ALLOY DEVELOPMENT FOR FRICTION STIR WELDING AND PROCESSING

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INTRODUCTION

❖ Friction Stir Processing (FSP) of Aluminum alloys – pros and cons

❖ Need to develop new alloys for Friction Stir Welding/ Processing (FSW/P)

Fig: Weld crack in AA6061 base plate during TIG welding (Courtesy: Welding Productivity).

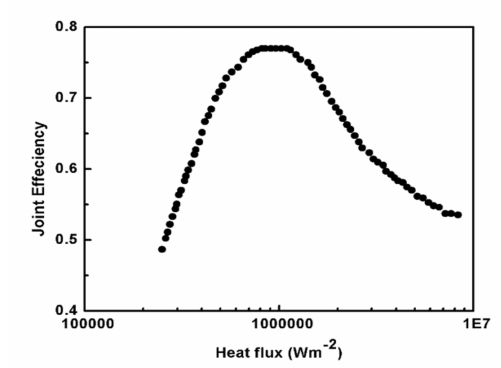


Fig: Variation of joint efficiency with heat flux for FSW of heat treatable Al alloys [1] .

❖ Choice for composite

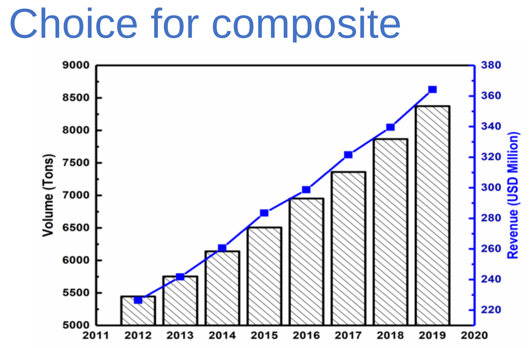


Fig: Global demand for composites [2].

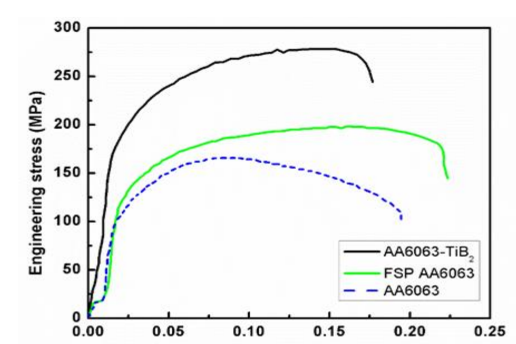


Fig: Engineering stress strain curves [3].

❖ Adverse effect of TiB_2 reinforcement

❖ Reinforcement using High Entropy Alloy (HEA)

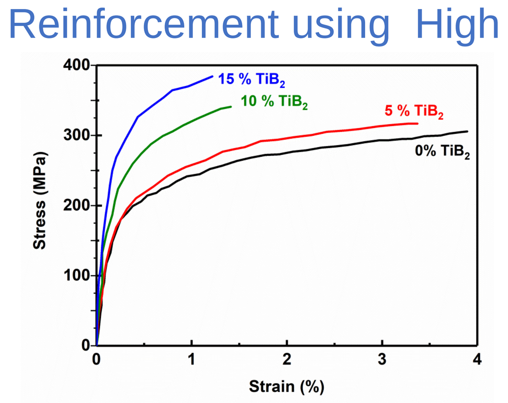


Fig: Stress strain curves with percentage of TiB_2 [4] .

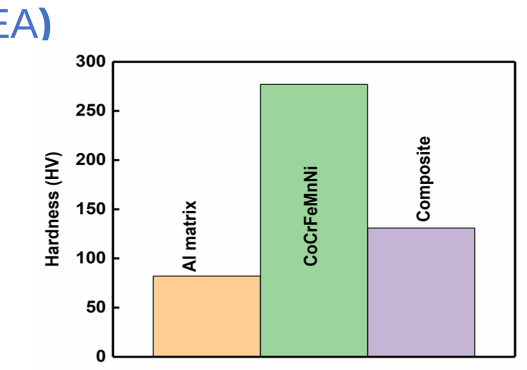


Fig: Al-7% CoCrFeMnNi composite with improved strength [5].

