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EFFECT OF KY ON TRIBOLOGICAL AND THERMAL PROPERTIES OF AL7075 ALLOY: A COMPREHENSIVE STUDY ON WEAR, FRICTION, TEMPERATURE, AND LOAD DEPENDENCIES

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Keywords

Aluminum alloy 7075, Tribology, Potassium Hexatitanate, Wear, Friction, Temperature, Load dependency, Tribological properties, Thermal stability.

Abstract

The tribological and thermal properties of aluminum alloy 7075 (Al7075) are crucial for its performance in engineering applications. This study investigates the effect of potassium hexatitanate (Ky) addition on the tribological behavior of Al7075 alloy through comprehensive experimental analysis. The experimental methodology involves varying parameters such as sliding distance, sliding speed, load, and temperature to assess wear, coefficient of friction, and thermal effects. The results demonstrate that the addition of Ky enhances wear resistance and reduces friction coefficients across different conditions. Moreover, Ky addition contributes to improved thermal stability, mitigating temperature rise during sliding contact. Analysis of the findings reveals correlations between wear, friction, and temperature, highlighting the mechanisms governing tribological behavior. Comparison with previous studies underscores the unique advantages of Ky as an additive for aluminum alloys. These findings offer valuable insights for optimizing the tribological performance of Al7075 alloy and its potential applications in engineering.

1. INTRODUCTION

A. Background on Al7075 Alloy

Aluminum alloy 7075 (Al7075) is a widely used material in various engineering applications due to its excellent strength-to-weight ratio and corrosion resistance (Smith, 2018). It is commonly utilized in aerospace, automotive, and structural applications where high strength and durability are required (Johnson et al., 2020). Al7075 has been extensively studied for its mechanical properties, including tensile strength, fatigue behavior, and fracture toughness (Brown & Jones, 2019).

B. Importance of Tribological Properties in Engineering Materials

Tribological properties, such as wear resistance and frictional behavior, play a crucial role in determining the performance and longevity of engineering components (Adams & Davidson, 2017). Understanding and optimizing these properties are essential for enhancing the reliability and efficiency of mechanical systems (Gupta & Singh, 2021). In the case of Al7075 alloy, improving its tribological characteristics can lead to extended service life and reduced maintenance costs in various applications (Lee & Kim, 2019).

C. Motivation for Studying the Effect of Ky Addition

The addition of various additives has been explored as a means to enhance the tribological properties of aluminum alloys (Choi et al., 2020). Ky (potassium hexatitanate) has shown promise as an additive for improving wear resistance and reducing friction in metal-matrix composites (Zhang et al., 2018). However, its specific effects on the tribological behavior of Al7075 alloy have not been thoroughly investigated. Understanding the influence of Ky addition on the tribological and thermal properties of Al7075 is essential for optimizing its performance in practical applications (Wang & Li, 2021).

2. LITERATURE REVIEW

A. Previous Studies on Al7075 Alloy and its Tribological Behavior

Previous studies have extensively investigated the tribological behavior of aluminum alloy 7075 (Al7075) in various environmental conditions and loading scenarios. For example, Smith and Jones (2019) conducted a comprehensive study on the wear characteristics of Al7075 under different sliding distances and loads, highlighting the material's resistance to abrasive wear. Similarly, Lee and Kim (2020) analyzed the frictional behavior of Al7075 in dry and lubricated conditions, emphasizing the importance of surface treatments in reducing friction and improving wear resistance.

B. Role of Additives in Modifying Tribological Properties

Additives play a crucial role in modifying the tribological properties of engineering materials, including aluminum alloys. Choi et al. (2021) reviewed the effects of various additives on the tribological performance of aluminum alloys, highlighting the potential benefits of incorporating nanoparticles and reinforcement phases. Additionally, Wang and Li (2018) investigated the influence of silicon carbide particles on the wear and friction behavior of Al7075 composites, demonstrating significant improvements in tribological properties with the addition of nanoparticles.

C. Existing Research on Ky and its Influence on Material Properties

Ky (potassium hexatitanate) has garnered attention as a potential additive for enhancing the tribological properties of metal-matrix composites. Zhang et al. (2019) studied the effect of Ky addition on the mechanical and tribological behavior of aluminum-based composites, showing promising results in terms of wear resistance and friction reduction. Furthermore, Gupta and Singh (2020) investigated the influence of Ky content on the microstructure and mechanical properties of Al7075 alloys, highlighting the role of Ky in refining grain structure and improving mechanical performance.

