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Laser cladding and applications

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Abstract
Laser coating is a material placement technique wherein a powder material is melted using a laser to coat a portion of a substrate. In this study, laser cladding and its applications are reviewed. First, the background of the technique and its important parameters are highlighted. Then, the control of the laser cladding procedure is criticized. As an example of the process, laser cladding of titanium alloys is investigated. Finally, applications of laser cladding on gas turbine engines, dies and drilling spindles, tools, and turbine blades are highlighted.

Keywords: Laser cladding, Applications, Ti-alloys, Biomaterials

1. Outline

With the fast development of laser claims and the decrease in the price of laser structures, laser material dispensation has added an increasing position in various productions such as aerospace, automotive, defense, and navy. In recent years, laser technology applications are gaining substantial attention because of their spread possibility for material dispensation for example laser and metallic coating. Laser coating is a mutual technology using design (CAD) and manufacturing sensors, robotics, and powder metallurgy. Laser plating uses a laser warmth basis to sum a skinny stratum of the anticipated metal onto a movable substrate. The accumulated stuff can be conveyed to the substrate by various approaches. The laser coating process offers an additive manufacturing and prototyping technique and allows complex components to be produced without intermediate steps. Laser plating proposes many compensations over traditional coating procedures such as arc welding and plasma spraying, with negligible distortion and improved surface quality. There is also a number of benefits to using this method as a rapid prototyping practice.

Rapid prototyping can be utilized to yield part homogeneous structures and improved mechanical properties. Parts produced utilizing the method are close to net shape, nonetheless, often need post-processing. Because of its additive environment, laser plating can be practiced in a diversity of parts, tools, and innovative production to overwhelm the boundaries of current metal production machineries. This provides a number of advantages such as [1, 2]: reduced production time, improved thermal control, part repair, fabrication of a functionally rated part, and production of the smart structure. Notwithstanding its clear profits, laser plating is not hitherto extensively used in metallic coating applications. Though laser plating proposes some compensations over traditional production machineries, the procedure may besides have disadvantages such as quality differences. High asset price, low efficiency of laser sources, and absence of control in coating are drawbacks of this equipment. However, high-power diode lasers (HPDL) show countless industrial potential for utilization in metallic coating requests. In this study, laser cladding will be overviewed introducing laser cladding equipment, controlling of laser cladding process, laser cladding of titanium alloys as well as practical applications will be highlighted.

2. Background

2.1. Laser material methods

A laser beam offers exclusive properties for material dispensation. The electromagnetic radiation of a laser beam is engrossed by the surface of opaque materials. The contact time between material and laser causes different procedures as revealed in Figure 1 [3]. These processes result from dissimilar groupings of absorption and heat conduction. Laser plating is one of the significant sorts of laser material dispensation, wherein a laser beam irradiates powder particles. A thin layer named "coating" is formed on the substrate.

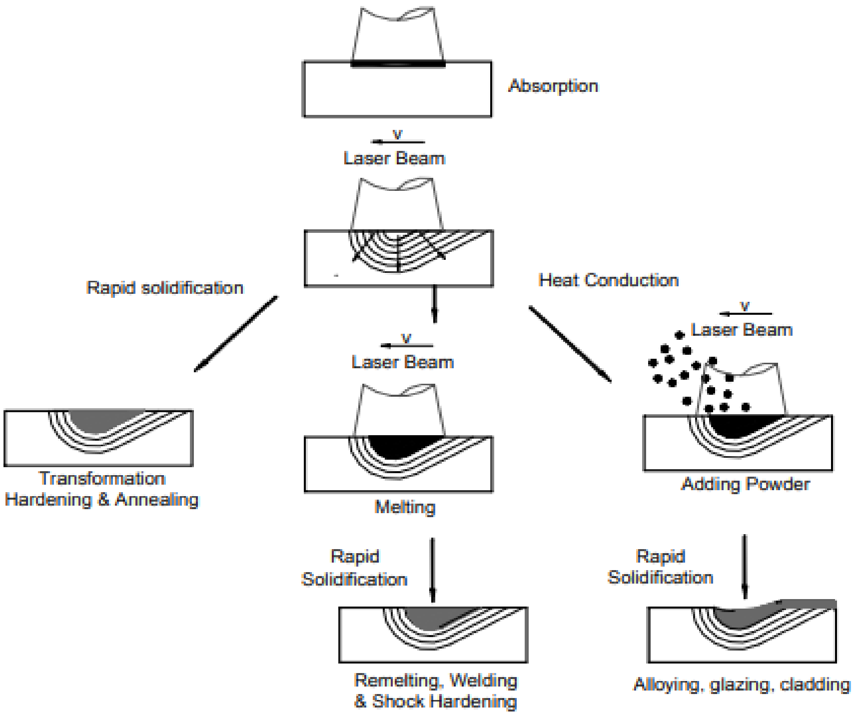

Figure 1. Diagram of different laser processing techniques [3]

2.2. Differences between laser plating and alloying

Adding powder to the molten pool can result in laser plating, glazing, and alloying yields, depending upon the category and quantity of additional material. Figure 2 shows plan cross-sections of the coating-substrate pair for these three procedures [3]. In laser alloying, a slight quantity of powder is nourished into the melt pond. In this way, consistent intercourse can be achieved through the melt zone [4]. Laser plating is similar to laser alloy except that dilution is reserved to the least and more substance is added to the surface [1].

