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Examination Of High-Temperature Tests Regarding Polyoxymethylbenzene (POM) Core Material On Aluminum Composite Panels (ACP)

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Abstract:
Background. Aluminum Composite Panels (ACPs) are widely used in construction and engineering applications because of their lightweight structure, corrosion resistance, and favorable strength-to-weight ratio. However, the thermal stability of the polymer core remains a critical concern when ACPs are exposed to elevated temperatures.
Aims. This study investigates the high-temperature behavior and microstructural changes of Polyoxymethylene (POM) used as an alternative core material in ACPs.
Methods. We fabricated the panels with 5052 aluminum alloy outer layers, POM as the core material, N-193 aluminum adhesive for interlayer bonding, and a fire-retardant coating. We heated the specimens to 300°C, 350°C, and 400°C for 1 h, then cooled them by annealing. We performed microstructural observations before and after thermal exposure using an optical microscope at 1000× magnification.
Result. The results showed that exposure to temperatures substantially above the POM melting point (~165°C) caused the POM core to melt and adhere to the aluminum layers. After high-temperature exposure, the specimens exhibited substantial morphological changes, with the molten POM remaining attached to the aluminum surfaces. Optical microscopy also revealed marked changes in the appearance and distribution of the POM-derived residue after thermal exposure. Overall, the findings show that POM can be incorporated as a core material in ACP fabrication but melts and degrades at 300–400°C.
Conclusion. These results provide experimental evidence of the thermal limitations of POM-core ACPs and highlight the importance of selecting thermally stable core materials for ACP applications involving elevated-temperature environments.

Keywords: Aluminum Composite Panel (ACP); Polyoxymethylene (POM); thermal degradation; high-temperature exposure; microstructure

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INTRODUCTION

Aluminum Composite Panel (ACP) is an innovative construction material that combines corrosion resistance, attractive aesthetics, and malleability, with an excellent strength-to-weight ratio, making it a popular choice in engineering and architectural applications (Lahoz et al., 2014). ACP's thermal performance indicates a high tolerance for temperature fluctuations, meaning it reliably maintains structural integrity under extreme conditions. These properties strengthen ACP's position as a superior choice in its various applications (Mohaney et al., 2018). ACP is a composite material consisting of two aluminum layers with a polymer core (Figure 1). This combination results in a lightweight, strong material, so it is widely used in the construction, automotive, and manufacturing industries (Callister et al., 2018). Core materials generally use *Polyethylene* (PE) and *Polyurethane* (PU) (Sihotang et al., 2021), but these two core materials are not resistant to high temperatures and fire, as their melting points are LDPE (*Low-Density Polyethylene*) melting around 105-115°C and HDPE (*High-Density Polyethylene*) melting around 120-135°C, while for PU the melting point is 163°C.



Figure 1 *Aluminum Composite Panel* (ACP) [6]

The disadvantages/weaknesses of the core materials of PE and PU are that they are not resistant to high temperatures, which is the background for the purpose of this study: to replace the core material with *PolyOxyMethylene* (POM), also known as acetal or polyacetal (Figure 1.2), which is tested for high-temperature resistance. This material is chosen because it has a slightly higher melting point than LDPE/HDPE and PU, which is around 165°C. POM is an engineering plastic with high strength, good wear resistance, and dimensional stability, making it widely used in precision engineering components (Kurniawan, 2020). POM's advantage over other polymers is its mechanical properties similar to light metals and its ability to maintain rigidity until temperatures near its melting point (Rahmadani et al.,

2021). However, in ACP, POM melting at high temperatures is a critical issue that needs further study. The thermal performance of ACP is greatly influenced by the interaction between the core material and the aluminum layer. At certain temperatures, the polymer core not only undergoes melting, but can also cause delamination between layers, changes in stress distribution, and an overall decrease in structural strength. This phenomenon poses a risk to the reliability of ACP in industrial applications that operate at high temperatures, such as in energy, transportation, and manufacturing facilities (Harioni et al., 2023). Engineers choose POM because it offers a superior combination of mechanical and physical properties. With a relatively high density compared to other engineering plastics, POM provides good strength and dimensional stability. This material remains stable at moderate operating temperatures, and its thermal conductivity allows for even heat dissipation. In addition, POM has wear-resistant properties, low friction coefficients, and good resistance to various chemicals such as solvents, oils, and fuels. Therefore, POM is also often applied to engine components such as *gears, bushings, bearings*, and pump components that require precision, strength, and a long service life. POM has several advantages that make it suitable as an engineering material, including good strength and rigidity, high wear resistance, low coefficient of friction, good dimensional stability, and resistance to various chemicals. In addition to its advantages, POM also has several disadvantages. POM has limited resistance to high temperatures and can undergo thermal degradation under heat loading. POM degradation can begin with the breakdown of the polymer's main chain and produce degradation products such as formaldehyde (Lutfi et al., 2006). Table 1 shows the physical and mechanical properties of POM. From Table 1, POM appears to have sufficient potential as a core material in ACP manufacturing. The combination of properties such as relatively high density, relatively stable melting point, moderate thermal conductivity, and resistance to friction and chemicals makes POM suitable for engineering applications that require precision, wear resistance, and dimensional stability. Figure 2 shows the chemical structure of POM.

