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Investigation of the mechanical and tribological properties of aluminum powder filled with cyclo-olefin-copolymer composites

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ABSTRACT

In this study, the changes on the mechanical and tribological properties of cyclo-olefin-copolymer (COC) composites with the addition different concentrations of aluminum (Al) powder. For this purpose, Al powder at 15 %, 25 %, 35 % and 45 % concentrations by weight were added to COC composites using extrusion and injection molding methods. The mechanical properties of the generated composites, including hardness, tensile strength, elongation at break, and modulus of elasticity, as well as their tribological properties such as friction coefficient and wear rate, were studied. Friction and wear experiments were carried out under dry ambient conditions using a pin-on-disc system (pin-disc), with 20-40-60 N loads and 0.5-1.0-1.5 m/s sliding speeds. The incorporation of 45 wt% Al powders increased the tensile strength (10.6 %) and modulus of elasticity (57.8 %), while decreasing the elongation at break (97.8 %) values of COC/Al composites. The friction coefficient (FoC) of COC polymer and Al powder-filled COC composites decreased due to increasing sliding speed and load, which led to an increase in wear rate (WR). The lowest FoC and WR were obtained in a 45 % Al-filled COC composite. The FoC decreased while the WR increased with applied loads and sliding speeds. The FoC and WR both fell by 151.7 % and 100.9 %, respectively, with the addition of the 45 % Al powder to the COC polymer.

1. Introduction

Cyclo-olefin copolymers (COC) are completely or highly amorphous polymers with superior mechanical properties, a high glass transition temperature (Tg), excellent transparency, low moisture absorption, and good resistance to solvents. They are created by copolymerizing olefins with monomers like norbornene in a cyclic structure. The physical properties of COCs vary depending on the ratio of the cyclic monomer (norbornene) they contain. In comparison to other polyolefin copolymers, COCs have a comparatively high Tg depending on the mole or weight ratio of norbornene units in the structure, offering a long lifetime with minimal loss in physical qualities. For instance, the Tg of COCs can change depending on the norbornene ratio in the structure and ranges from 78 to 180 °C (Akın et al., 2014; Sunanda et al., 2014; Yoon et al., 2007). COCs are used especially in areas that require optical permeability, such as cameras and camera lenses, contact lenses, CD and DVD lenses, in sectors such as pharmaceutical packaging, where a certain level of tear resistance is required and very low gas and water vapor permeability values, and in sectors that require high mechanical and thermal strength. It is utilized in parts in the automobile sector. COCs' thermal, optical, and mechanical characteristics are comparable to those of polycarbonate (PC), a material that is widely utilized in many fields. However, polycarbonates are not favored since they contain bisphenol-A, which poses serious health risks, particularly in the food and pharmaceutical industries. In this way, COCs, which do not contain any chemicals that pose a health risk, constitute the most suitable material alternative for polycarbonates, which are widely used today. The optical properties of COC are comparable to those of poly (methyl methacrylate) (PMMA), but it has substantially better thermal characteristics. Additionally, the moisture absorption of COC is 10 times less than that of PMMA. When hardness properties are evaluated, it is known that COC is approximately 75 % harder than polycarbonate (PC) (Lago et al., 2017; Ou & Hsu, 2007; Saravanan et al., 2015; Sunanda et al., 2014).

Glass, carbon, and aramid fillers are used sparingly to lower the cost of polymer composites while also improving the tensile strength, modulus, and wear resistance. Metallic fillers have been employed to increase density, induce magnetism, and thermal stability as well as to enhance thermal and electrical properties (Laad & Jatti, 2015; Yetgin, 2019). Aluminum stands out among these metal fillers and has gained popularity for its use as a thermal conductive material in the thermal management sector due to its high thermal conductivity of 237 W/(mK).

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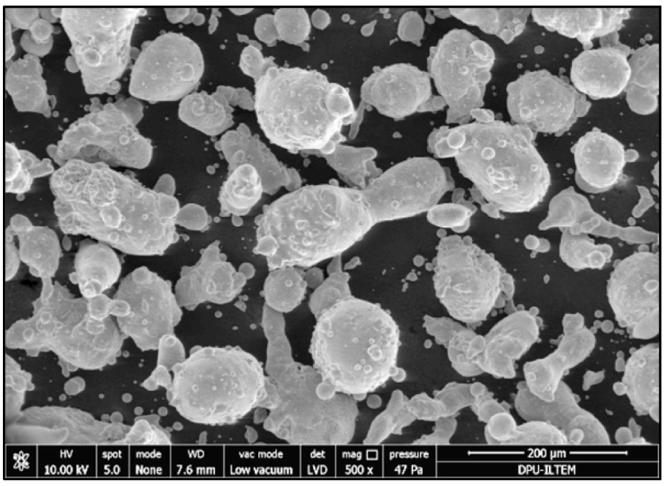


Fig. 1. SEM imagine of Al powder.

Table 1
- The compositions of the Al powder-filled COC composites.

