SSN COLLEGE OF ENGINEERING
KALAVAKKAM-603110

INTERNALLY FUNDED STUDENT PROJECT – 2021

Hot corrosion resistance of laser powder bed fusion based additive manufactured titanium alloy

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Budget: **31,000 Project**

Duration: 12 Months

Signature of the Project Students

Signature of the Project Guide(s)

Signature of the HOD

1. Project Title : Hot corrosion resistance of laser powder bed fusion based additive manufactured titanium alloy

2. Broad Subject : Material Science and Manufacturing technology

3. Project Duration : 12 months

4. Budget : 31,000

5. Project summary :

This project aims to explore the hot corrosion resistance of titanium alloy fabricated using laser powder bed fusion based additive manufacturing process and the results will be correlated with micro-structural characteristics of the prepared samples.

6. Keywords

- Titanium alloy
- Laser powder bed fusion
- Additive Manufacturing

7. Objectives :

- To characterise the micro-structural characteristics of titanium alloy samples prepared by laser powder bed fusion based additive manufacturing.
- To correlate the hot corrosion resistance with the micro-structures of the fabricated titanium alloy samples under optimum process conditions.

8. Introduction :

Titanium alloy, Ti–6Al–4V occupies almost a half of the market share of titanium products used in the world today. Ti–6Al–4V alloy was originally developed for aircraft structural applications in 1950s. This lightweight and yet strong alloy saves weight in highly loaded structures and is hence extremely suitable for jet engines, gas turbines and many air-frame components. While the aerospace industry still dominates the Ti–6Al–4V demand, other application fields such as marine, automobile, energy, chemical and biomedical industries have also found its wide acceptance during the last half a century. Its applications have also been extended to the marine and chemical industries due to its high corrosion resistance to most corrosive acids and alkali.

Despite the high demand, manufacture of Ti–6Al–4V products is always challenging due to its poor thermal conductivity, the propensity to strain hardening and active chemical reactivity to oxygen. Conventional manufacture of Ti–6Al–4V products relies on forging, casting and rolling of bulk feed stock materials, followed by subsequent machining to final shapes and dimensions. These traditional manufacturing processes always inevitably result in a large amount of material waste, high manufacturing cost and long lead time.

Under such circumstances, additive manufacturing (AM), an advanced manufacturing technology of producing near-net shape structures directly from CAD models by adding materials in a layer-by-layer fashion, offers its beneficial capability for fabrication of Ti–6Al–4V products with geometric complexities. Although titanium based alloys exhibit good corrosion resistance due to the formation of Titania on its surface, the nature, composition and thickness of the protective oxide scales depend on environmental conditions. Titanium alloys exposed to elevated temperature (500 °C) and corrosive environments show an affinity towards oxygen in air and forms α case, which gets enhanced at and above 800 °C [9]. The details of hot corrosion behavior of additive manufactured titanium alloy are not available in the literature. Hence this study explores the hot corrosion resistance of titanium alloy fabricated using laser powder fusion bed additive manufacturing process and the results will be correlated with microstructural characteristics of the prepared samples.

9. Definition

A thorough understanding of high temperature corrosion behavior of Ti–6Al–4V is very essential for its viable applications in gas turbine components. It is essential to understand the degradation mechanism of titanium alloys prepared by laser powder fusion bed additive manufacturing under hot corrosion conditions. Hence this study is proposed.

10. Review of status of research and development in the subject

1. International Status:

In a study by Martina et al., the benefits of plasma deposition for the additive layer manufacturing of Ti-6Al-4V is investigated. It is cited that the microstructure consist of Widmanstätten microstructure embedded in large columnar grains. The parts experienced oxidation and distortion when the deposition takes place outside the protective atmosphere.

In a study by Zhu et al., microstructure and mechanical properties of hybrid fabricated Ti–6.5Al–3.5Mo–1.5Zr–0.3Si alloy are investigated. It is stated that hybrid fabricated parts generally consists of three different zones: (i) the laser additive manufacturing zone, (ii) the wrought substrate zone and (iii) the bonding zone. Superfine basket-wave microstructure within coarse prior β grains forms in the laser additive manufacturing zone this provides enhanced tensile strength to the AM parts. In a study by Uhlmann et al., the AM of Ti alloy for aircraft components is investigated. It is cited that the microhardness values are 316 HV30 in xy-direction is and 320 HV30 in xz-direction. This corresponds to 88 % and 89 % in reference to the average literature value of Ti-6Al-4V. Zhang et al., attempted to develop titanium–copper alloys that have a high constitutional supercooling capacity as a result of partitioning of the alloying element during solidification, which can override the negative effect of a high thermal gradient in the laser-melted region during additive manufacturing. Nonetheless, it has to be mentioned that no work has been done on hot corrosion resistance of additive manufactured titanium alloy internationally.