Table 1. Physical and mechanical properties of POM (*polyoxymethylene*)

Properties	Value
Chemical formula	$(CH_2O)n$
Density	± 1.41 g/cm³ (1410 kg/m³)
Melting point	± 165 °C

Thermal conductivity	0.31 W/(m·K)
Violence	80-90 HRM(Rockwell M)
Coefficient of motion	Low (self-lubricating)
Chemical resistance	Resistant to solvents, oils, fuels

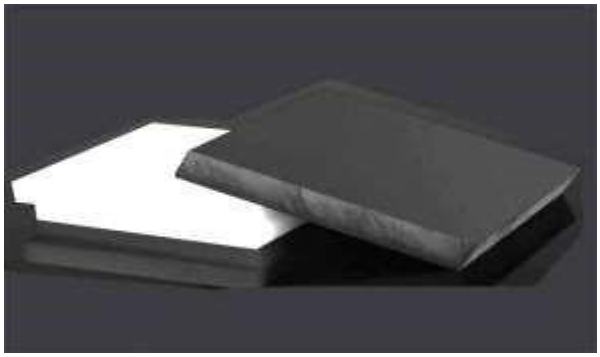


Figure 2: Polyoxymethylene (POM) *material* in sheet form.

LITERATURE REVIEW

Aluminum Composite Panel (ACP) is a composite material consisting of two aluminum layers with a polymer core. ACP is widely used in the construction, automotive, and manufacturing industries because it is lightweight, strong, corrosion-resistant, and has a good strength-to-weight ratio (Lahoz & Hernández de Olivares, 2014; Callister & Rethwisch, 2018).

The core materials commonly used in ACP are Polyethylene (PE) and Polyurethane (PU), but both have limitations at high temperatures because they have relatively low melting points. Polyoxymethylene (POM) is an engineering plastic with good strength and rigidity, high wear resistance, low friction, and good dimensional stability. POM has a melting point of around 165°C and is widely used in engineering components that require wear resistance and dimensional precision. However, POM also has limitations at high temperatures and can undergo thermal degradation under heat loading. (Lüftl et al., 2006).

Using POM as an ACP core material is an alternative that needs to be studied because core-material behavior can affect ACP performance at high temperatures. Previous studies on ACP with a Low Density Polyethylene (LDPE) core showed that the core material can evaporate during high-temperature testing, leaving only the aluminum layer. Other studies have also shown that core-material variation can affect the thermal behavior of ACP.

Based on previous research, studies on using POM as an ACP core material still need to be carried out, especially to determine the changes that occur in the material after exposure to high temperatures. Therefore, this study observed the microstructure of ACP with POM core material before and after testing at 300°C, 350°C, and 400°C using an optical microscope at 1000× magnification.

Previous studies on the thermal performance of Aluminum Composite Panels have predominantly focused on conventional polymer cores such as polyethylene (PE), low-density polyethylene (LDPE), and polyurethane (PU), while experimental investigations of Polyoxymethylene (POM) as an ACP core remain limited. In particular, information on POM's morphological and microstructural response when integrated between aluminum skins and exposed to temperatures substantially above its melting point remains limited. To address this gap, this study fabricates ACP specimens with 5052 aluminum skins and a POM core and experimentally evaluates their behavior after exposure to 300°C, 350°C, and 400°C for one hour. The novelty of the study is the direct experimental assessment of POM as an alternative ACP core under severe thermal conditions, combined with comparative optical microscopy observations at 1000× magnification before and after thermal exposure. This approach provides experimental evidence regarding POM melting, morphological changes, and its interaction with the aluminum layers, thereby contributing to the evaluation of the suitability and thermal limitations of POM-core ACPs for elevated-temperature applications.

