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Abstract title: Healing Fatigue Cracks in Aluminum Alloys

Aluminum alloys can have high strength-to-weight ratios that make them important materials for aerospace applications. For example, the airframe of the F-16 fighter jet is about 80% aluminum. Over many flights, metal parts in aircraft experience fatigue, which can lead to cracks and eventually catastrophic failure if left untreated. When aircraft parts exhibit cracks that need repair, some are hidden in areas that are difficult to access and require lengthy disassembly procedures. Unfortunately, this reduces the availability of aircraft for service, whether for civilian or military operations (the capable rate / up-time for most military fighters is roughly 50%). In this work, we propose a repair solution for airframes via a new surface treatment process that heals cracks in metals with minimal disassembly of the plane. Our crack-healing treatment enables the repair and reuse of aircraft parts in a continuous cycle towards infinitely repairable airframes.

In this work, we demonstrate the first recorded instance of transient liquid phase crack healing for metals. To test this process, we cracked, coated, heat treated, and then tested aluminum 7075 compact tension samples. In detail, these samples were subjected to cyclic loading until a proper crack formed as defined by the ASTM guidelines. We then electroplated a metallic coating on the samples before placing them in a vacuum tube furnace and heat-treating them. The electroplated metal on the surface of the samples melted and wicked into the cracks via capillary action.

The metals used as coating were zinc, copper, and tin. With our new crack-healing process, these metals healed the cracks in aluminum 7075 samples. Each treated sample was analyzed under a microscope to determine whether the crack had been sealed and healed through the treatment process. We found that the copper and zinc coatings healed the fatigue cracks. Testing is ongoing to optimize the heat treatment process (especially to reintroduce precipitates in the alloy via aging) and quantify the performance of healed specimens under subsequent fatigue loading. If successful, our new crack-healing process will be a step towards rapid repairs of aluminum aircraft parts, such as seaside repairs for the naval air defense fleet.