Press Release

Repair Rather Than Replace: EHLA Restores High-Strength Landing Gear Components

Landing gear assemblies are among the most heavily loaded parts of an aircraft. During takeoff, landing and taxiing, wheel axles, pistons, pins and other safety-critical components withstand substantial forces; at their functional surfaces, bearings, bushings and seals contact component surfaces. Friction, localized pressure peaks and repeated loading cause wear at these points. Cold, heat, moisture, kerosene, cleaning and deicing agents as well as ice, sand and dust also attack the surfaces and promote corrosion.

Landing gear assemblies are among the most heavily loaded parts of an aircraft. During takeoff, landing and taxiing, wheel axles, pistons, pins and other safety-critical components withstand substantial forces; at their functional surfaces, bearings, bushings and seals contact component surfaces. Friction, localized pressure peaks and repeated loading cause wear at these points. Cold, heat, moisture, kerosene, cleaning and deicing agents as well as ice, sand and dust also attack the surfaces and promote corrosion.

During landing gear maintenance, technicians remove components, clean and inspect them, and measure their dimensions. They grind away minor damage where repair limits permit. If too much material has been lost, replacement is often the only option. This increases costs, extends aircraft downtime and consumes resources.

Hard chromium plating traditionally protects functional surfaces against wear and corrosion. Stricter environmental and occupational safety requirements, however, are increasing the need for alternatives. Protection alone is not enough for damaged areas: A repair process must also restore lost material precisely without compromising the properties of the high-strength base material.

Conventional welding processes are only partly suitable for this task. Excessive heat can alter the microstructure of high-strength aerospace steels, affect their mechanical properties and cause distortion that changes component geometry. The heat-affected zone is particularly critical. A suitable repair process must, therefore, form a reliable metallurgical bond while limiting heat input.

LEGATO develops a new repair process chain

The LEGATO research project addresses this challenge. The broader project investigates several aspects of future landing gear systems, bringing together expertise from industry and research. As part of this effort, the Fraunhofer Institute for Laser Technology ILT is developing a laser-based repair process chain for heavily loaded landing gear components.

"Our research focuses on three steps," says Kim Julia Kallies, project manager at Fraunhofer ILT. "Restoring material locally, tailoring the mechanical properties of the surface layer, and reliably inspecting the resulting coating."

Industry partner Liebherr-Aerospace is contributing practical requirements from manufacturing, maintenance, and repair: actual components and damage patterns, as well as specifications regarding materials, hardness, surface quality, and low heat input. The associated partner, Hegenscheidt-MFD, is assisting the project with its expertise in roller burnishing and deep rolling processes.

"Ultimately, it is not enough for a coating to perform well in the laboratory," explains Harald Betsch of Liebherr-Aerospace, Senior Expert Thermal Spraying/Welding in Materials and Processes. "What matters is whether the process is suitable for real landing gear components under load, including their materials, damage patterns and repair limits. These are precisely the requirements we bring to LEGATO from development, manufacturing and maintenance."

EHLA deposits the material. This high-speed variant of laser metal deposition (LMD) uses a laser to melt metallic powder and deposit it locally on the component surface. EHLA's high processing speed and relatively low heat input make it particularly promising for heat-sensitive, high-strength materials.

For the project, Kim Kallies and her research group are investigating several material combinations relevant to the application. For example, the team has repaired 300M steel using matching material. For corrosion-resistant coatings, they are testing a martensitic stainless steel developed specifically for EHLA, among other materials. The researchers are also studying 15-5PH, a high-strength, corrosion-resistant steel used in landing gear structures.

One special characteristic of EHLA leads directly to the next step: Its processing speeds are much closer to those of mechanical machining processes than conventional LMD speeds are. This allows the team to combine material deposition directly with mechanical finishing—the approach behind SCaRB.

EHLA and roller burnishing in a single process

SCaRB stands for Simultaneous Coating and Roller Burnishing. It combines EHLA deposition with roller burnishing immediately afterward. As the laser deposits metallic powder onto the component surface, a burnishing tool follows at a defined distance, working the newly deposited layer while coating process is still underway.

EHLA's high processing speed makes this combination possible: Deposition and burnishing take place in a single process sequence. The team does not need to re-clamp the component between coating and mechanical finishing, thereby reducing setup time and taking advantage of the short interval between the two steps.

