Electromagnetic Crimping on a Variation of Impact Target Geometry

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Electromagnetic crimping

- Electromagnetic crimping is an impulse or high-speed forming technology using pulsed magnetic field to apply Lorentz' forces to workpieces made of a highly electrically conductive material without mechanical contact.

- Electromagnetic crimping is a versatile and efficient manufacturing method, particularly suitable for applications where high-speed, precision, and complex shaping are essential.

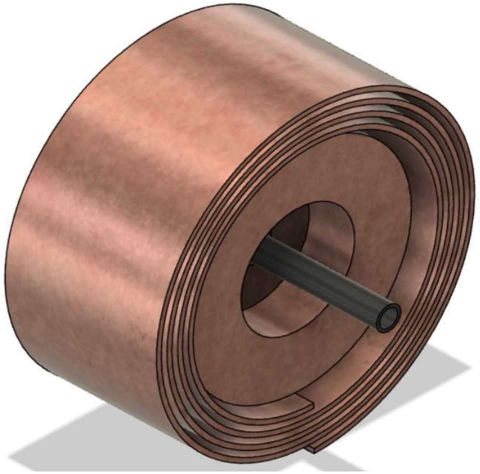


Fig. Crimping setup

Principle of crimping process

This works on the principle of Electromagnetic induction. Eddy currents induced inside the conductors develop lorentz forces which deform the workpiece.

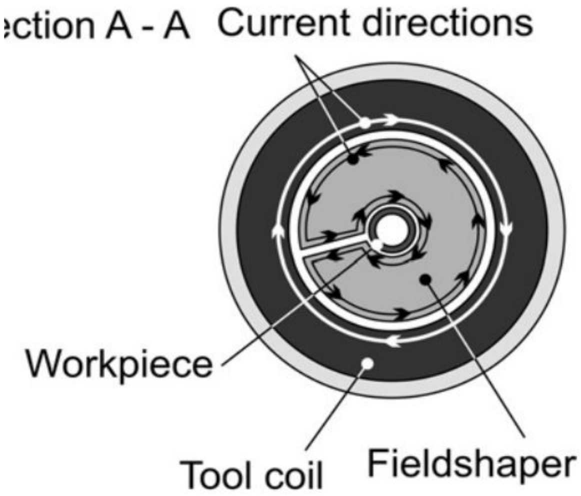


Figure .current directions in tool coil fieldshaper and workpiece

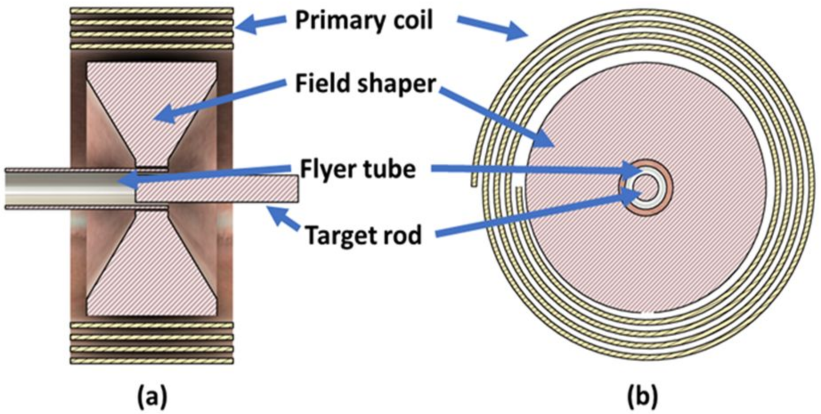


Figure. Primary coil arrangement for crimping (a) front half cross-sectional view (b) side half cross-sectional view.

