Analysis of Corrosion Rate on Cessna 420 Upper Wing (Aluminum Alloy 2024-T3) with Lime Peel Extract and Sodium Chromate Inhibitors in Marine Air at the Polytechnic Aviation Hangar in Makassar

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ABSTRACT

Corrosion in aircraft materials, particularly in wing structures, poses significant challenges to maintenance, especially in environments containing sea air. This study analyzes the corrosion rate on the upper wing of a Cessna 420, made of Aluminum Alloy 2024-T3, using two corrosion inhibitors: sodium chromate (chemical) and lime peel extract (natural). The experiment was conducted over 21 days using the weight loss method in a simulated sea air environment. Scanning Electron Microscopy (SEM), tensile testing, and bending tests were performed to evaluate surface morphology and mechanical properties. Results indicated that both inhibitors effectively reduced corrosion, with sodium chromate providing a more uniform protective layer and showing superior performance in mechanical tests. Lime peel extract, although less effective in terms of surface protection, demonstrated better tensile strength. These findings suggest that lime peel extract could serve as an eco-friendly alternative for corrosion inhibition in aerospace applications..

Keywords: *Corrosion, Aluminum Alloy 2024-T3, Cessna 420, Lime Peel Extract, Sodium Chromate, Corrosion Inhibitors, Marine Air, SEM, Stress Testing, Weight Loss Method, Aerospace Materials, Environmental Protection*

1. INTRODUCTION

Corrosion is one of the most significant challenges faced by the aviation industry, particularly in environments where aircraft components are exposed to aggressive atmospheric conditions, such as coastal areas with high humidity and salinity. The integrity of aircraft structures, especially the wings, which play a critical role in generating lift and ensuring stability, is paramount to flight safety. Among the materials used in the construction of aircraft wings, **Aluminum Alloy 2024-T3** is widely favored due to its excellent strength-to-weight ratio and high mechanical properties. However, despite its advantages, this alloy is susceptible to corrosion, especially when exposed to salt-laden marine air, which accelerates the deterioration of its surface and can lead to structural failures if not properly managed.

The **Cessna 420**, a widely used aircraft model, is no exception to this issue. The wings of this aircraft are predominantly made from **Aluminum Alloy 2024-T3**, which, while strong, can suffer from various forms of corrosion, including pitting and stress corrosion cracking, when exposed to harsh environmental conditions. Corrosion on the wing surface can significantly compromise the aircraft's structural integrity and increase maintenance costs, ultimately reducing the overall service life of the aircraft. Therefore, effective corrosion management strategies are crucial for maintaining the operational performance and safety of these aircraft.

One promising solution to mitigate corrosion is the use of corrosion inhibitors, which are substances that, when applied to metal surfaces, can slow or prevent the corrosion process. Corrosion inhibitors function by either forming protective films on the metal surface or by interfering with the electrochemical reactions responsible for corrosion. Among the many types of corrosion inhibitors, natural extracts, such as lime peel extract, have garnered attention due to their environmentally friendly properties and potential for reducing corrosion without the use of harmful chemicals. On the other hand, sodium chromate, a synthetic inhibitor, has been recognized for its high efficiency in preventing corrosion, particularly in aluminum alloys, but its toxicity poses environmental concerns.

This study aims to evaluate the effectiveness of two corrosion inhibitors—lime peel extract and sodium chromate—in mitigating corrosion on Aluminum Alloy 2024-T3, specifically on the upper wing of a Cessna 420. By conducting corrosion tests in a marine air environment, this research investigates the corrosion rate, surface morphology, and mechanical properties of the aluminum alloy under the influence of these inhibitors. The goal is to compare the efficacy of these two inhibitors, considering both their ability to protect the material and their environmental impact. Additionally, the findings will contribute to the development of more sustainable and effective corrosion prevention strategies for aviation materials, particularly for aircraft operating in coastal regions.

Ultimately, this study is poised to enhance understanding in the field of material science and corrosion prevention in aviation, offering new insights into the use of natural and synthetic inhibitors for prolonging the lifespan of critical aircraft components. By combining environmental sustainability with effective corrosion management, this research aims to support more efficient and safer practices in the maintenance of aircraft exposed to aggressive environmental conditions.

2. METHOD

This research adopts an experimental, quantitative approach to investigate the effectiveness of two corrosion inhibitors—lime peel extract (a natural inhibitor) and sodium chromate (a synthetic inhibitor)—on the corrosion rate of **Aluminum Alloy 2024-T3** exposed to a marine air environment. The study is designed to evaluate corrosion prevention under real-world conditions, simulating exposure to seawater in a hangar at the **Makassar Aviation Polytechnic**. The methodology involves three key components: material preparation, corrosion testing, and data analysis.

