Madanapalle Institute of Technology and Science

Department of Mechanical Engineering

Project work: Phase II

Electric Discharge Machining of additive manufactured Ti-6Al-4v alloy

PROJECT GUIDE

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Introduction – Additive manufacturing

- Rapid prototyping, also known as additive manufacturing or 3D printing, is described as a quick process for creating a prototype based on design data with the aid of a computer.
- Since the introduction of 3D printing technology in the 1980s, the term “3D printing” has been used in many industries such as the automotive, aerospace, electronics and biomedical industries.
- Metal prints are a variation of traditional printing styles that imbue color into metal materials (usually aluminum) to create a durable display. The most common printing technology used to print metal prints is dye sublimation, which helps ensure the final result is as accurate as possible.
- 3D printing commonly used for prototyping in production-grade materials and producing functional, end-use parts. It's also a good option for manufacturing parts with complex geometries and reducing the number of metal components in an assembly.

Introduction – Ti alloys

Titanium and titanium alloys are currently finding increasingly widespread use in many industries due to their desirable combination of properties.

Notable among these are their low densities, which give very attractive strength-to-weight ratios, high temperature capability and almost total immunity to corrosion in many environments.

Although the titanium materials are still considered as expensive materials, for many applications the cost of titanium alloys can be justified on the basis of their desirable properties.

Aluminum (Al): Aluminum is the second most abundant element in this alloy, comprising 6% by weight. Aluminum enhances the strength and stiffness of the alloy, and also improves its high-temperature performance.

Tin (Sn): Tin constitutes 2% of the alloy's composition by weight. Tin improves the alloy's weldability and corrosion resistance, particularly in seawater.

Zirconium(Zr): Zirconium makes up 4% of the alloy's composition by weight. Zirconium improves the alloy's strength and fracture toughness, and also enhances its resistance to corrosion and fatigue.

Molybdenum (Mo): Molybdenum comprises 2% of the alloy's composition by weight. Molybdenum improves the alloy's high-temperature performance and also enhances its resistance to corrosion and fatigue.

Problem statement

- Ti–6Al–4V is a commonly used titanium alloy in aerospace and biomedical applications due to its excellent mechanical properties. However, the post-processing of this alloy using electrical discharge machining (EDM) is challenging due to the formation of a recast layer and microcracks on the machined surface. The problem is to investigate the effect of EDM post-processing on the microstructure, surface quality, and mechanical properties of Ti–6Al–4V and to develop effective strategies to overcome the issues associated with EDM post-processing of this alloy.

Literature Review

- Manuela Galati (2021) et.al:An investigation on the processing conditions of Ti-6Al-4V by electron beam powder bed fusion: Microstructure, defect distribution, mechanical properties and dimensional accuracy.

In comparison with Ti-6Al-4V, which is the most common titanium alloy, Ti-6Al-4V is a crucial structural material with a maximum service temperature of 540 °C. One of the key applications of this alloy is in the hot sections of power generation systems, such as impeller.

Literature Review

- **A Azhagurajan(2019) et.al :** Statistical evaluation and performance analysis of electrical discharge machining (EDM) characteristics of hard Ti-6Al-4V alloy

➢ The electrical discharge machining (EDM) process is used to machine hard titanium alloys, and the study focuses on the Ti-6Al-4V alloy.

➢ The machining performance is affected by process parameters, which were analyzed statistically to determine optimum performance.

➢ The Taguchi orthogonal array method was used for the experiments, and the most significant parameters were found to be peak current, pulse on time, and voltage.

➢ The study also used SEM analysis to characterize the machined surface, which showed the presence of craters, surface cracks, globules, and a recast layer.

Literature Review

R. Prithivirajan(2021) et.al: Influence of Optimization Techniques on Wire Electrical Discharge Machining of Ti–6Al–2Sn–4Zr–2Mo Alloy using Modeling Approach.

- Wire Electrical Discharge Machining (WEDM) is another non-conventional machining process used to cut hard titanium alloys.
- In this study, the Ti-6Al-2Sn-4Zr-2Mo alloy was machined using WEDM, and surface roughness (SR) and material removal rate (MRR) were statistically evaluated for optimum performance.
- The pulse on-time current and pulse off time were found to be important parameters for MRR, and pulse on time, pulse off time, and a combination of both were found to be significant parameters for SR. The machined surface was examined using SEM.