Methodology

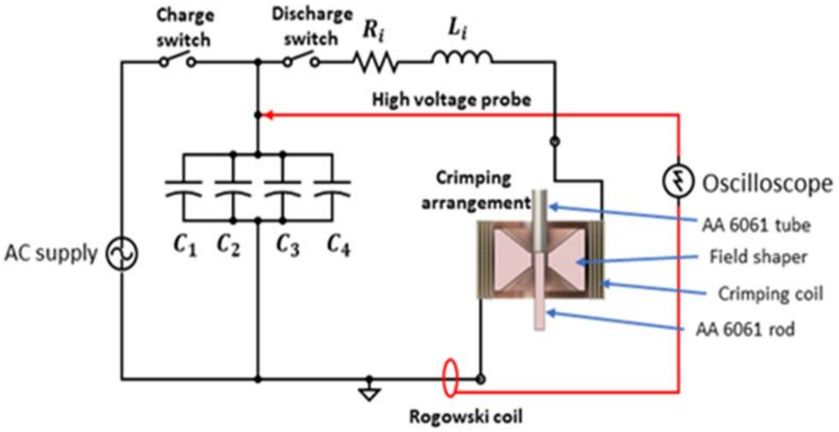


Figure. Circuit diagram

- ➢ The capacitor bank is fully charged.
- ➢ Quick discharge of capacitor bank and the current flows in the primary coil.
- ➢ Magnetic field induced by the coil generates eddy currents in Field shaper.
- ➢ This further induces eddy currents in flyer tube.
- ➢ These currents interact with Magnetic field and produce lorentz forces.
- ➢ These forces crimp/compress the flyer tube.

Advantages over mechanical crimping

1. High Forming Speed
2. Minimal Tool Wear
3. Contactless Process
4. Ability to Join Dissimilar Metals
5. Precision and Control
6. Reduced Forming Temperature
7. Energy Efficiency

Applications:

Figure. Joining dissimilar material

Aerospace Components

Medical Device Manufacturing

Prototyping and Small-Batch Production

Joining of Dissimilar Materials

Literature Review

Authors (Year)	Paper Title	Summary
H. Suzuki et al. (1987) [2]	The effect of a field shaper in electromagnetic tube bulging.	•Studied the effect of cylindrical, concave, and convex type field shaper (FS).
A. K. Rajak et al. (2018) [3]	Application of electromagnetic forming in terminal crimping using different types of field shapers.	•FS optimization for constant FS length, effective working length and slit width. •Single step FS gives maximum radial deformation.
D. Kumar et al. (2021) [4]	Interference-fit joining of Cu-SS composite tubes by electromagnetic crimping for different surface profiles.	•Knurled samples are better for versatile load. •Threaded samples are better for axial load.

Objective:

Experimental study on the effect of the variation of impact target geometry in the high strain rate electromagnetic crimping process of AA 6061 flyer tube and target rod.

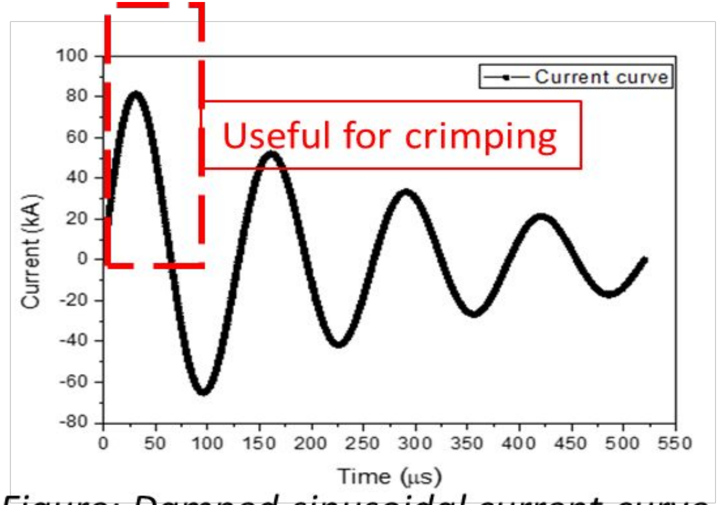
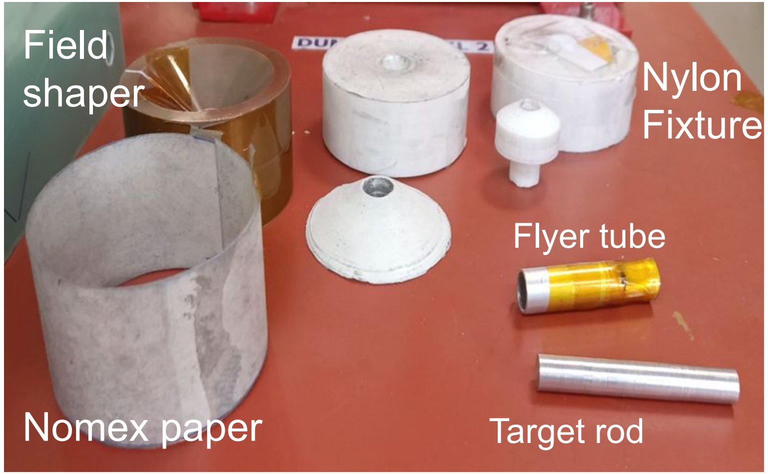


