Influence Of Laser Cladding on Behavior of Fatigue and Fatigue Corrosion

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Abstract. Nickle based super alloys such as Inconel 600 are being extensively used to manufacture turbine blades for jet engines since their superior mechanical characteristics at higher working temps. The chemical composition of steam turbine blades show that is steel 52 it has a wide range of Energy, Tanks, Rail, Yellow Goods, Engineering, Bridges, Construction, applications. Laser cladding seems to be a surfacing method that uses lasers to improve the characteristics of a component's surface and/or renew it. Laser cladding involves absorption of laser light that melts a small area of the substrates against which the substance was being introduced and fuses the coating substance to the substrates, resulting in the formation of a new layer. This research aims to investigate the fatigue and fatigue corrosion behavior of these turbine blades before and after exposure to laser cladding. The cladding process applied with this parameter Pulse energy = 11 joules, Pulse width = 6 Ms., Pulse frequency = 12 Hz, Laser Average Power = 132 W, Laser peak power = 1.83 KW. The results show, after cladding process the microstructure of the specimen is smooth and increase the cyclic of fatigue comparison with specimen without laser cladding process. So, the fatigue resistance is increased.

Keywords: Turbine blades, Fatigue failure, remelting process.

1. Introduction

The turbine steam blades transform the linear motion of high pressure and high temp steam flowing down a pressure difference into a rotational motion of the turbine shaft in power plants. Power stations will shut down if turbine blades fail [1–3]. These substances may be used in corrosive and/or high-temp settings including rotors, turbine blades, and steam pipes [4]. The steam environment isn't only pure steam; it's also full with hazardous pollutants. Oxidized scale from the super heaters, dissolving from the vapor in the boiler feed water, or dissolving in the mist following saturated steam are all examples of impurities [5]. On turbine blade deposits, more than eighty different chemical substances including sulfate, silicate, and oxide, and oxide have been discovered.

The majority of compounds have been washed away with water during the turbine's wet phase. Contaminants accumulate in irregular sections of the turbine during the wet–dry alternating stage. It is well accepted that corrosion fatigue failure of steam turbine blades happens in a repetitive stress region if contaminants concentrate in the low-pressure steam turbine's wet–dry alternating stage [6]. The flaws that lead to steam turbine failure may be caused by the deterioration of turbine service over time, in which the blades develop severe irregularities in the minimal throat. The most significant turbine's components in power production are becoming the blades of the final stage in the LP. In power plants, these blades provide 10–15 percent of overall steam turbine efficiency [7].
Surface cladding using a laser is a well-known method for obtaining wear and corrosion resistant coatings or repairing damaged components [1]. Laser cladding is indeed a surfacing method that uses lasers to improve the characteristics of a component's surface and/or renew it. Laser cladding involves absorption of laser light, which melts a small area of the substrates where the coating substrate was introduced and fuses the coating substrate to the substrates, resulting in the formation of a new layer. Laser cladding seems to be superior to other thermo-mechanical mechanisms based on its ability to generate lower dilution levels and finer micro-structures in the clad layer; as a result, this technique has been used to improve surface characteristics, such as resistant against corrosion, wear resistance, and surface hardness [8].

Brazing an erosion shield often at open arc hard facing, the turbine blade's leading edges, and cladding with materials resistant against erosion utilizing gas tungsten, manual metals, or plasma transferring arc welding are all traditional methods for extending service life. Since 2001, the researchers were researching the application of laser cladding technologies to deposit a highly-quality, erosion-resistant protective layer on the leading edge of Low-pressure blades [9]. The turbine blades' leading edge of a lower-pressure (LP) steam turbine is degraded in service by water droplets in the steam environment in the power generating sector. Due to its ability to create controlled diffusion and fusing bonding between the substrate and clad's layer, as well as minimal distortion, laser cladding was shown to be the best method for repairing turbine blades [10].

Laser cladding involves melting and fusing a metal alloy powder onto a substrate with characteristics that are comparable to or better than those of the application. The powder alloy may be adjusted by altering the alloying compositions of the powders to maximize the mechanical characteristics, which is a significant benefit of laser cladding. Since aerospace elements are bigger, more complicated formed, laser cladding is especially well suited to them, and if the procedure is effective, it will result in significant cost savings [11]. The purpose of this research was to investigate the impact of the cladding procedure on fatigue resistance utilizing Inconel alloy.

