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Investigation of transient processes in magnetic pulse welding system using CMR B-scalar sensors.

Pavel Piatrou[1], Voitech Stankevic[1,2], Skirmantas Kersulis[1] and Nerija Zurauskiene[1,2]

[1]Department of Functional Materials and Electronics, Center for Physical Sciences and Technology, LT-10257 Vilnius, Lithuania;
[2]Faculty of Electronics, Vilnius Gediminas Technical University, LT-10105 Vilnius, Lithuania
Email: pavel.piatrou@ftmc.lt.

Magnetic pulse welding (MPW) is an advanced solid-state joining technique that uses transient electromagnetic forces to accelerate a flyer workpiece toward a parent workpiece, enabling high-velocity impact and metallurgical bonding between them. MPW is widely recognized for its ability to join dissimilar materials [1].

Direct experimental identification of transient process stages remains a significant challenge. The onset of flyer deformation and the precise moment of collision between workpieces occur on a microsecond time scale, while the process itself is accompanied by intense electromagnetic interference. Therefore, high-speed in-situ measurements of deformation, collision, and magnetic-field dynamics are difficult to perform using conventional diagnostic techniques.

This study presents an experimental and numerical investigation of transient magnetic field evolution during MPW of an AA6063 aluminum tube onto an AISI 304 stainless-steel rod. The main objective is to measure the magnetic field directly in the narrow 1 mm gap between the field shaper and the flyer tube and to correlate its dynamics with flyer deformation and impact. For this purpose, a non-invasive technique based on thin CMR B-scalar sensors was developed. In combination with the measurement module, these sensors enable orientation-independent real-time measurement of high-amplitude, microsecond-duration magnetic field pulses up to several tens of tesla, while suppressing parasitic electromotive forces.

To support the experimental findings and interpret the measured magnetic field dynamics, a coupled electromagnetic–mechanical model was developed in COMSOL Multiphysics. The mechanical performance of the welded joints was evaluated by tensile testing.

Overall, the results demonstrate that CMR B-scalar sensors with the measurement module provide an effective tool for direct measurement of transient magnetic fields in MPW. These measurements enable the identification of deformation and collision stages and can support further optimization of the process for industrial applications.

REFERENCES

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