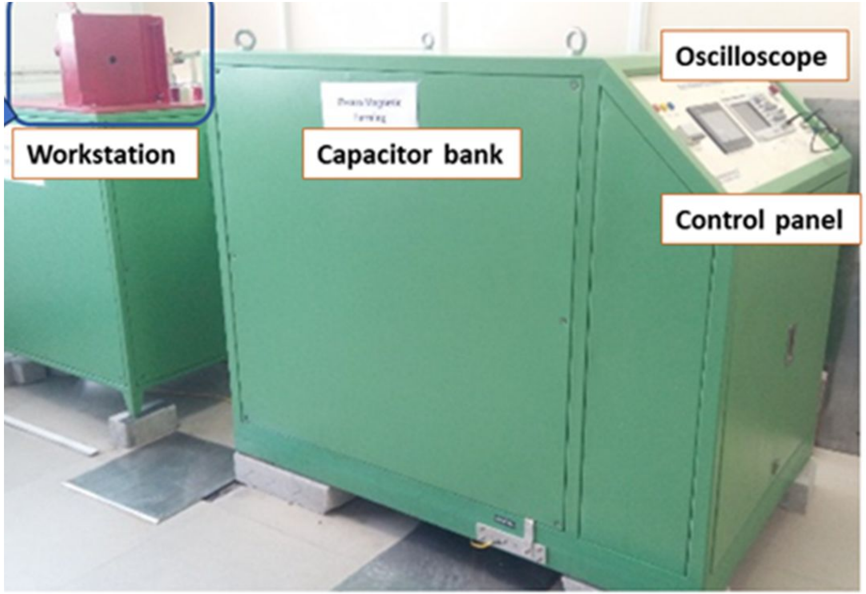
Figure: Damped sinusoidal current curve

- ❖ The crimping is so quick and happens within 100 microseconds.

Set up includes:

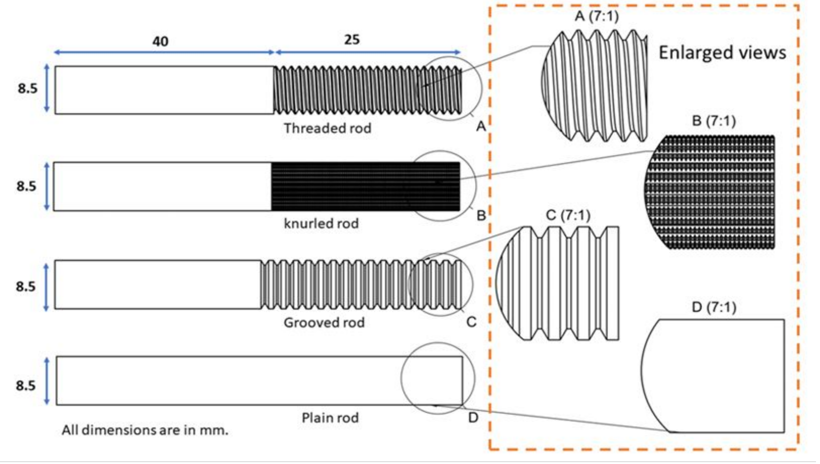
- Energy storage system
- Pulse generator
- Coil, workpiece, Fieldshaper
- Control system





