

Laser-Based Repair System Reclaims High Value Military Components

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Repair operations such as welding extend the life of high-value components in aircraft, tanks, and other military vehicles. In many cases, however, high-temperature welding processes will distort and weaken delicate metal components. Deemed irreparable, these expensive components are scrapped and replaced with new parts. Due to the age of some weapon systems, many times it is difficult locating new parts via the supply chain.

To reclaim damaged parts, military facilities are turning to a new repair technique called Laser Engineered Net Shaping, or LENS™. In a LENS machine, designed by Optomec Inc. (Albuquerque, NM), a laser beam is directed towards a small area on a damaged metal component, producing a molten puddle. A nozzle blows metal powder into the puddle, which quickly solidifies creating a metallurgical bond with the part. A repair tool path is created using a vision system to deposit the lines of metal, guided by a computerized blueprint. LENS deposits one layer on top of another until it has created the desired repair.

The LENS process induces much less heat into a part than conventional welding techniques, greatly reducing the heat-affected zone (HAZ). Critical areas of a part can be compromised with distortion and cracking by the formation of a large HAZ. LENS can repair components that cannot take the heat from other welding processes.

What's more, LENS produces fully dense features with greater strength and ductility than conventional welding methods. The process is also much faster, more cost-effective, and wastes less material than its competitors.

By giving new life to high-priced Abrams M1 tank engine components, LENS is saving DoD millions of dollars a year. The savings are sure to grow as more repair facilities adopt the technology to rescue damaged metal parts from the scrap heap.

1.0 BACKGROUND: STATEMENT OF THE PROBLEM

To extend the life of aging aircraft, combat vehicles, artillery and small arms for the Department of Defense, there is a need for more sophisticated component repair and overhaul (R&O) techniques. This includes improving existing methods, as well as developing novel processes to enhance repair capabilities. Components such as turbine blades, vanes, impellers, stator assemblies, and rotating air seals are just a few types of the high cost components requiring repair to extend weapon system life. Due to corrosion, fatigue, wear, stress and damage, components require repair or replacement during the overhaul process.

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As tanks, ships, submarines, and aircraft continue to operate beyond their intended life, part obsolescence management becomes an increasing challenge for asset sustainment, compromising military readiness. Vendor attrition, supply base degradation, long lead times for forged & cast parts, lack of available technical data packages, and logistics management are becoming more common, significantly increasing the cost of sustainment. If an overhaul line is stopped because a component is unavailable, the cost of the component itself becomes irrelevant compared to the cost of the delay.

The performance and reliability of components and assemblies are critical to insure that weapon systems are combat ready. For some parts, a hard facing layer may provide an adequate solution for wear and/or corrosion resistance. However, many other critical components, made from difficult to process materials, require more complicated repair processes. These repairs can involve three-dimensional features, radial oriented structures and directionally solidified or single crystal materials.

Many of today's repair procedures give inconsistent results and do not lend themselves to automated operations. Manual processes such as welding can add several variables into the repair process that could affect the quality and the cost of the finished product. Operator fatigue, skill, experience, humidity and other environmental factors present variables which have a direct effect on repair reliability and repeatability.

Due to exacting metallurgical requirements for many gas turbine engine components, traditional repair technologies have compromised part integrity, deeming some components non-repairable. Traditional repair techniques have failed for many reasons, including:

