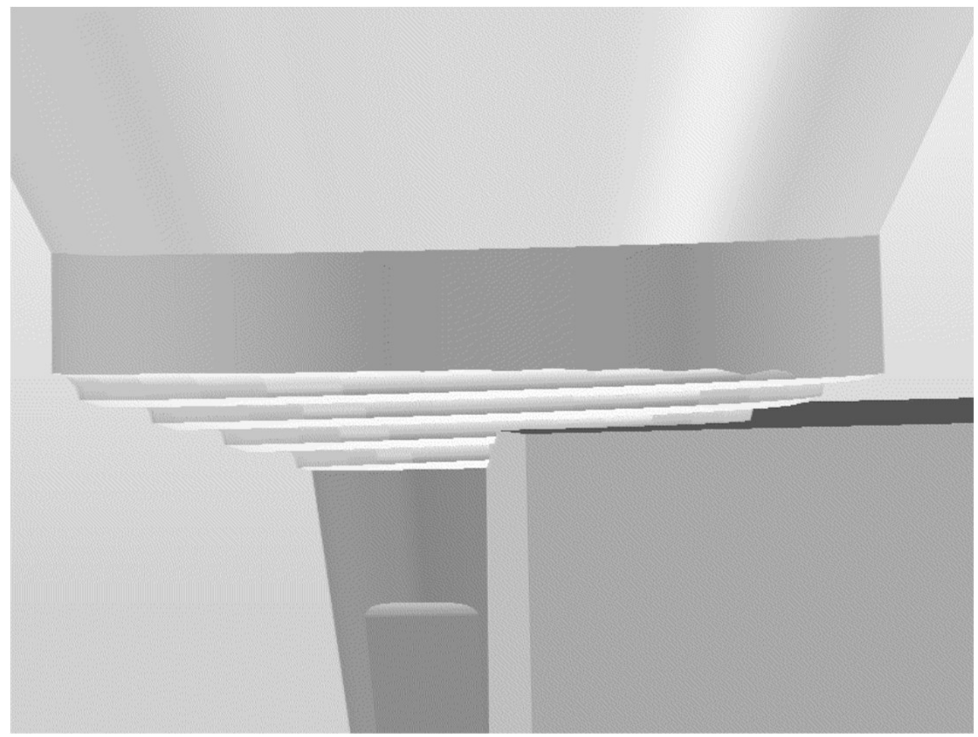
Background

- **The tapered shoulder, combined with a scrolled profile, can be embedded in the surface of the workpiece**
- **As long as the workpiece surface hits the taper/scroll at some point, a good crown surface is produced**





Tapered shoulder tool embedded in a workpiece, (workpiece cut away for clarity).

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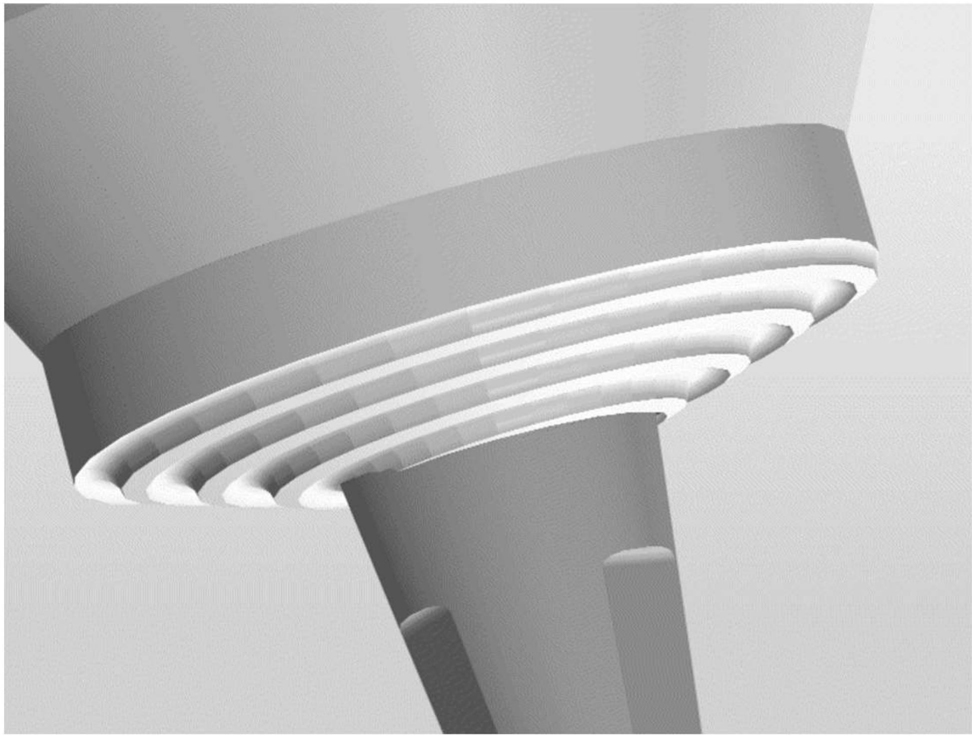
Background