Workpiece specifications

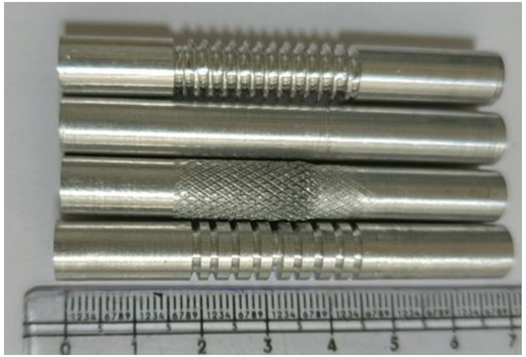
Parts	Material	Outer diameter (mm)	Inner diameter (mm)	Length(mm)
Flyer tube(outer tube)	AA 6061	12	10	50
Target rod (inner rod)	AA 6061	8.5	-	65



Experimental work to study feasibility

% energy of machine capacity	Discharge energy(kJ)	Result
60%	4.05	No Crimping
70%	5.5	Poor joint strength
75%	6.27	Proper joint

Optimized discharge energy is 6.27 kJ, Beyond that field shaper slit space is getting expanded.



Threaded sample

Plain sample

Knurled sample

Grooved sample

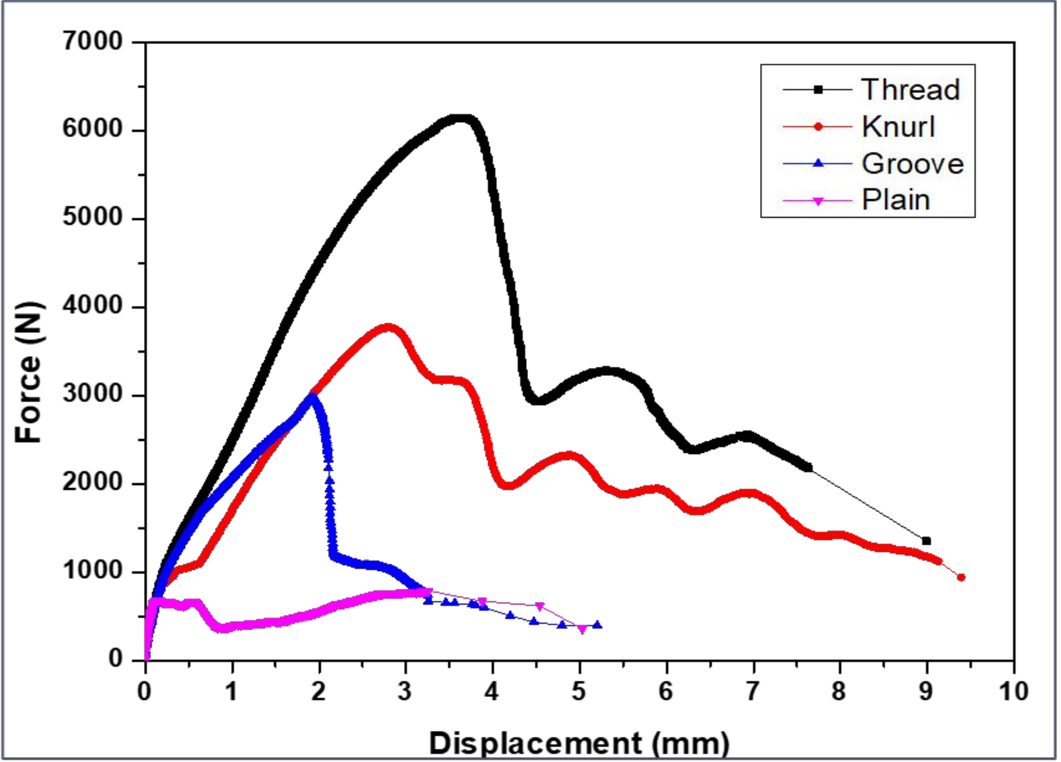


Figure: Variation in Pullout strength with different target rod surface geometry.