Samples	COC	Al (% by weight)
COC	100	0
AL15	85	15
AL25	75	25
AL35	65	35
AL45	55	45

Easily obtainable, micro-sized Al particles are widely used in the manufacturing industry (Zhang et al., 2021). Recently, there has been an increasing interest in studies evaluating the mechanical, thermal, and conductivity characteristics of Al powder-filled polymer composites. Janusz (Janusz, 2015) analysed the mechanical and processing characteristics of polypropylene (PP) products filled with metallic powder fillers such as iron, zinc, copper and Al, with their contents varying from 2.5 to 15 wt%. As a result of the study, it was stated that tensile and impact strength decreased due to increasing filler amounts. Dinesh et al. (Dinesh et al., 2021) examined the mechanical properties of epoxy composites with Al particles added at 20, 40 and 60 % by weight. Srivastava and Verma (Srivastava & Verma, 2015) investigated the impact of Al and copper particles on the mechanical characteristics of epoxy resin at weight percentages of 1 %, 5 %, 8 %, and 10 %. Their findings show that as the filler content was increased, the tensile strength and wear loss gradually decreased. The hardness, compressive strength, and FoC increased with an increase in the weight percentage of Cu and Al fillers' content. Anuar et al. (Anuar et al., 2007) studied the effects of Al and zinc fillers on the thermal, electrical, mechanical, and swelling behavior of natural rubber (NR), as well as its curing characteristics. Rheometer results indicated that the incorporation of Al and zinc fillers enhanced the curing process. In terms of mechanical characteristics, adding more zinc filler to NR composites increased their tensile strength, elongation at break, and tensile modulus. However, although the addition of Al fillers in NR showed an increase in tensile modulus, it reduced the tensile strength and elongation at break. The composites filled with Al filler showed the best electrical conductivity. The results of the tests demonstrated that both fillers' particle sizes have an impact on the electrical characteristics of NR composites.

Adeosun et al. (Adeosun et al., 2012) examined the mechanical characteristics of PP by adding Al dross in 2–50 wt% for particle sizes 53 m and 150 m. The findings indicate that compared to conventional PP, tensile strength improved by 68 % at 15 wt% Al-dross addition, and density and water absorption increased by 54 % at 50 wt % and 500 % at 8 wt% Al-dross addition, respectively. The impact resistance of the composite was obtained to be the same (68 J) as that of conventional PP at 15 wt% Al dross. Zhang et al. (Zhang et al., 2021) used the hot-pressing technique to create the micro-scale Al particle-filled poly (vinylidene fluoride) (PVDF)-based composite. As a result of the study, the thermal conductivity value was found to be 767 % higher than that of pure PVDF. Compared with the pure polymer, the mechanical performances, including tensile strength and modulus, were also significantly improved by 99 % and 517 %, respectively. Vinay et al. (Vinay et al., 2023) compared the mechanical characteristics such as hardness, ultimate tensile strength, yield strength, and percentage elongation of unreinforced PLA composites and Al powder-reinforced polylactic Acid (PLA) composites. It was discovered that the addition of Al powder reinforcements improved the material's hardness, ultimate tensile strength, and yield strength while also lowering the percentage of elongation. The tensile and yield strengths of PLA increased by 46 % and 84 %, respectively, with the addition of 20 wt% of Al. Osman and Mariatti (Osman & Mariatti, 2006a) prepared the Al-filled PP composites with different filler particle shapes (flake and spherical) and filler loadings ranging from 0 % to 55 % by volume. Tensile strength decreased with increasing Al amounts. Compared to composites made with spherical particles, flaky composites are more prone to failure. Anis et al. (Anis et al., 2022) examined the mechanical properties of amorphous poly ethylene terephthalate (PET) polymer composites with Al nanoplatelet addition. As a result of the study, it was stated that the tensile strength and modulus, and bending strength and modulus increased and the elongation at break decreased compared to pure PET. Laad and Jatti (Laad & Jatti, 2015) investigated the effect of different compositions of Al powder on the mechanical properties of the acrylonitrile butadiene styrene (ABS)-Al composites. Their results demonstrated a decrease in the mechanical and hardness values of ABS/Al composites. It has been stated that, compared to ABS/Al composites, pure ABS polymer has a lower coefficient of friction and higher wear resistance due to its self-lubricating feature. Sarkar et al. (Sarkar et al., 2017, 2018) experimentally investigated the mechanical and tribological characteristics of glass epoxy composites with Al particulate (5–15 wt%) filler. Czel et al. (Czel et al., 2023) studied the influence of alumina (Al_2O_3), magnesium oxide (MgO), two glass powders with different silicon dioxide (SiO_2) contents, and natural zeolite powder on the thermal and abrasive wear properties of polyamide-6 (PA6). The findings demonstrate that the PA6/70 wt% Al_2O_3 and PA6/hybrid fillers at 75 wt% have the highest thermal conductive enhancement factors (145 and 92 %, respectively). Jayanthan et al. (Jayanthan et al., 2020) examined the tribological properties of PTFE composites with alumina additives at different rates. They stated that the composite had the least wear value when the reinforcement rate was increased from 0 % to 15 %, and an increase in the wear rate was observed when the reinforcement amount was greater than 15 %. It is anticipated that COC polymers may find potential applications in different industries due to their superior thermal and mechanical properties as well as their ability to reduce wear and friction. An extensive literature survey reveals that little has been done to investigate the use of Al powder as filler for the mechanical and tribological properties of COC composites. Therefore, it was to investigate the effect of Al powder addition on the friction and wear behavior as well as the mechanical properties of COC polymers. Al powder-filled COC composites were prepared using extrusion and injection molding methods. Wear tests were carried out using a pin-disc system against an AISI 1040 steel disk at room temperature in dry conditions at sliding speeds of 0.5–1.0-1.5 m/s and loads of 20-40-60 N, and the effects of sliding speed and load were also examined.