- **Combination of the scrolled shoulder with the tapered profile allows embedding of the shoulder in the workpiece**
- **Scrolled shoulder + tapered profile = improvements in tool performance:**
  - **variable shoulder depth**
  - **fixed-geometry bobbin**
  - **mismatch**
  - **complex contour**



Tapered shoulder design, patented by CTC (US patent 6,669,075)

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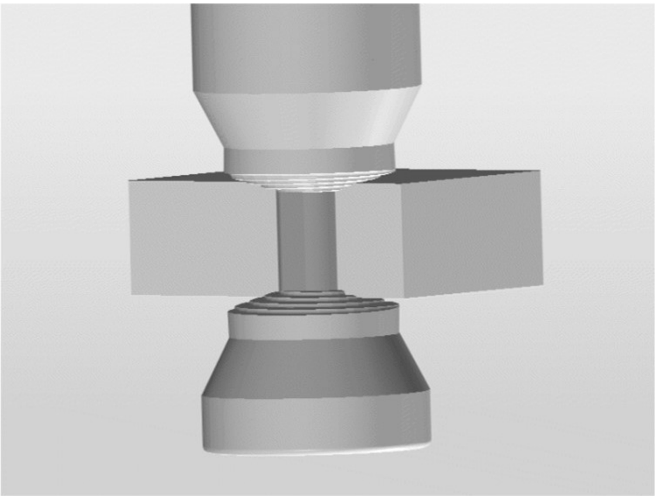
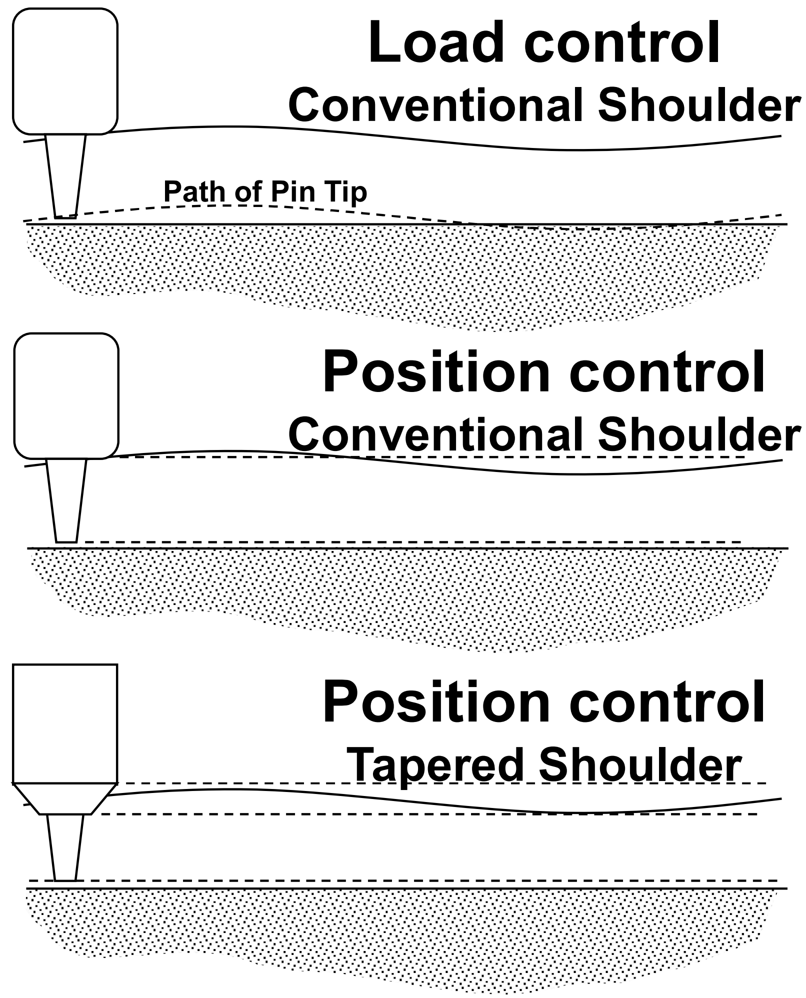
Case Studies