Literature Review

- Haiyang Fan(2020) et.al: Effects of direct aging on near-alpha Ti–6Al–2Sn–4Zr–2Mo (Ti-6242) titanium alloy fabricated by selective laser melting (SLM)

The Selective Laser Melting (SLM) process is used to fabricate complex parts from 3D models by selectively melting layers of powder using a laser beam.

➢ SLM has been used for processing various titanium alloys, including alpha, alpha + beta, beta, and intermetallic γ-TiAl, but there is limited research on near-alpha titanium for high-temperature applications.

➢ The conventional casting process of Ti-6242 typically produces a near-α microstructure with a small amount of β phase, but this microstructure is sensitive to cooling rates and post-heat treatments.

➢ Increasing laser energy density promotes in-situ martensite decomposition into α/β lamellar microstructure. SLM-induced martensite's can also be decomposed into lamellar α/β by post-heat treatments below the Tβ while maintaining the initial acicular morphology.

Literature Review

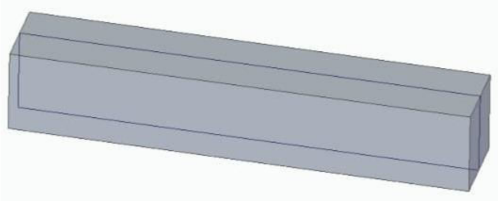
Shang Sui (2022) et.al : Effect of cyclic heat treatment on microstructure and mechanical properties of laser aided additive manufacturing Ti–6Al–2Sn–4Zr–2Mo alloy.

- The study aimed to investigate the cyclic heat treatment (CHT) procedures suitable for LAAM-built near-α titanium alloy Ti–6Al–2Sn–4Zr–2Mo (Ti6242) to attain globular α phases and improve its ductility.
- The results showed that 980 °C is the most suitable upper temperature limit for CHT, but achieving a high, volume fraction of globular α phases is difficult due to low composition gradient caused by more α-stabilizing elements and fewer β-stabilizing elements.
- However, after 980 °C CHT and 980 °C CHT with solution heat-treatment, the formation of globular α phases significantly increased the elongation to 13.5% and 12.9%, respectively, exceeding the standard. Although mechanical strength reduced after heat-treatment, the samples displayed ductile fracture behavior.