Pull-out test

Pull rate : 0.5mm/min

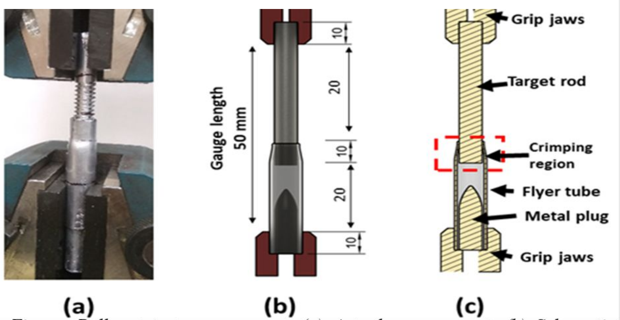


Figure: Pull out test arrangement. (a) Actual arrangement, (b) Schematic diagram, (c) Cross-sectional view.

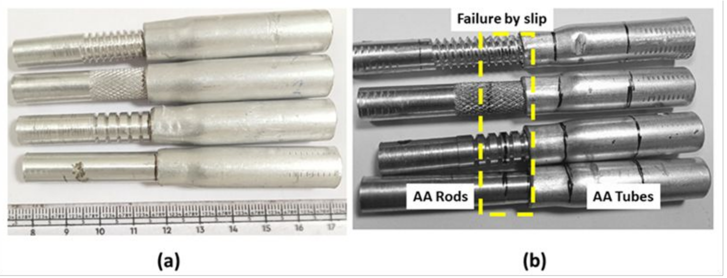
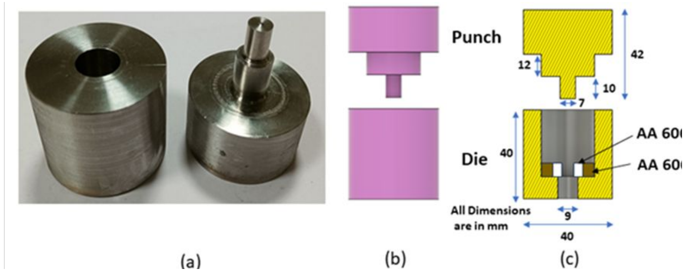


Figure: Pull out test samples (a) before the test and (b) after the test.