- Case 1 - variable depth welding
- Case 2 - fixed-geometry bobbin welding
- Case 3 - pipe welding



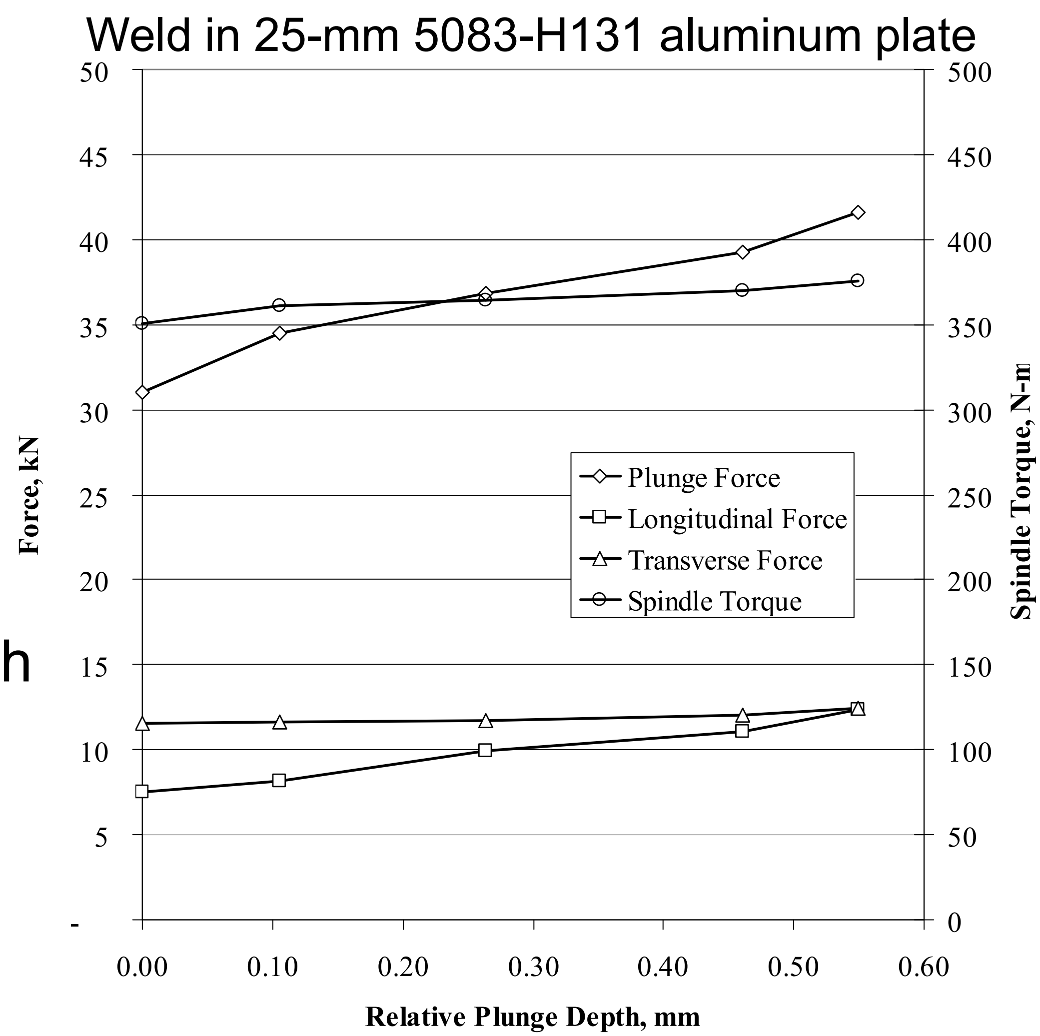
Case Study 1 - Variable Welding Depth

- Current state-of-the-art welding tool approaches:
  - Normal to the plate, load control
  - Normal to the plate, position control
- Both approaches risk problems:
  - Insufficient plunge depth
  - Insufficient shoulder contact
- The tapered shoulder tool makes it possible to do position control with less regard to shoulder contact
