Pin Tool Geometry Effects in Friction Stir Welding

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Abstract

In friction stir welding (FSW) there is significant evidence that material can take one of two different flow paths when being displaced from its original position in front of the pin tool to its final position in the wake of the weld. The geometry of the pin tool, along with the process parameters, plays an important role in dictating the path that the material takes. Each flow path will impart a different thermomechanical history on the material, consequently altering the material microstructure and subsequent weld properties. The intention of this research is to isolate the effect that different pin tool attributes have on the flow paths imparted on the FSWed material. Based on published weld tool geometries, a variety of weld tools were fabricated and used to join AA2219. Results from the tensile properties and microstructural characterization will be presented.

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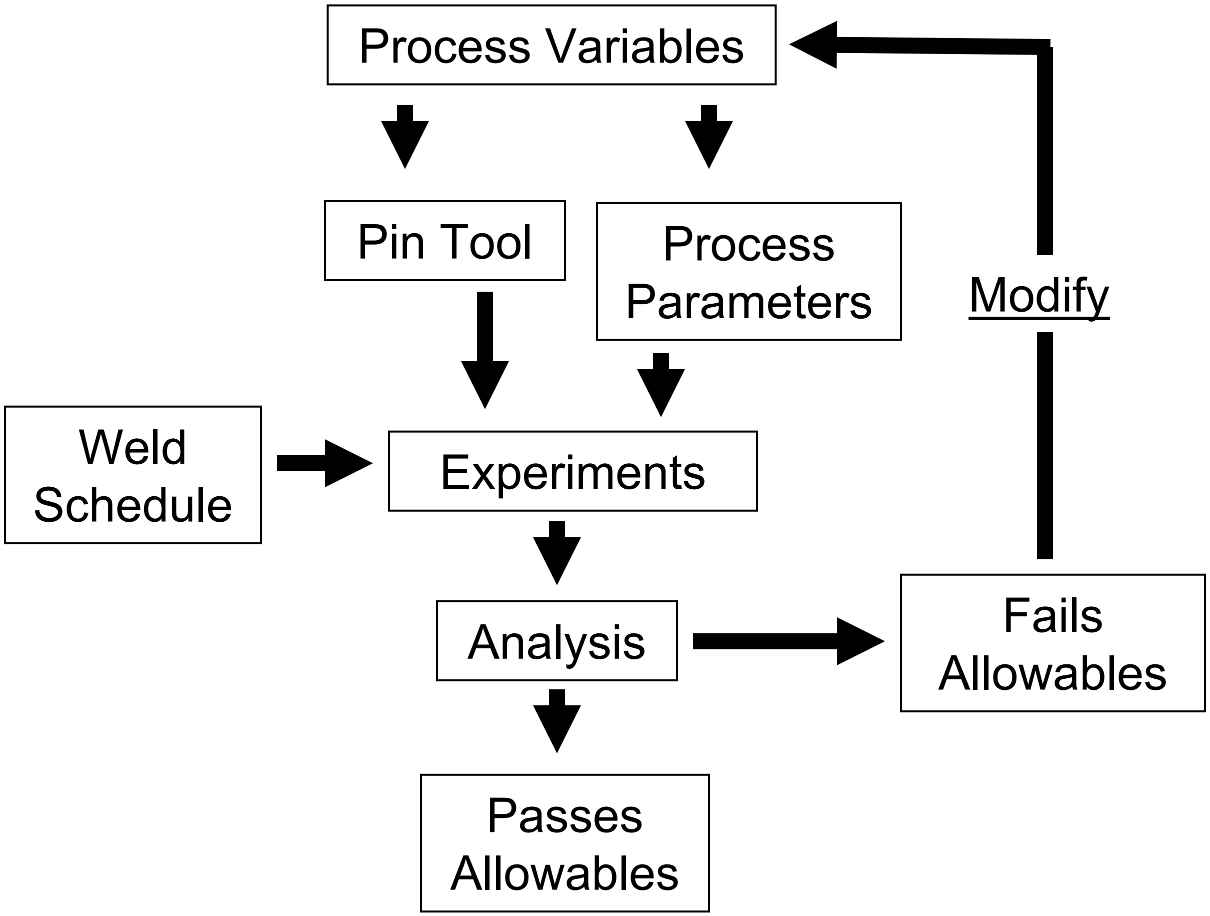
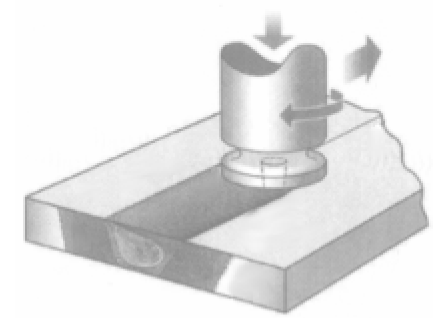
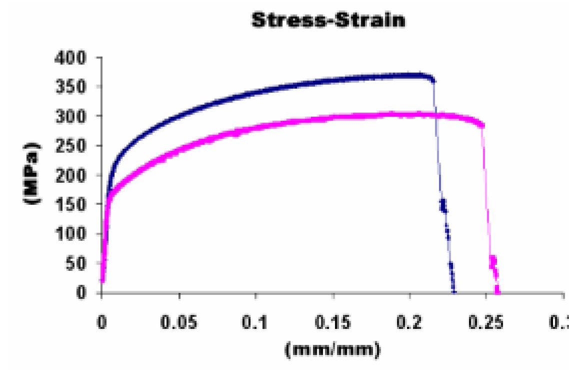
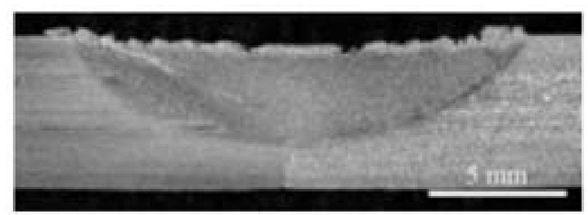
Motivation