2. Materials and methods

2.1. Materials and sample preparation

Commercial cyclo-olefin copolymer (COC) coded Topas® 5013 was used as the polymer matrix. Al powder with 100-200-µm powder size,

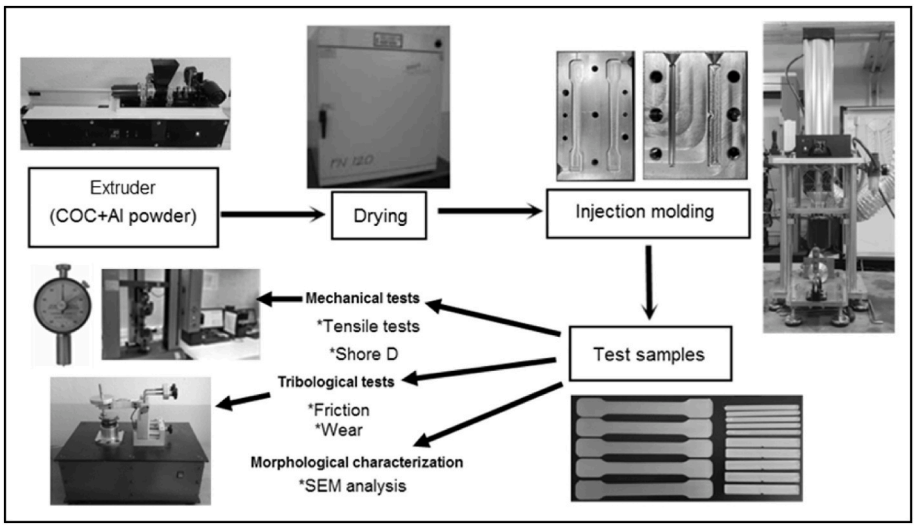


Fig. 2. Production scheme of COC and Al-filled COC composites.

produced using a gas atomization unit, was used as the filler material (Fig. 1). Al powder-filled COC composites are Rondol brand, Microlab model laboratory scale, 10 mm screw diameter (L/D = 20), segmented screw, co-rotating, and intermeshing according to the melt blending method, prepared in a twin screw extruder. Then, the samples were passed through the extruder and turned into granules in the cutter. Temperature settings for the extruder barrel ranged from 185 to 200 to 220 to 220 °C from the inlet to the head exit area (die). Table 1 provides sample identifying codes and compositions of the produced composites. Then, test samples in accordance with the standards for mechanical and tribological tests were prepared by the injection molding method. The temperature distribution for the injection molding process was found to be between 180 and 220 °C. Fig. 2 shows the production scheme of COC polymer and Al-filled COC composites.

2.2. Mechanical and tribological tests

Hardness tests were carried out in accordance with the ASTM D2240 standard, and hardness was measured in Shore D. At least 10 hardness measurements were taken on each test sample during the hardness measurements. Tensile tests were prepared in accordance with the ASTM D638 standard. The tests were carried out on a Zwick brand Z020 model tensile tester. Each tensile test sample was averaged after being measured at least five times. Tensile tests were carried out at a tensile speed of 10 mm/min. Tribology tests were carried out on a pin-disc wear device under dry environmental conditions. AISI 1040 steel was used as the counter disk. Polymer pin materials are 6 mm in diameter and 50 mm in length. Tribology tests were carried out in accordance with the ASTM G99 standard. Wear and friction tests were carried out on a 1000-m sliding path under 20-40-60 N loads and 0.5-1.0-1.5 m/s sliding speeds. Prior to the wear test, the weight of the pin samples was measured on a precision scale from the Radwag brand with a sensitivity of 0.0001 g (m_1), and then the weight of the worn pin sample was measured after the test (m_2). The weight difference before and after the experiment was calculated by taking (m_1-m_2) = Δ_m and dividing it by the density of the pin sample, sliding path and normal load using the formula given in Equation (1) (Friedrich, 1989). In the formula, K_o: wear rate (mm^3/Nm), ρ: density of the pin sample (g/cm^3), S: sliding path (m), F: normal load (N).

$$K_0 = \frac{\Delta m}{S\rho F} \quad (1)$$

3. Results and discussion

Fig. 3 shows scanning electron microscope (SEM) images and EDS analysis results of COC polymer and COC/Al composites taken from broken surfaces. It is clear that the Al powder particles are homogeneously dispersed in the COC matrix without obvious agglomeration and without debonding creation. EDS analysis results confirm the presence of Al powder in the COC polymer. The less or more incorporation of reinforcing quantity in the matrix represents the efficacy engaged in interfacial contact and distribution. The homogeneous distribution allows the reinforcement particles to be transferred from the polymer matrix to the filler, which provides better mechanical and thermal properties compared to pure polymer (Mei et al., 2023).

Fig. 4 a-d shows the results of the tensile test for tensile strength, tensile modulus, elongation at break, and Shore D hardness. As seen in Fig. 4-a, the COC polymer's tensile strength increased as Al powder was added. The tensile strength of the COC polymer, which is 49.5 MPa, was obtained as 51.4, 52.3, 53.8 and 54.8 MPa for AL15, AL25, AL35 and AL45 composites, respectively. Compared to COC polymers, the tensile strengths of AL15, AL25, AL35, and AL45 composites increased by 3.8 %, 5.5 %, 8.6 %, and 10.6 %, respectively. It is also found that there is a gradual increase in tensile modulus with an increase in Al powder content. The COC polymer has tensile modulus of 1531 MPa, and these values increases to 1674 MPa, 1897 MPa, 2204 MPa and 2416 MPa with Al powder addition of 15 wt%, 25 wt%, 35 wt% and 45 wt% respectively. The tensile modulus of AL15, AL25, AL35, and AL45 composites increased by 9.3 %, 23.8 %, 43.9 %, and 57.8 %, respectively, compared to COC polymers. It is thought that the increase in tensile strength and modulus with the addition of Al powder is due to the decrease in the distance between the Al powders due to the increasing amount of Al powder, the increase in the chemical bond strength between Al and COC polymer, and the fact that the Al powder additive transfers the load homogeneously during tensile stress and prevents the COC polymer from deforming. This situation is shown in Fig. 5, and it is seen that the distance between particles decreases with an increasing amount of Al powder. When subjected to external loading conditions, the reinforcing particles play a key role in carrying the majority of the load. Several parameters influence the load-bearing capability of the reinforcement phase, including the wetting ability of the reinforcing agents with the matrix elements, reinforcement phase distribution, and reinforcing weight percent (Vinay et al., 2023). The increase in mechanical properties is also explained by the theory of percolation by He and Jiang (He & Jiang, 1993). This hypothesis states that the polymer zone surrounding each particle is affected by the stress concentration. This

