Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 45 No. 02 (2024)

Influence of Eco-Friendly Reinforcement Additives on Corrosion Behaviour of Al7050 and Its Welded Joints

Durai J[1], Dr. C. Anil Kumar[2], Dr. Abhinav[3]

[1]Assistant Professor, Department of Mechanical Engineering, Sri Sairam College of Engineering, Anekal, Bangalore, Visvesvaraya Technological University, Belagavi
[2]Professor, Department of Mechanical Engineering, Sri Sairam College of Engineering, Anekal, Bangalore, Visvesvaraya Technological University, Belagavi
[3]Department of Mechanical Engineering, Dayananda Sagar Academy of Technology and Management, Bangalore, Visvesvaraya Technological University, Belagavi

Abstract*: This study examines the corrosion behaviour of Al7050 and its friction stir welded (FSW) joints with different volume fractions (0%, 2%, 4%, and 6%) of Multani Mitti and Cow Dung Ash (CDA) as eco-friendly reinforcement supplementary materials. Specimens were submerged in a 1M hydrochloric acid (HCl) solution for 6 days, measuring weight loss every 48 hours to evaluate resistance to corrosion. It was found that welded joints always had greater corrosion rate than the base alloy in all compositions. In addition, it was observed that Multani Mitti and CDA addition owing to their lower corrosion rates increased corrosion resistance of base Al7050 alloy. The 6% additive combination provided the greatest protection; reducing material loss to 85% versus untreated alloy, which had 100% material loss. This study shows the capability of natural additives to enhance the corrosion resistance of aluminum alloys, especially for non-welded structures.*

Keywords: *Al7050 alloy, Friction Stir Welding (FSW), Corrosion resistance, Multani Mitti, Cow Dung Ash (CDA), Weight loss method, Composite materials.*

1. Introduction

Emphasizing more on the work done on Al7075 towards improving corrosion resistance using ceramic and natural reinforcement in metal matrix composites, advanced surface treatments to enhance performance under extreme environmental conditions, could also be useful on aerospace and marine applications [1]. In line with this research, H.K. Shivanand et al. [2] have discussed the applications of Aluminium-Magnesium alloys in invasive ways into sectors such as aerospace, automotive, and marine because of their interesting mechanical properties. A hybrid composite was developed using stir casting consolidation with a constant amount of Micro-Titanium (Ti) and varying amounts of Boron Carbide (B4C) to produce reinforcement in the alloy. This study's main exploration was on corrosion behavior through salt spray test methods. Results obtained revealed excellent resistance on a 5% NaCl solution base, supported by weight loss measurement and SEM images showing localized corrosion close to enhance-reinforced particles. Interestingly, a different approach works for improving mechanical properties of MMCs designed with two different phases yielding better properties. AA6063 alloy matrix composites reinforced with Zircon Sand and Silicon Carbide by stir casting have further identified important processing parameters that influence the quality of synthesis. High strength and ductility materials are requirements of the aerospace and automotive sectors [4]. Innovative processing techniques, namely Friction Stir Processing

(FSP) and Equal Channel Angular Extrusion (ECAE), were introduced here targeting optimization of microstructure through control of process parameters in FS-processed AA5052. Mohsen Soori and Davut Solyali [5], have reviewed the exciting novel progress in Friction Stir Welding (FSW), solid-state welding developed by The Welding Institute in 1991. Well, FSW alleviated all the welding defects and also could be applied extensively in many sectors. Their study on material flow, stress distribution, and tool behavior in relation to FSW operations has given insight into the possibility of enhancing the process while minimizing damage. Further work is, therefore, focused on investigating the geochemical profile of Multani Mitti clay sourced from the Gazij formation, looking at rare earth and high field strength elements by INAA [6]. The clay showed LREE and trace elements like Zr and Th enrichment, which suggest it comes from a felsic source and has possible environmental implications. Accordingly, further studies go with these, such as the traditional and modern application of Multani Mitti in skin and face pack purposes [7]. Shivani Singh and Shashikant Maury et al. [8] focused on the preparation of herbal face packs with ingredients like Multani Mitti, turmeric, aloe vera, and sandalwood. These type of formulations are stable, non-irritant, and could benefit everyone as they provide an alternative without side effects. While another approach on a new solid film peel-off application this time incorporating Multani Mitti proved to be effective in removing dead skin cells, debris, and excess oil without any damage caused[9]. It has shown favorable spreadability, peel-off behavior, and stability under thermal conditions.