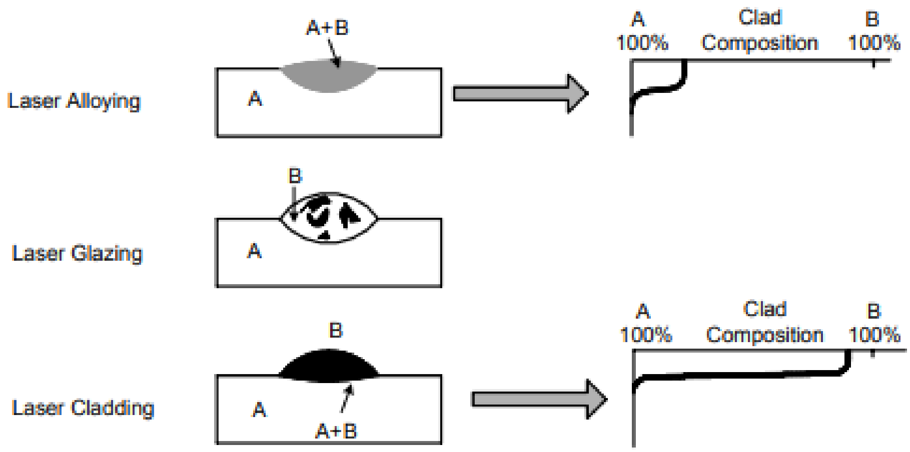

Figure 2. Different micrographs of laser cladding [3]

By utilizing laser plating, the subsequent compensations can be achieved associated with other surface material treating [5]:

1. Enhanced wear resistance of a portion,
2. Abridged warm air degradation,
3. Condensed sponginess in laser coating,
4. Developed controllability of the procedure,
5. Reducing post-coating processing cost and time.

2.3. Significant factors in laser cladding by powder injection

A wide diversity of parameters controls the excellence of the laser coating. Figure 3 abridges these factors, designated as inputs, procedures, and outputs. Inputs include laser, motion device, powder feeder set points, substance, and media possessions. Among the outputs of the procedure, we can show the coating geometry, sponginess, microstructure, residual stresses, and surface coarseness [6].

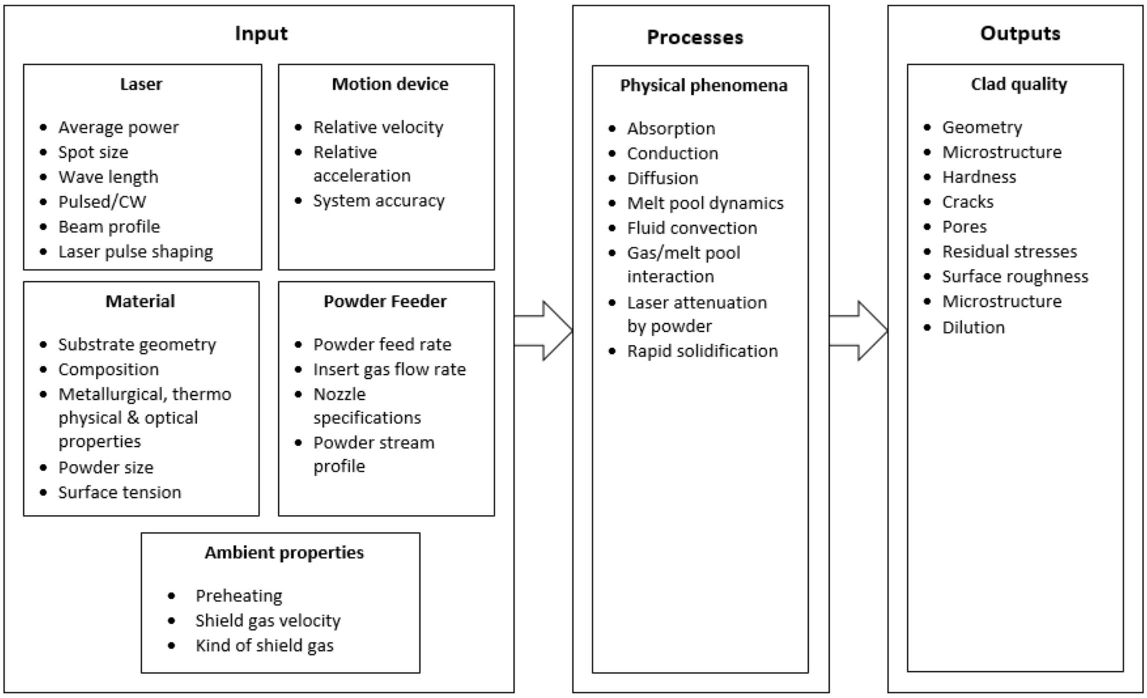

Figure 3. Inputs, outputs, and procedure factors of laser cladding via powder injection [6]

2.4 Evaluation concerning laser cladding and other coating methods

Laser coating applications must compete with several major coating methods for example physical (PVD), and chemical vapor deposition (CVD), and thermal spraying. It can be divided into three methods: thermal spray, combustion torch, electric arc, and plasma arc. Also, PVD can be classified as ion plating and ion implantation. CVD is classified as sputtering, ion plating, ion beam, low-pressure CVD, plasma and laser-enhanced CVD, and laser evaporation [7]. Table 1 associates the advantages and disadvantages of various coating applications. In laser coating, a very strong bond is formed on the substrate where the small heat-affected zone (HAZ) is produced [3]. However, at present, the investment cost and maintenance costs of the laser coating machine is high.

