Entrapment of Al_2O_3 and SiC particles in 6061 Aluminum by Friction Stir Welding

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NSF Award Number 0852057 REU Site: Back to the Future
NSF Award Number 0437396 NSF I/UCRC Site: Center for Friction Stir Processing

Objective

- Use FSW to disperse ceramic particles deposited by Cold Spray into the surface of 6061 T6 aluminum plate.
- Compare behavior of Al_2O_3 and SiC particles.
- See how the weld and particles affect the microstructure and properties of the plate.

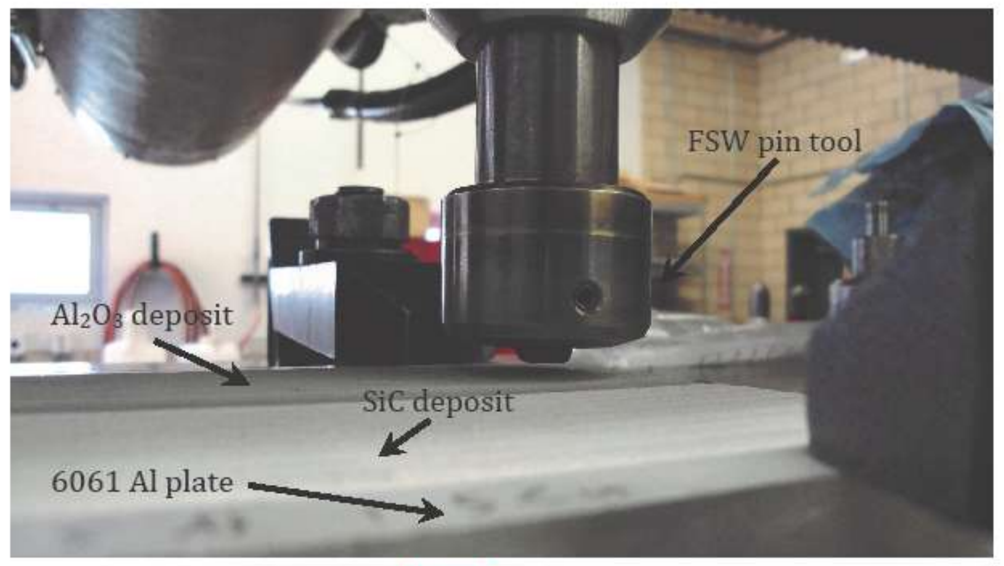

Figure 1. Layout

Procedure

- (By weight) 50% ceramic, 45% Al, 5% Cu powder mixture deposited onto 6061 plate using CS. Figures 7, 8.
- FSW over the deposits with shallow pin tool. Figures 9, 10.
- Cut and polish cross-sectional samples to 1200 grit followed by 6μm and 1μm diamond slurry polish.
- Micrographs taken with Leco LX31 microscope.
- Vickers hardness tested at 100g load, 15 second dwell.

