Effects of Cooling Media on Mechanical and Microstructural Properties of Friction Stir Welded AA6061-T6 in a CNC Machine

PennState College of Engineering

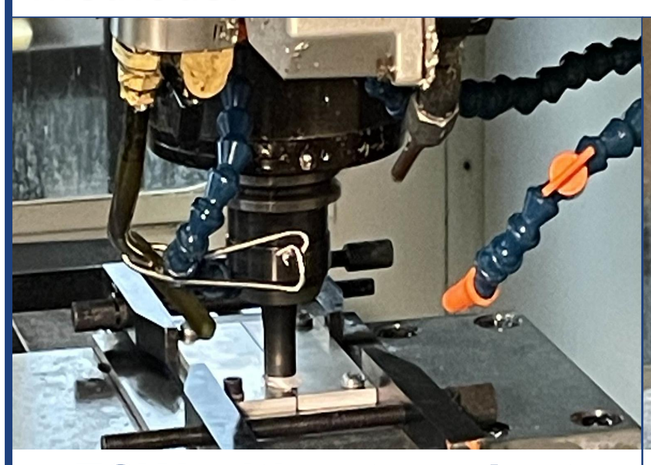
Austin Clark and Ihab Ragai
Pennsylvania State University

1. PROBLEM STATEMENT

- Friction Stir Welding (FSW) in a CNC machine generates substantial heat at the tool creating potential for thermal creep into the machine which can damage the spindle and reduce tool life.
- A practical method was tested utilizing existing coolant supply to maintain ambient temperature at the spindle and tool while allowing ample heat for welding.

2. METHODS

- Cooling methods consisted of forced air cooling, flooded coolant media, and no cooling as a control.
- 6.35 mm Aluminum 6061-T6 plates were butt welded utilizing the 3 levels of cooling.
- 3 levels of feed rates (100/200/300 mm/min) were tested to evaluate parametric effects on cooling methods.