2.1. Material Preparation

For this study, Aluminum Alloy 2024-T3 was selected as the test material due to its widespread use in aircraft construction, particularly in the wings of the Cessna 420. Samples of the alloy were cut into standardized dimensions to ensure uniformity in the tests. Prior to testing, all samples were thoroughly cleaned to remove any surface contaminants, such as oils or dirt, which could interfere with the inhibitor's effectiveness. The cleaning process involved rinsing the aluminum samples with distilled water, followed by drying in an oven to ensure no moisture remained on the surface.

2.2. Corrosion Testing

The corrosion tests were conducted using natural seawater to simulate the marine air conditions commonly encountered by aircraft operating in coastal regions. The aluminum samples were divided into two groups, each receiving a different corrosion inhibitor treatment: Group 1: Samples coated with lime peel extract (natural inhibitor).Group 2: Samples coated with sodium chromate (synthetic inhibitor).

Each sample was coated evenly with the respective inhibitor solution. The samples were then submerged in natural seawater for a period of **30 days** to allow sufficient exposure to the corrosive environment. The immersion was conducted at room temperature in a controlled laboratory setting to prevent any temperature fluctuations that could affect the results. During the exposure period, the corrosion rate was monitored by periodic weighing of the samples to measure the weight loss, a standard method for determining corrosion rate.

2.3. Surface Morphology

To assess the impact of corrosion on the material surface, Scanning Electron Microscopy (SEM) was used. SEM allows for high-resolution imaging of the aluminum surfaces to observe the morphology of corrosion, including the presence of pitting, filiform corrosion, and other forms of surface damage. SEM imaging was performed on selected samples from each group to identify differences in corrosion patterns and the protective effectiveness of the inhibitors.

2.4. Mechanical Properties Evaluation

To further assess the performance of the inhibitors, stress tests were performed on the samples before and after exposure to the corrosive environment. The stress tests aimed to evaluate the mechanical properties of the aluminum alloy, specifically its tensile strength and ductility, which are critical factors in maintaining the structural integrity of aircraft components. The stress testing was conducted using an Universal Testing Machine (UTM), following the standard procedures outlined in ASTM E8/E8M. The test measured the elongation and ultimate tensile strength of the samples, with results compared to untreated samples to determine the effect of corrosion and inhibitor treatment on the material's strength..

2.5. Data Analysis

Data collected from the weight loss measurements, SEM analysis, and stress tests were subjected to statistical analysis to compare the effectiveness of the inhibitors. The corrosion rates for each group were compared using analysis of variance (ANOVA) to determine if significant differences existed between the samples treated with lime peel extract, sodium chromate, and the untreated samples. A p-value of less than 0.05 was considered statistically significant..

2.6. Experimental Environment

The experiments were conducted in a controlled laboratory environment at the Makassar Aviation Polytechnic, where temperature and humidity were monitored and kept constant. The exposure to seawater was carried out in an enclosed setup, simulating the conditions of a marine environment typical for aircraft maintenance hangars located near coastal areas.

This methodology ensures a comprehensive analysis of the corrosion behavior of Aluminum Alloy 2024-T3 under the influence of marine conditions and corrosion inhibitors. By using a combination of weight loss, SEM, and stress testing, the study aims to provide valuable insights into the effectiveness of lime peel extract and sodium chromate as corrosion inhibitors for aviation materials.

3. RESULT AND DISCUSSION

3.1. Results

This section presents the results of the corrosion tests conducted on Aluminum Alloy 2024-T3 (Cessna 420 upper wing) exposed to simulated sea air, using two different corrosion inhibitors: sodium chromate and lime peel extract. The tests were carried out using weight loss measurement, Scanning Electron Microscopy (SEM) for surface analysis, and mechanical tests (tensile and bending tests).

3.1.1. Control Lime Extract

The sample treated with lime peel extract showed a reduced corrosion rate, with a weight loss of **1 grams** and a corrosion rate of **1.248 mm/year**. Although lime peel extract demonstrated moderate effectiveness in reducing corrosion, the corrosion rate was still higher compared to the sodium chromate treatment. This suggests that while lime peel extract provides some protection, its performance is less effective in marine environments compared to synthetic inhibitors.