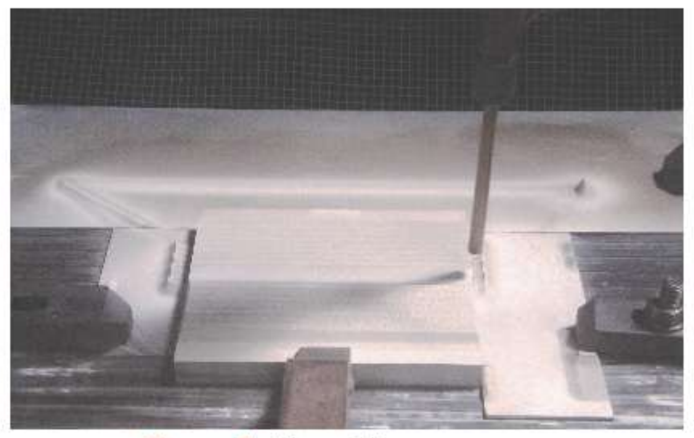

Figure 7. The cold spray process

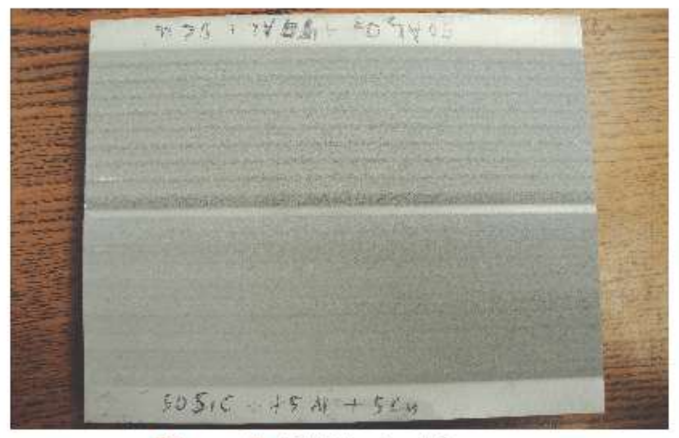

Figure 8. Finished cold spray

Figure 9. The FSW process

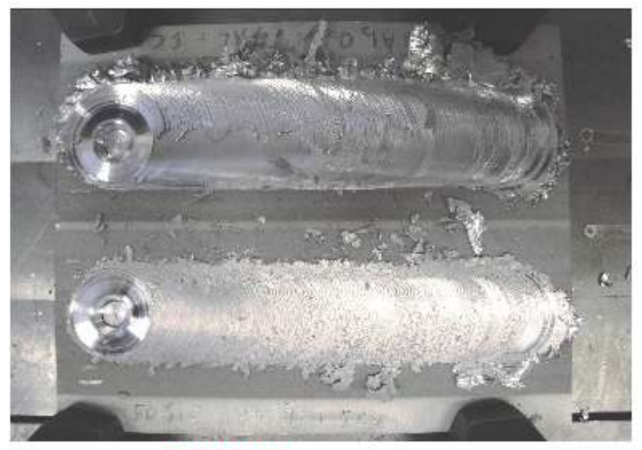

Figure 10. Finished FSW

Abstract

Multi-layer armors composed of stacked ceramic and aluminum plates are common in light to heavy personnel and equipment transportation. While these armors effectively block projectiles they are expensive to produce and repair. The Friction Stir Welding (FSW) and the Cold Spray (CS) processes are evaluated for the use in bonding a ceramic powder top layer to a base plate of aluminum. The weld is then analyzed for microstructure and hardness. The use of ceramic powder with FSW should produce a bonded metal matrix layer on top of the aluminum plate with properties acceptable for use in armor at a reduced expense and increased ease of reparability.