SCaRB does not only take advantage of EHLA's speed, but also of its residual heat. Shortly after deposition, the new layer is still warm and, therefore, easier to deform plastically. The distance between the laser and burnishing tool determines how warm and deformable the layer remains when the tool reaches it. This distance helps control surface characteristics, hardness and residual stresses.

Hegenscheidt-MFD has developed a burnishing tool for the process, which Fraunhofer ILT integrated into the machine. The team adjusts the burnishing force by changing the tool's feed rate and uses interchangeable rollers to select the radius and hardness appropriate for each application.

"The key for us is to use the layer while it is still warm, rather than finishing the EHLA coating in a separate operation afterward," explains the project manager. "Roller burnishing smooths the surface while also affecting hardness and residual stresses. SCaRB therefore turns material deposition into a process that lets us tailor the repaired area to its intended function."

Tailoring material properties

Restoring the original geometry alone is not enough to ensure that a repaired landing gear component performs as required. Its surface and heat-affected zone must also have properties suited to the loads they will encounter. This is SCaRB's principal advantage: The roller smooths the deposited layer, increases hardness near the surface and modifies residual stresses.

Depending on the process, deposition can generate tensile residual stresses, which promote fatigue cracks under cyclic loading. Roller burnishing reduces these stresses and, under suitable conditions, converts them into compressive residual stresses. The repaired area can, thus, be adapted not only geometrically but also functionally to its future loading conditions.

The team can control the desired properties of the repaired area by adjusting the process parameters. Laser and powder parameters, the distance between the laser and burnishing tool, burnishing force, roller radius and roller hardness all affect surface characteristics, hardness and residual stress to different degrees. The researchers then examine coating adhesion, microstructure, hardness, residual stresses, surface quality and, above all, fatigue behavior under realistic loads.

Fatigue strength is particularly important for landing gear components because they have to repeatedly withstand high mechanical loads during operation. The next phase of research will investigate how the residual stresses introduced by SCaRB affect the service life of repaired components. Throughout their service life, the components must continue to meet the required performance specifications.

The repair process chain also needs a suitable inspection process, which is where Fraunhofer IWS comes in. This institute contributes LAwave, short for laser-induced surface acoustic wave spectroscopy. A laser generates acoustic surface waves, whose behavior is analyzed to provide precise information about the near-surface properties of the coating and the material beneath it—without damaging the component.

LAwave fills a crucial role in the process chain: EHLA rebuilds material locally or creates a protective layer, SCaRB mechanically adjusts the surface and edge zone, and LAwave provides non-destructive data on the treated areas. This brings repair, function, and inspection closely together.

Further development and qualification will be needed before this approach can become a standardized aerospace repair process. The team is currently transferring its findings to real

component geometries and representative loads and gathering the evidence needed for possible future use.

Toward an automated repair process chain

In the long term, LEGATO aims to establish a fully integrated digital repair process chain. It begins with an automated scan of the damaged component. Using the geometry data, the system determines the extent of the damage and the amount of material lost, then calculates the tool path for subsequent deposition.

EHLA restores the damaged area locally. Immediately afterward, the SCaRB tool works the newly deposited layer to tailor the surface and edge zones. Depending on the functional surface, a targeted polishing or grinding step follows. Nondestructive inspection completes the sequence.

The envisioned system will carry out all these steps in a single setup, without re-clamping the component between operations. Scanning, deposition, mechanical finishing and inspection will no longer be separate operations but interconnected stages of one process chain.

Liebherr-Aerospace Lindenberg GmbH
Specialist in integrated aerospace systems

Founded in 1960, **Liebherr-Aerospace Lindenberg GmbH** employs approximately 4,000 people at its site in Lindenberg, Germany. The company develops, manufactures and supports integrated systems for the aerospace industry. Its portfolio includes landing gear systems, flight control and actuation systems, gearboxes and electronics. It has also established a successful presence in the rapidly growing advanced air mobility market. Liebherr-Aerospace handles key aspects of landing gear development and support, from engineering and design to load and fatigue calculations, manufacturing, testing and maintenance. Among the structural components it develops and manufactures are main fittings, sliding tubes, struts, locking elements, wheel axles and drag braces.

EHLA

EHLA stands for Extreme High-Speed Laser Material Deposition (from the German "Extreme Hochgeschwindigkeits-Laserauftragschweißen"). The process uses a laser to deposit metallic powder locally onto a component surface. This creates a metallically bonded layer that replaces missing material or serves a protective function. Compared to conventional LMD, EHLA operates at higher process speeds and with lower heat input. This is advantageous for high-strength aerospace steels because less heat enters the base material.