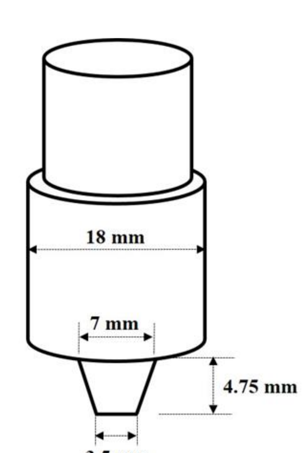
OBJECTIVES

- Microstructure and corrosion property investigation of an as-cast and FSP Al-TiB_2 composite.
- To investigate the oxidation property of an AlCuFeMn high entropy alloy.

MATERIALS AND METHODS

- Test plates prepared by in-situ stir casting process and Friction Stir Processed.

K_2TiF_6 (l) + KBF_4 (l) + Al (l) → TiB_2 (s) + AlB_2 (l) + Al_3Ti (s) + K_3AlF_6 (l) + $KAlF_4$ (l) (800 ºC)



→ Tool rotation speed: 660 rpm
Traverse speed: 40mm/min

- Polarization tests in 3.5 wt.% NaCl solution for corrosion.
- AlCuFeMn High Entropy Alloy developed by arc melting and annealed at 900ºC under vacuum.
- Investigation of microstructure and oxidation resistance of the HEA at 500ºC and 1000ºC for 50 hrs.

RESULTS

1. Corrosion property of Al-TiB_2 composite

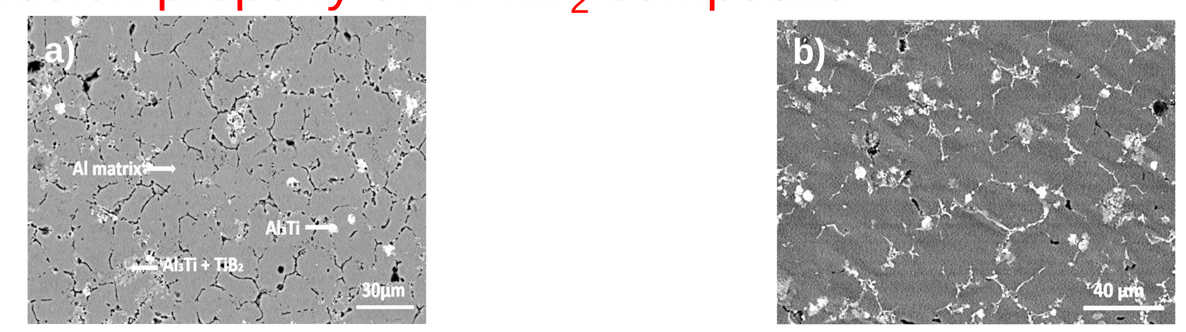


Fig: SEM image of a) as-cast b) FSP Al-TiB_2 composite.