2. National Status

Though few works on additive manufacturing of titanium alloys are available, no work has been done on hot corrosion resistance of additive manufactured titanium alloy nationally.

12. Patent Details: Not applicable

13. Work Plan and Detailed Technical Information

1. Purchase of additive manufactured and wrought titanium samples and consumables.
2. Macrostructural and microstructural characeristics using optical microscopy.
3. Hot corrosion studies on the additive manufactured titanium samples.
4. Characterisation of samples using scanning electron microscopy.
5. Analysis & Documentation.

14. Time Schedule

Objectives/Timeframe	0-3 Months	4-6 Months	7-9 Months	10-12 Months
Purchase of additive manufactured and wrought titanium samples and consumables				
Macrostructural and microstructural characeristics using optical microscopy.				
Hot corrosion studies on the additive manufactured titanium samples				

Characterisation of samples using scanning electron microscopy				
Analysis, Documentation manuscript preparation				

15. Deliverables

- ? To generate a data base with the obtained results that could be used in the development of high performance titanium alloy for high temperature applications.
- ? Publications in reputed international journals.

16. Target beneficiaries of the proposed work

- ? Aerospace industry

17. Suggested plan of action for utilisation of research outcome expected from the project

- ? **Journal Publication:** The results of the experiments will be converted into a research paper that will be sent for publication.
- ? **Project display:** The project produced will be put up for display for future references and modifications

18. References

Martina, F., Mehnen, J., Williams, S.W., Colegrove, P., and Wang, F., (2012), "Investigation of the benefits of plasma deposition for the additive layer manufacture of Ti–6Al–4V." Journal of Materials Processing Technology, 212(6), 1377-1386.

Zhu, Y., Li, J., Tian, X., Wang, H., and Liu, D., (2014), "Microstructure and mechanical properties of hybrid fabricated Ti–6.5 Al–3.5 Mo–1.5 Zr–0.3 Si titanium alloy by laser additive manufacturing." Materials Science and Engineering: A, 607, pp.427-434.

Uhlmann, E., Kersting, R., Klein, T.B., Cruz, M.F. and Borille, A.V., (2015), "Additive Manufacturing of Titanium Alloy for Aircraft Components." Procedia CIRP, 35, 55-60.

Zhang, D., Qiu, D ., Gibson, M., Zheng, Y., Fraser, H., StJohn, D., and Easton, M., (2019) "Additive manufacturing of ultrafine-grained high-strength titanium alloys" Nature volume 576, pages 91–95

19. List of facilities and Equipments available within the department for the project:

SI. No	Name of the Equipment	Model & Make	Year of Purchase
1	Gas Tungsten arc Welding Machine	Dynasty – 350, Miller	2010
2	Electromechanical Tensile Testing Machine	LSW50, Bluestar	2012

3	Upright Metallurgical Microscope	Olympus	2012
4	Specimen Cut off Machine, 3HP table top model	MECATOME T255/300	2012
5	Double disc Polishing Machine -8" disc	OPTIPOL2,	2012
6	Metallography Specimen Moulding Press	HT8122B	2012
7	Vicker's hardness testing machine with 70X magnification	FIE make	2012
8	Labview Temperature data module and acquisaton system	NI	2015
9	IR Infrared Camera	FLIR	2017
10	Hot corrosion setup	INFAR	2018

20. Budget Estimate:

S.No.	Material	Quantity	Amount(Rs.)
1.	Titanium alloy samples (Laser fusion bed & Wrought)	---	18000
2.	Emery sheets, Chemicals for Etching & Hot Corrosion Testing	1	3000
3.	Materials and Fabrication of fixtures for testing	1	4000
4.	Tensile sample preparation, Micro-hardness measurements, SEM analysis	---	6000
		Total	31000

21. Budget justification

- Titanium alloy samples (Laser fusion bed & Wrought)
- Purchase of Emery sheets, chemical for etching and hot corrosion studies -

  Metallography and Chemicals for micro structural analysis
- EDM wire cutting to study the cross sectional micro structure as per ASTM standards
- Sub size samples need to be prepared and for testing, fixtures need to be fabricated.
- Micro-hardness testing testing on payment basis at SRM or Annamalai University.