Table 1. Contrast among laser cladding and other coating methods [3]

Feature	Laser Cladding	Welding	Thermal spray	CVD	PVD
Bonding strength	High	High	Moderate	Low	Low
Dilution	High	High	Nil	Nil	Nil

Feature	Laser Cladding	Welding	Thermal spray	CVD	PVD
Coating materials	Metals, ceramics	Metals	Metals. ceramics	Metals, ceramics	Metals, ceramics
Coating thickness	50 µm to 2 mm	1 to several mm	50 µm to several mm	0.05 µm to 20 µm	0.05 µm to 10 µm
Repeatability	Moderate to high	Moderate	Moderate	High	High
Heat-affected zone (HAZ)	Low	High	High	Very low	Very low
Controllability	Moderate to high	Low	Moderate	Moderate to high	Moderate to high
Cost	High	Moderate	Moderate	High	High

3. Switch of laser cladding procedure

Despite the numerous compensations of laser coating, its industrial uses are restricted due to its high cost and vulnerability to degradation. The significant factors that define the coating quality can be divided into internal and external. Intrinsic factors are those linked to substrate and powder possessions. These factors comprise thermal conductivity, thermal distribution, and work-piece geometry. The external factors are laser energy, laser focus, nozzle location, powder feeder flow, and alignment and speed of the laser and substrate linked to the hardware utilized in the procedure, for example, the laser, powder feeder, and locating system. Generally, there is no straight control over internal factors; nevertheless, the effects of alterations in internal factors can be remunerated by monitoring external factors. For instance, the alteration in absorption can be attuned by adjusting the laser's regular power. At large, an open loop switch of laser coating is beneficial when the use is fixed and reiterated repeatedly. The definition of the right factors is very time-consuming; nevertheless, this method of control is efficient and effective if there is no alteration in practice. The advantages of this technique are that there is no need for additional costs, and the application is easy. The shortcomings of the open loop switch are: it is very sensitive to changes, and the tooling time is long.

3.1. Sensors

Measurement of feedback factors can designate the coating quality. The factors connected to the melt pool are temperature, size, and solidification rate. The factors related to the pavement size are height and width. The roughness of the coated surface can be projected circuitously by measuring the coating geometry and the solidification rate. A non-contact sensor is required for the temperature measurement of the melt pool [8]. In dimension measurement, cameras and phototransistors are the utmost mutual expedients for coated geometry measurement. The difficulties encountered when utilizing these expedients in the laser coating procedure are that the images may contain plasma, dust particles, etc. It is the real-time processing of images to remove contamination with coatings as well as coating geometry. Meriaudeau and co-workers [9] utilized a CCD camera to measure the summit of a pavement and enhance the procedure by averaging the summit of the pavement. Though, their investigation does not demonstrate a closed-loop mechanism.

3.2. Closed loop switch of laser coating

Controlling the laser coating mostly depends upon the sort of equipment utilized. For instance, compared to a CO2 laser, a Nd:YAG laser delivers more tractability in monitoring the input power. Developing a closed-loop switch of laser coating involves selecting a control input, measuring and controlling coating properties for the feedback signal. Figure 4 displays the general structure of the closed-loop switch system of the laser coating procedure [3]. In a single outlet (SISO) switch system, the powder feeder and locating system are independently adjusted to the powder speed and specified path motion. Li and co-workers [10] established a real-time laser coating control system to define the optimal working circumstances for a specific condition and online liability judgment and alteration.

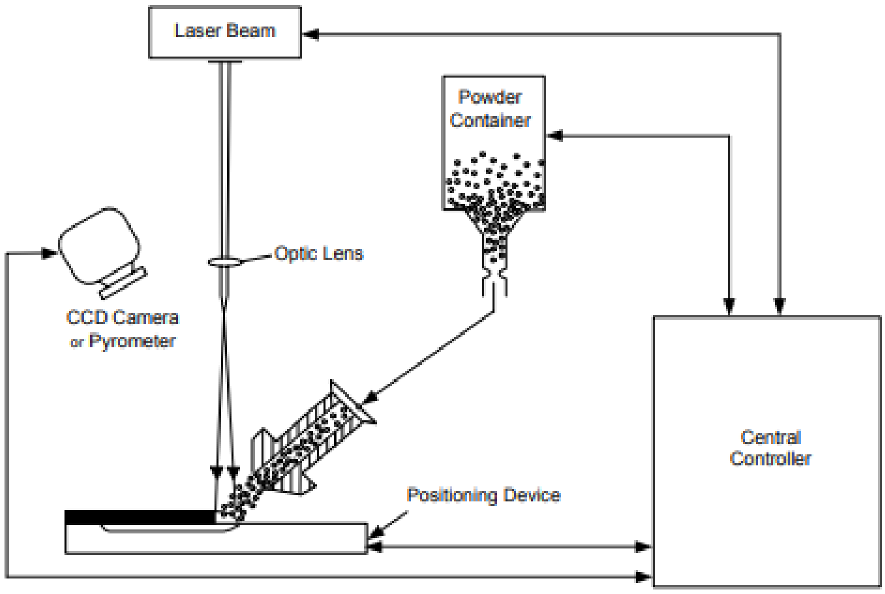

Figure 4. Closed-loop switch of laser cladding

According to Mazumder et al. [11] described a feedback regulator to adjust the laser power in the machining area. With this controller, the laser beam is switched on and off for certain periods of time with the adapted analog signal sent to the laser.