❖ Volume fraction

- As-cast: TiB_2 ~ 5%, Al_3Ti ~ 9.2%
- FSP: TiB_2 ~ 4%, Al_3Ti ~ 8.4%

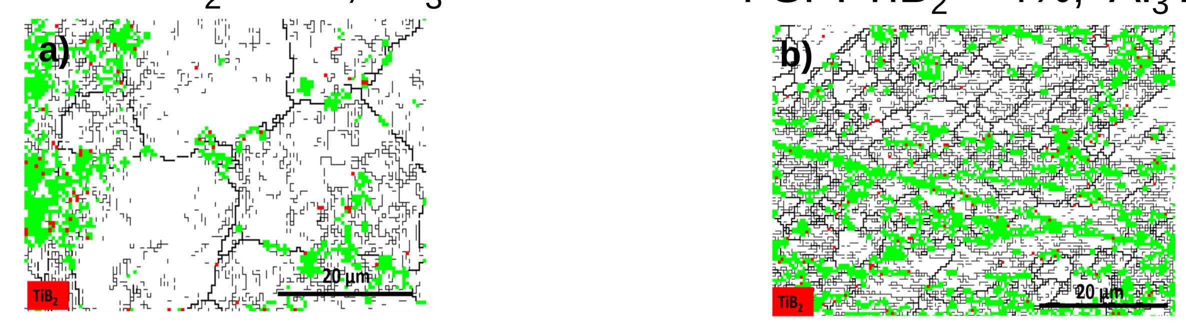


Fig: OIM image of a) as-cast b) FSP Al-TiB_2 composite.

❖ Grain size and Hardness

- As-cast: 16.8 ± 2.4 µm, 61 ± 1 HV
- FSP: 5.3 ± 2.3µm, 65 ± 2HV

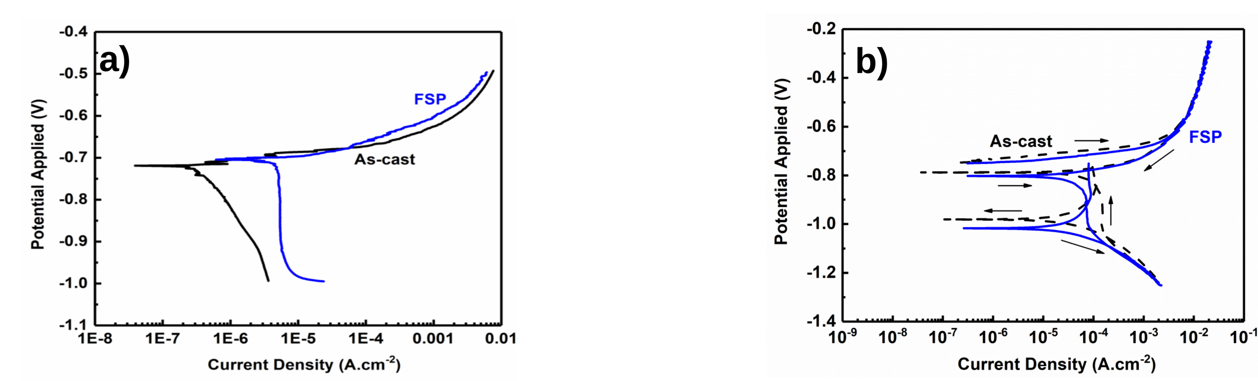


Fig: a) Tafel plots b) Cyclic polarization curves for as-cast and FSP Al-TiB_2 composite.

❖ Corrosion current and corrosion rate

- As-cast: 2.03 ± 0.30 µA.cm^{-2}
  0.022 ± 0.004 mm.a^{-1}
- FSP: 1.30 ± 0.20 µA.cm^{-2}
  0.014 ± 0.003 mm.a^{-1}

2. Oxidation property of AlCuFeMn HEA

Fig: SEM image of AlCuFeMn HEA oxidized at a) 500ºC b) 1000ºC for 50 hours respectively.