  - variation in plunge force
  - variation in crown width
  - no significant change in joint properties



Variable Depth Welding

- Variable shoulder penetration results in variable plunge force
  - weld in 25-mm 5083
  - 5 plunge depth settings
  - increases plunge force
  - increases crown width
  - increases heat input



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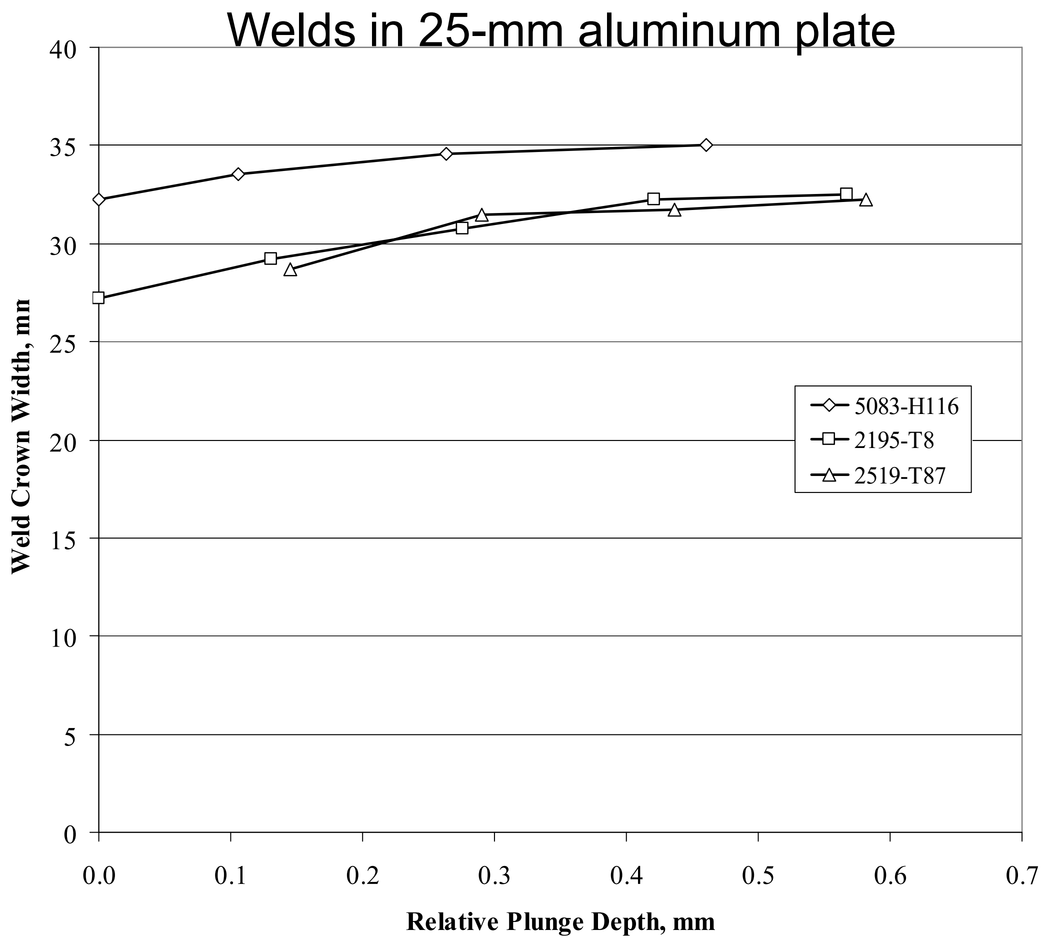
Variable Depth Welding