METHOD

This research was carried out at the Mechanical Engineering laboratory of Muhammadiyah Sidoarjo University, starting in July 2024. It began with providing materials for this research, then continued with fabrication, testing, and result analysis. The full research stages are shown in the flowchart in Figure 3 below.

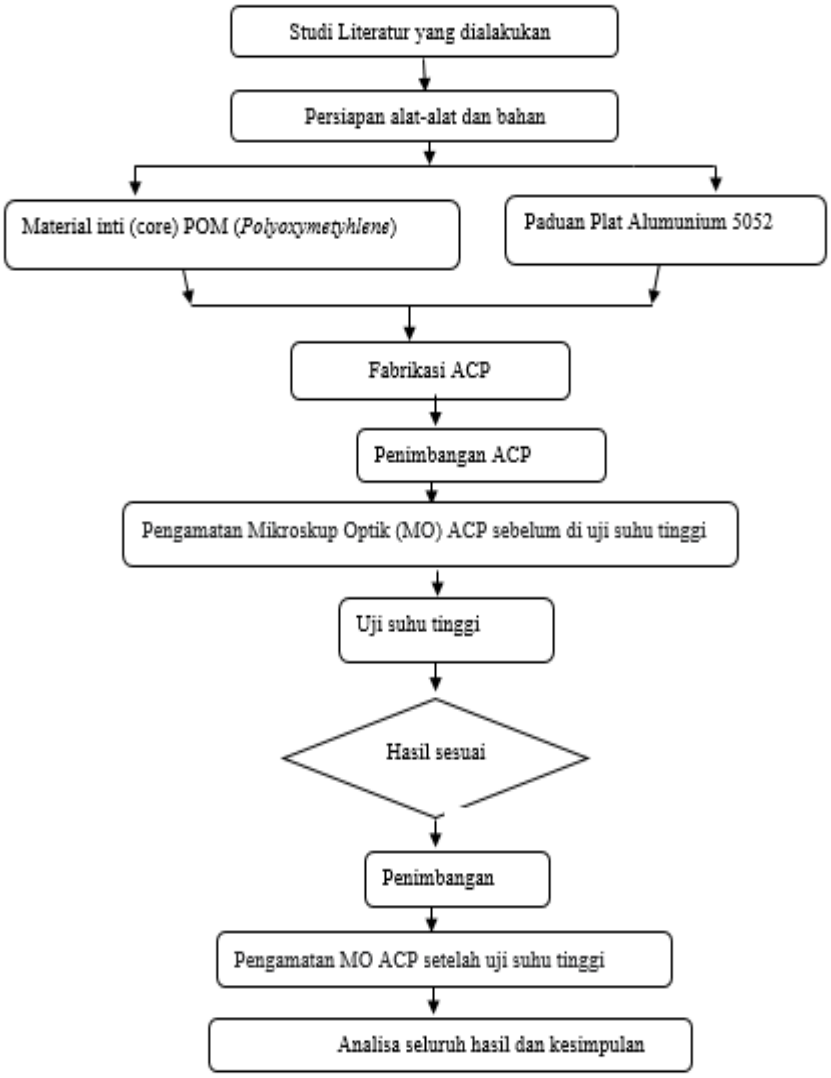


Figure 3 Research Flowchart

Tools For ACP Fabrication

The equipment used for ACP fabrication includes elbow rulers, meters, black markers, *compressors*, digital scales, *heat guns,* grinding machines, and press machines.

ACP Fabrication Morphology Diagram

Table 2 Morphology Diagram of ACP Fabrication

Process/Parts	Options Used	Remarks
A. Coating Material (Skin)	Aluminum 5052 	Outer layer of the front and back of the ACP.

B. Core Material	POM (Polyoxymethylene) 	As a core material of ACP.
C. Adhesive	Aluminum glue type N-193 	As an adhesive between aluminum and POM.
D. Cutting Process	Measurement and cutting of Aluminum 5052 and POM 	Aluminum 5052: 25 cm × 24 cm × 5 mm. POM: 25 cm × 25 cm × 5 mm.
E. Consolidation Process	Aluminum – POM – Aluminum using N-193 glue 	5052 and POM aluminum sheets are held together using N-193 aluminum glue.
F. Press Process	Pressing using a press machine 	To strengthen the bonds between layers. The press time needs to be adjusted to the original data because the manuscript lists 1 hour and 45 minutes in the description and 45 minutes in the caption of Figure 2.4.
G. Finishing/Coating	Fire-Retardant Coating (FRT) 	The finished ACP sample is coated with fire-retardant coating (FRT).