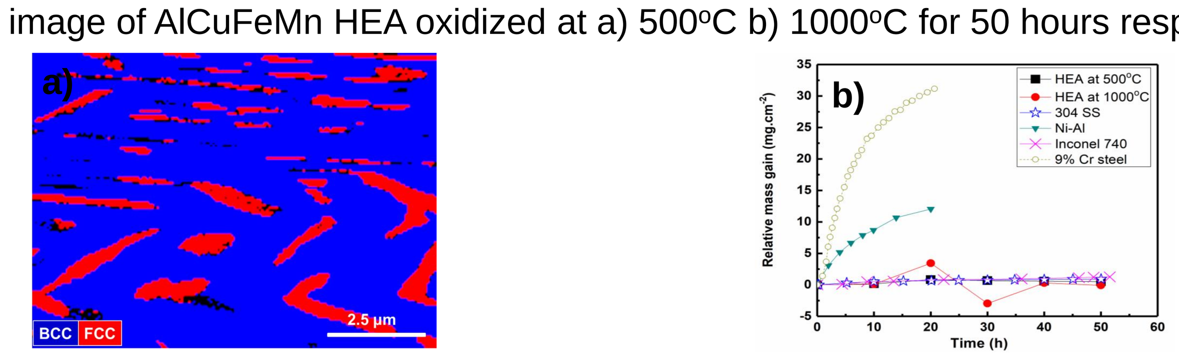


Fig: a) OIM image of the HEA b) Relative mass change vs. time plot of the HEA after oxidation.

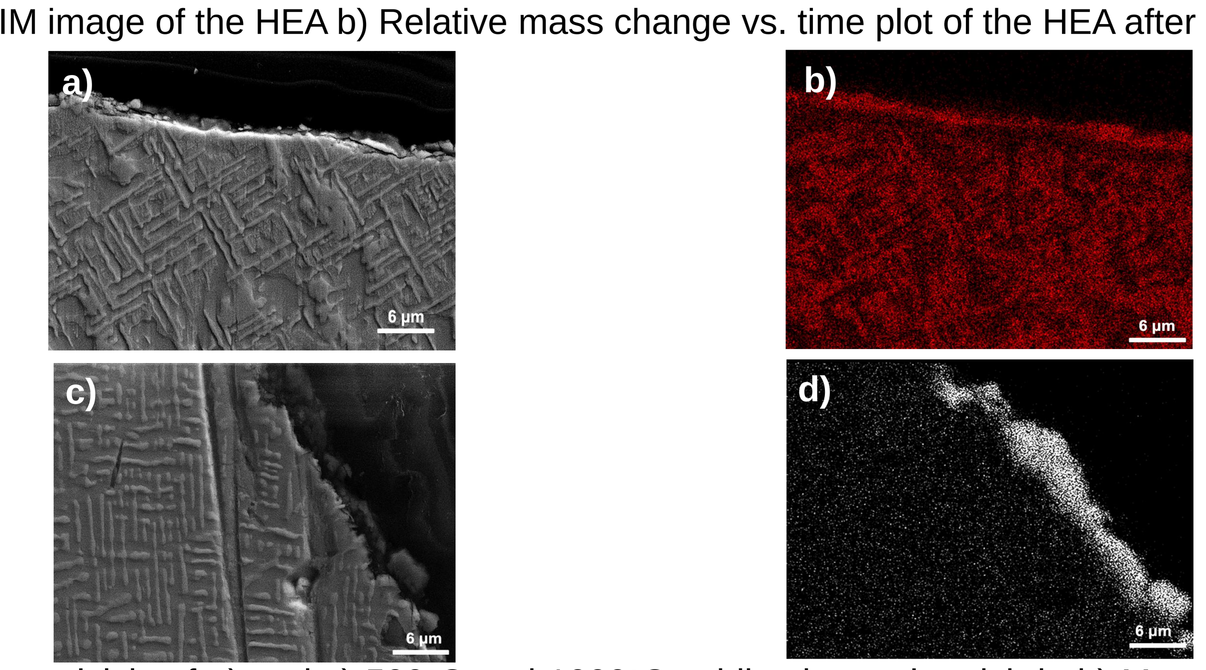


Fig: EDS analyisis of a) and c) 500ºC and 1000ºC oxidized samples rich in b) Mn oxide d) Al oxide respectively .

DISCUSSION

❖ Clustering in the composite occurs due to [6-7]

- High interfacial energy between Al and TiB_2.
- Interface velocity lower than critical velocity.

❖ High hardness

- Lower grain size.
- Uniform distribution of TiB_2 and Al_3Ti.