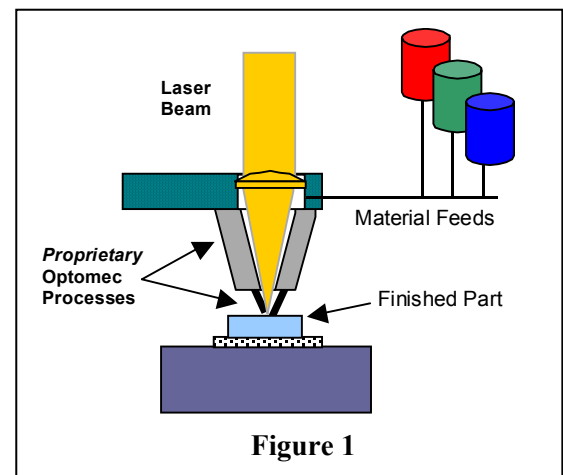
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| ❶ excessive heat input causing part distortion | ❷ inconsistent manual processes |
| ❸ uncontrolled atmosphere and process environments | ❹ dwindling welding artisan skill base |
| ❺ unacceptable material properties (i.e.: porosity) | ❻ lack of in-situ process controls. |

In summary, there is a need for improved repair techniques to provide cost avoidance for both defense and commercial enterprises. Such techniques can also provide benefit in lead-time reduction, quality improvement and repeatability.

1.1 LENS OVERVIEW

Developed at Sandia National Laboratories, Optomec's Laser Engineered Net Shaping (LENS) direct metal deposition technology provides a solution to reduce repair costs and provide higher quality parts when compared to traditional repair methods. A high-powered laser beam is focused onto a part where metallic powder is injected under computer guidance to build up three-dimensional layers, until the part repair is complete. The LENS machine is used to build material up on the surface of an existing component, and is able to restore the original material that has been lost due to wear, mis-machining, impact or other damage. Refer to Figure 1.

LENS generates very little heat, keeping the Heat Affected Zone (HAZ) size to a minimum. Since the HAZ does not spread to critical areas, LENS can repair parts once classified as non-repairable due to strength loss or distortion that is caused by heat from a conventional welding process.



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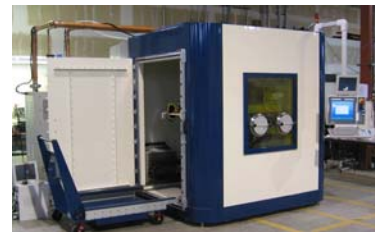
In most cases, the tiny molten pool produced by LENS cools at a rate of 1000-5000°C per second. This rapid solidification typically gives greater strength and ductility in the metal deposit than do other welding techniques. In some cases, LENS repairs exhibit mechanical properties that are superior to the original material. This translates to components that can stay in service longer after repair than before. LENS repairs also exhibit no sink or undercut, further increasing the range of repair possibilities.

The LENS process produces fully dense material, which eliminates the need for heat treating for many applications. The LENS process is performed in an inert atmosphere which can be operated unattended for extended periods of time. The same system can be used for repair, surface treatments, and fabricating three-dimensional metal parts.

LENS technology offers many advantages over traditional repair techniques (ie: TIG Welding) and other Laser Cladding Systems (ie: CO2 laser based systems). A few advantages include:

- 1) Process automation with closed loop feedback to provide precise control over deposition parameters. LENS' automated control system removes many operator manual functions, while at the same time producing material with superior mechanical properties. LENS does not require the service of skilled artisans with years of experience, as required for manual welding repair.
- 2) A single LENS system can repair components of many materials, including 316 stainless steel, Inconel 625, titanium, as well as many nickel-based super-alloys, including Waspalloy.
- 3) LENS introduces very significantly less distortion into the part than welding techniques, due to the low-power laser used.
- 4) LENS deposits materials in almost the exact amount required, minimizing post process cleanup and machining. For example, after the repair of a blisk fan blade, machining away the excess material took only one minute, compared to 30 minutes of machining required to remove large amounts of titanium deposited via a conventional welding technique.

Besides the laser, LENS is comprised of an integration of numerous sub-systems including an atmosphere controlled chamber, powder feeder(s), motion control hardware/software, "teach & learn" repair tool path software, closed loop sensors & software to monitor and dynamically change process parameters, parts handling for chamber entry & exit, and part fixturing. A Class I laser enclosure is provided to offer safe operation without the need for laser safety glasses.





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