- **Increasing plunge depth also increases crown width**
  - **crown has generally good appearance with minimal flash**
  - **width simply changes with different plunge depths**



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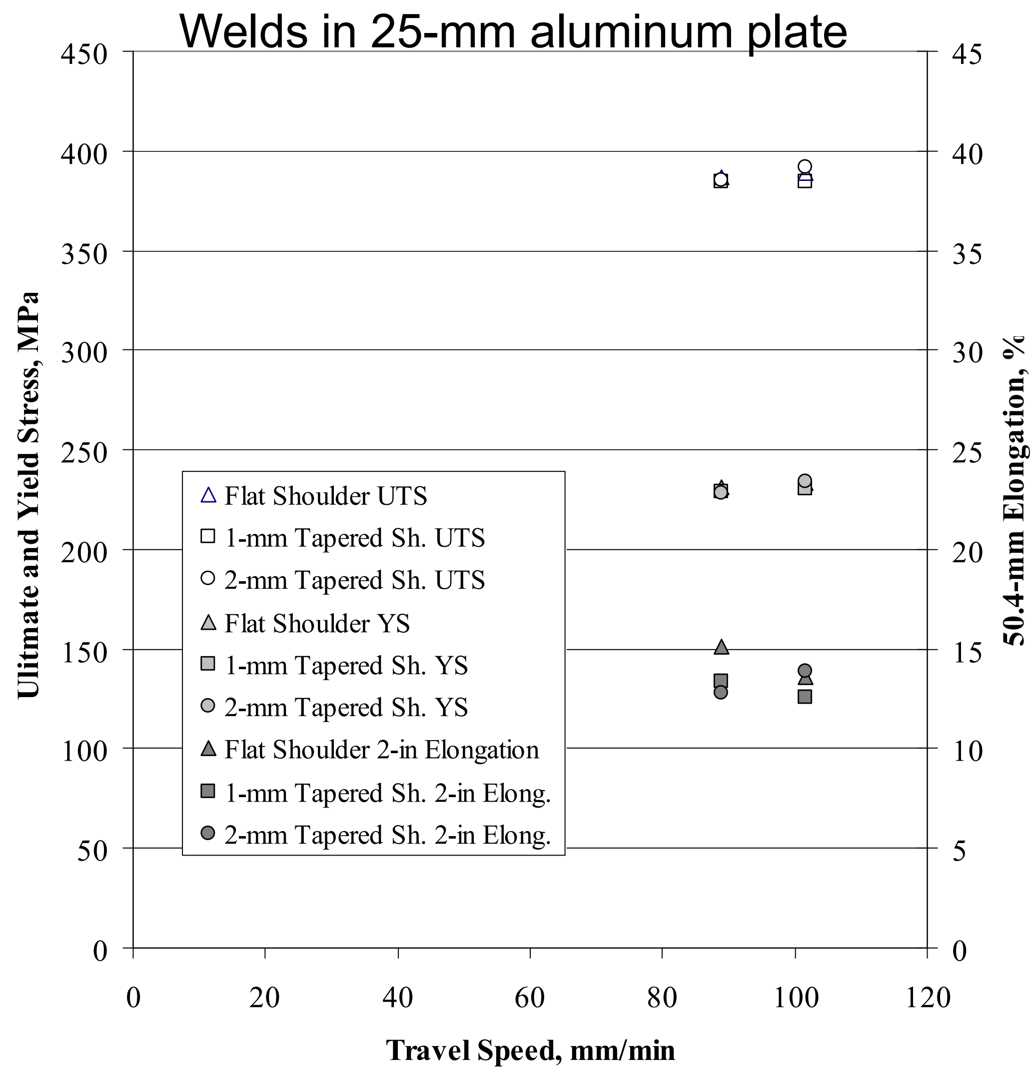
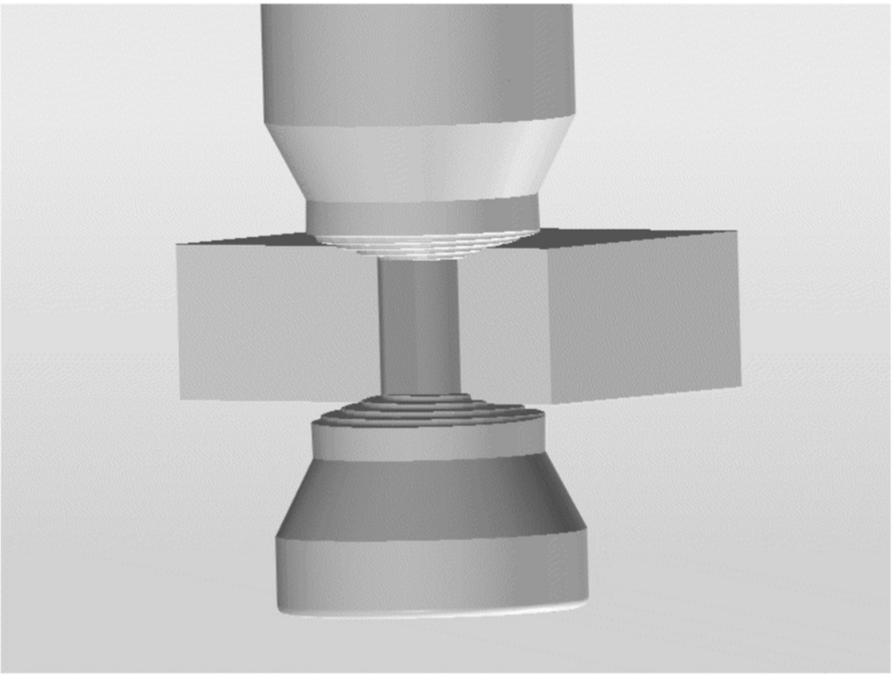
Variable Depth Welding