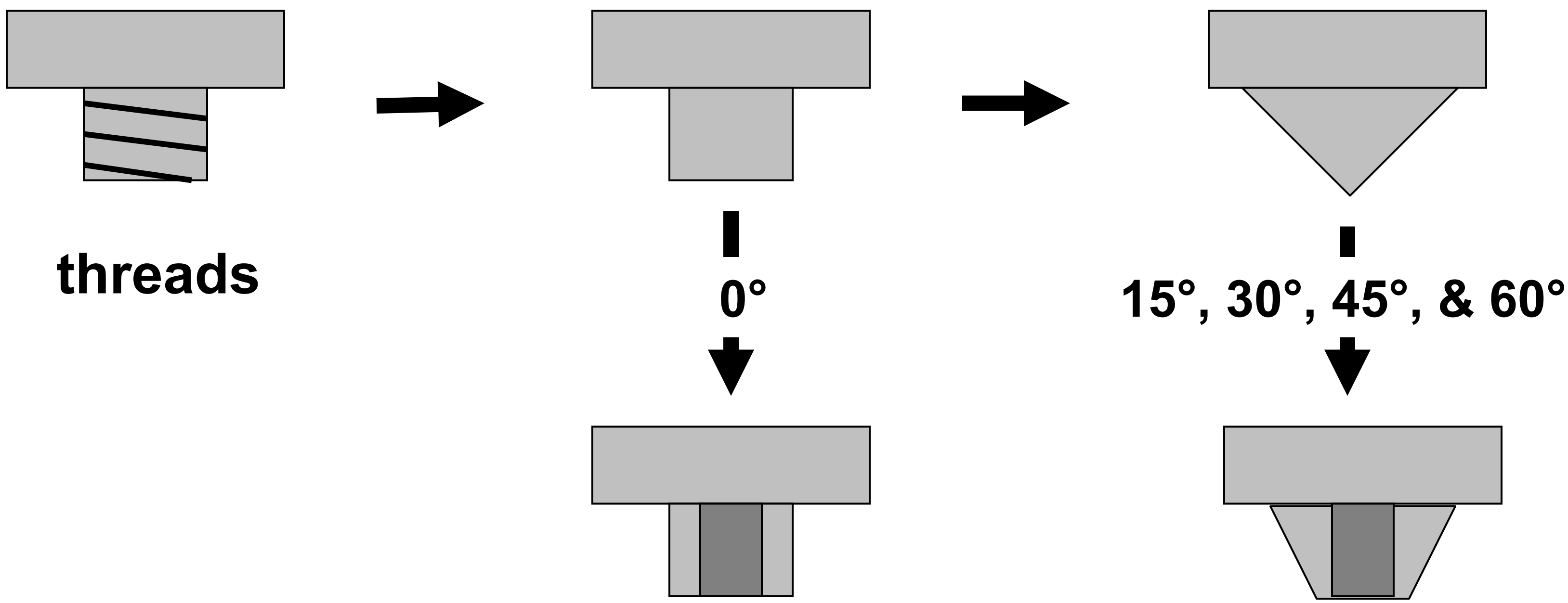




Minimize testing & increase productivity.

Problem Statement

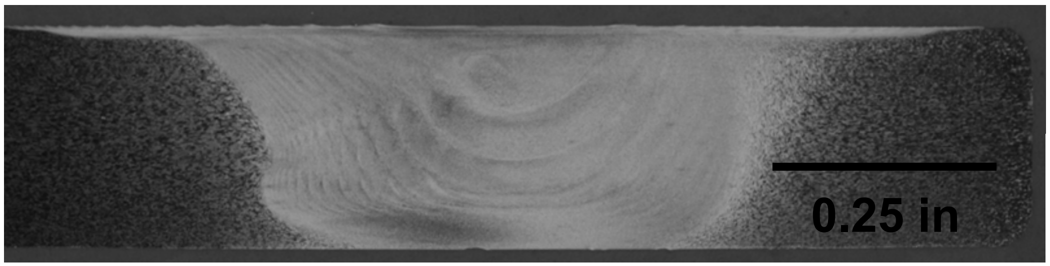
Determine how pin tool attributes affect material flow.