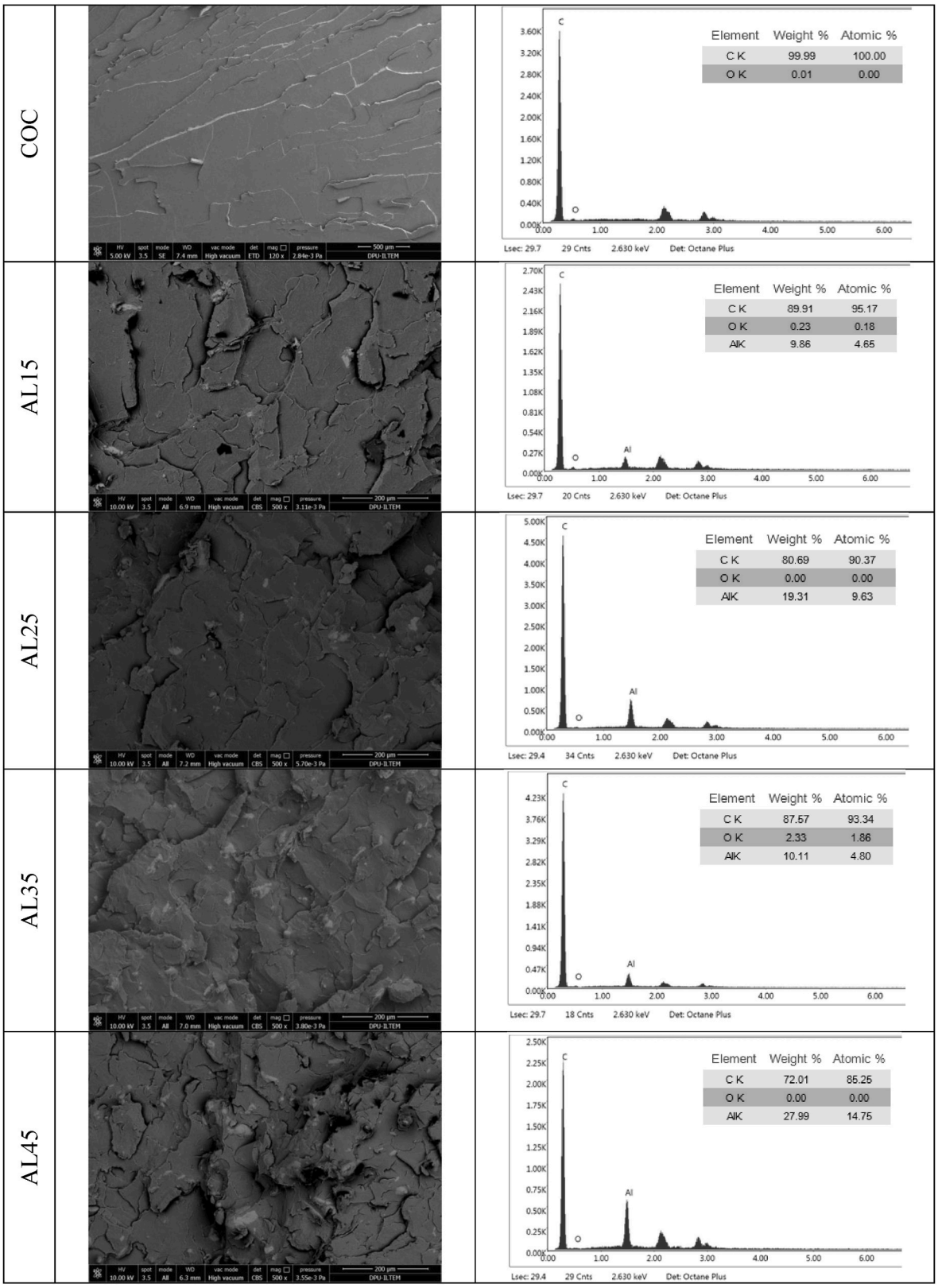


Fig. 3. SEM images and EDS analysis results of fractured surfaces of COC polymer and COC/Al composites.

causes these regions to collide and create the percolation network, which increases the tensile modulus if the space between the particles is too small. Increase in tensile modulus of COC/AL composite samples is also attributed to better distribution of Al powder in the COC polymer. The higher surface area of filler gives better adhesion in composites, thus forming a stiffer material, which is attributed to the higher modulus (Rozman et al., 1998). Similar to the results obtained by Anis et al. (Sarkar et al., 2018), they used Al flakes as a reinforcing element in the amorphous PET polymer matrix and achieved an increase in tensile strength and tensile modulus values. In their study, the tensile strength