3.3 Use of knowledge-based switch to laser cladding

Laser coating is an intricate procedure with numerous reservations. The use of conventional regulators may not be suitable for such systems. Knowledge-based control methods, for example, fuzzy logic or neural networks can handle these systems more easily. In the control development process, it implements a fuzzy logic controller. With fuzzy logic, it is likely to examine complex schemes without having mathematical models [12, 13]. Figure 5 displays a fuzzy switch strategy in which a fuzzy logic regulator and a fuzzy gain planner are included in the supervisory judgment-making part.

This approach maps the error $e = yd - y$ to the switch action u. At the heart of this switch scheme is a fuzzy logic switch algorithm that maps the regularized error addition and error change rate dk to the alteration in switch output or δuk. The characteristic rule in the fuzzy logic regulator is:

If the appendix is LP or SP and dk is LN or SN, δuk is Z, where LP, SP, LN, SN, and Z denote large positive, small positive, large negative, small negative, and zero, correspondingly [14].

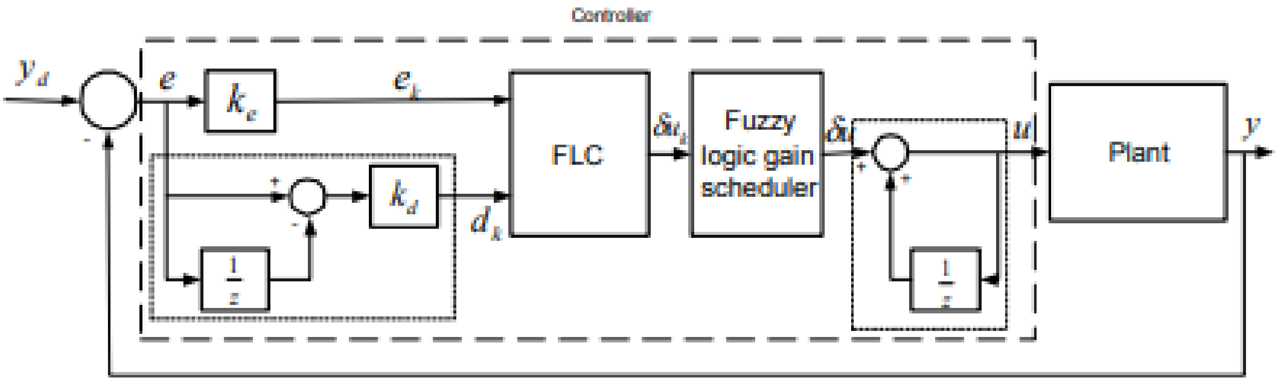

Figure 5. Proposed fuzzy logic controller

A normal fuzzy controller is also applied to the model to examine the effect of the fuzzy regulator. The normal fuzzy controller has a similar structure excluding that the fuzzy improvement table is eradicated. The classical fuzzy regulator gives a slow reply as perceived in Figure 6 [3]. As shown in the figure, it can significantly reduce system response time and significantly improve system response.

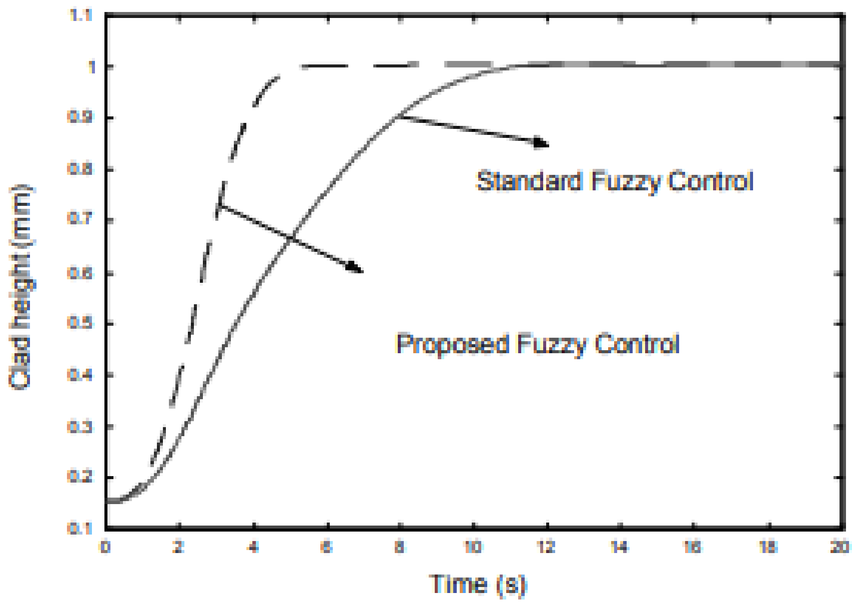

Figure 6. Contrast amid the normal fuzzy logic and projected fuzzy logic [3]