Remarks: The morphological diagram shows the materials and stages of ACP fabrication with POM core material and 5052 Aluminum coating.

ACP Fabrication

For the next stage after the tools and materials are available, it is to fabricate for the manufacture of ACP by measuring and cutting 5052 aluminum sheets (Figure 4) as the outer layer of the front and back of ACP with a length of 25 cm x width of 24 cm x thickness of 5mm and fabrication of measurement and cutting of *POM* core material (Figure 5) with the sample size used for ACP being 25cm long, 25cm wide and 5 mm thick.

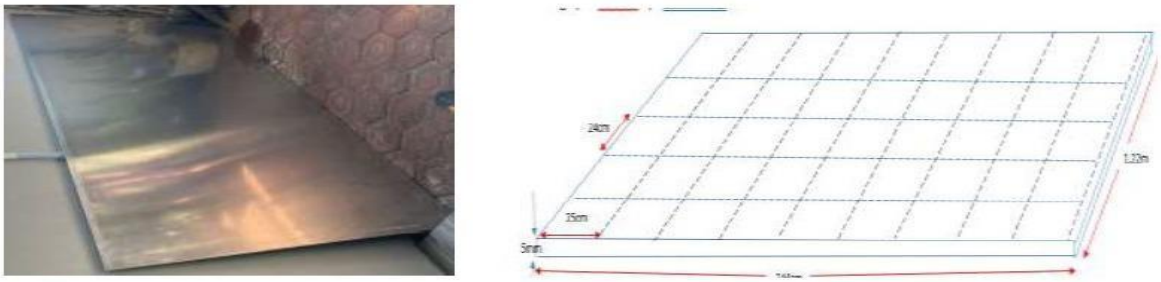


Figure 4 5052 aluminum sheet with its cutting scheme

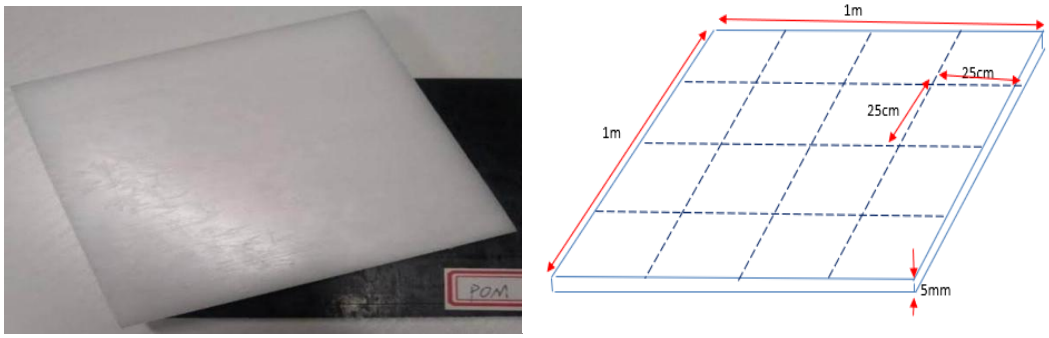


Figure 5 Polyoxymethylene (POM) material sheet cutting scheme POM sheet

The next step is to measure and cut the 5052 and POM aluminum sheets (**Figure 6a**), then bond them with N 193 aluminum glue (Figure 6b) and press them for about 1 hour and 45 minutes to strengthen adhesion (**Figure 6c**). After the ACP becomes fully sticky, the finished ACP is shown in Figure 7. Figure 8 shows the finished ACP sample from above, with the final stage of the ACP sample coated with a layer of fire-retardant coating (FRT). Details of the dimensions and thickness of each layer of the ACP sample are shown in

Table

Table 3 Dimensions of finished ACP samples

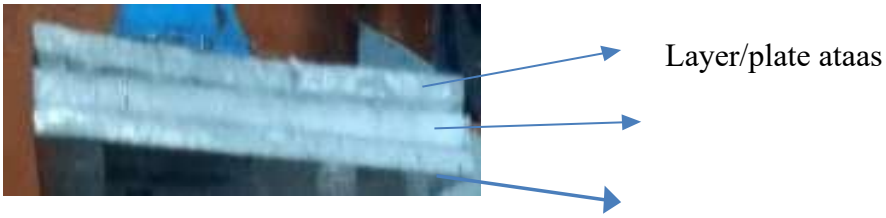
Sections	Material	Dimensions/Thickness
Top layer	Aluminum (Al)	5 mm

Core material	POM (Polyoxymethylene)	5 mm
Bottom layer	Aluminum (Al)	5 mm
Sample size	ACP	5 cm × 2 cm
Total thickness	ACP	15 m



(6a) (6b) (6c)

(6a) Measuring and cutting aluminum sheet 5052 and POM.
(6b) Sticking ACP with N 193 aluminum glue.
(6c) Press to strengthen adhesion for 45 minutes.