Other features: flats

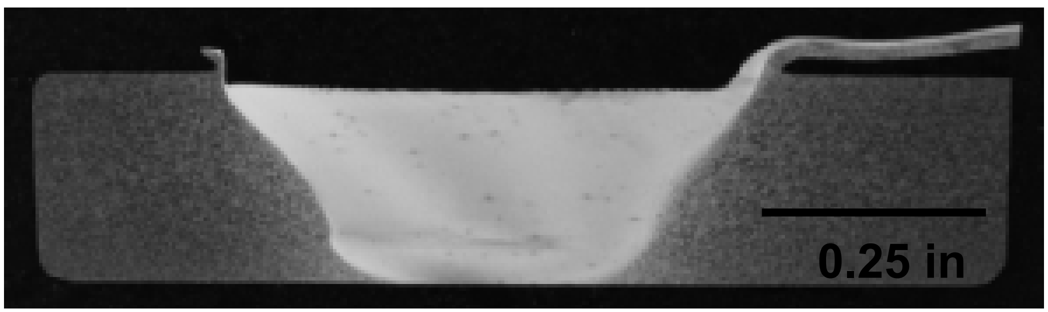
Transverse Macrographs of AA2219 FSWs

AS RS



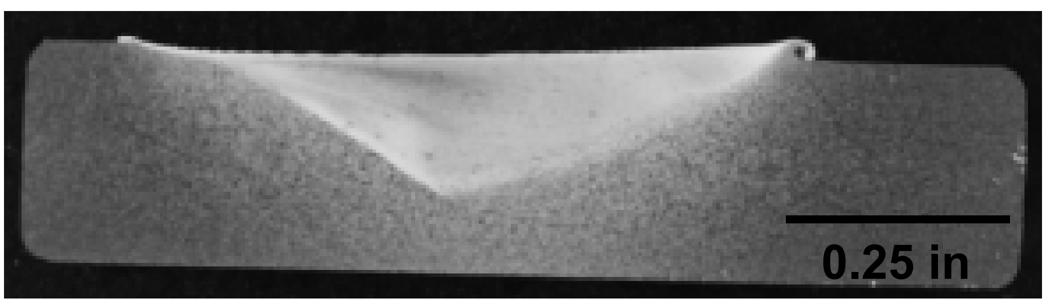
0 deg, threaded

200 rpm, 4.5 ipm, 7000 lbf



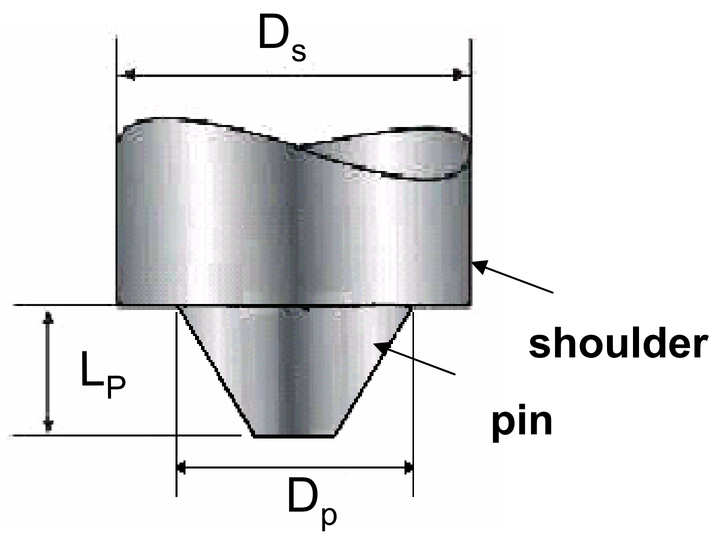
0 deg, no threads

200 rpm, 1.8 ipm, 4000 lbf



60 deg taper

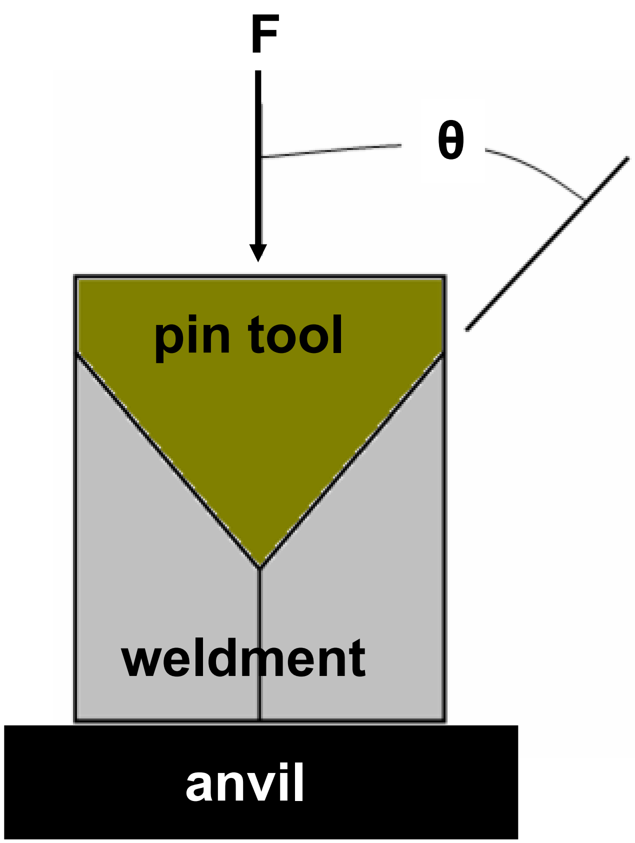
400 rpm, 7.1 ipm, 5500 lbf

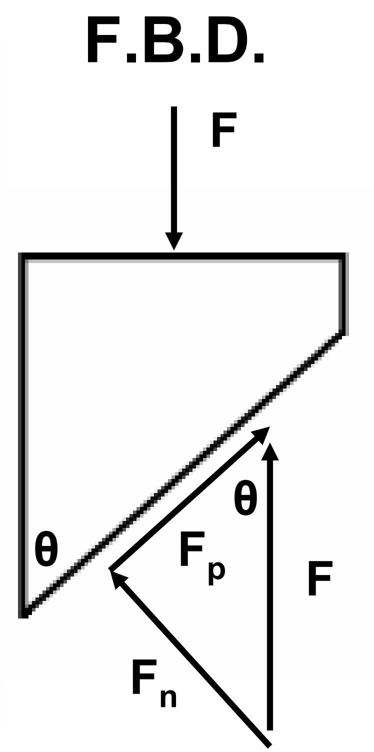


Reported Weld Tool Designs Vary with Material Joined

Weld Tool Geometry	Al	Ti	Steel (HMTM)
D_s/D_p	2.4	1.2-3.8	2.3-2.4
D_p/L_p	1.5	1.4-1.9	1.7-2.0
Pin surface	threads	smooth	smooth
Taper (deg)	0	30-60	30-60