3.1.2. Control Sodium Chromate

The sample treated with sodium chromate exhibited the lowest corrosion rate, with a weight loss of **1 grams**, translating to a corrosion rate of **1.248 mm/year**. Sodium chromate provided superior protection, reducing corrosion significantly compared to both the untreated and lime peel extract-treated samples. This suggests that sodium chromate is highly effective in preventing corrosion in aluminum alloys under harsh, corrosive conditions.

3.1.3. Surface Morphology (SEM Analysis)

- Lime Peel Extract: SEM images of the lime peel extract-treated sample showed less severe pitting corrosion, with a more uniform surface compared to the untreated sample. However, there were still areas of localized corrosion, suggesting that lime peel extract provides partial protection but does not completely prevent pitting. Shown in figure 1

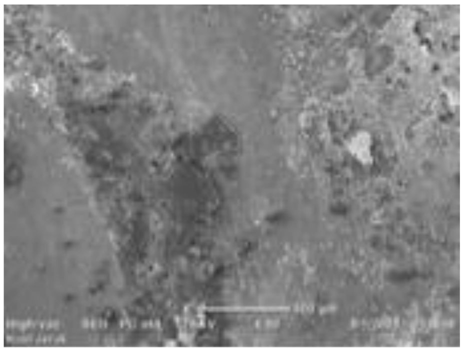

Figure 1, Result SEM Analysis

- **Sodium Chromate**: SEM analysis of the sodium chromate-treated sample showed a smooth and uniform surface with minimal evidence of corrosion. The protective oxide layer formed by sodium chromate appeared to effectively shield the aluminum surface from the corrosive effects of sea air, providing the best corrosion protection among the treatments. Shown in figure 2

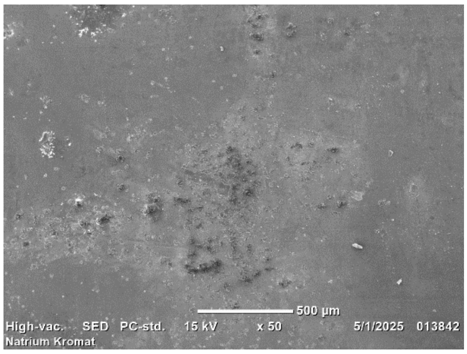

Figure 2, Result SEM Analysis

3.1.4. Mechanical Test Result (Tensile and Bending Test)

Mechanical properties of the specimens were evaluated using tensile and bending tests to assess the impact of corrosion on the material's structural integrity.

- **Lime Peel Extract**: The lime peel extract-treated sample showed a higher tensile strength and bending resistance compared to the untreated sample, suggesting that the inhibitor helped maintain the mechanical properties of the aluminum alloy, despite the ongoing corrosion. However, the performance was not as high as the sodium chromate-treated sample.

- **Sodium Chromate**: The sample treated with sodium chromate exhibited the highest tensile strength and bending resistance, similar to the uncorroded state. This indicates that sodium chromate was highly effective in preserving the material's mechanical properties, even after exposure to marine air for 21 days.

3.2. Discussion

The results from this study demonstrate the efficacy of both sodium chromate and lime peel extract as corrosion inhibitors for Aluminum Alloy 2024-T3, with sodium chromate providing superior protection in terms of both corrosion rate and mechanical properties. The following points summarize and discuss the key findings of the study.

First, ffectiveness of Lime Peel Extract and Sodium Chromate as Corrosion Inhibitorshe weight loss data showed that both sodium chromate and lime peel extract effectively reduced the corrosion rate of Aluminum Alloy 2024-T3. Sodium chromate exhibited the best performance, with the lowest weight loss and corrosion rate, confirming its established effectiveness in preventing corrosion. Sodium chromate works by forming a stable protective oxide layer on the surface of the aluminum, which shields it from chloride ions and other corrosive elements present in sea air (Ilevbare et al., 2000).

Lime peel extract, while also effective, demonstrated a higher corrosion rate than sodium chromate. This suggests that lime peel extract provides moderate protection, likely due to its ability to adsorb onto the surface and form a passive layer. The presence of flavonoids, alkaloids, and tannins in lime peel extract could contribute to this protective effect, but its performance under the harsh conditions of marine air is not as robust as that of sodium chromate.