- **Welds made with flat and tapered shoulders resulted in essentially the same weld strength**



Case Study 2 - Fixed-Geometry Bobbin Welding

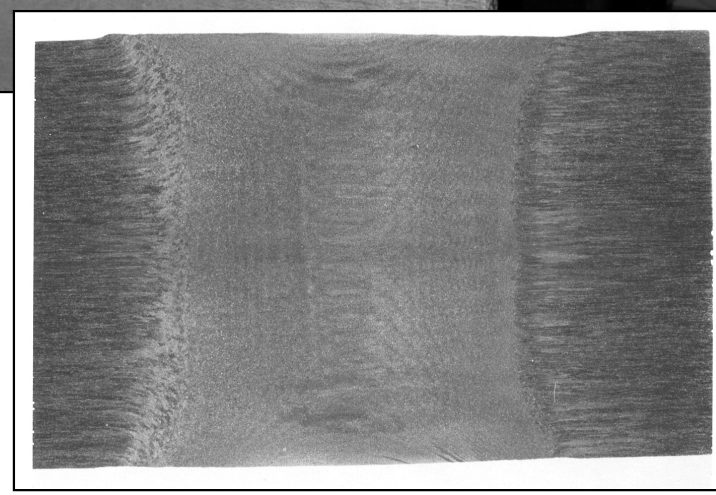
- **Current state-of-the-art self-reacting tools require actuation of the pin relative to the shoulder, making it impractical for many welding machines.**
- **The tapered shoulder design makes practical a fixed-geometry bobbin tool:**
  - **usable on all welding machines, machine tools**
  - **simple operation - adjust gap to accommodate plate variation and do load controlled weld with zero plunge force**



Tapered shoulder bobbin tool embedded in a workpiece, (workpiece cut away for clarity).