Tapered Weld Tools Can Create Rotational/Stir Zone

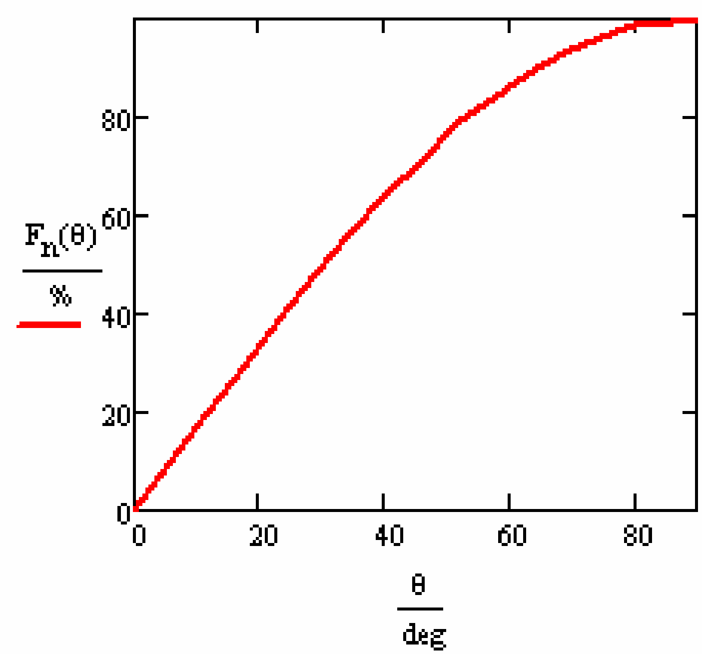




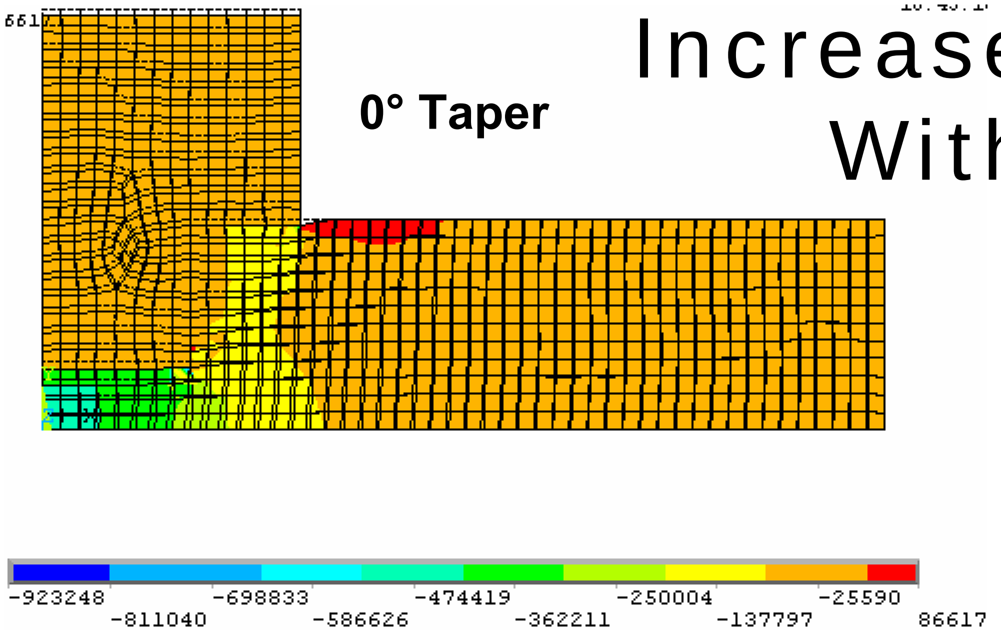
$$F_n \equiv F\cos(90° - \theta)$$

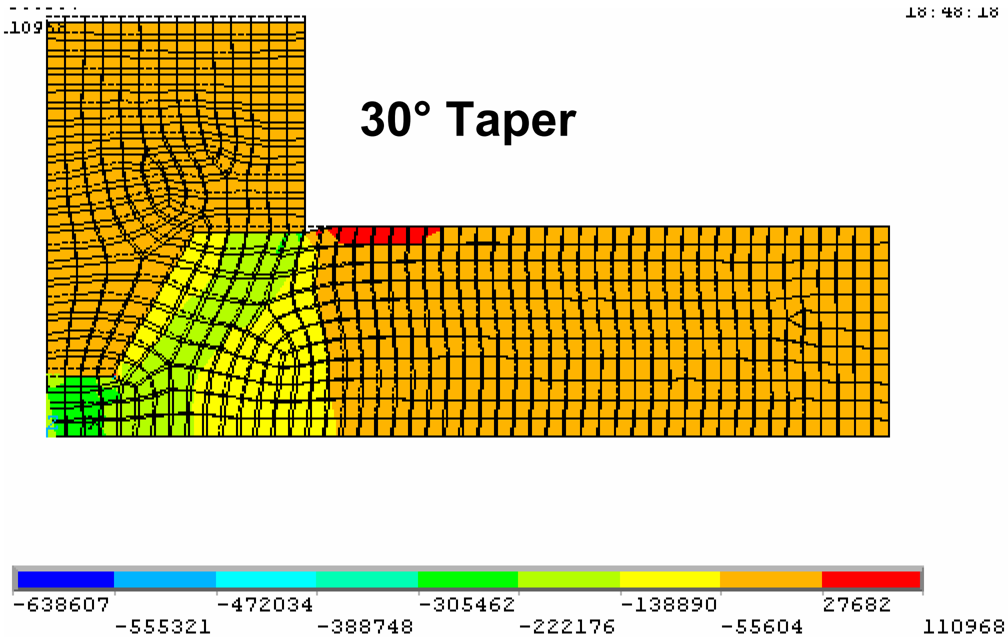
$$F_p \equiv F\sin(90° - \theta)$$

% of plunge force converted to normal force at pin interface.