❖ Uniform corrosion

- FSP sample less susceptible to corrosion than as-cast as higher fraction of low angle grain boundaries in FSP sample.

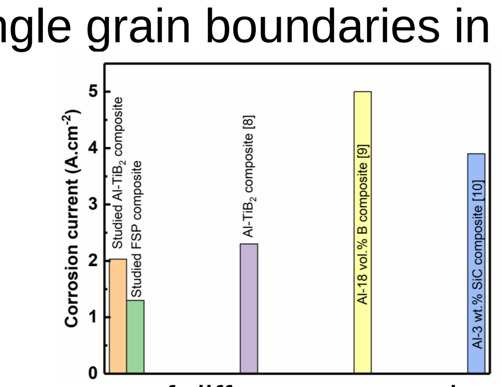


Fig: Comparison of corrosion current of different composites with the studied composite.

❖ No pitting corrosion

- In Al-TiB_2 composite, after immersion in ocean water at room temperature, TiB_2 forms an oxide layer of TiO_2-H_2O [11].
- Volume fraction of Al_3Ti is small and homogeneously distributed.
- Further improvement is done by FSP.

❖ Oxidation of AlCuFeMn alloy

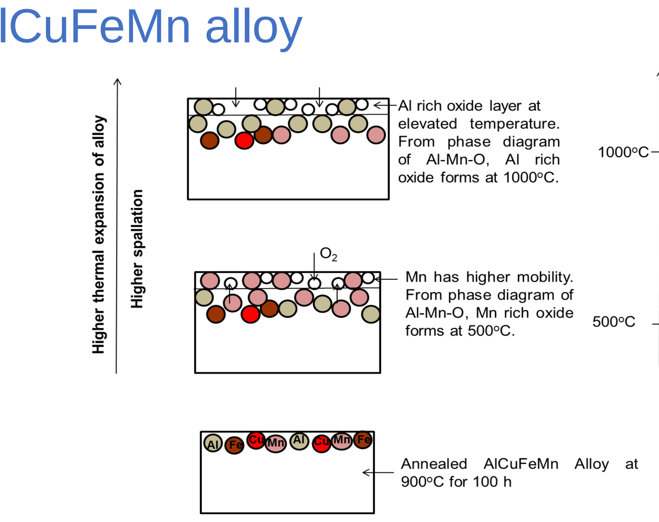


Fig: Schematic of the oxidation process at 500ºC and 1000ºC after 50 hours of exposure.

CONCLUSION

❖ The Al−TiB_2 composite (as-cast and friction stir processed) exhibits much better corrosion resistance compared to Al−B and Al−SiC based composites.

❖ Both friction stir processed and the as-cast Al−TiB_2 based composite resists pitting corrosion.

❖ The annealed HEA forms a Mn-rich oxide scale and Al- rich oxide scale at 500ºC and 1000ºC respectively.

❖ The HEA exhibits better or comparable oxidation resistance than most of the conventional alloys.

REFERENCE

[1] Mishra et al., Springer, 2014.
[2] Salih et al. Mater. And Des., 2015, 86, pp. 61-71.
[3] Narimani et al., Materi.Sci.and Eng. A, 2016, 673, pp. 436-444.
[4] Lu et al., Scrip. Mater., 2001, 45, pp. 1017-1023.
[5] Kumar et al., J. Alloy. And Comp., 2015, 640, pp. 421-427.
[6] Youssef et al.,Composites, 2005, 36, pp. 747-763.
[7] Chawla et al., Springer, 2006.
[8] Majumadar et al., Surf. Coat. Tech., 2006, 201, pp. 1236-1242.
[9] Pohlman S.L., Corrosion, 1978, 34, pp. 156-159.
[10] Mosleh et al., Trans. Non Ferr. Met. Soc. China, 2016, 26, pp. 1801-1808.
[11] Covino et al.,J. Less Comm. Metals, 1975, 41, pp. 211-224.

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