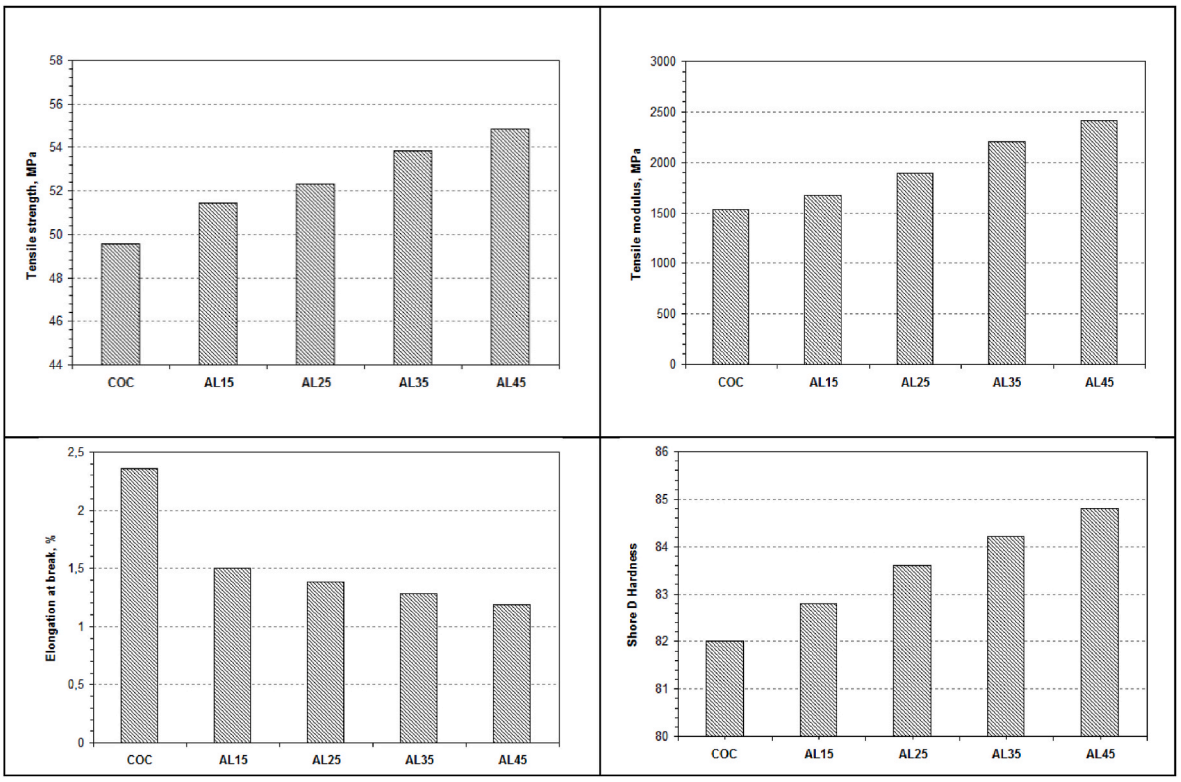


Fig. 4. - Tensile test and Shore D results of COC polymer and COC/Al composites.

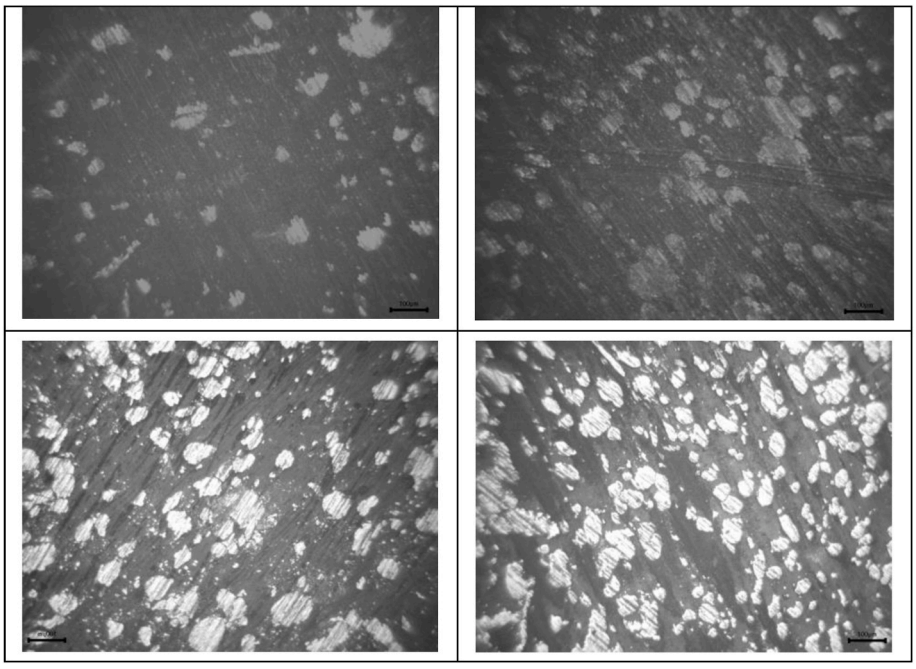


Fig. 5. - Optical microscope images of COC/Al composites.

increased from 60.7 MPa to 79 MPa at 15 vol% of Al flakes. Zhang et al. (Zhang et al., 2021) also stated that the tensile strength and the values of modulus of micro-scale Al particle-filled PVDF composites increased by 99 % and 517 %, respectively. They attributed this to the fact that the Al particles in the PVDF composite provide effective heat transfer. In PP filled with Al particles, Osman and Mariatti (Osman & Mariatti, 2006b) demonstrated that the tensile strength decreased monotonically; by 30 % vol. of Al, the tensile strength of the Al-PP composite was reduced by half. Other studies using flaky and spherical nano-aluminum (Al) in PP (Osman & Mariatti, 2006a) and Al powder in PP (Janusz, 2015) also reported deterioration in tensile strength due to the filler particles' inability to transfer the applied stress and the agglomeration of Al filler at high filler loading. According to Nicolais and Nicodemo, adding Al and Fe powders to styrene acrylonitrile (SAN) plastic led to an increase