Core POM material

Bottom lining/plate

Figure 7 ACP sample in the finished one seen from above



(8a) (8b)

Figure 8 (8a) ACP coated with *fire-retardant coating* (FRT) using *a compressor.* (8b) ACP coated with flame-retardant paint

Weighting, High Temperature Testing and Microstructure Observation

Based on the dimensions of the next-stage ACP sample, weighing is carried out to determine the initial mass before and after the high-temperature test. After weighing, the sample is observed microscopically using an Optical Microscope (MO) of the core material (POM) at 1000× magnification. The high-temperature test is carried out in a furnace (Figure 9a); the test conditions are varied by varying the temperature and holding time. The tested temperatures were 300 °C, 350 °C, and 400 °C, with a holding time of 1 hour and *annealing* cooling (Figure **9b).**



(9a) (9b)

Figure (9a) Sample of ACP with POM core material during high-temperature test *(9b) Furnace* for high-temperature test

DISCUSSION

Aluminum Composite Panels (ACPs) have been extensively developed as lightweight sandwich structures consisting of two aluminum skins bonded to a polymeric core. Their combination of low weight, corrosion resistance, mechanical strength, and favorable strength-to-weight ratio has led to widespread applications in construction, transportation, and manufacturing. Conventional ACPs predominantly employ polyethylene (PE), including low-density polyethylene (LDPE), or polyurethane (PU) as core materials. However, the relatively low thermal resistance of these polymers represents an important limitation, particularly in applications involving elevated temperatures. Previous studies have therefore focused on the thermal and fire performance of ACPs, the influence of core-material variations, and the degradation behavior of polymer cores during thermal exposure.

Polyoxymethylene (POM) is an engineering thermoplastic characterized by relatively high strength and rigidity, wear resistance, a low coefficient of friction, chemical resistance, and good dimensional stability. These characteristics have supported its use in

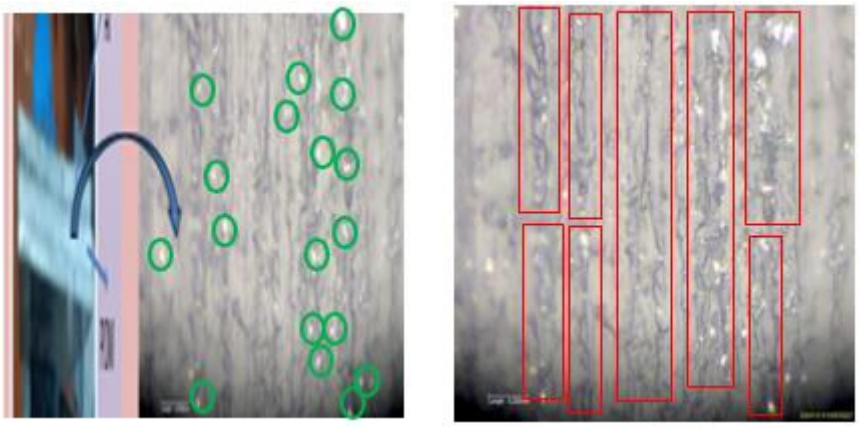
precision engineering components. Nevertheless, POM has a melting point of approximately 165°C and may undergo thermal degradation at elevated temperatures. Consequently, although POM possesses mechanical properties that make it potentially attractive as an alternative ACP core, its behavior when integrated into an aluminum sandwich structure and subjected to severe thermal exposure requires further investigation.

Previous research cited in the manuscript has investigated ACPs containing LDPE cores and has shown substantial deterioration of the polymer core during high-temperature exposure. Other studies have examined variations in ACP core materials and their influence on thermal behavior. However, the manuscript identifies limited experimental evidence concerning **POM specifically used as an ACP core material**, particularly regarding its morphological and microstructural behavior after exposure to temperatures substantially exceeding its melting point.

