Lawrence Livermore National Laboratory,
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Laser Science & Technology

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Laser Peenforming—A New Precision Metal-Forming Technology

In a collaborative effort with Metal Improvement Co. Inc., of Paramus, N.J., we are evaluating the effectiveness of laser peenforming to precisely form metal panels for aerospace and defense applications. Using a kilowatt-class pulsed Nd:glass laser, we are able to selectively place residual compressive stress into the surfaces of thick metal panels to form them into precise and complex shapes without yielding the metal and leaving both surfaces in crack-resistant compressive stress state.

Similar to the laser peening process originally developed for increasing fatigue and corrosion resistance of metals, the peenforming technique, recently developed by LS&T, uses a high-energy and high-intensity solid-state laser to impress a deep level of residual stress into selected surfaces of the metal. The strain associated with the compressive residual stress causes the treated surface to elongate, effectively curving the metal within the peened area. By optimizing the process parameters such as laser fluence (~100 J/cm^2), intensity (5 to 10 GW/cm^2), and number and location of treatment pulses, we are able to precisely form a broad range of aluminum alloys to contours and shapes that could not be adequately made using conventional methods.

Figure 1 shows three aerospace-grade 2024-T-3 aluminum alloy plates 1 in., 3/4 in., and 5/8 in. thick formed by the laser peenforming technique. We were able to form them to precise curvatures and bend radius by adjusting the laser peening parameters and peening location. We have also formed a 5/8-in.-thick aluminum plate (Figure 2) into a precise saddle shape with 150-in. radius of curvature, concave and convex on alternating surfaces.

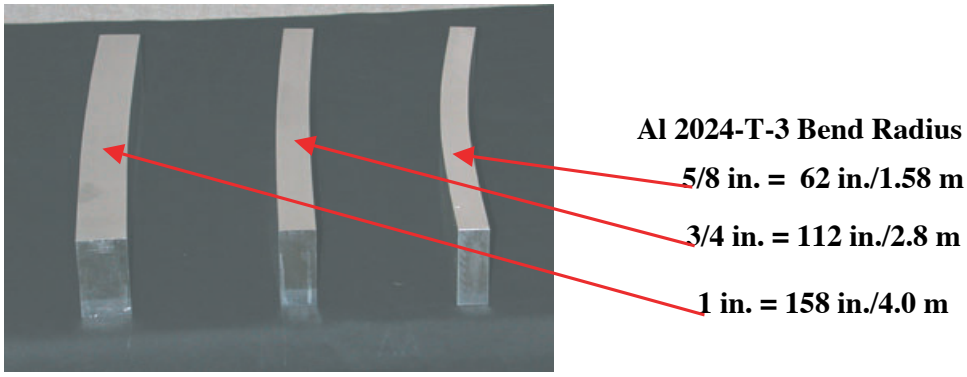

Figure1. Thick aluminum metal sections have been formed by laser peenforming without yielding the metal and leaving both surfaces in a crack-resistant compressive stress state.

Forming is critically important to the fabrication of structural wing skins for large commercial and military aircraft. Many components on aircraft such as wing skins, elevator and rudder panels, and winglets need to be formed to precise complex curvatures both to meet aerodynamic requirements and to fit precisely on the airframe for stress-free fastening. These structural components cannot be bent using conventional hydraulic or other force forming techniques because bending causes undesirable yielding of metal. Metal yielding causes loss of mechanical strength and always leaves surfaces in tension, thus susceptible to fatigue fracture and corrosion cracking. In the past, the aerospace industry has used an iterative forming process (repeated mechanical shot peening and thermal age creeping) to form and shape metal panels. This iterative process works well but is limited to only 7000 series aluminum to which age creep forming can be applied. The process is not precise, and parts have to be repeatedly treated and checked in a forming jig until the fit meets specification. Using laser peenforming, one could potentially make the 40-meter outer skin of an airplane wing fit precisely onto its frame with just one or two treatments.

Figure 2. A 5/8-in.-thick 2024 T-3 aluminum plate formed to a saddle shape by laser peenforming. Laser peenforming can form metal panels with complex curvatures.

The laser peenforming process will dramatically change aircraft manufacturing in terms of cost and efficiency as well as the introduction of a new capability for designing and forming of metal components. The ability to form large structural members using lighter-weight panels and fewer joints can significantly reduce aircraft weight and increase payload and fuel efficiency. We are working closely with industry to commercialize this technology.

—Lloyd A. Hackel

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