The above works have very little empirical scientific evidence for dermatological effectiveness. They have much caution regarding their application. Other works wrote making herbal face packs such as Multani Mitti, turmeric, aloe vera, and sandalwood. From these natural formulation findings, skin care alternatives could be found: stable, non-irritating, suitable for all skin types without side effects. A different approach has introduced a novel peel-off solid film mask containing Multani Mitti that was comparably efficient in removing dead skin, debris, and extra oil from the skin but without irritation from any products applied afterwards [9]. The mask showed good spreadability, peel-off behavior, and stability under thermal conditions. Additional work bases on this foundation had been addressed by Rashmi Saxena Pal et al. [10], establishing the efficacy of herbal face packs on skin rejuvenation, elasticity enhancement, and effects against common concerns like acne and early aging. Their study promotes natural therapies in place of chemical methods to deliver safer cosmetic alternatives. Finally, Bo Zhou et al. [11] have looked at the increasing demand for light high-strength aluminum alloys, especially for aerospace and automotive applications, where the substitution of heavier traditional materials such as steel is critical to improving structural performance and fuel economy.

The present investigation focuses on the fabrication of Al7050-based metal matrix composites (MMCs) reinforced with cow dung ash and hybrid composites with Multani Mitti using the stir casting technique. Various reinforcement percentages (0%, 2%, 4%, 6%, and 8%), and are incorporated to analyze their effects. The cast composites are then butt-welded using Friction Stir Welding (FSW). The primary objective of the study is to assess the corrosion resistance of the composites with varying compositions of cow dung ash and Multani Mitti.

2. Material and Methods

In this investigations, Al7050 alloy was selected as the base material refer Fig.1(a) due to its widespread application in aerospace and structural components. The chemical composition is

given in Table 1. To investigate the effect of natural reinforcements on corrosion resistance, Multani Mitti and Cow Dung Ash (CDA) were used in varying volume fractions of 0%, 2%, 4%, and 6% refer Fig.1 (b). The composite specimens were fabricated using a stir casting process, followed by the preparation of fully welded joints through Friction Stir Welding (FSW) refer Fig. 1(c).

Figure 1: Aluminium 7050 alloy ingot

Figure:1(b) Addition of reinforcement during stir casting process (c) Friction Stir Welding (FSW) tool

Table:1

Weight%	Zr	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
Alloy 7050 Actual Value	0.15	0.12	0.15	2.6	0.10	2.6	0.04	6.7	0.06

The specimens were then machined into standard dimensions, with each sample consisting of two regions: a fully welded portion and an unwelded base alloy portion. For corrosion testing, a 1 M hydrochloric acid (HCl) solution was prepared by mixing 83 mL of concentrated HCl with one liter of distilled water. Specimens were immersed in the solution for a total duration of 6 days at room temperature, with weight loss measurements recorded every 48 hours to monitor corrosion progression. The weight loss method was employed to quantify material degradation, and the results were plotted to evaluate the corrosion behaviour across different compositions.

3. Result and Discussion

The corroded specimens (S1, S2) along with disintegration of weld joints (S3) are illustrated in Fig.2. Also, Fig. 3.0 (a) and (b) illustrates the beaker with HCl and specimen at the start and end of the corrosion test, respectively.