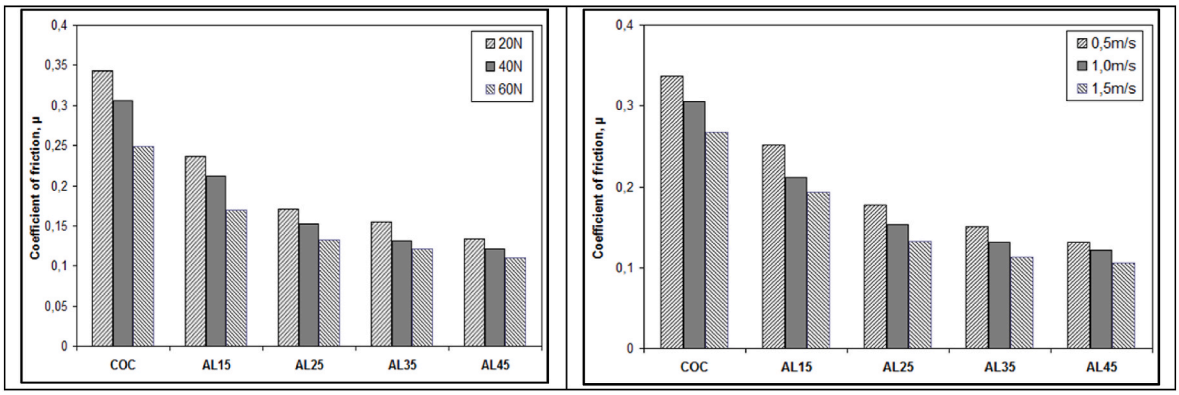


Fig. 6. - Change of friction coefficient of pure COC and Al powder-filled COC composites under a) 1.0 m/s sliding speed, b) 40 N load.

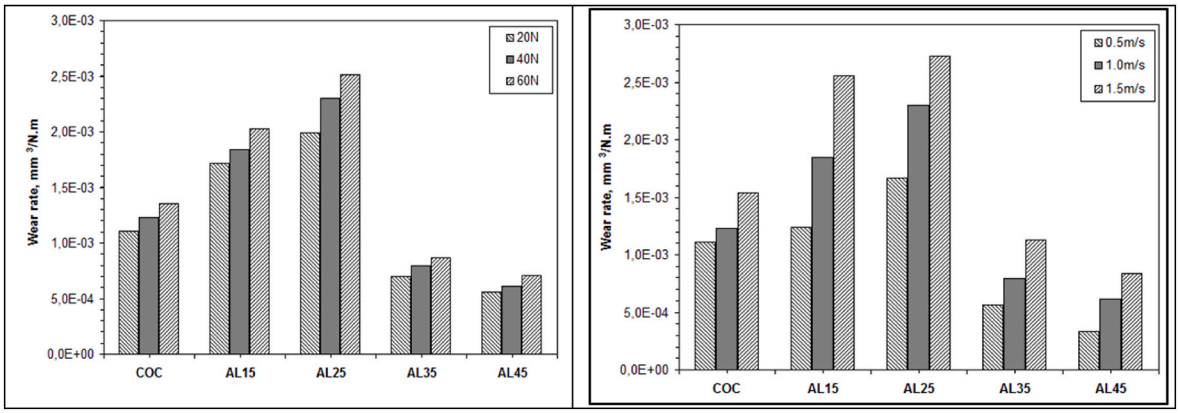


Fig. 7. - Change of wear rate of pure COC and Al powder-added COC composites under a) 1.0 m/s sliding speed, b) 40 N load.

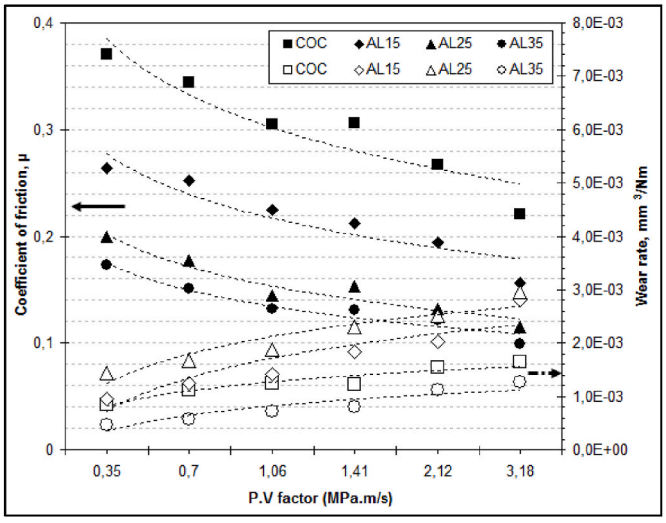


Fig. 8. Friction coefficient and wear rate change depending on the P.V factor.

in modulus but a major decrease in tensile strength and elongation-to-break (Nicodemo & Nicolais, 1983). In Fig. 4-c and d, the variation of % elongation and hardness (Shore D) values according to the Al powder additive ratio is given. The COC polymer, which had a low elongation at break, had significant reductions in elongation at break values when Al powder was added. The AL45 composite sample reduced the elongation at break by 97.8 % compared to the COC polymer. Similar results were obtained in studies conducted by Anis et al. (Sarkar et al., 2018). The reason for the increase in mechanical properties could be a restriction in the chain mobility and decreased deformation ability of the matrix with the addition of Al. The restriction on polymer chain mobility reduces stress transfer across the entire composite, increasing rigidity and stiffness and decreasing elongation at break (Altay et al., 2021). Al powder added to COC polymer slightly increased Shore D hardness, and Shore D hardness values of COC and COC/Al composites were determined to be between 82 and 84.8 Shore D.