4. Laser cladding of Ti alloys

4.1. Introduction

Many people use "biomaterials" to repair or replace diseased or damaged tissue. Biomaterials are artificial or usual stuff utilized to heal, treat, or replace living tissues or organs [15]. Biomaterials must be blood compatible, non-inflammatory, non-allergic, non-toxic, stable, and mechanically robust enough to endure reiterated forces. There is a wide variety of materials being investigated as biomaterials, for example, metals, ceramics, polymers, and composites. Among the metals, stainless steel [16], Co-Cr alloys [17], and Ti-alloys [18] are the most common metallic materials.

One of the greatest talented engineering substances, titanium and its alloys, for example, Ti-6Al-4 V have attracted attention in biomedical uses because of their outstanding mechanical possessions. Nevertheless, inertness and low biocompatibility are the most thoughtful hindrances to their use in biomedicine [19]. Therefore, surface alteration of Ti-alloys appears necessary to improve its applications in numerous arenas of science and industry.

Laser technology is extensively utilized in surface alteration of dissimilar metals due to its high coherence, directionality, and high energy densities. Laser surface melting [20] and laser coating [21] have been investigated to improve different surface properties. The laser coating technique is widely utilized to arrange many sorts of coatings, as it can achieve high fabrication efficacy and outstanding switch of the deposition procedure.

4.2. Biomaterials

Biomaterials contain stuff that does not have toxic reactions in interaction with the body for therapeutic purposes. Biocompatibility is the most significant and fundamental condition for the existence of numerous types of biomaterials. Therefore, biocompatibility can be demarcated as the receipt of the implant by the neighboring tissues and all tissues of the body [22].
At large, biomaterials should have chemical impartiality, high fatigue strength, and body-compatible properties. All biomaterials fall into three groups: bioinert, biodegradable, and bioactive. Bioinert is a material that does not unswervingly bond with any of the neighboring tissues. Bioactive materials are chemically bound to contiguous tissues and biodegradable ingredients are demolished over time. The selection, properties, and applications of different biomaterials are indicated in Table 2 [23].

Table 2. Features of some metals utilized in biomedical arenas [23]

Material	Normal analysis (w/o)	Modulus of elasticity GN/m^2 (psi x 10')	Ultimate tensile strength MN/m^2 (ksi)	Elongation to fracture (SE)	Surface
Titanium	99 + Ti	97 (14)	240-550 (25-70)	>15	Ti oxide
Titanium-aluminum-vanadium (Ti-AI-V)	90Ti-6A1-4V	117 (17)	869-896 (125-130)	>12	Ti oxide
Cobalt-chromium-molybdenum (casting)	66Co-27Cr-7Mo	235 (34)	655 (95)	>8	Cr oxide
(Co-Cr-Mo)					
Stainless steel (316 L)	70Fe-18Cr- I2Ni	193 (28)	480-1000 (70-145)	>30	Cr oxide
Zirconium *(Zr)*	99 + Zr	97 (14)	552 (80)	20	Zr oxide
Tantalum (Ta)	99 + Ta	-	690 (100)	II	Ta oxide
Gold (Au)	99 + Au	97 (14)	207-310 (30-45)	>30	Au
Platinum (Pt)	99+ Pt	166 (24)	131 (19)		Pt

Metallic biomaterials are utilized to substitute the structural mechanisms of the human body as they are better than ceramic or polymeric materials in terms of mechanical properties. Numerous medical devices, for example, bimetals artificial joints, dental implants, and stents are widely used. Presently, some Ti-Al-V alloys are utilized in the medical industry as dental implants as well as knee and hip combined prostheses [24, 25]. However, despite their notable compensations, the toxicity of Ti-Al-V constituents, for example, aluminum and vanadium have become a matter of apprehension [26]. The discharge of Al and especially V ions from this alloy can cause lasting health glitches, like Alzheimer's illness and outlying neuropathy [27]. Ti alloys have mechanical properties alike to bone. Nevertheless, the poor resistance to wear and oxidation and low hardness of Ti alloys may limit their uses. The most common problem especially in Ti alloys in joint substitutes such as total knee and hip prostheses, in which the ball slips in the socket owing to the drive of the hip joints; consequently, Al and V ions are unconfined in the body. Therefore, it is necessary to alter the nature of the surface of the Ti alloy by means of dissimilar surface engineering methods. To improve Ti's biocompatibility, mechanical and corrosion properties, and improve surface integrity, Ti alloys are exposed to surface alterations utilizing dissimilar substances and coating methods. The choice of material is an important factor in having a fruitful coating, which affects the mechanical possessions of the material, for example, hardness, corrosion, and wear resistance. Polymers, ceramics, metals, and composites are utilized to coat metallic surfaces as a defensive layer.