Methodology

Ti-6Al-4V
ALLOY

SLM 3D METAL PRINTING



3D PRINTED OBJECT

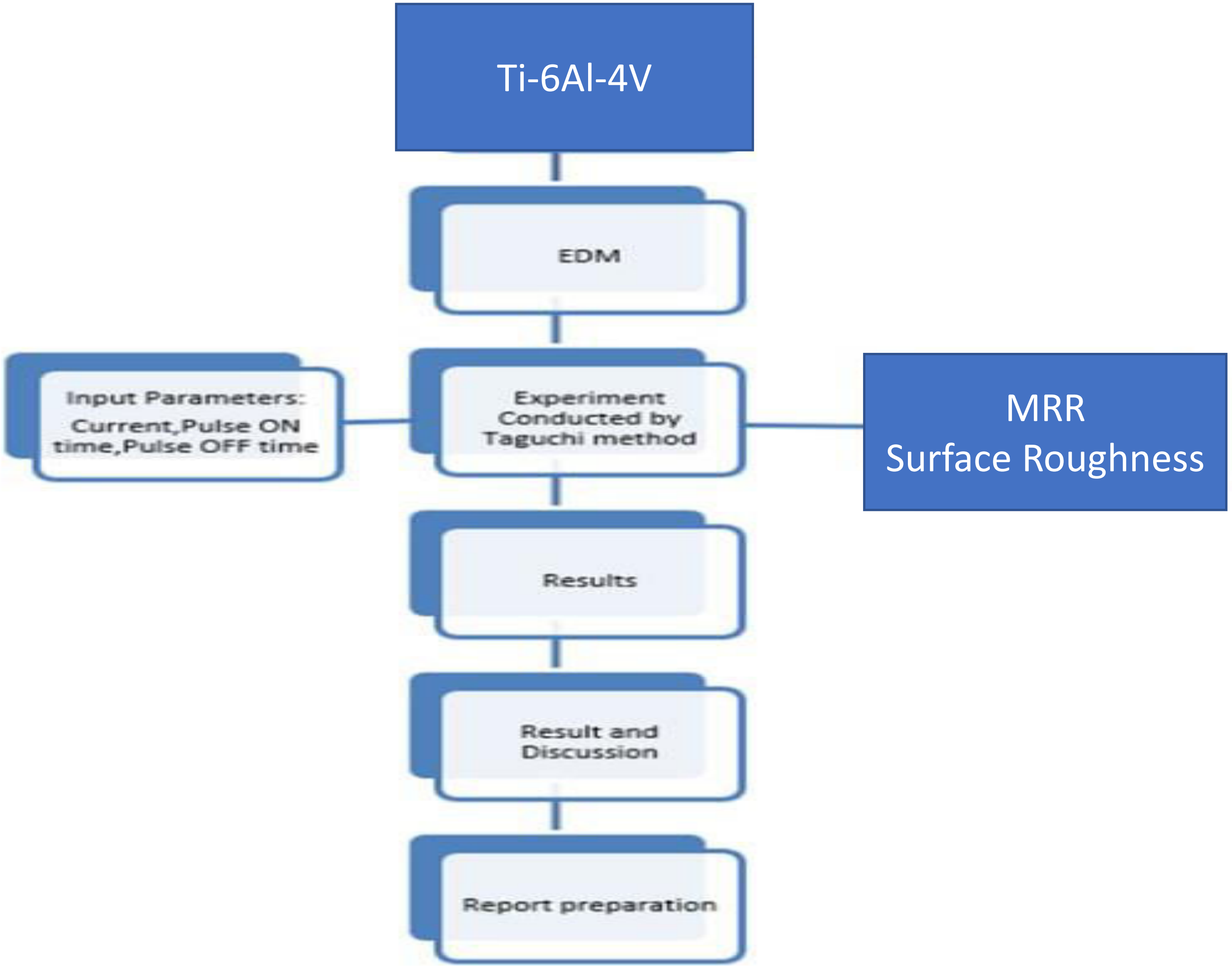
EDM

MRR, Surface Roughness,
Overcut

Methodology

SLM 3D Printing

Methodology



Result

Ti-6Al-4V Machined with Copper Electrode

Copper Electrode
A copper electrode is commonly used in electrical discharge machining (EDM) to generate the required form in a workpiece consisting of a conductive material such as titanium alloy Ti-6Al-4V.

Result

Ti-6Al-4V Machined with Brass Electrode

Brass Electrode

A brass electrode is another alternative for generating the desired form in a workpiece consisting of a conductive material such as titanium alloy Ti-6Al-4V in electrical discharge machining (EDM).

Result

Brass Electrode Calculations and surface roughness

Sl.no	Ra	Rq	Rz
1	4.568	5.875	21.854
2	4.765	5.693	21.764
3	4.242	5.382	21.432
4	4.201	4.537	18.986
5	3.987	4.179	17.852
6	4.853	5.612	22.322
7	4.774	5.487	20.658
8	4.228	4.653	20.490
9	3.910	4.321	20.302
10	3.359	4.156	19.876
11	4.763	4.987	26.543
12	4.423	5.342	25.654
13	4.508	5.297	25.986
14	4.281	5.096	24.765
15	3.507	4.421	23.986
16	4.423	5.764	23.753
17	4.765	6.832	23.987
18	4.873	5.432	23.465
19	3.569	5.238	21.764
20	4.002	6.964	21.561

Result

Evaluation of MRR

The MRR is expressed as the ratio of the difference of weight of the workpiece before and after machining to the machining time and density of the material.

$$MRR = \frac{Wjb - Wja}{t\rho} \text{ x } 1000$$

Where,

Wjb = Weight of workpiece before machining.

Wja = Weight of workpiece after machining.

t = Machining time.

ρ = Density of material.

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THANK YOU