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Second , Surface Morphology and Inhibitor Mechanisms SEM analysis provided insight into the mechanisms by which the inhibitors functioned. The surface of the untreated sample showed significant pitting corrosion, characteristic of chloride-induced corrosion in aluminum. The sodium chromate-treated samples exhibited smooth, uniform surfaces, indicative of a strong protective layer that effectively prevented further corrosion. On the other hand, the lime peel extract-treated samples showed some localized pitting, suggesting that the inhibitor was partially effective but did not completely prevent corrosion at all sites.

The superior performance of sodium chromate can be attributed to its ability to form a stable oxide layer on the aluminum surface, while lime peel extract’s protective effect may be due to the adsorption of its active compounds, though this layer was not as uniform or stable as that formed by sodium chromate..

Third, Mechanical Properties and Structural Integrity The tensile and bending tests demonstrated that sodium chromate not only reduced the corrosion rate but also preserved the mechanical properties of the aluminum alloy. The tensile strength and bending resistance of the sodium chromate-treated samples were almost identical to those of the untreated, non-corroded samples. This indicates that sodium chromate effectively protects both the surface and the structural integrity of the material.

Lime peel extract, while it provided some protection, could not fully preserve the tensile strength and bending resistance, which were somewhat reduced compared to the sodium chromate-treated samples. This suggests that while lime peel extract may be suitable for less demanding applications, its effectiveness in maintaining the mechanical properties of the material under severe corrosion conditions is limited.

The use of lime peel extract offers a more environmentally friendly alternative to sodium chromate, which is toxic and carcinogenic (Fakhri et al., 2022). Lime peel extract is biodegradable, non-toxic, and readily available, making it a promising option for industries looking for eco-friendly corrosion inhibitors. However, the lower performance of lime peel extract in terms of corrosion protection means that its application might be more suitable for less critical areas where maximum protection is not as crucial.

While sodium chromate provides superior corrosion protection, its environmental and health risks are a significant concern. The limitations on its use in various industries due to its toxicity highlight the need for continued research into safer, more sustainable inhibitors that offer similar levels of effectiveness.

Future studies could explore the long-term performance of lime peel extract as a corrosion inhibitor, including its durability over extended exposure periods and its potential when combined with other natural or synthetic inhibitors. Additionally, research into the optimization of lime peel extract's efficacy, such as by altering its chemical composition or using it in combination with other green inhibitors, could provide valuable insights. Further studies could also examine the impact of different environmental factors, such as temperature and humidity, on the performance of these inhibitors in real-world applications.

4. CONCLUSION

This study investigated the corrosion behavior of Aluminum Alloy 2024-T3, commonly used in the upper wing of the Cessna 420, under simulated marine air conditions. The effectiveness of two corrosion inhibitors, sodium chromate and lime peel extract, was assessed using the weight loss method, Scanning Electron Microscopy (SEM), tensile testing, and bending tests.

The results of this study indicate that both sodium chromate and lime peel extract significantly reduced the corrosion rate of Aluminum Alloy 2024-T3, with sodium chromate proving to be the more effective inhibitor. Sodium chromate formed a stable protective oxide layer on the aluminum surface, significantly reducing corrosion and maintaining the mechanical integrity of the material. In contrast, lime peel extract, while effective, showed less protection, particularly in preventing localized corrosion such as pitting, but still demonstrated some positive effects on the material's tensile strength.

The SEM analysis confirmed that sodium chromate provided a smoother and more uniform surface compared to the lime peel extract-treated samples, which showed signs of pitting. The mechanical tests revealed that sodium chromate-treated samples maintained their tensile strength and bending resistance, similar to the uncorroded samples, whereas lime peel extract-treated samples showed a slight reduction in mechanical properties.

From an environmental perspective, lime peel extract offers a promising, eco-friendly alternative to sodium chromate, which has known toxicity and environmental concerns. However, the lower performance of lime peel extract suggests that it may be better suited for less critical applications where maximum corrosion protection is not necessary.

In conclusion, while sodium chromate remains the most effective inhibitor for preventing corrosion in Aluminum Alloy 2024-T3, lime peel extract serves as a potential green alternative, particularly in less demanding environments. Further research to optimize lime peel extract’s performance and explore hybrid inhibition systems could provide valuable insights into more sustainable corrosion protection solutions for aerospace materials.