Compression shear test

Compression rate: 0.5mm/min



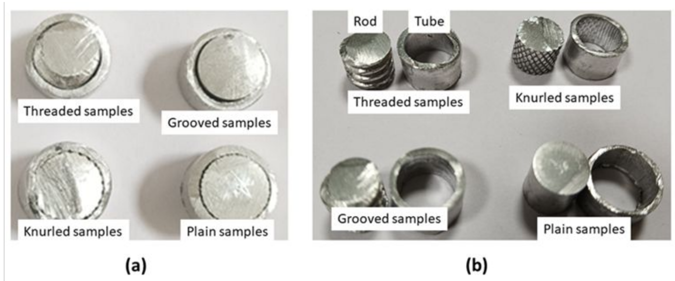


Figure: Samples (a) Before the test and (b) after the test

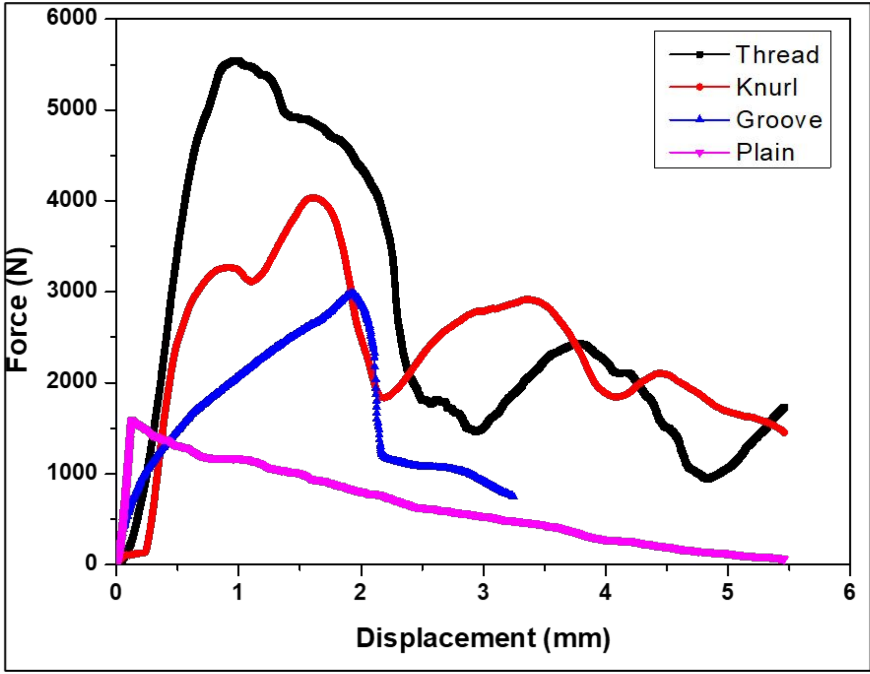


Figure: Variation in Compressive shear strength with different target rod surface geometry

Microhardness analysis

Vicker’s hardness test

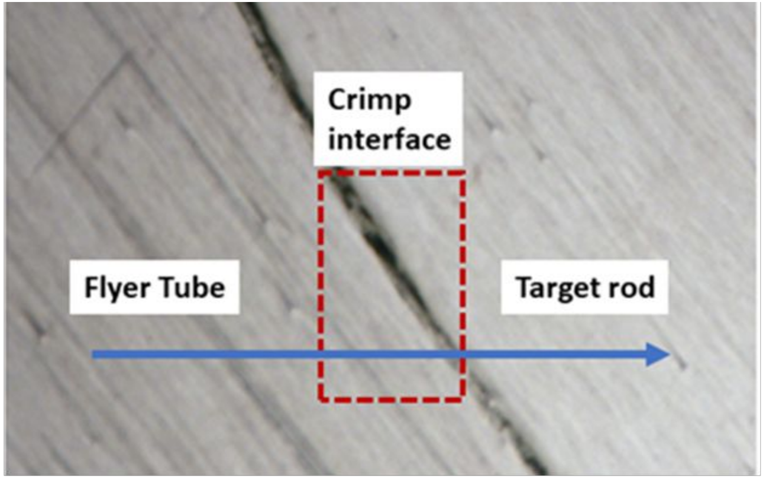


Figure: Representation of microhardness measurement direction.

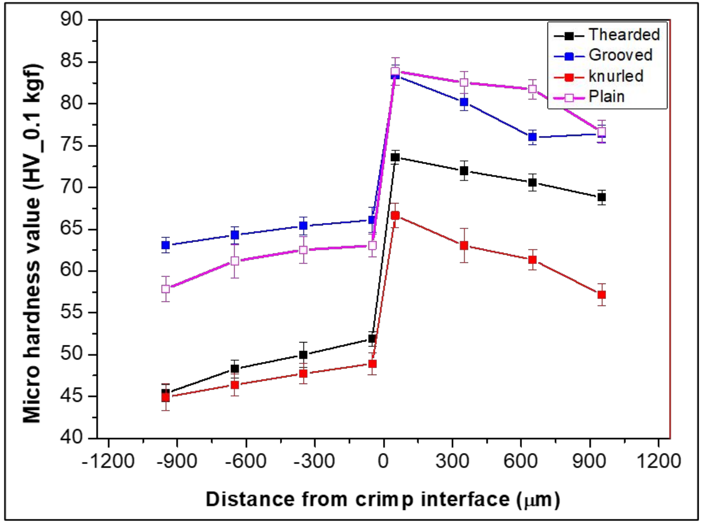


Figure: Variation of microhardness values across the interface at HV_0.1.