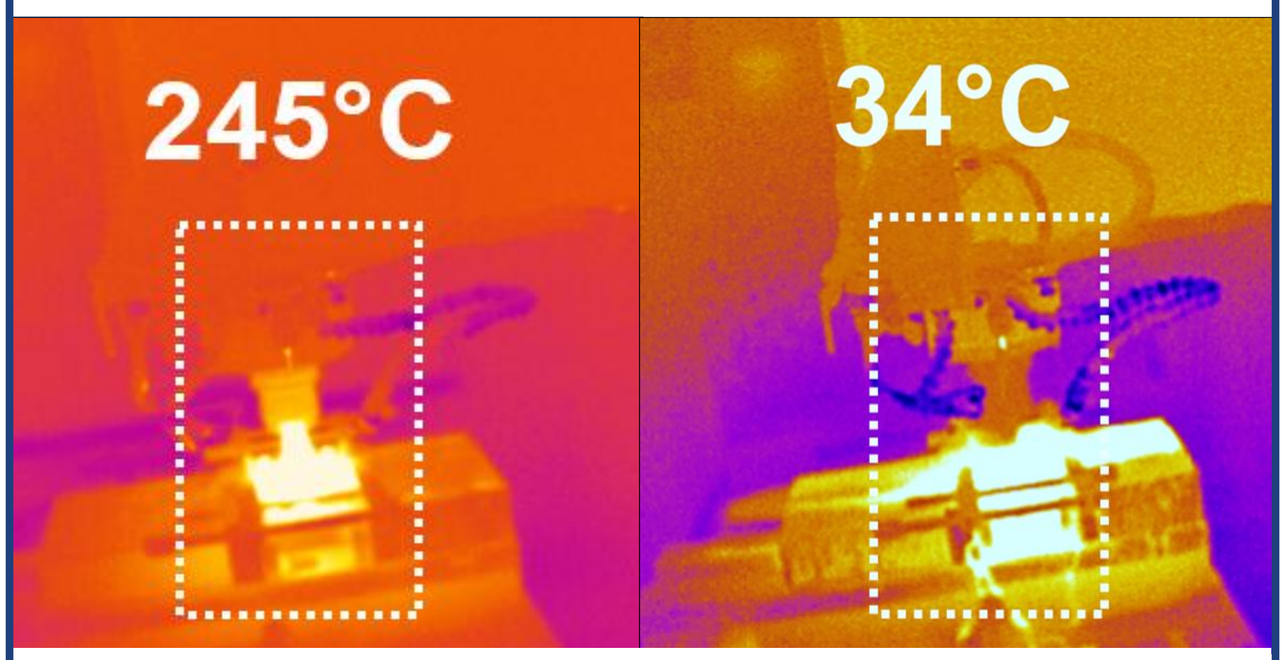


FSW without coolant

FSW with coolant

3. RESULTS

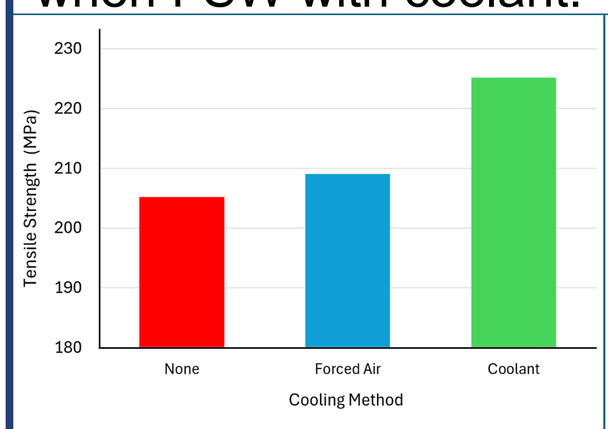
- Flood coolant media significantly reduced the temperature at the weld as measured by an Optris 640i LT infrared (IR) camera.
- Forced air cooling had a less significant effect than flood coolant.
- Both cooling methods exhibited improved mechanical properties and reduced temperatures compared to no cooling.
- No loss in ductility was found in tensile samples between samples welded with cooling vs no cooling.

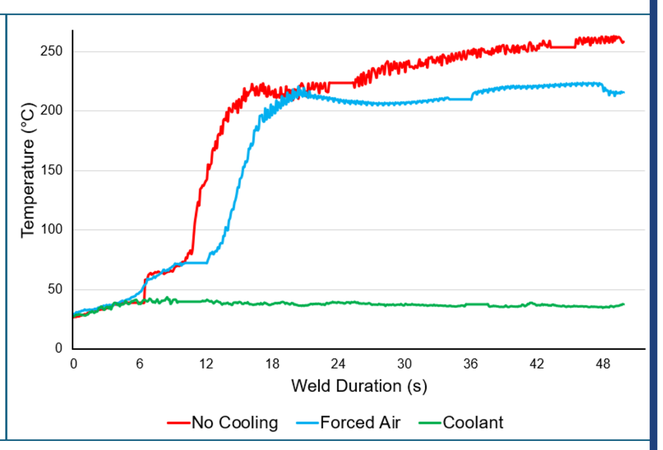


Thermal images of FSW without coolant (left) and with coolant (right)

4. MECHANICAL ANALYSIS

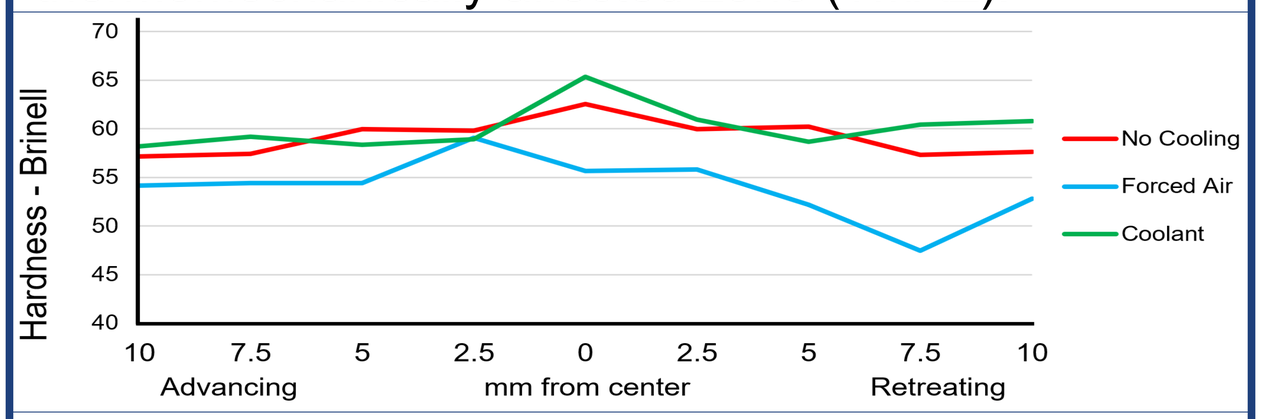
- Flood coolant media exhibited the greatest reduction in temperature while also increasing the tensile strength more so than welds performed with forced air cooling and no cooling.
- Correlation between higher tensile strength and reduced temperature was observed.
- 76% weld efficiency in tensile strength achieved when FSW with coolant.





Tensile Strength vs Temperature Distribution

- Peak hardness in the Stir Zone (SZ) increased when coolant was implemented.
- FSW with coolant shifted the lowest hardness zone from the heat affected zone (HAZ) to the thermomechanically affected zone (TMAZ).



Hardness Map

5. MICROSTRUCTURAL ANALYSIS

- The HAZ was reduced when flood coolant was implemented due to dynamic recrystallization and reduced thermal input.
- Interstitial striations formed along the retreating side (RS) as the FSW tool plastically deformed material along the pitch of the tool threads from the surface and the advancing side (AS).
- Voids were present near the surface of the RS when coolant was utilized due to a lack of heat generated for thorough mixing to occur along with reduced material flow attributed to cooler temperatures within the weld zone.

FSW without coolant

FSW with coolant

6. CONCLUSION

- 85% reduction in temperature at the tool with flood coolant.
- Sound welds performed at 6% Melting Onset temperature of AA6061-T6 (580°C).
- 10% increase in tensile strength vs no cooling.

7. ACKNOWLEDGEMENTS

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