Stresses Predicted to Increase Along Shear Line With Increasing Taper





Software: *Ansys*

Solution:

Axisymmetric,

Large deformation

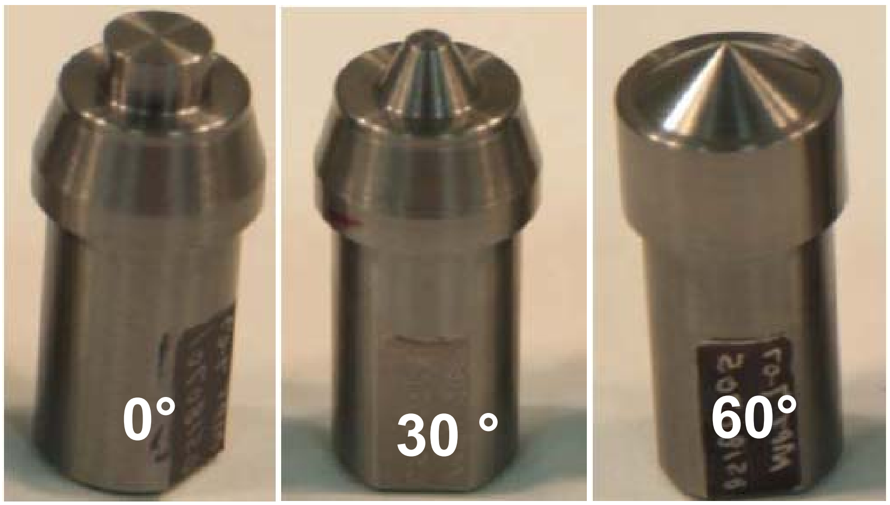
BCs: *Symmetric*

Assumptions:

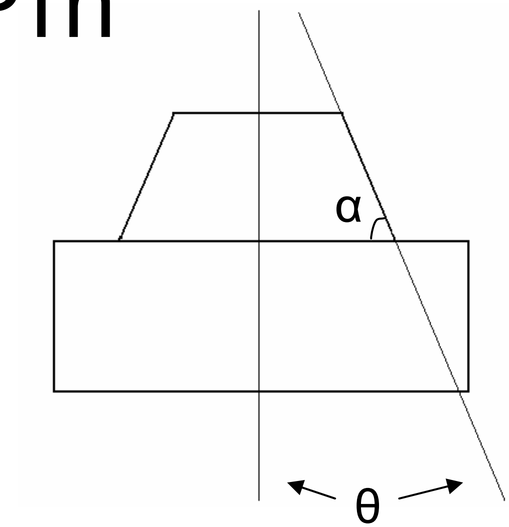
Prescribed displacement,

No slip

Investigate Differences in Material Flow Path Using Taper Rather than Threaded Pin