Research Gap

Despite advances in the investigation of ACP thermal performance, several gaps are identifiable from the literature reviewed in the manuscript. First, previous studies have predominantly focused on conventional PE/LDPE and PU cores, whereas experimental investigation of POM as an alternative ACP core remains limited. Second, there is insufficient evidence describing how POM behaves when it is physically integrated between aluminum skins and exposed to severe temperatures above its nominal melting point. Third, the manuscript identifies a need for direct observation of the changes occurring in POM-core ACPs before and after thermal exposure rather than relying solely on the thermal characteristics of POM as an isolated polymer. Finally, comparative microstructural observations of POM-core ACP specimens before and after exposure at 300°C, 350°C, and 400°C have not been adequately addressed by the studies discussed in the manuscript

Figure 3.1 (a) shows the ACP microstructure with POM core material observed using an Optical Microscope (OM) at 1000x magnification before the high-temperature test. The microstructure of the POM core material shows many carbon elements (C) (green circles), because POM consists of hydrogen (H), Oxygen (O), and carbon (C). H and O are gases, so only C is visible. Meanwhile, Figure 3.1 (b) shows the microstructure after the high-temperature test at 1000x magnification. It appears that element C spreads and attaches to the aluminum (red box), but C does not melt because the melting temperature of carbon (C) is high at 3,550°C.



(a) (b)

Figure 10 (a) Observation of ACP microstructure/microstructure with POM core material **before** the high-temperature test using a 1000x magnification Optical Microscope (MO). (b) Observation of ACP microstructure with POM core material after the high-temperature test using a 1000x optical microscope (MO).

ACP Results With POM Core Material After High Temperature Test

After the high-temperature test, all POM core materials melted and became sticky to aluminum (**Figure 11a**). Figures 11 b and 11c show the side view of ACP. This occurs because POM melts around 165 °C, while the high-temperature test reaches 400 °C. However, aluminum remains intact because its melting point is 700 °C. Table 4 shows the mass of ACP with POM core material before and after the high-temperature test; the average mass after the high-temperature test is higher than that of the high-temperature test cell. This is because the three samples are attached to one (POM and aluminum). In comparison with ACP research using Low Density Polyethylene (LDPE) as the core material, the results for all core materials were obtained using only aluminum metal [11]. While the study used numerical simulation *of* Ansys 2024 R2 software, analyzing the effect on fire resistance in ACP with variations in core materials using LDPE with temperature variations of 150°C, 200°C, 250°C, 300°C, 350°C, 400°C, the average temperature of LDPE core material at 400°C resulted in an average temperature of 102.86°C, so it appears that LDPE core material does not withstand high temperatures when compared to POM core material (Wicaksono et al., 2024).



(a) (b) (c)

Figure 11 ACP with POM core material after high-temperature test,
(a) Top appearance, sticky POM with aluminum
(b),(c) Side view, melted POM adheres to aluminum

Table 4 Weight/mass of ACP sample For POM *core* material

Sample to	**Type Material Core**	**Weight (grams) before testing**	**Average (grams) after test**	**Average weight after test (grams)**	**Remarks**
POM (for High Temperature Test)			2350,333	4925	The weight increases because the three ACP samples stick together during the high-temperature test.
1		2259			
2		2479			
3		2313			

The novelty of this research lies in the experimental application and evaluation of Polyoxymethylene (POM) as an alternative core material for Aluminum Composite Panels under severe high-temperature conditions. Unlike conventional studies centered on PE/LDPE or PU cores, this study fabricates an ACP configuration consisting of 5052 aluminum/POM/5052 aluminum, bonded using N-193 aluminum adhesive and finished with a fire-retardant coating. The fabricated specimens are then subjected to controlled thermal exposure at 300°C, 350°C, and 400°C for one hour.

A further contribution is the observation of the POM-core ACP microstructure before and after high-temperature treatment using optical microscopy at 1000× magnification, allowing the study to document changes associated with POM melting and adhesion to the aluminum layers. The experiment shows that POM melts and adheres to the aluminum surfaces at the investigated temperatures, while the aluminum layers remain intact under the reported test conditions.

CONCLUSION

Aluminum Composite *Panel (ACP) can* be made with *Polyoxymethylene* (POM) core material. The high-temperature test results (300 °C, 350 °C, and 400 °C) show that the POM core material sticks to the aluminum, increasing the mass. Observation of ACP microstructure/microstructure with POM core material using an Optical Microscope (MO) of 1000x magnification: before the high-temperature test, there was a lot of carbon (C) element in the microstructure/microstructure of the POM core material, because POM consisted of elements Hydrogen (H), Oxygen (O), and C. However, when tested at high temperatures, H and O were released (as gas); only element C was left.

Aknowlegment

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