4.3. Laser cladding

Laser plating (LC) for the manufacture of composite coatings includes melting and adding alternative material. In this way, a new crack-free and porous-free layer is formed on the surface [28]. LC can be utilized to produce a variety of surface alloys and composites with adapted possessions on request.

Different laser coating methods

There are various nourishing ways of coating a material, for example, paste and wire feeding as well as powder injection. Powder-injected LC is more general [29]. The advantages and disadvantages of laser coating are as listed below. The benefits of the laser coating method are:

1. Laser beam as a manageable heat source
2. Checking the coating thickness

3. Has an actual slender heat affected zone (HAZ)
4. It is inexpensive in terms of cost associated to traditional approaches.

Nevertheless, the high investment price, low output of laser sources, and absence of switch over the coating procedure are the drawbacks of by means of this coating skill. Today, with continued developments, the laser coating process has serious industrial impending for usage in metal coating and prototyping.

4.4. Aspects distressing laser coating procedure

Discerning additives, substrate, beam and working factors greatly influence the microstructure, attachment, and excellence of the coated layer. Actual energy monitors the amount of energy transmitted to the procedure by the laser. This energy is mainly accountable for melting the substrate surface and powder and equation (1) [30]:

$$E = P/VD \tag{1}$$

where P is the laser power, V is the scanning haste of the substrate and D is the diameter of the laser beam. The actual energy E is measured in units of j/cm2.

Dust deposition density is similarly a decent display of the extent of dust fed to a unit zone of the substrate during deposition. The dust deposition density is considered by Equation. (2) [30]:

$$PDD = R/VD \tag{2}$$

where R is the feeding speed of powder. Dust deposition density is dignified in PDD, g/mm^2.

As the scanning haste increases, the absorption of the laser beam by mutually the feed powder and the substrate decreases, and as a result, the thickness, depth and width of the coated layer decreases. Instead, growing the laser intensity at an inferior level scanning haste increases the involvement energy density and increases the coating depth subsequently fast solidification [31].
The excellence of the laser-coated layer is demarcated by the attenuation rate, so a better-coated layer quality is essential at inferior dilution [32]. Increasing laser power and decreasing laser beam spot size is associated with an upsurge in the input laser intensity followed by an upsurge in the dilution rate [33].

In fact, the bonding between the coating layer and the substrate and the fine microstructure of the coating layer depends upon the shape and velocity of the feed powder. Irregularly shaped feed powder causes reduced flowability resulting in powder’s incomplete melting, and pores appearing at the interface and surface-coated layer. In addition, owing to the restricted melting of the feed powder, the metallurgical bond amid the coated layer and the substrate cannot be accomplished in the circumstance of elevation feed powder [34].

5. Applications

Laser coating has several different applications. Coating outcomes in the deposition of a thin layer of substance on the surface of a nominated material. This replaces the surface possessions of the substrate with those of the deposited substance. Several different kinds of metals can be used in metallic plating, for example, Ti, Cu, Cr, Ni and Cd. There are numerous coating deposition methods obtainable. Although laser plating has potential for use in metallic coatings, its use in metallic coating is restricted owing to its great price and little processing haste. Nevertheless, there is a robust budding for laser coating to be extensively utilized in coating requests with increased laser efficiency and lower laser cost.

Most of the published articles on metallic plating by laser plating deal with the use of various materials in automotive, medical, and aerospace productions. Ti-based alloys [35, 36], nickel-based superalloys [37, 38], and Co-based alloys [39, 40] are some of the significant alloys. Studies are also carried out on alloys deposited on different surfaces, for example alloyed and unalloyed and stainless steels, Al, cast irons and Ni-based alloys. Recently, bio-ceramic coating on Ti-alloys has similarly been achieved by laser plating; the coated portions are then utilized in orthopedic implants with a calcium phosphate layer to endorse bone development when the implant is placed in the body [41].

The foremost metallic coating souk for laser coating is coating for profitable aircraft gas turbines. Moreover, laser plating has other coating requests to fabricate abrasive and adhesive wear-resistant surfaces of industrial parts. Some of the laser-encrusted metallic coated products are shafts utilized in drilling tools, engine valve chairs, utensils hard facing, hydraulic pump mechanisms, and dies.

Figure 7 displays one of the laser coating used for coating oil rigs that are subject to noteworthy wear in their work [42, 43].

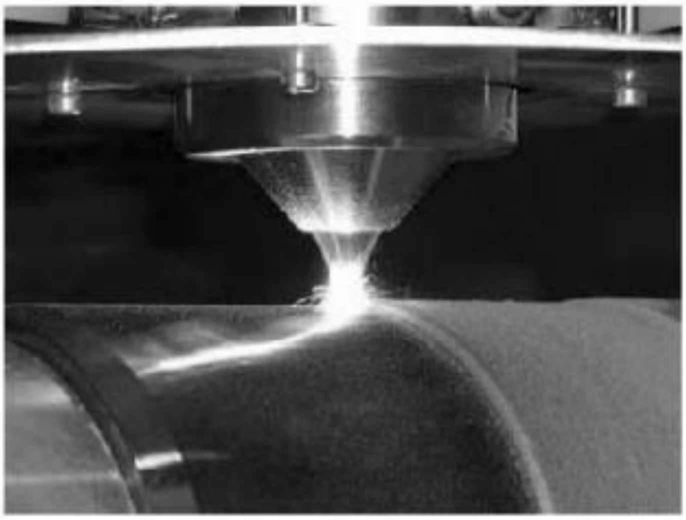

Figure 7. Coating of oil drilling apparatuses through laser cladding [42]