Weld Tools: MP159 & WCCo



Ratio&Tapers	**MSU**
D_s/D_p	1.75
$D_p/t_{mater.}$	1.4
Taper (θ)	0°, 30°, 60°

FSW Test Matrix for AA2219-T87

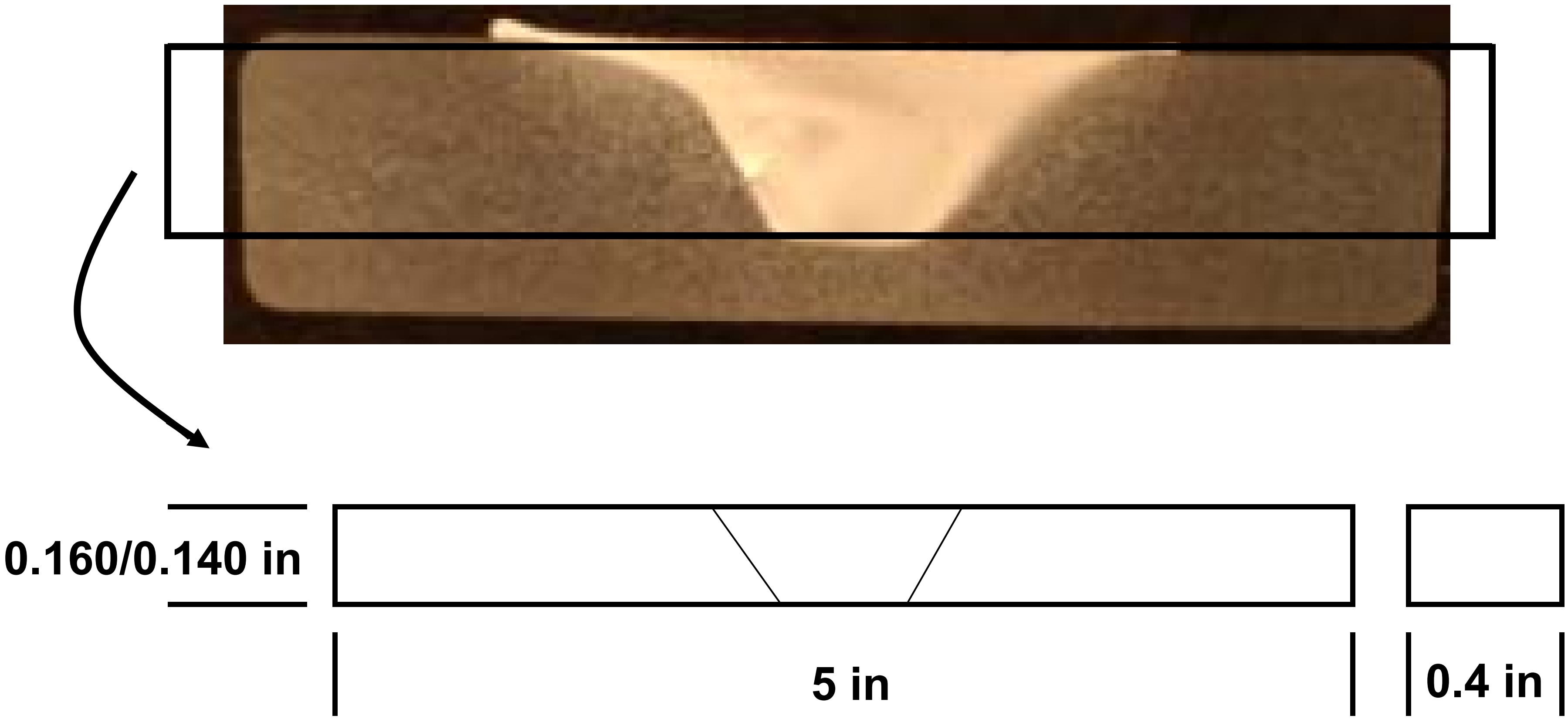
RPM	Travel Speed (in/min)	Forge force (lbf)			Travel Speed/rpm (in/rev)
		0°	30°	60°	
200	1.8	4000	3500	5500	0.009
300	4.0	4000	3500	5500	0.013
400	7.1	4000	3500	5500	0.018
500	11.1	4000	3500	5500	0.022

$$PHI = \frac{rpm^2}{Travel\ Speed}$$

PHI – Pseudo heat index, qualitative comparison for heat input

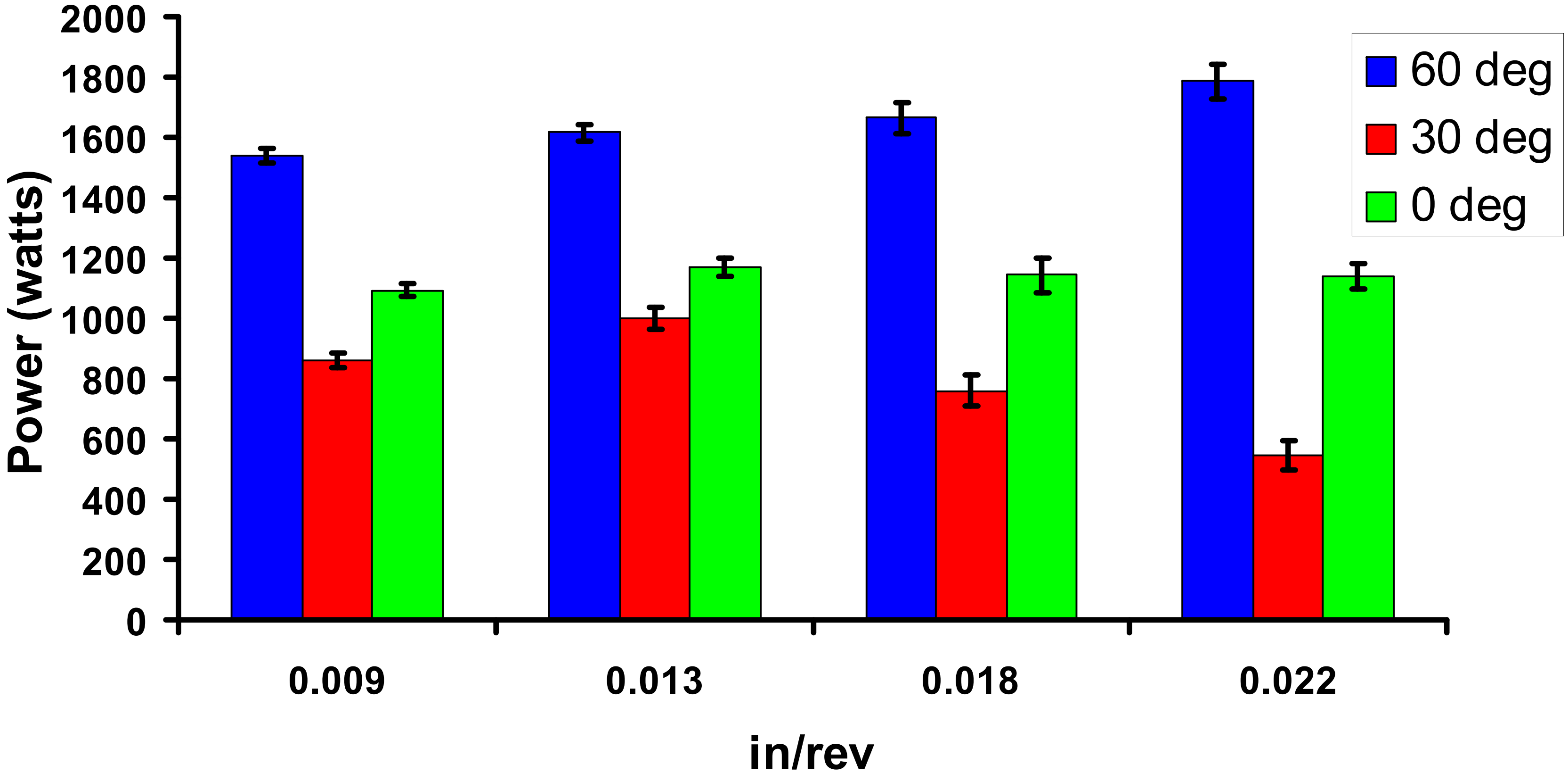
S. Kandukuri et. al., Friction Stir Welding and Processing IV, TMS Annual 2007