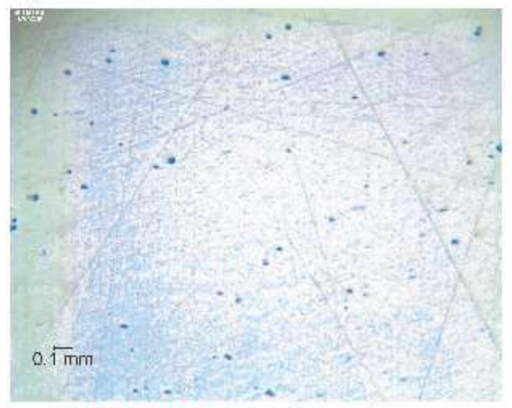

Figure 2. 6061 base plate

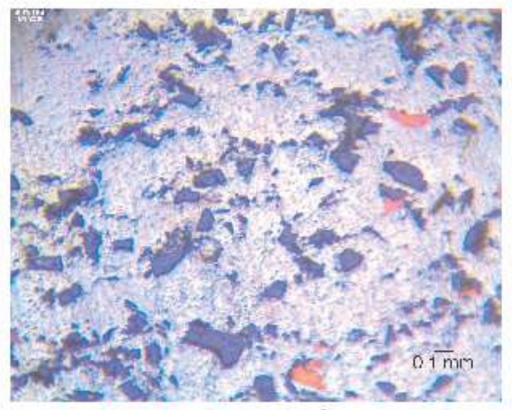

Figure 3. SiC CS deposit

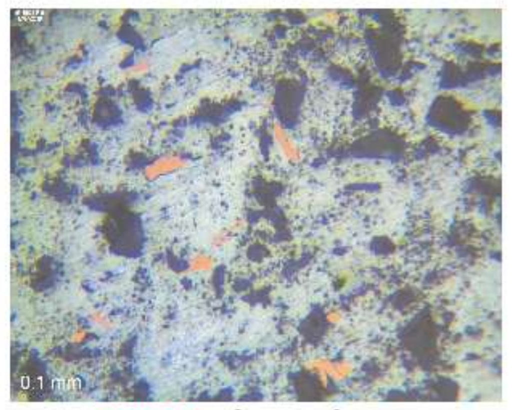

Figure 4. Al_2O_3 CS deposit

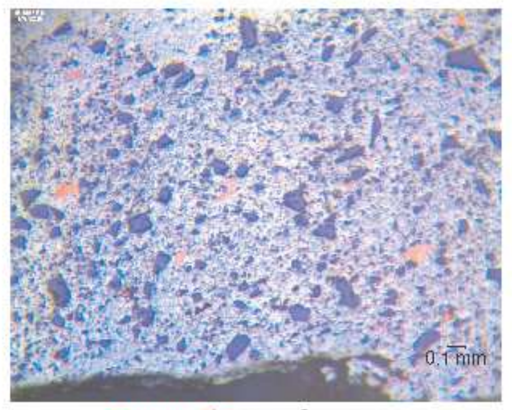

Figure 5. SiC after FSW

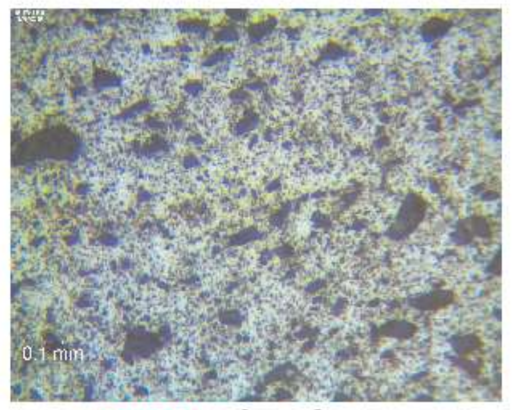

Figure 6. Al_2O_3 after FSW

Conclusion

- The CS and FSW processes are capable of quickly producing thick, uniform metal matrix composites of Al with Al_2O_3 or SiC particles.
- The properties of the Al_2O_3 and SiC deposits are similar enough to share machine parameters.
- The embedded particles appear to locally raise the hardness of the deposit vs. a pure metal deposit.

Future Work

- Test thicker deposits for averaged hardness of the metal matrix.
- Try different Al alloys for metal matrix.
- Try different sized powders.
- Vary ceramic to metal ratio in coating.
- Prepare large plate samples of variations and test ballistic penetrability.

Results

- The Cold Spray process successfully produced a metal matrix composite coating with ceramic particles. Figures 3, 4.
- The FSW process broke up the larger ceramic particles and produced a even distribution of smaller particles. Figures 5, 6.
- No significant difference in material properties appeared between Al_2O_3 or SiC. However, the Al_2O_3 particles had a tendency to come loose while polishing.
- Microhardness of the Al matrix was softer then the 6061 plate, yet the point hardness on a particle was harder then the plate. Table 1, Figures 11, 12.

