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RESEARCH ON LASER CLADDING REPAIR AND ENGINEERING APPLICATION OF HIGH-STRENGTH PRECIPITATION-HARDENING STEEL XM-25

Abstract. XM-25, a high-strength martensitic precipitation-hardening stainless steel used in steam turbine blades, suffers from water erosion. This study restores large XM-25 blades using DED laser cladding. Results show enhanced tensile strength (>1200 MPa), yield strength (>1050 MPa), microhardness (>415 HBW), reduced residual stress, and 95% higher fatigue limit. The cladding layer demonstrates effective precipitation strengthening with uniformly dispersed strengthening phase particles, confirming restoration effectiveness.

Key words: Martensitic, Precipitation hardened,DED, Laser Cladding, Repaire

Introduction. Precipitation-hardened martensitic stainless steels, like 17-4PH, 15-5PH, and 13-8Mo, have gained significant attention due to their high strength, corrosion resistance, and application in industries such as aerospace and power generation. ASME A705_XM-25, a higher-strength alternative, combines elements from 17-4PH and 13-8Mo, offering improved wear and corrosion resistance, making it ideal for demanding applications like steam turbine blades. However, despite its enhanced properties, XM-25 faces issues with surface wear and water erosion, especially in turbine blades exposed to high-speed steam-water mixtures. To address these challenges, laser cladding technologies, such as Directed Energy Deposition (DED), have been explored to restore and enhance the material's surface performance. Laser cladding enables improved wear resistance, reduced thermal deformation, and stronger metallurgical bonds compared to traditional methods. While much research has focused on materials like 17-4PH, limited studies have been conducted on XM-25, highlighting the need for further investigation into its laser cladding performance. This study aims to evaluate the effectiveness of laser cladding on XM-25, using different alloy powders to improve wear resistance, corrosion resistance, and overall material strength, ultimately offering solutions for turbine blade restoration and surface modification.

Research methods and results:

Table 1. The Chemical Composition of XM-25 Blade and the powders (%)

Material	C	W	O	Mn	Si	Cr	Ni	Cu	Mo	Nb	Al	V	Fe
XM-25 Blade	0.039	0.01	0.016	0.55	0.30	14.62	6.75	1.56	0.68	0.52	0.007	0.061	**Bal**
XM-25 Powders	0.035	0.01	0.013	0.54	0.30	14.37	6.66	1.56	0.69	0.50	0.014	0.062	**Bal**

This study investigates the repair of water-eroded low-pressure turbine blades made from XM-25 alloy using Directed Energy Deposition (DED) laser cladding and subsequent aging at 480°C for 4 hours. The repaired blades were tested for mechanical performance, microstructure, and fatigue resistance.

The cladding powder, derived from XM-25 material and processed using vacuum air atomization, was applied using a Trumpf 8000W laser and a KUKA robot. The repaired blades underwent non-destructive testing (PT and RT) to check for defects, revealing no significant macroscopic flaws.

Tensile tests indicated that the tensile strength of the repaired blades exceeded 90% of the base material's strength, and the yield strength improved significantly after aging, meeting engineering requirements. Microhardness testing showed that the cladding layer had higher hardness than the base material, contributing to improved erosion resistance. Metallographic analysis revealed columnar crystals and a precipitation-hardening phase that enhanced the mechanical properties. Fatigue testing demonstrated that the fatigue strength of the repaired blades reached 586.25 MPa, 95% of the base material's fatigue strength, confirming the repair's suitability for engineering applications. Residual stress in the cladding area was approximately 30% of the material's yield strength, indicating minimal deformation. High-cycle fatigue tests further validated the repair's reliability.

Conclusions. DED laser cladding combined with aging treatment is an effective repair method for restoring turbine blades, providing improved mechanical properties, erosion resistance, and fatigue life, ensuring its feasibility for long-term operational use in power plants.

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