Figure 2: Corroded specimen (S1), (S2) and disintegration of the welded joint (S3)

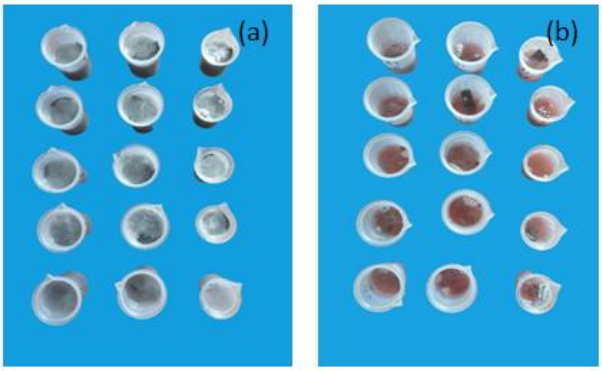


Figure 3.0: (a) Beaker containing HCl and the specimen at the beginning of the corrosion test(b) specimen at the end of the corrosion test.

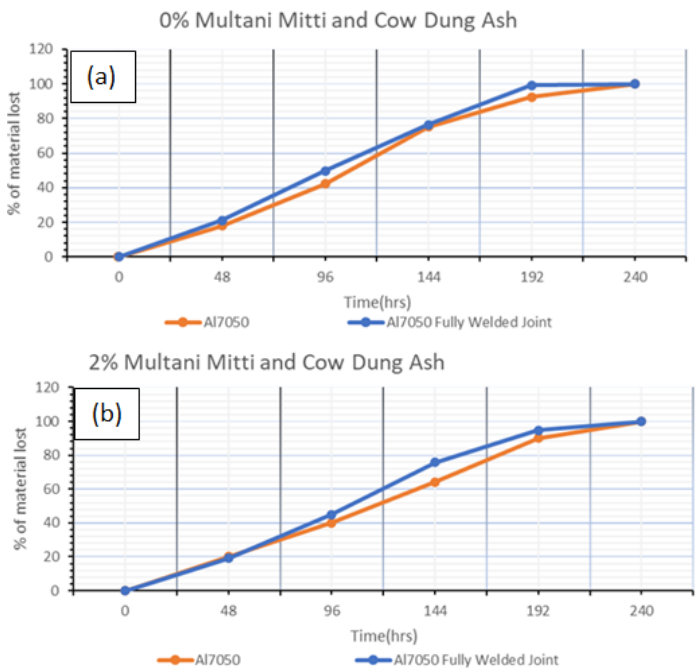
3.1 Comparative Corrosion Analysis of Al7050 alloy and its fully welded joints

A detailed investigation into the corrosion behaviour of Al7050 alloy and its fully welded joints with varying percentages of Multani Mitti and Cow Dung Ash additives was conducted. The specimens were exposed to a corrosive environment of a 1 M solution of HCl for 240 hours, the weight loss was then recorded to quantify the corrosion level. Both welded and unwelded samples exhibited distinct corrosion patterns based on concentration of additives. The performance was analyzed at 0%, 2%, 4%, 6%, and 8% reinforcement levels. The analysis that follows demonstrates the effect of those natural additives on corrosion resistance in welded and base alloy conditions:

The corrosion rates of the Al7050 base alloy and welded joint were very similar in the early hours of exposure to the 1 M HCl solution. After 96 hours, it seems the fully welded joint started to corrode at a much faster rate than the base alloy; perhaps a result of microstructural changes or residual stresses induced during welding. At the end of the 240 hours, almost equal amounts of material loss are recorded for both specimens, pointing toward extreme corrosion with the welded joint being slightly more degraded. At 2% Multani Mitti and Cow Dung Ash refer Fig.(b) the difference in corrosion behaviour between the Al7050 base alloy and the fully welded joint becomes even more conspicuous. The welded joint, with almost total material loss attained by the end of the exposure time, corroded at an accelerated rate, while the base alloy Al7050 was found to exhibit better corrosion resistance with about 90%

material loss. The inference is that the ash-based additive started to confer some corrosion resistance to the base alloy; however, its effect on the welded regions is comparatively less, most likely due to the complex microstructural changes that ensued during welding. Similarly at 4% Multani Mitti and Cow Dung ashes, Fig. 4 (c) shows that the difference of corrosion behaviour becomes increasingly more pronounced between the Al7050 base alloy and the fully welded joint, where a much higher corrosion rate is seen of the welded joint exceeding eventually more than 100% loss of material by the end of the 240 hours, signalling extreme degradation. On the other hand, the base Al7050 alloy has shown improved corrosion resistance with repair material loss limited to around 90%. This shows that with an increase in the amount of additive, further improvement is seen in the corrosion resistance of the base alloy, although this remains less effective in protecting the welded regions. Again, at 6% Multani Mitti and Cow Dung Ash, the difference in corrosion behaviour shows the highest contrast between the Al7050 base alloy and the fully welded joint.