Traditional approaches utilize welding to recover these impaired constituents; nevertheless, these approaches are often destructive owing to the extremely dispersed temperature over the repair zone. This thermal obliteration originates from poor mechanical excellence, cracking, porosity, and short life of the constituent. Laser plating can offer perpetual structural renovation and replacement in numerous alloys (for example, Al alloys) that are usually reflected non-weldable by unoriginal approaches. The achievement of laser coating knowledge in this field is owing to the trifling heat zone, fast solidification, augmented cleanliness, inferior thinning, and enlarged controllability over the penetration of the heat-affected zone. An instance of laser plating overhaul of a shell made of great strength Al alloys (i.e. 7075/7475 Al alloys) is exposed in Figure 8 [44].

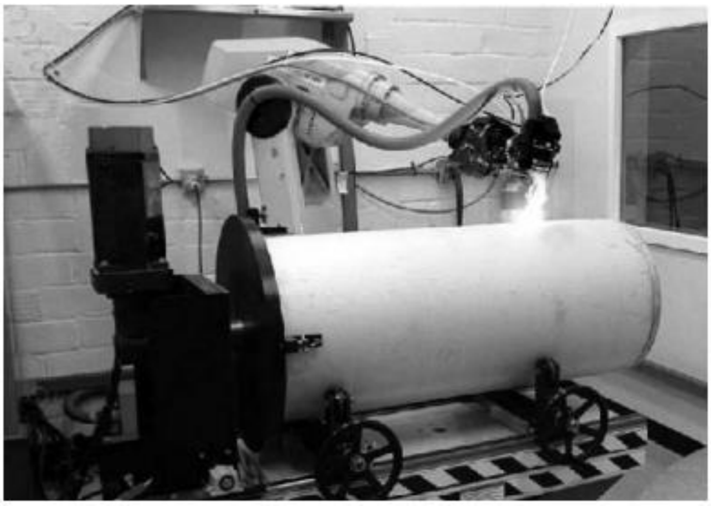

Figure 8. Overhaul by laser cladding of a shell made from Al-alloys [44]

The little heat contribution characteristic of laser coating is the most unique feature of this skill, making it gorgeous for jet engine constituent repair requests. Superalloys are extremely vulnerable to loss of strength and physical deterioration once uncovered to extreme temperature changes. Conservative repair methods for instance metal inert gas, plasma, and electron beam welding generate large expanses of heat, resulting in big temperature rises in the build of the constituent. Consequently, the heat inputs are inferior to throughout conservative welding, resulting in abridged residual stresses and a lesser heat-affected zone [45].

A smooth larger repair market budding happens for the use of laser coating on turbine engines. Laser coating is quickly documented as a perilous and fundamental technology in the production and repair of gas turbine engines [46]. The extent of the repair and replacement souk is huge. Aircraft engine upkeep accounts for 30 % of the entire aircraft upkeep cost, which is a good indicator of the extent of the current market. The worldwide market for the overhaul of aircraft engine turbines and compressor blades utilized in civil and military requests is projected at approximately $4.3 billion each year [47].

6. Recent developments

Many studies on “laser cladding” have been made and continue to be done. When the keyword "laser cladding" is written in "Web of Science", it is understood that more than 14000 articles were published. Some of these articles published in recent years will be briefly mentioned here.

Firstly, an article has been published in 2019, on the additive manufacturing (AM) production of some metallic materials (Al, Mg, Ti, Ni, Co, steels, etc.), metal matrix composites (Al, Ti, Ni, Co, Fe based), ceramics and polymeric materials [48]. In this article, amorphous coatings with laser cladding methods are also examined. As is known, amorphous materials are preferred because of their excellent magnetic, electrical, and mechanical properties. Because of the high rates of heating and cooling throughout laser cladding, it is favorable for the formation of amorphous phases.

In another article published in 2020 [49], a study for high-entropy alloys and conventional alloys produced by laser plating is made. In this study, advances in laser cladding with good corrosion and oxidation resistance and improved medical biocompatibility are studied. It has been reported that laser cladding of high entropy alloys can recover corrosion resistance, regulate grain dimension, and upsurge microhardness. Laser cladding is a technique for improving mechanical possessions, improving microstructure, and repairing damaged parts. Because of these advantages, laser cladding has effective uses in car and aerospace manufacturing and ship construction.