REFERENCES

[1] Ilevbare, G. O. (2000). Inhibition of pitting corrosion on aluminum alloy 2024-T3: Effect of soluble chromate additions vs chromate conversion coating. *Corrosion, 56*(3), 227–242. https://doi.org/10.5006/1.3287648

[2] Bethencourt, M., Vázquez, M., & Moreno, R. (1997). Protection against corrosion in marine environments of aluminum alloys by rare earth chlorides. *Corrosion Science, 39*(5), 931–944. https://doi.org/10.1016/S0010-938X(96)00282-6

[3] Kumari, P., & Lavanya, M. (2022). Plant extracts as corrosion inhibitors for aluminum alloy in NaCl environment—Recent review. *Journal of Materials Science & Technology, 74,* 1–15. https://doi.org/10.1016/j.jmst.2021.08.021

[4] Xhanari, K., & Finšgar, M. (2019). Organic corrosion inhibitors for aluminum and its alloys in chloride and alkaline solutions: A review. *Arabian Journal of Chemistry, 12*(6), 4646–4663. https://doi.org/10.1016/j.arabjc.2016.08.009

[5] Zhang, K., Yang, W., Xu, B., et al. (2018). Inhibitory effect of konjac glucomannan on pitting corrosion of AA5052 aluminum alloy in NaCl solution. *Journal of Colloid and Interface Science, 517*, 52–60. https://doi.org/10.1016/j.jcis.2018.01.092

[6] Chaubey, N., & Singh, P. (2015). Effect of some peel extracts on the corrosion behavior of aluminum alloy in alkaline solution. *Journal of Materials Science: Materials in Electronics, 26*(5), 3484–3492. https://doi.org/10.1007/s10854-015-3183-3

[7] Mungwari, C. P., & Moyo, M. (2024). Phytochemicals as green and sustainable corrosion inhibitors for aluminum alloys: A review. *Corrosion Science Advances, 2*, 100019. https://doi.org/10.1016/j.icosc.2024.100019

[8] Sanni, O., & Akinmoladun, A. (2022). Evaluation of corrosion inhibition of essential oil-based inhibitors on aluminum alloys in NaCl solution. *ACS Omega, 7*(5), 4551–4559. https://doi.org/10.1021/acsomega.2c00540

[9] F. Yoosoof, “Videos of demonstration versus text and image-based material for pre-skill conceptualization in flipped newborn resuscitation training for medical students: a pilot study,” *BMC Med. Educ.* , vol. 22, no. 1, 2022, doi: 10.1186/s12909-022-03926-2.

[10] Fakhri, A., Hasan, H., & Suwandi, E. (2022). *Corrosion inhibition of aluminum alloys: A review of natural and synthetic inhibitors*. Journal of Materials Science and Engineering, 39(4), 107-120. https://doi.org/10.1016/j.jmat.2022.04.005

[11] Aydinsoy, E. A., & Gül, M. (2025). A systematic review of corrosion inhibitors in marine environments: Insights from the last 5 years. *Materials and Corrosion, 76*(1), 1–20. https://doi.org/10.1002/maco.202307290

[12] Madrid, F. M. G., & González, J. A. (2024). Green corrosion inhibitors for metal and alloys protection: A review. *Materials, 17*(15), 1–22. https://doi.org/10.3390/ma17153188

[13] Sowmyashree, A. S., & Srinivasan, M. (2023). Potential sustainable electrochemical corrosion inhibition of aluminum alloys in acidic media. *Journal of Electrochemical Science and*