The welded specimen continues to severely corrode, approaching nearly 100% material loss, while the base alloy shows much improved corrosion resistance and limits material loss to 85%. Thus, the 6% additive composition seems to provide the best corrosion protection to the unwelded Al7050, most likely due to forming a more stable or protective surface layer though relatively ineffective in protecting the welded zone. Further, referring to Fig 4 (e) the addition of 8% Multani Mitti and Cow Dung Ash, in the first place, both specimens have shown a gradual increase in material loss, with the base alloy rather degrading slightly more than the other one up to 48 hours. Upon increasing the exposure time, a significant rise in corrosion for both samples takes place, but from 96 hours onward, the semi-welded specimen suffers almost double deterioration. At 240 hours, the semi-welded sample experiences total material loss (100%), while the base alloy follows closely behind. It implies that while the 8% additive does offer some protection, it is less efficient in protecting the welded zone probably because of welding-induced microstructural alterations and residual stresses.



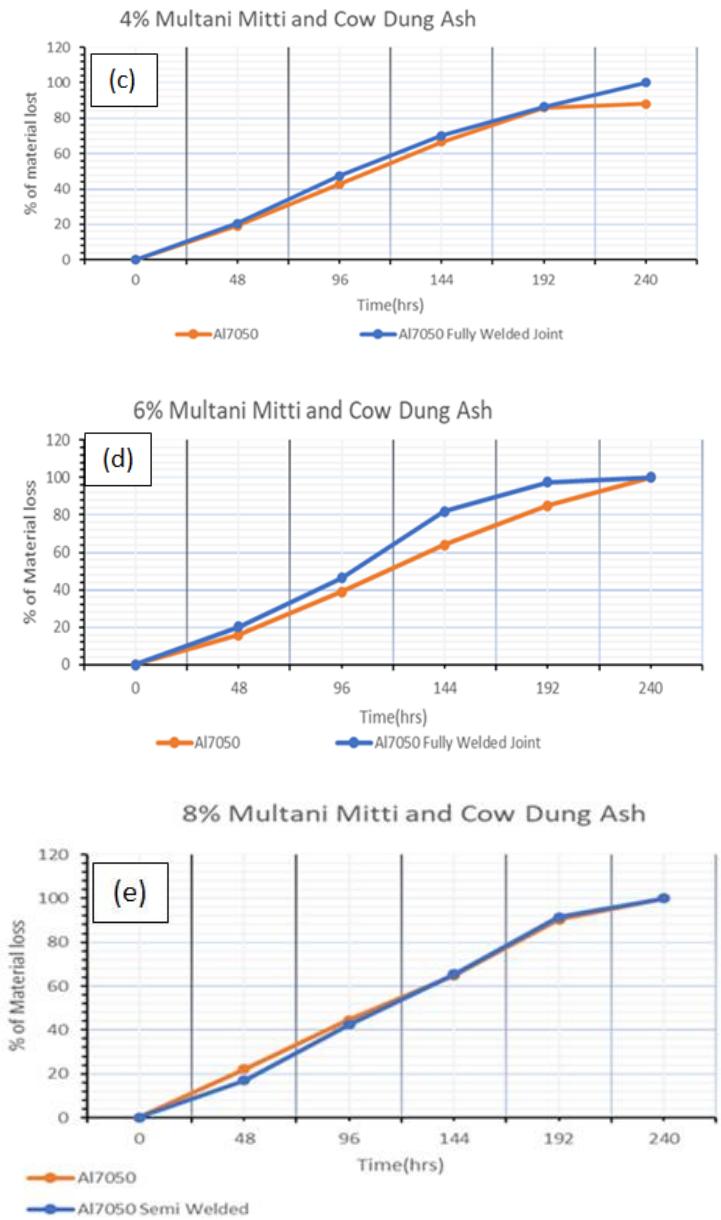


Figure 4: (a)Percentage weight loss of the fully welded specimen with 0% Multani Mitti and Cow Dung Ash (b) specimen with 2% (c) specimen with 4% (d) specimen with 6 % (e) specimen with 8 %