In a study on nano-coatings [50], it was reported that nano-coatings have good surface and volume influence and can successfully recover the mechanical possessions, corrosion, and wear resistance of coatings. It is significant to increase the wear resistance of the substance surface. Effective groundwork of nano-coatings straight distresses the use of nano-coatings. Initially, conventional surface coating groundwork approaches, for example, chemical and physical vapor deposition, and surface coating groundwork approaches for instance newly developed sol-gel method, laser coating, and thermal spraying were studied in detail. Secondly, nano-coating material types are abridged and examined by various nanomaterial coatings. As a result, it was understood that nano-coatings emerged as wear-resistant mechanisms, grain modification, strengthening mechanisms, and nano properties. In productions such as petrochemical, automobile, and aerospace, numerous portions of dissimilar machines are located in high-pressure and temperature environments and are prone to wear and corrosion. Therefore, further improvement of wear resistance and firmness underneath in elevation temperature is required. Today, laser coating (LC) is extensively utilized in the repair and useful coating of machine parts because of its compensations. In a 2021 study [51], LC was investigated in detail in terms of route simulation, observation, and factor optimization. Simultaneously, a complete study of the LC material system is presented in the article, as high entropy alloys (HEAs), amorphous alloy, and single crystal alloy progressively display their compensations over conventional metallic materials in LC. Furthermore, the uses of LC in useful coatings and upkeep of instrument portions are summarized. Engineering alloys are used as essential materials in fields such as aerospace, electronics, and metallurgy due to their loftier mechanical and electrical possessions. However, they have limited use due to their low hardness, wear, and poor oxidation resistance. In reply to this issue, the improvement of laser coating (LC) know-how has delivered novel attitudes for surface alteration of engineering alloys. In another study [52] reported in 2021, recent advances in the groundwork of engineering alloys with LC know-how are extensively explored. Again, in this article, LC dispensation approaches and material schemes are studied, and coatings associated to this arena are investigated.

In a paper published in 2022 [53], crosswise Anderson localization was perceived for the primary period in an optical fiber with an accidental crosswise refractive index outline. This initiated the expansion of a whole new class of light-directing optical fiber using Anderson localization, anywhere light can be directed in any position along the crosswise outline of the fiber. In this study, a short-lived part of the actions that led to the progress of the research groups and the fibers used was examined.

Another article published in 2022 [54] describes the progress of nanocomposite coating on the surfaces of metallic materials formed by laser surface coating and alloying procedure. Nanocomposite coatings are used in the aerospace and automobile industries because of their possessions such as extraordinary hardness, decent tribological possessions, corrosion, and oxidation resistance. The nanocomposite coating can be formed from transition metals, alloys, ceramics, and rare earth oxides. The creation of the nanocomposite coating rests on the laser procedure factors and the assortment of nanoparticles during the coating procedure. The numerous laser processing factors that regulate the formation of the nanocomposite coating are the argon flow rate, the powder feed rate, the wavelength of the laser beam, and the laser frequency. Nanocomposite-coated metallic substances can be utilized in the manufacture of mechanical constituents such as turbine blades, friction expedients, and auto parts, which can be applied to severe wear and corrosive conditions. In this article, the problem and its control throughout laser dispensation for nanocomposite coating creation on numerous metallic substances are described. Welding of damaged equipment in the marine environment should be carried out in aqueous environments. The underwater laser welding/coating method is a progressive method for the maintenance of damaged equipment. In a recent article [55], an examination and engineering outline of the underwater laser welding/coating method is aimed. Foremost, the latest developments and important problems in drainage nozzles all over the world are examined in detail. Next, underwater laser dispensation and metallurgical performance of fixed maritime substances are presented. Finally, future recommendations are presented to assist the progress of underwater laser welding/coating expertise.

Finally, in an article published in 2022 [56], coating technologies on light alloys used in aerospace were examined. Thermal sputtering, laser coating, cold sputtering (CS), and supersonic laser deposition (SLD) technologies are included in this study. Likened with outdated thermal sputtering expertise, CS has many compensations, for example, low sputtering temperature, low oxygen content of the coating, and low pores, which can prevent oxidation, combustion loss, phase change, and grain size during thermal sputtering. In the future, both technologies will be widely used in aerospace repair and remanufacturing. Based on the CS and SLD principles, this article introduces the coating deposition mechanism in detail, and specific application examples of CS in aerospace are described at this stage.

7. Conclusions

Laser cladding is a method of material laying wherein a substrate is combined using laser to coat part of it. It is regularly utilized to develop mechanical possessions, upsurge corrosion resistance and overhaul worn portions. The ensuing implications can be drawn from the remaining investigation:

- By using laser coating, the following advantages can be achieved: the wear resistance of the part can be increased, thermal degradation is reduced, porosity can be reduced, and the cost is low.
- Despite the numerous benefits of laser coating, its industrial requests are restricted. Because laser systems have relatively high cost and high susceptibility to coating degradation.
- There is an extensive diversity of materials being investigated as biomaterials, for example polymers, ceramics, metals, and composites. Stainless steel, Co-Cr alloys, and Ti-based alloys are the greatest communal metallic biomaterials.

- Selective additives, substrate, beam and working constraints greatly influence the microstructure, connection, and excellence of the coated layer. As the scanning haste of the laser beam increases, the width, depth, and thickness of the coated layer decrease. However, growing the laser intensity at an inferior scanning rate increases the depth of coating after rapid solidification.
- To develop a higher efficiency, inferior price industrial gas turbine engine, high-strength, high-temperature-capable substances for example Ni-based super-alloys are plated into the turbine housings. In addition, laser plating has coating applications such as dies and drilling spindles to produce abrasive, abrasive, and adhesive wear resistant surfaces of industrial parts.

Declaration of competing interest
The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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