Fixed-Geometry Bobbin Welding

- **Tool demonstrated here in 25-mm 6061-T6**
  - **Tool entered/exited from edge of plate**
  - **Weld crossed itself with no change in gap adjustment and no defect**
  - **Sound weld produced with only control variables being travel speed and spindle speed**
  - **Tool also demonstrated in other alloys (2195, 5083)**



Transverse macro section of fixed-geometry bobbin weld in 25-mm 6061-T6

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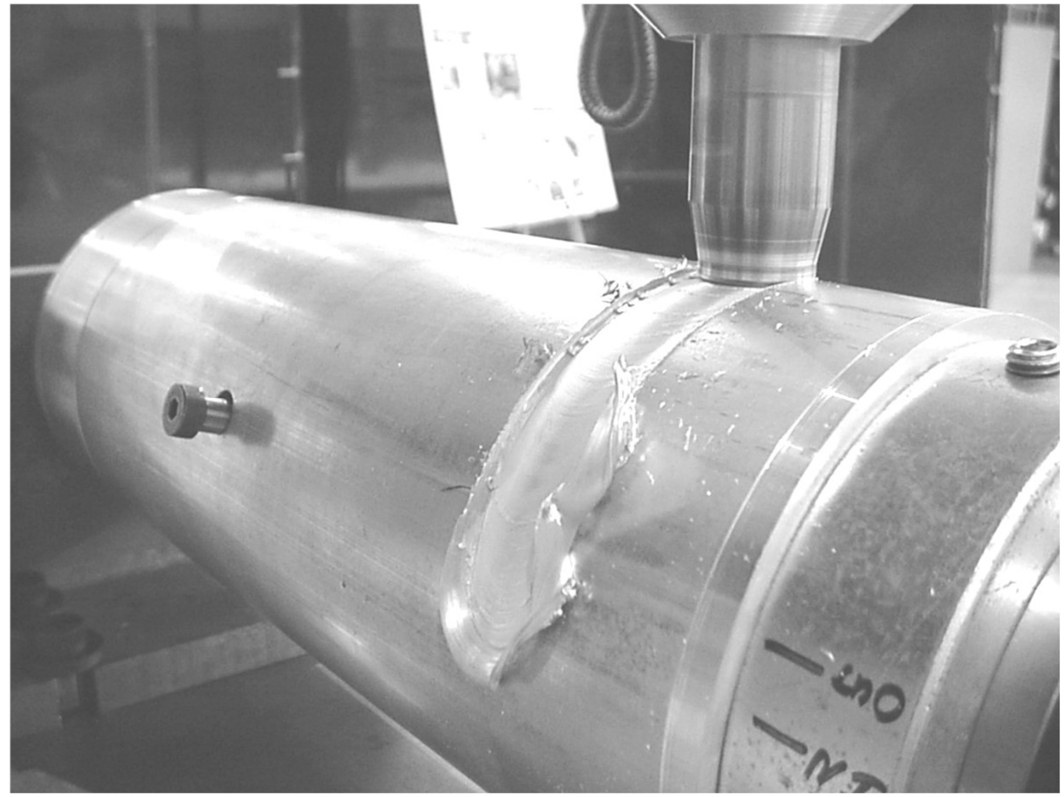
Case Study 3 - Pipe Welding

- **Tapered shoulder tool accommodates work with surface curvature**
- **Applications for:**
  - **pipe welding**
  - **inclined-axis welding**
  - **complex workpiece curvature**



125mm ID pipe, 19mm wall thickness

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Conclusions

- **The development of new tool design concepts has lead application development:**
  - **thicker workpieces**
  - **higher travel speeds**
  - **improved quality**
- **The outwardly tapered shoulder design is useful for a number of applications:**
  - **variable depth welding**
  - **fixed-geometry bobbin tools**
  - **work with curvature**