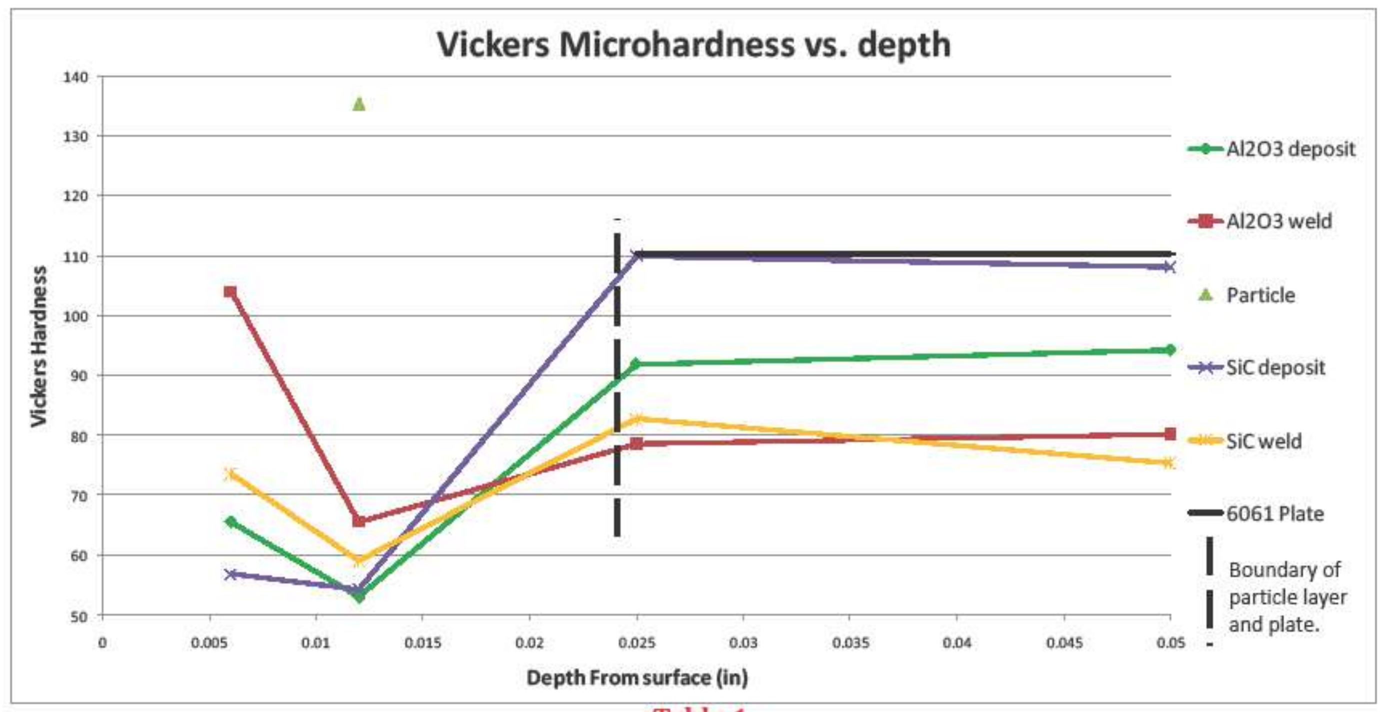

Table 1.

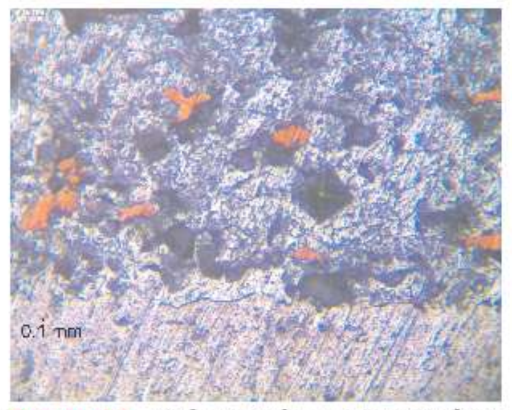

Figure 11. Vickers indent on FSW Al_2O_3.

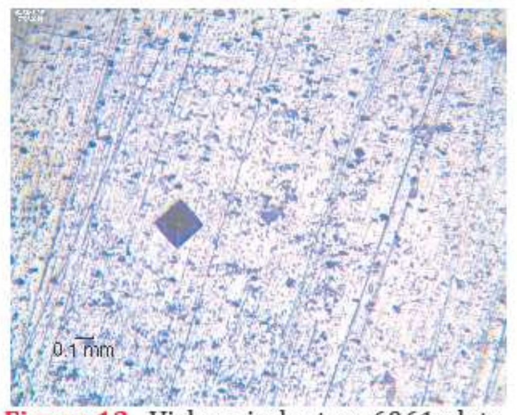

Figure 12. Vickers indent on 6061 plate.

Discussion

- CS powder mixes with less then 45% by weight Al have greatly reduced deposition efficiency, with very little increase in the ratio of ceramic to metal in the deposit.
- While the deposit is readily stir welded, too deep of a shoulder plunge with the pin tool will prevent the metal matrix from re-forming all the way across the weld. See top weld Figures 9,10.
- Vickers microhardness is not recommended for finding the overall hardness of a metal matrix composite due to the non-homogenous nature of the material at that scale.