Image 1:
Landing gear component test rig: This setup allows researchers to investigate the loads experienced by safety-critical components in service. Wheel axles, pistons, pins and contact surfaces for bearings, bushings and seals are subject to particularly high stresses.
© Liebherr-Aerospace Lindenberg GmbH.

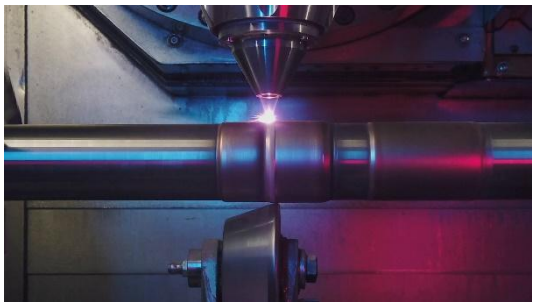


Image 2:
A machine setup was developed to combine EHLA and roller burnishing in a coupled process. Hegenscheidt-MFD developed a burnishing tool that was integrated into the machine turret.
© Fraunhofer ILT, Aachen, Germany.

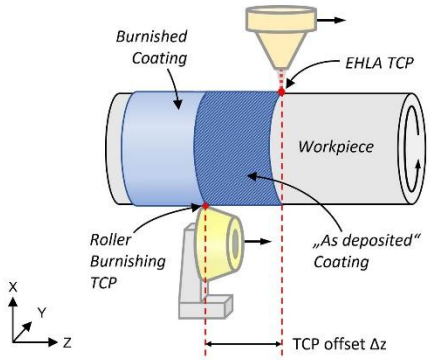


Image 3:
SCaRB combines EHLA and roller burnishing in one process. The burnishing tool uses residual heat from deposition to plastically deform the surface and near-surface region. The interaction between laser-to-roller distance, burnishing force and roller radius is critical.
© Fraunhofer ILT, Aachen, Germany.

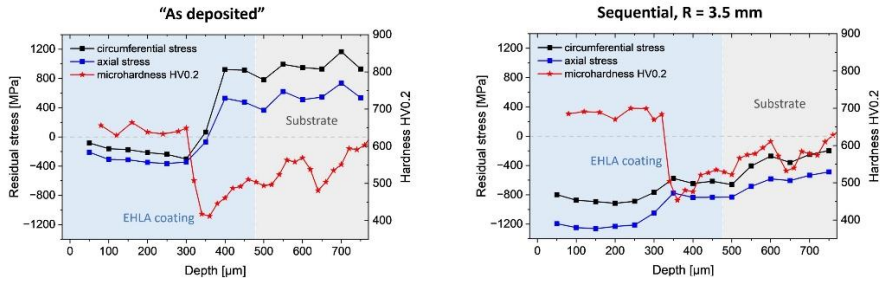


Image 4;
Comparison of an EHLA coating before and after roller burnishing: The graph on the left shows the layer immediately after deposition; the graph on the right shows it after burnishing. Roller burnishing substantially changes residual stresses and microhardness through the depth of the material, shifting the near-surface stress state toward beneficial compressive residual stresses.
© Liebherr-Aerospace Lindenberg GmbH.

The Fraunhofer-Gesellschaft, headquartered in Germany, is a leading organization for applied research. It plays a pivotal role in innovation by focusing on cutting-edge technologies and transferring research results to industry in order to strengthen Germany as a business location and benefit society. Since its founding as a nonprofit in 1949, Fraunhofer has held a unique position in the German research and innovation ecosystem.
With more than 30,000 employees at 74 institutes and independent research units in Germany, Fraunhofer operates with an annual budget of 3.6 billion euros. Contract research, Fraunhofer's mainstay, generates 3.2 billion of this budget.

Contact

Technical Contacts

Kim Kallies
Fraunhofer Institute for Laser Technology
Group Coating LMD and Heat Treatment
Phone +49 241 8906-556
kim.kallies@ilt.fraunhofer.de

Viktor Glushych
Fraunhofer Institute for Laser Technology
Group Leader Coating LMD and Heat Treatment
Phone +49 241 8906-152
viktor.glushych@ilt.fraunhofer.de

Press Contact

Petra Nolis
Fraunhofer Institute for Laser Technology
Communications
Group Manager
Phone +49 1714115001
petra.nolis@ilt.fraunhofer.de

www.ilt.fraunhofer.de