Fig. 6 a–b shows the friction coefficient changes of COC polymer and COC/Al composites depending on the applied sliding speed and load. As shown in Fig. 6-a, the FoC of COC and COC/Al composites decreased significantly with increasing the amount of load. As the load increases, the contact temperature will generally increase due to friction heat. This increasing interface temperature will reduce the shear stress by softening the polymer matrix and thus the coefficient of friction will decrease (Sudheera et al., 2014). In the study conducted by Jayanthan et al. (Jayanthan et al., 2020), it was stated that the surface contact area increased with increasing load and therefore the friction force increased. It has been stated that metal additives generally increase the abrasive force and reduce the actual contact area during the friction process (Kolesnikov, 2016). The fact that Al powder self-lubricates could also be a significant factor in the reduction of friction coefficient. Fig. 6-b shows how the friction coefficient changes depending on the sliding speed applied under a 40 N load. Due to increasing sliding speed, the friction coefficients of COC polymers and COC/Al composites decreased. By increasing the sliding speed by 200 %, the FoC decreased by 25.9 % for the COC polymer, 30.0 % for the AL15 composite, 33.5 % for the AL25 composite, 33.8 % for the AL35 composite and 25.1 % for the AL45 composite. Different amounts of Al filler added to the COC polymer also caused a significant decrease in the FoC. This reduction is calculated as

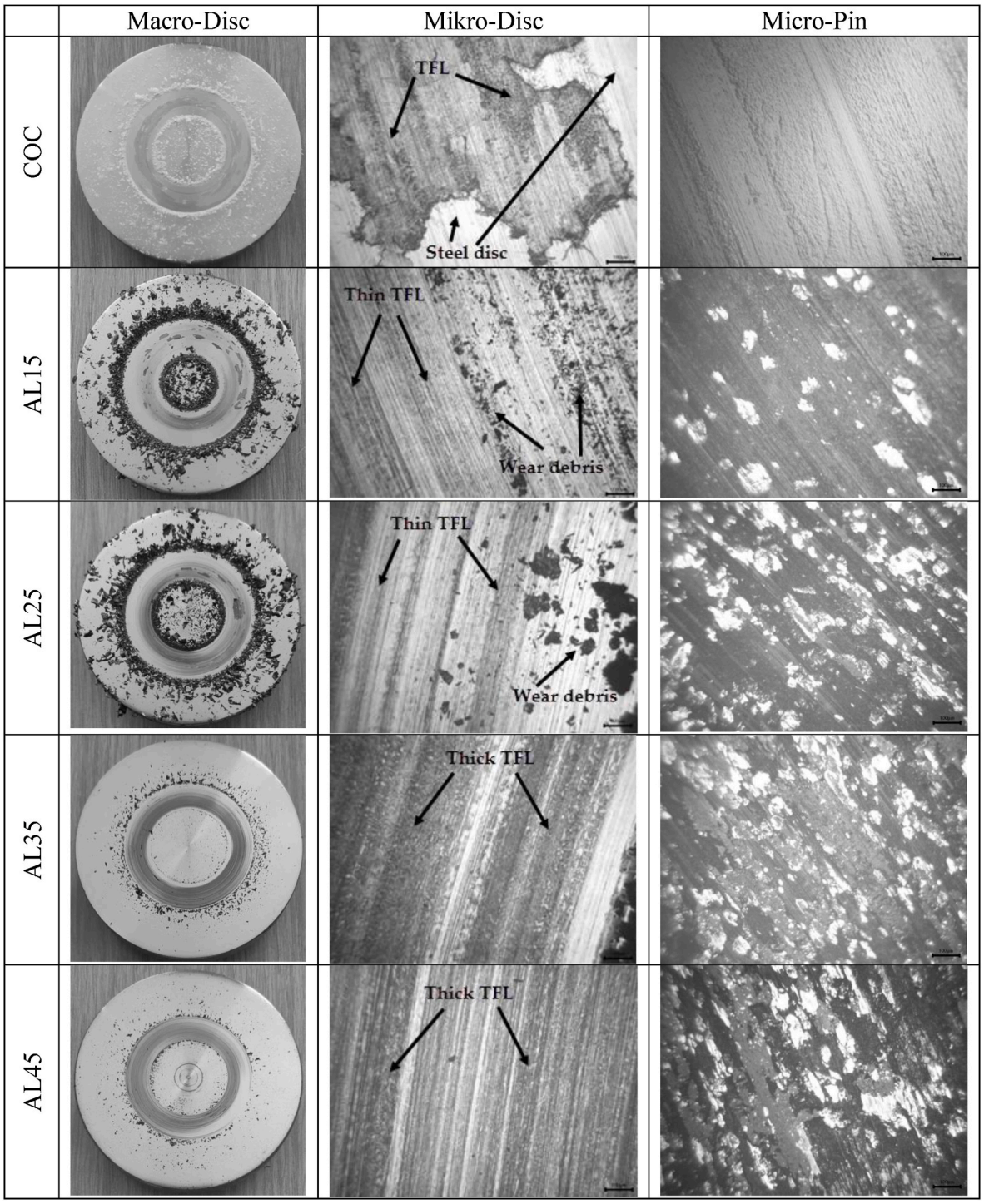


Fig. 9. Disc images of pure COC and Al powder-filled COC composites (sliding speed: 1.0 m/s, applied load: 40 N, x100).

44.0 % for AL15 composite, 100.1 % for AL25 composite, 133.8 % for AL35 composite, and 151.7 % for AL45 composite when assessed for 1.0 m/s and a 40 N load. It has been determined that the most effective parameter in reducing the FoC in the applied sliding speed and load ranges is the load. The COC polymer demonstrated the highest FoC with a value of 0.3707 under 0.5 m/s sliding speed and 20 N force, while the AL45 composite demonstrated the lowest FoC with a value of 0.0953 under 1.5 m/s sliding speed and 60 N load. Aluminum has good thermal conductivity. Better thermal conductivity contributes to a more efficient dissipation of the heat generated in the contact area. Heat dissipation from the contact surface will rise as the amount of Al rises (Zhou, 2011). The energy loss during the sliding process raises the temperature on the contact surface. COC polymer is a poor thermal conductive material, as a result of which the heat generated in the contact zone is retained there and utilized for thermal penetration, which softens the matrix material (Sarkar et al., 2017).

