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Toward energy-efficient multi-step electromagnetic forming process by using a curved-geometry field shaper: Principle, Prototype Design, and Experiments

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Electromagnetic forming (EMF) is an important application of pulsed magnetic field technology, which uses a pulsed magnetic field to induce a Lorentz force on a metal workpiece, thus shaping the workpiece into desired geometry. Compared to conventional forming processes, EMF can significantly enhance the formability of materials, making it a promising option for high strength metal alloys which generally have poor plasticity. However, due to severe mechanical and thermal loadings, the coil shall face a critical concern on its performance life when used for forming high strength metals.

One feasible method to overcome this barrier is using multi-step forming strategy, which replaces a single high energy discharge with multiple successive low energy discharges, thus incrementally shaping the metal workpiece into desired geometry. By using much lower discharge energy, this strategy significantly reduces the coil's loadings, thus effectively improving its performance life. However, for conventional coil design, the multi-step forming strategy could lead to a very low energy-efficiency, because the in-consistent geometries between the deformed workpiece and the coil would result in a weak electromagnetic coupling between them.

This paper shall overcome the above problem by using a novel field generator, which consists of a solenoid coil coupled with a curved field shaper made of conductive materials. While the solenoid coil creates a primary pulsed magnetic field, the dedicated field shaper further reshapes its spatial distribution toward maintaining a strong electromagnetic coupling between the coil and the deformed workpiece. To validate the effectiveness of the proposed process, we developed a prototype for the process, experimentally characterized its magnetic field distribution, and performed a series of multi-step EMF experiments on aluminum alloy 5083 sheet workpieces.

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