Investigation results showed that, upon increase in percentage composition of the additive, the corrosion rate lowered appreciably from 6% onward, which observed lesser material loss by the end of the test. There was mild increase in corrosion resistance at 8% with respect to 6% specimens after 192 hours, indicating maximum corrosion resistance at 6%. This would mean ash-based additives mitigate corrosion against a certain threshold at which their performance is no longer adequate see Fig. 5. Also, Fig. 6 indicates that all the specimens corroded over time. The 0% additive showed the maximum material loss during the entire exposure period, close to 100% at 240 hours. With an increase in percentage, the additives decrease the corrosion rate, thereby improving resistance. Best performance was attained by the 8% additive sample with reduced material loss at the end of the test period. This trend

suggests that the incorporation of Multani Mitti and Cow Dung Ash would greatly help in improving the corrosion resistance of the Al7050 alloy in mildly acidic environments.

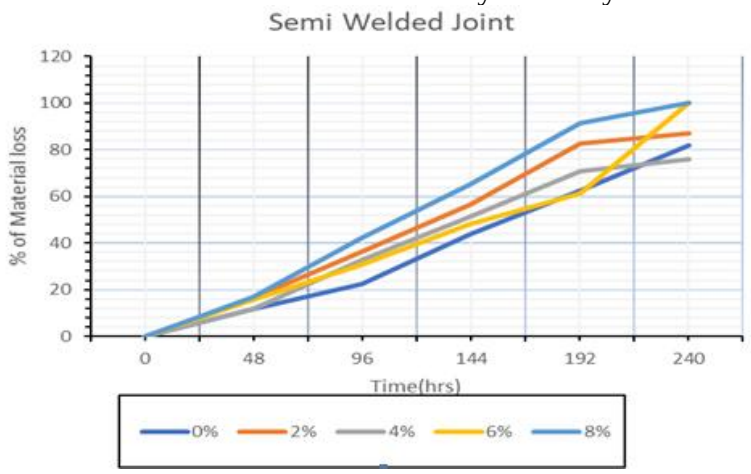


Figure: 5 Corrosion Behaviour of Semi-Welded Al7050 Joints with Varying Percentages of Multani Mitti and Cow Dung Ash