Tensile Specimens Machined to Eliminate Parent Material in Gage Section

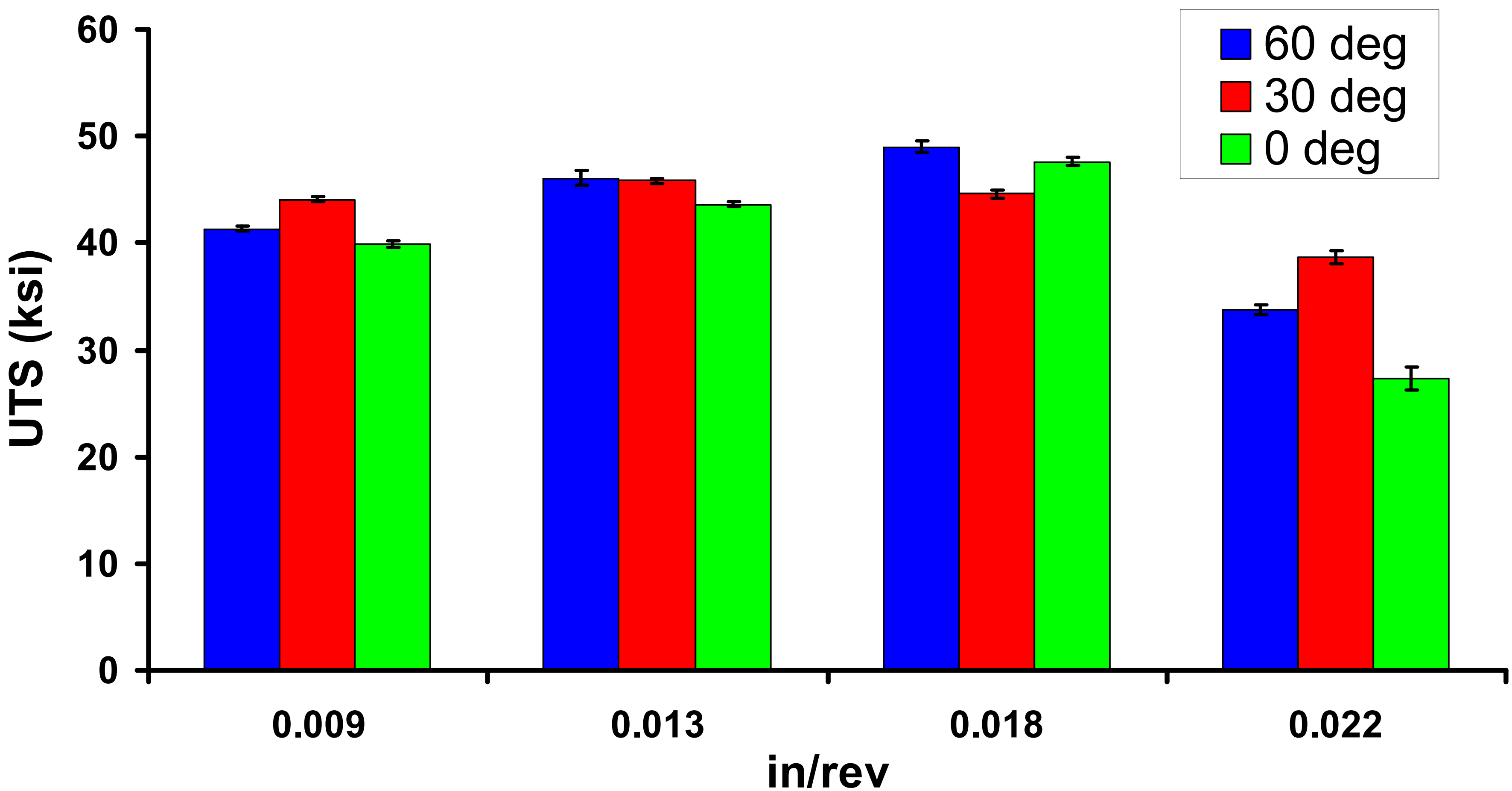


Weld Tool Geometry Strongly Affects Consumed Power

Power = 2πf * Torque   f = frequency (rpm)