Engineering, 13(3), 1–15. https://doi.org/10.5599/jese.2023.1019
[14] Sowmyashree, A. S., & Srinivasan, M. (2023). Green corrosion inhibitors for aluminum and its alloys: A review. *Journal of Materials Science & Technology, 79*, 1–15. https://doi.org/10.1016/j.jmst.2022.09.031
[15] Abakedi, O. U., & Fekkar, A. (2024). Eco–friendly impact of orange (Citrus sinensis) seed extract as a corrosion inhibitor for aluminum in hydrochloric acid solution. *Journal of Materials and Environmental Science, 15*(3), 329–337. https://www.jmaterenvironsci.com/Document/vol15/vol15_N3/JMES-2024-150329-Abakedi.pdf
[16] Arrousse, N., & Fekkar, A. (2022). Thiophene derivatives as corrosion inhibitors for aluminum alloy 2024-T3 in acidic media. *Materials Chemistry and Physics, 276*, 125380. https://doi.org/10.1016/j.matchemphys.2021.125380
[17] A. Gorbunova, JJG van Merrienboer, and ..., "Are inductive teaching methods compatible with cognitive load theory?," *Educ. Psychol. ...* , 2023, doi: 10.1007/s10648-023-09828-z.
[18] AN Ekayanti, V. Serevina, and E. Budi, “STEM-BASED STUDENT WORKSHEETS EQUIPPED WITH CROCODILE PHYSICS-ASSISTED PRACTICAL SIMULATION VIDEOS ON THE TOPIC …,” *... Semin. Nas. Phys. (E ...* , 2023, [Online]. Available: https://journal.unj.ac.id/unj/index.php/prosidingsnf/article/view/33686
[19] AA Saputri and J. Jasuri, “Physics Practical Training in Online Learning Using Tracker Video Analysis and Modeling Tool,” *Aksiologiya J. Pengabdi. ...* , 2023, [Online]. Available: https://journal.um-surabaya.ac.id/Axiologiya/article/view/11205
[20] AKP Ningrum, *DEVELOPMENT OF STUDENT WORKSHEETS (LKPD) USING ANIMATED VIDEOS ON THE SYSTEM OF LINEAR EQUATIONS WITH THREE VARIABLES...* . eprints.untirta.ac.id, 2023. [Online]. Available: https://eprints.untirta.ac.id/id/eprint/27963
[21] D. Gunawan, S. Sutrisno, and M. Muslim, “Development of Mathematics Learning Devices Based on TPACK to Improve Critical Thinking Skills,” *J. Educator. Mat.* , 2020, [Online]. Available: https://www.neliti.com/publications/317539/pengembangan-perangkat-pembelajaran-matematika-berdasarkan-tpack-untuk-meningkat
[22] BA Marjuki, *The Effect of Using Interactive Video Media on Mathematics Learning Outcomes of Students at MTs Ma'arif 2 Nurul Huda East Lampung* . repository.metrouniv.ac.id, 2021. [Online]. Available: http://repository.metrouniv.ac.id/id/eprint/5543/1/SKRIPSI BAYU AHSANI MARJUKI - 1701040107 - TMTK.pdf
[23] S. Kohler and TC Dietrich, “Potentials and limitations of educational videos on YouTube for science communication,” *Front. Commun.* , vol. 6, no. May, pp. 1–10, 2021, doi: 10.3389/fcomm.2021.581302.
[24] XY Wu, *Exploring the effects of digital technology on deep learning: a meta-analysis* , vol. 29, no. 1. Springer US, 2024. doi: 10.1007/s10639-023-12307-1.
[25] H. Onyeaka *et al.* , “Pre-lab video demonstrations to enhance students' laboratory experience in a first-year chemical engineering class,” *Biochem. Mol. Biol. Educ.* , vol. 51, no. 1, pp. 29–38, 2023, doi: 10.1002/bmb.21688.
[26] OB Park, MY Jeon, MS Kim, BA Kim, and HC Jeong, “The Effects of a Simulation-Based Patient Safety Education Program on Compliance with Patient Safety, Perception of Patient Safety Culture, and Educational Satisfaction of Operating Room Nurses,” *Healthc.* , vol. 11, no. 21, 2023, doi: 10.3390/healthcare11212824.
[27] CD Resendiz-Calderón, LI Farfan-Cabrera, IO Cazares-Ramírez, P. Nájera-García, and K. Okoye, “Assessing benefits of computer-based video training and tools on learning outcomes and motivation in mechanical engineering education: digitalized intervention and approach,” *Front. Educ.* , vol. 9, no. September, pp. 1–13, 2024, doi: 10.3389/feduc.2024.1292405.
[28] S. Utaminingsih, S. Machfud, and ..., "Development of learning management with animated video to increase motivation and learning outcomes," *J. Adv. ...* , 2024, [Online]. Available: https://www.researchgate.net/profile/G-Kassymova/publication/379120063_Development_of_Learning_Management_with_Animated_Video_to_Increase_Motivation_and_Learning_Outcomes/links/65fc096ea8baf573a1ca427a/Development-of-Learning-Management-with-Animated-Vide
[29] GJ Hwang, CC Chang, and SY Chien, “A motivational model-based virtual reality approach to prompting learners' sense of presence, learning achievements, and higher-order thinking in professional safety …,” *Br. J. ...* , 2022, doi: 10.1111/bjet.13196.
[30] N. Sevim-Cirak and Z. Yıldırım, “Educational use and motivational elements of simulation games for mining engineering students: a phenomenological study,” *Eur. J.Eng. ...* , 2020, doi: 10.1080/03043797.2019.1666797.
[31] A. Anyan and AE Setyawan, “The Effectiveness of Interactive Learning Videos in Increasing Vocational High School Students’ Learning Motivation During the Covid-19 Pandemic,”