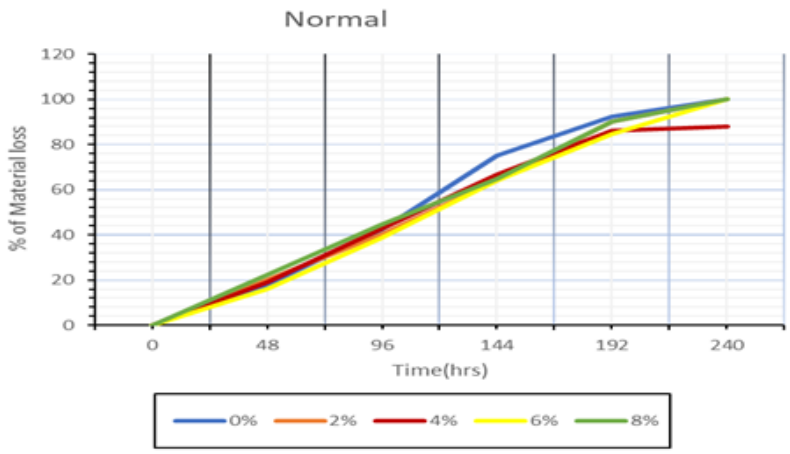


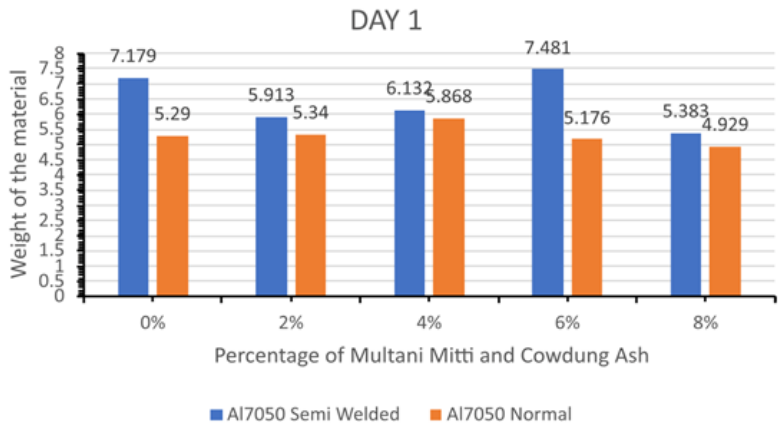
Figure 6: Percentage of Material Loss in Normal Al7050 Specimens

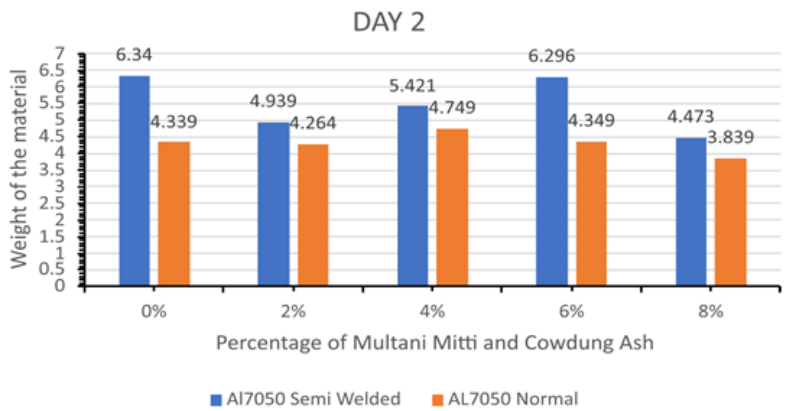
3.2 Comparative Corrosion Analysis of Welded and Unwelded Al7050 with Eco-Friendly Additives Day Wise

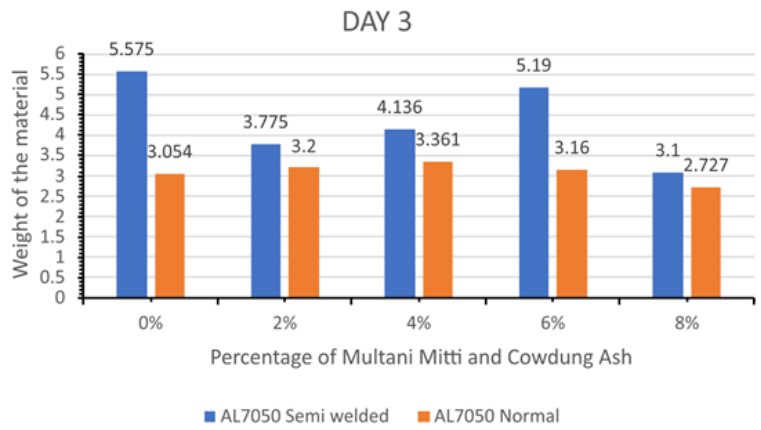
The corrosion behaviour of Al7050 was analysed for both fully welded and normal conditions over a six-day experimental period with varying percentages (0%-8%) of additives, namely Multani Mitti and cow dung ash. On Day 1, all the samples had relatively high initial weights, wherein the fully welded specimens were observed to have slightly lower mass as compared to the normal ones. As the days progressed, a constant decrease in weight was noted, showing material loss due to corrosion. By the end of Days 2 and 3, corrosion effects became visibly pronounced, especially in the fully welded samples, which showed a sharper weight drop when compared to the normal ones at 4% and 6% levels of additives.