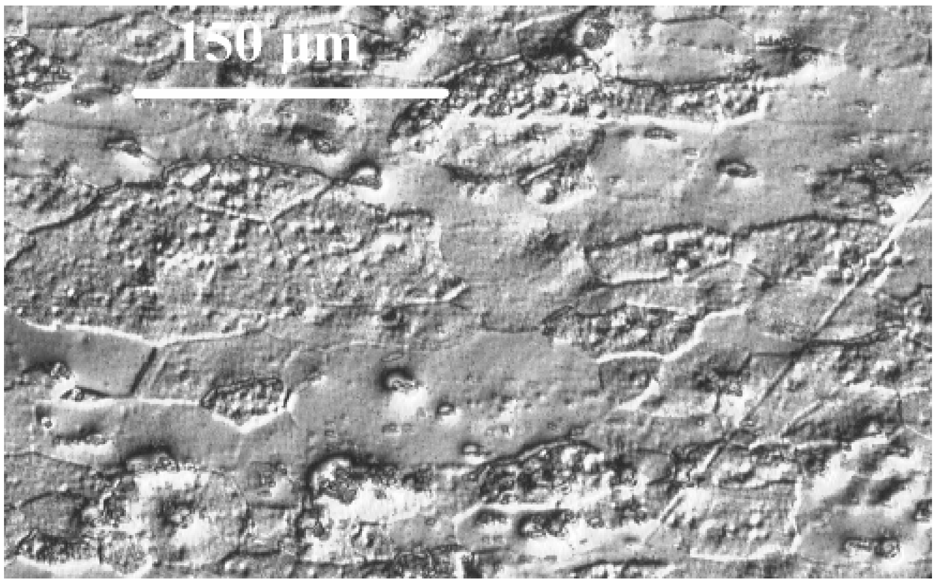


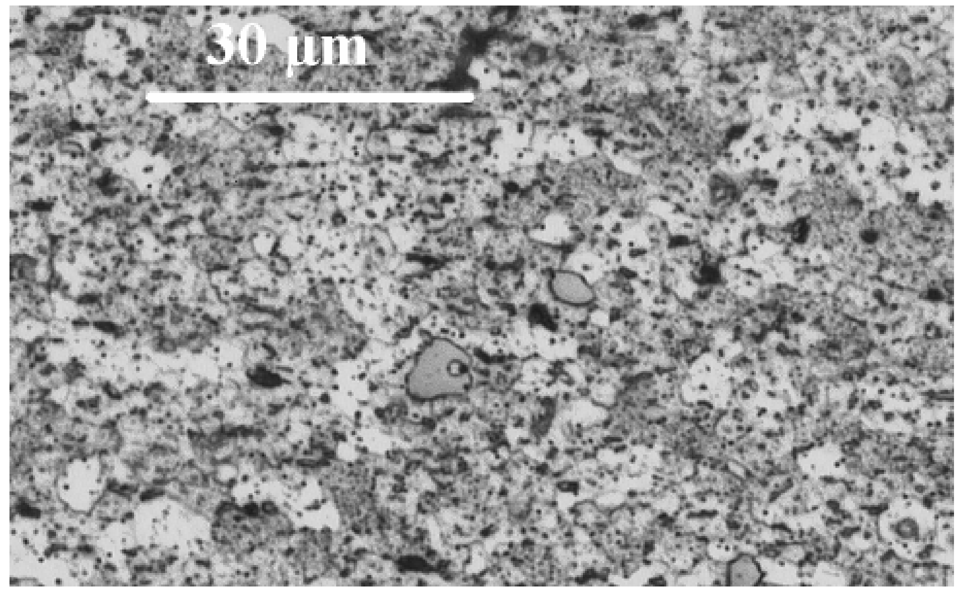
Tensile Strength Increases With in/rev Until Defects Occur



Typical Grain Refinement Observed in all Welds

AA2219-T87





Parent Material

Grain Size = 100-200 µm

Nugget Zone

Grain Size = 4-7 µm

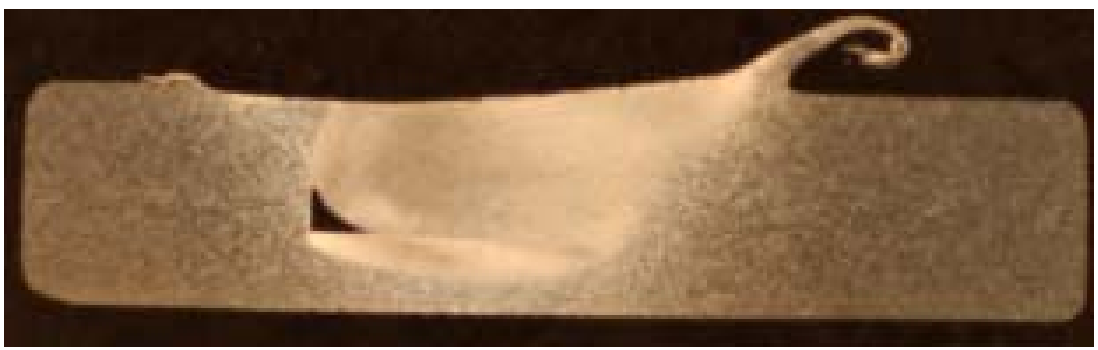
FSW Defects Observed at Highest RPM and TS

60° Pin Tool
500 rpm & 11.1 ipm

J12-A

30° Pin Tool
500 rpm & 11.1 ipm

J14-A



0° Pin Tool
500 rpm & 11.1 ipm

J16-A

Investigate Function of Flats in FSW

Swept volume: W.M. Thomas et. al., TMS2001: Aluminum and Joining Sessions

Summary

- **Refined grains were observed in all AA2219 FSWs.**
- **Similar joint efficiency was achieved for all tools evaluated.**
- **Two tools were down selected and used in FSWing of Ti-6Al-4V.**
- **Analysis of weld data with incorporated flats in the weld tool is on going.**

Acknowledgements

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