Cross-section analysis

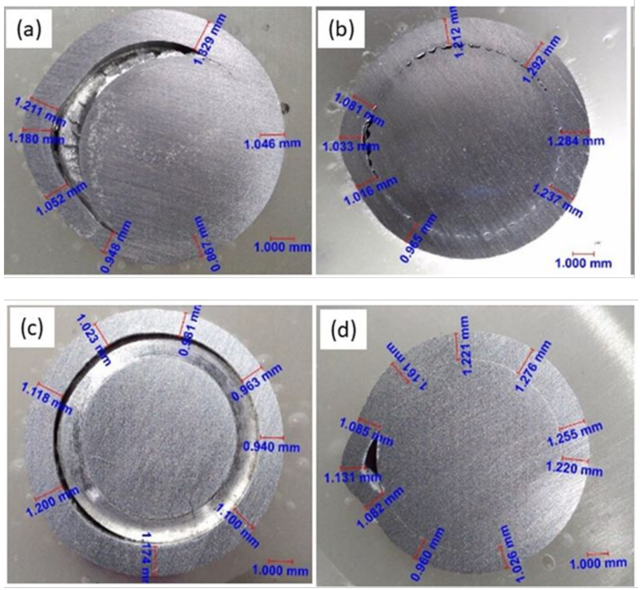


Figure: A radial cross-sectional view of crimped joints (a) Thread, (b) Knurl, (c) Groove, and (d) Plain sample

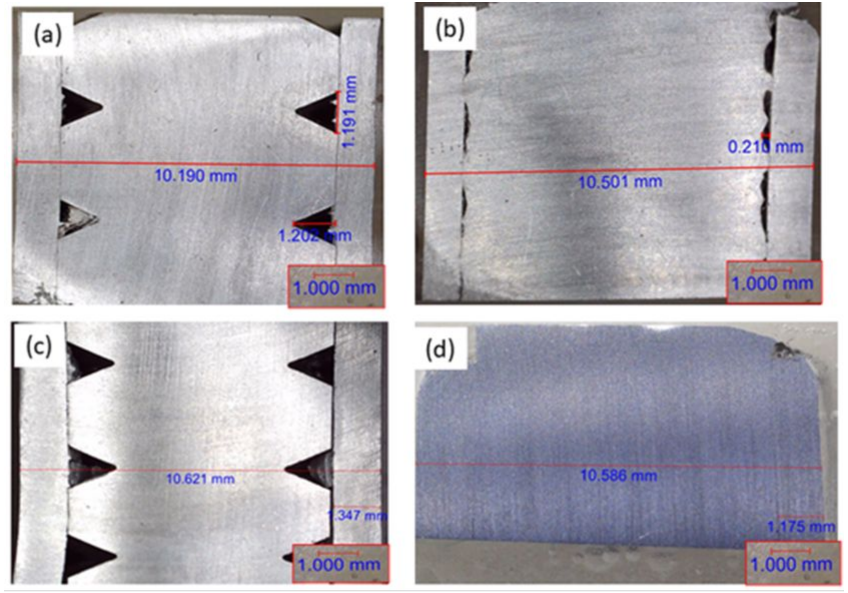


Figure: A longitudinal cross-sectional view of crimped joints (a) Thread, (b) Knurl, (c) Groove, and (d) Plain sample

Conclusions

- ➔ Using the electromagnetic forming machine, the AA6061 tube and rod are successfully electromagnetically crimped.
- ➔ Crimped joints at 6.27 kJ were analyzed for different surface geometries such as threading, knurling, grooving, and plain
- ➔ Pull-out test results show that threaded samples possess the highest pullout load bearing capacities of 6.14 kN among all other geometries.
- ➔ The threaded samples have the highest compressive shear load-bearing capacity (5.7 kN) of any geometries, according to the findings of the compression shear test.
- ➔ According to cross-sectional examination, the threaded samples had the highest maximum and lowest tube thicknesses of 1.329 and 0.867 mm, respectively, out of all the samples.
- ➔ Because of the high strain rate of plastic deformation and the high velocity impact, the hardness value of the tube and rod increases close to the contact.

References

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4. Rajak, Ashish K., and Sachin D. Kore. "Application of electromagnetic forming in terminal crimping using different types of field shapers." *Journal of Mechanical Science and Technology* 32 (2018): 4291-4297.
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THANK YOU