A very strong divergence was recorded on Day 4, in which fully welded samples lost more amounts of materials than their normal counterparts. However, for 6% additive, the base alloy preserved a better weight profile. By Day 5, all the fully welded samples had almost degraded across all additive percentages, especially at 0% and 6%, where weights were nearly dropping to zero. Notably, the 4% normal sample retained more weight than others, which could mean that corrosion resistance is temporarily improving at that concentration.

In conclusion, on the sixth day, all fully welded samples were already lost (weight = 0), leaving only a trace amount of 0.7 g for the 4% normal sample, thus implying some resistance. Such a seeming contradiction shows that while welding promotes corrosion, some concentrations of the additive (4% in particular) can afford some degree of protection on unwelded Al7050, though not sufficiently over long exposure. The study concludes that the corrosion resistance of Al7050 greatly depends on the nature of the welding and additive concentration, with 6% being able to protect the base alloy while fully welded joint is constantly exposed.







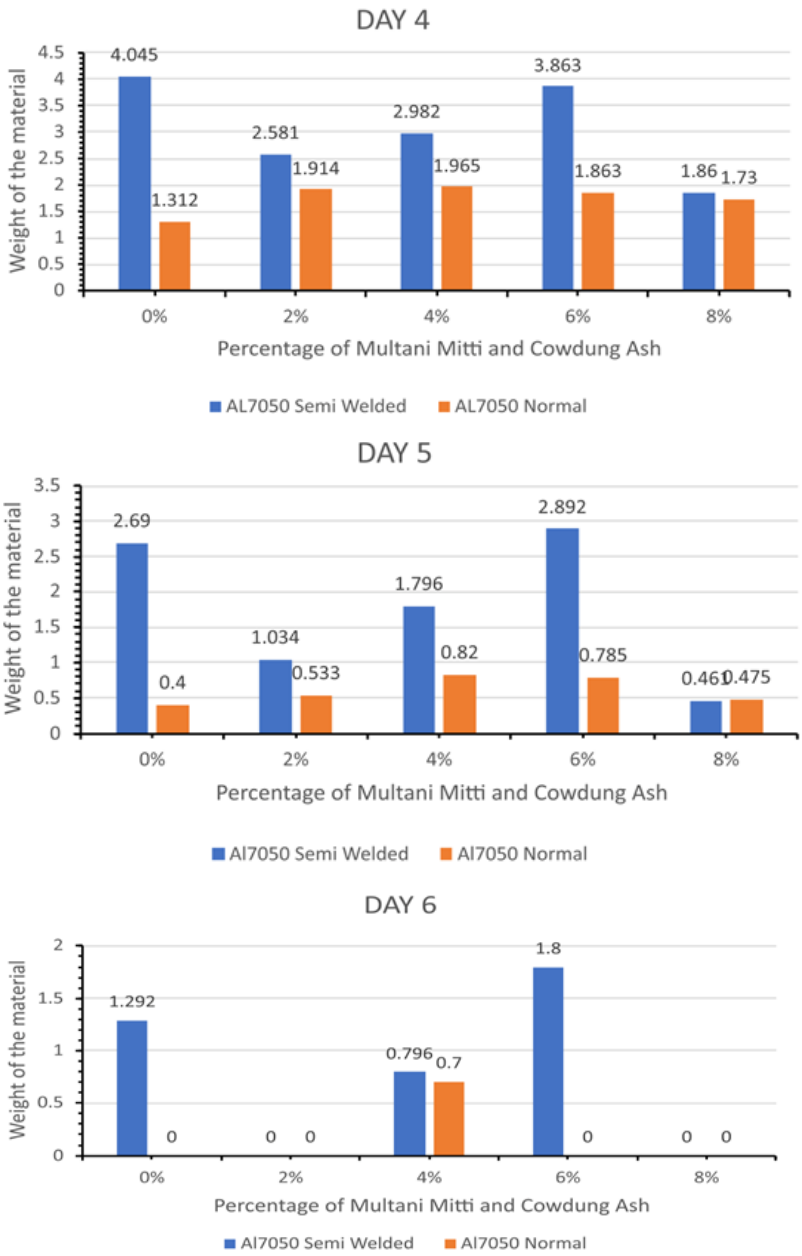


Figure: 7 Illustrates weight loss of the corroded specimen at Day 1; 0 hrs. Day 2 ;48 hrs. Day 3 ; 96 hrs. Day 4 ; 144 hrs. Day 5 192 hrs. Day 6; 240 hrs.

4. Conclusion

1) The incorporation of Multani Mitti and cow dung ash into Al7050 alloy improves corrosion resistance in unwelded specimens, with optimal performance observed at 6% additive content.
2) Material loss in the base alloy decreases progressively with increasing additive concentration, suggesting the formation of a protective barrier from the natural additives.
3) Welded joints exhibit significantly higher corrosion rates across all additive concentrations, highlighting the detrimental effects of welding-induced defects and residual stresses.

4) The 6% additive composition provides the best overall corrosion resistance for the base alloy but fails to adequately protect welded regions.
5) Additional strategies such as post-weld heat treatments or hybrid surface coatings may be necessary to enhance corrosion resistance in welded joints of Al7050 composites.

5. References