2. Experimental work

2.1. Material Selection
This project utilized a part of the damaged steam turbine blades from the Al-Doura thermal power's plant. Table 1 shows the chemical analysis of the blades.

| Table 1. Chemical composition of S52 |
|--------------------------------------|
| **Element wt.%** | Fe | C | Si | Mn | Cr | Mo | Ni | AL |
| Measured wt% | 85.5 | 0.204 | 0.342 | 0.540 | 12.8 | 0.0782 | 0.355 | 0.0210 |
| **Element wt%** | Co | Cu | Nb | Ti | V | W | Pb |
| Measured wt% | 0.0298 | 0.191 | 0.0036 | 0.0040 | 0.0164 | <0.0400 | <0.0150 |

2.2. Specimen Preparation
To conduct the electro-chemical testing, a section of a steam turbine's blade has been sliced into a 30 mm x 90 mm shape with a 2mm thickness, as illustrated in Figure 1. After cutting, the samples have indeed been ground with abrasive papers in a series of 2000, 1200, 800, 600, 400 and 300 grit using a Grinder and Polisher MoPao 160E to achieve a level and scratch-free surface.
2.3. Corrosion Test

Corrosion measurements for samples have been conducted in corrosion fatigue devise in production Eng. and metallurgy department in university of technology. in two grope first grope in air after laser cladding and second grope in solution after laser cladding (The solution may provide reliable measurements of the corrosion rate by simulating the steam environment in the final stage of steam turbine blades under constant circumstances). We used the same solution that used in Al-Doura power plants. The properties of the solution vapor used was 100c temperature with 3ml per min velocity.

2.4. Cladding process

By interacting with powder material with a laser beam, a molten pool of blown or pasted powder was created on the substrate. This contact period is critical for achieving the required cladding results. Cladding was performed on all specimens in INLC (Iranian national laser center) using a laser system, Laser Peak Power = 1.83 KW with a Pulse energy = 11 Joule.

3. Results and Discussion

3.1. Corrosion Behavior

Figure 2 and figure 3 illustrates the number of cycle for fatigue corrosion of specimen in air and number of cycle for fatigue corrosion in solution. number of cycle of fatigue corrosion in air was 46427 while the number of cycle of fatigue corrosion for specimen in solution was 33452. The number of cycle is obtaining from corrosion fatigue devise in counter of cycle.
Figure 2. Fatigue specimen in air

Figure 3. Fatigue corrosion of specimen in solution

In Figure (2 and 3) show that the fatigue resistance for specimens after laser cladding in air was more than the fatigue resistance for specimens in solution because the specimens in air it take more cycle before failure occurs.

3.2. Laser cladding process

Before cladding, the specimens have been cleaned by emery paper for removing the oxidization layer. Cladding has been conducted on all samples by using alloys of Inconel and a laser system was, Laser Peak Power = 1.83 KW with a Pulse energy = 11 Joule. The number of fatigue cycle for specimen after laser cladding in air was (55774), and the number of fatigue cycle for specimen after laser
cladding in solution was (24450). Figures 4, 5, 6, 7 shows the behavior of fatigue corrosion for steam turbine blades after laser cladding.

![Figure 4](image1.png)

**Figure 4.** Fatigue specimen in air after laser cladding

![Figure 5](image2.png)

**Figure 5.** Fatigue corrosion of specimen in solution after laser cladding

Figure (4 and 5) show that the fatigue resistance for specimens in air after laser cladding was more than the fatigue resistance for specimens in solution after laser cladding because the specimens in air need more fatigue cycles before failure specimens occurs.
In Figure (6 and 7) show the comparison between the fatigue specimens in air without any addition and fatigue specimens after laser cladding. The curves show that fatigue resistance for specimens in air after laser cladding was more than the fatigue resistance for specimens in solution after laser cladding because the specimens in air need more fatigue cycles before failure occurs.
3.3. SEM inspection

Scan Electrons Microscope (SEM) was used to examine the sample's particle dispersion and surface topography. Figures 8 demonstrate the SEM before corrosion the microstructure of steam turbine blades is ferrite and perlite. The microstructure of steam turbine blades is about bolls of ferrite with white color and perlite with black color. Figure 9 show the specimen surface in air for dry fatigue Shows the start of specimen’s failure due to the rotary motion of the blade. Figure 10 show the specimen surface in solution for liquid fatigue. This figure shows more than one crack occur in specimens because of fatigue corrosion. Figure 11 shows the specimen surface after laser cladding it is show that the specimen consists of two layer first one was the substrate and the second layer was laser cladding. It has been shown that a short contact period generates fine microstructures with low dilution and therefore greater hardness than a longer interaction duration with coarse structure, more dilution, and a lower hardness magnitude [12].
Figure 9. SEM for st.52 after fatigue in air

Figure 10. SEM for st.52 after fatigue corrosion in solution
Figure 11. SEM for st.52 after laser cladding

4. Conclusion

- Owing to the combination of a laser clad's layer, specimens produced by laser clad have a shorter fatigue life than specimens of similar size with absence of cladding.
- As a consequence of the propensity laser clad's layer samples, expanding the coating thickness decreased the strain rate of laser clad samples with the similar final structure size.
- The fatigue resistance of the specimen in air is better than the specimens in solution because of the number of cycle for fatigue test in air was (46427) and the number of cycle in solution was (33452) while the number of cycle for fatigue test after laser cladding in air was (55774) and the number of cycle in solution was (24450).
- According to the findings that gained from the SEM inspection, there are more than one layer obtained after laser cladding first layer was the base material and the second layer was laser cladding.

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