Fig. 7 a-b shows the WR changes of COC polymer and COC/Al composites depending on the applied sliding speed and load. In general, the WR of COC polymer and COC/Al composites was obtained between 10^{-3} and 10^{-4} mm^3/N.m. The WR increased with both sliding speed and load increase. By increasing the applied load from 20 N to 60 N, the WR increased by 22.5 % for COC polymer, 17.8 % for AL15 composite, 26.1

% for AL25 composite, 23.3 % for AL35 composite and 28.0 % for AL45 composite. As the sliding speed increased from 0.5 m/s to 1.5 m/s, the WR increased by 38.1 %, 105.9 %, 63.2 %, 99.6 %, and 153.4 % for COC polymers, AL15, AL25, AL35, and AL45 composites, respectively. WR in AL35 and AL45 composites reduced by 54.6 % and 100.9 %, respectively, whereas WR in COC polymers increased by 49.7 % and 86.8 % when 15 % and 25 % Al fillers were introduced. The highest WR was obtained in AL25 composite under 1.5 m/s sliding speed and 60 N load, while the lowest WR obtained in AL45 composite under 0.5 m/s sliding speed and 20 N load. Aluminum has good thermal and electrical conductivity (Zhou, 2011). The stiffness and thermal conductivity of the material will increase when small amounts of Al powder are added to it. The thermal conductivity will increase higher as the amount of Al powder increases. Better thermal conductivity contributes to a more effective dissipation of the heat generated in the contact area. As a result, matrix wear is reduced by reducing the plastic deformation of the soft matrix. In AL35 and AL45 composites, WR have decreased significantly as the Al powder particles distributed homogeneously within the matrix reduce the void fractions, provide inter-surface bond strength due to the increased surface area, and therefore increase the strength and rigidity values of the COC/Al composite. Li and Liang (Li & Liang, 2010) also found that the specific WR is highly reliant on the pace at which transfer film forms on the materials' contact surfaces. However, Laad and Jatti (Laad & Jatti, 2015) stated that the FoC and wear amount increased with the addition of Al to the ABS polymer. They explained that the reason for this is the decrease in hardness values due to the increasing amount of Al in ABS/Al composites.

Fig. 8 shows the P.V factor graph showing the effect of load and speed on the wear rate and friction coefficient of COC polymer and Al powder-filled COC composites. The P.V factor is calculated with Equation (2) (Abdelbary, 2015).

$$P.V\ factor = \frac{Load\ x\ Sliding\ speed}{Area\ of\ pin} \tag{2}$$

The applied sliding speed and load had an impact on the FoC and WR. It has been observed that as the P.V factor increases, the WR increases and the FoC decreases. It has also been determined that the WR and FoC vary depending on the Al content. While the FoC decreased with the addition of Al to the COC polymer and increasing Al powder, the WR decreased in samples with 35 % and 45 % Al powder added.

As it is known, in tribological events, material transfer at contact points (metal/metal, polymer/metal, polymer/polymer) plays an important role in shaping wear and friction behaviours. Polymer/metal contact is preferred in many applications due to reasons such as incompatibility between materials and heat transfer properties depending on the material. Many parameters such as sliding speed, applied load, temperature, polymer type, mechanical and thermal properties affect the formation of the transfer film layer (TFL) on the disc surface (Bahadur, 2000). Fig. 9 shows optical microscope images of the disc and pin surfaces of COC polymer and COC/Al composites after tribology tests. As seen in the disc images, it was observed that TFL and wear debris formed on the surfaces of the samples. This TFL formed thinly and non-uniformly on the surface of 15AL and 25AL composites with COC polymers. In 35AL and 45AL composites, TFL was formed in a uniform distribution, continuous and thicker manner. This is believed to be the result of wear debris that remains on the surface and contributes to the formation of TFL, as seen in the figure. This explains why AL35 and AL45 composites have low WR and low FoC. TFL and the density of this layer affected the wear and friction behaviour of COC composites. Czel et al. (Czel et al., 2023) also stated in their study that the wear particles on the wear surface support the adhesive wear mechanism. When the pin pictures were examined, deep and wide grooves were observed on the surfaces of the COC polymer. Under high abrasive conditions, the adhesion of wear debris to the metal surface decreases. Larger asperities on the metal counter surface deformed the polymer surface, causing plowing and micro-cutting, resulting in the formation of deep wear marks. In 35AL and 45AL composites, due to the TFL effect, the number and effect of grooves decreased and a softer surface was obtained. At the same time, the COC polymer adhered to the pin surfaces in a plastered form and was effective in reducing the WR and FoC. Al powder added to the COC polymer acted as a solid lubricant and was effective in reducing the FoC during the contact of the polymer composite with the steel disc. It has been reported that the submicron particles added to the polymer matrix affect the tribological properties by forming a TFL on the counter disc (Danilova et al., 2021; Latha & Rao, 2018). Samyn and Schoukens also attributed the decrease in the FoC to geometric considerations, deformation, and the development of the transfer film layer (Samyn & Schoukens, 2009). The FoC of tin-filled PP composites also dropped as a result of the introduction of the TFL, which prevented direct contact between the disc material and polymer matrix (Mustafa et al., 2022).

4. Conclusion

As a result of the study examining the mechanical and tribological properties of COC composites with Al powder added at different rates, the following results were obtained. The incorporation of 45 wt% Al powders increased the tensile strength (10.6 %) and modulus of elasticity (57.8 %), while decreasing the elongation at break (97.8 %) values of COC/Al composites. The FoC decreased while the WR increased with applied loads and sliding speeds. With the 45 % Al powder filler added to the COC polymer, the FoC decreased by 151.7 % and the WR decreased by 100.9 %. As the P.V factor increased, the FoC decreased and the WR increased. The transfer film layer changed the wear mechanism from abrasive to adhesive, and the FoC decreased and wear resistance increased. This simple and effective strategy provides a suitable method for producing thermoplastic polymeric composites with superior mechanical and tribological properties used for high-performance aerospace equipment.

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