1. Rajendran, P., & Muthukumaran, S. (2020). Corrosion behavior of surface modified Al7075 aluminium alloy: A review. *Materials Today:Proceedings*,*33*,1477–1482. https://doi.org/10.1016/j.matpr.2020.04.027
2. Madegowda, B., Shivalinga, S., Vidyasagar, H. N., Shivanand, H. K., Bylappa, B. K., & Janardhan, C. V. (2017, October). Corrosion study on Al-Mg alloy reinforced with micro titanium and boron carbide particulate hybrid metal matrix composites. International Research Journal of Engineering and Technology (IRJET), 4(10). e-ISSN: 2395-0056.
3. Jenix Rino, J., Chandramohan, D., & Daniel Jebin, V. (2012, September). Research review on corrosion behaviour of metal matrix composites. International Journal of Current Research, 4(9), 179–186. ISSN: 0975-833X.
4. Itharaju, R. R. (2001). Friction based technologies for joining and processing. In K. V. Jata, M. W. Mahoney, R. S. Mishra, S. L. Semiatin, & D. P. Field (Eds.), Friction stir welding and processing (pp. 3–13). TMS.
5. Soori, M., & Solyali, D. (2010). Comparative investigation of tungsten inert gas and friction stir welding characteristics of Al-Mg-Sc alloy plates. Materials & Design, 31(1), 306–311.
6. Waheed, S., & Faiz, Y. (1984). Report on intercomparison IAEA/Soil-7 for the determination of trace elements in soil. IAEA/RL/112, International Atomic Energy Agency (Vienna), 142–144.
7. Pareek, A., Jain, V., & Ratan, Y. (2012). Mushrooming of herbals in new emerging markets of cosmeceuticals. International Journal of Advanced Research in Pharmaceutical and Biological Sciences, 2(4), 473–480.
8. Singh, S., & Maury, S. (2015). Possible health implications associated with cosmetics: A review. Science Journal of Public Health, 3(5–1), 58–63.
9. Vyas, J., Chauhan, J., Choudhary, U., & Dabgar, Y. (n.d.). Optimisation and development of the peel-off gel formulation for the decontamination of radiological contaminants from skin. pp. 164–184.
10. Pal, R. S., Pal, Y., & Shamantha, P. (2015). Folation & evaluation of poly-beral face wash. World Journal of Pharmaceutical and Pharmaceutical Sciences, 4(6), 385–388.
11. Zhou, B., Liu, B., & Zhang, S. (1946). Fuller's Earth in India. Transactions of the Indian Ceramic Society, 5(3), 104–124. https://doi.org/10.1080/0371750x.1946.10877805