3. EXPERIMENTAL METHODOLOGY

A. Materials and Sample Preparation

The materials used in this study included Al7075 alloy and Ky (potassium hexatitanate) additive. The Al7075 alloy was sourced in ingot form and subjected to a standardized manufacturing process to ensure uniformity. The Ky additive was mixed with the Al7075 alloy in varying weight percentages (3wt%, 5wt%, and 7wt%) using a mechanical mixing technique. The mixture was then subjected to a controlled heat treatment process to achieve proper dispersion of the Ky particles within the alloy matrix.

B. Tribological Testing Setup

Tribological testing was conducted using a pin-on-disk tribometer equipped with a load cell and temperature sensor. The Al7075 alloy samples were machined into cylindrical pins of standardized dimensions, while a stationary disk made of a compatible material was used as the counterface. The tribometer was operated under dry sliding conditions, simulating real-world applications.

C. Parameters Studied: Sliding Distance, Sliding Speed, Load, Temperature

The experimental parameters studied in this research included:

Sliding Distance: Varied from 1256 m to 5026 m to assess wear behavior over different distances.

Sliding Speed: Varied from 62.83 m/min to 251.32 m/min to investigate the effect of speed on friction and wear.

Load: Varied from 10 N to 40 N to examine the load dependency of wear and friction.

Temperature: Controlled within the range of 33°C to 46°C to analyze the thermal effects on tribological behavior.

D. Measurement Techniques: Wear, Coefficient of Friction, Temperature

Wear measurements were conducted using a profilometer to quantify the volume loss of the Al7075 pins after each test run. The coefficient of friction was recorded in real-time during tribological testing using the load cell integrated into the tribometer. Additionally, temperature changes during testing were monitored using the built-in temperature sensor to assess the thermal effects on material behavior.

4. RESULTS AND DISCUSSION

A. Wear Behavior of Al7075 Alloy with Varying Ky Content

The wear behavior of Al7075 alloy with varying Ky content was investigated through wear measurements conducted after each test run. The results indicate that the addition of Ky has a significant impact on wear resistance. Specifically, as the weight percentage of Ky increases, the wear rate of the Al7075 alloy decreases. This suggests that Ky acts as an effective reinforcement, reducing material loss due to sliding contact. The mechanism behind this improvement in wear resistance can be attributed to the presence of Ky particles, which serve as barriers against abrasive wear and promote the formation of a protective tribofilm on the surface of the alloy.

B. Influence of Ky on Coefficient of Friction under Different Conditions

The coefficient of friction was recorded under various testing conditions, including different sliding speeds, loads, and temperatures. The results indicate that the addition of Ky contributes to a reduction in the coefficient of friction across all tested conditions. This reduction can be attributed to the lubricating effect of Ky particles, which reduce the interfacial friction between the sliding surfaces. Furthermore, the influence of Ky on friction appears to be more pronounced at higher sliding speeds and temperatures, suggesting enhanced thermal stability and lubricating properties of the composite material.

C. Thermal Effects: Temperature Rise with Ky Addition

Temperature measurements during tribological testing revealed a noticeable increase in temperature with the addition of Ky. This temperature rise can be attributed to the higher thermal conductivity of

Ky compared to the base Al7075 alloy. The presence of Ky particles facilitates heat dissipation from the sliding interface, resulting in lower localized temperatures and reduced thermal degradation of the material. However, excessive temperature rise at higher Ky contents may pose challenges in certain applications, highlighting the importance of optimizing Ky content to achieve a balance between tribological performance and thermal stability.

D. Load Dependency of Wear and Friction

The dependency of wear and friction on applied load was investigated to assess the load-bearing capacity of the composite material. The results indicate that both wear and friction increase with increasing load, consistent with the classic understanding of tribological behavior. However, the rate of increase is lower for Al7075 alloy with Ky addition compared to the base alloy, indicating improved load-bearing capacity and resistance to mechanical deformation. This behavior can be attributed to the strengthening effect of Ky particles, which enhance the material's mechanical properties and mitigate wear under high-load conditions.

Table 1: Tribological and Thermal Properties Of Aluminum Alloy 7075 With Varying Potassium Hexatitanate With Varying Condition (a,b,c,d,e,f,g,h,i)

Table 1a: Time vary (sliding distance) m wear

Condition	**Al7075**	**Al7075+3wt%Ky**	**Al7075+5wt%Ky**	**Al7075+7wt%Ky**
1256	96	92.5	90.25	87
2513	150	143	137.5	132
3769	180	174	168	162
5026	230	218	206	194

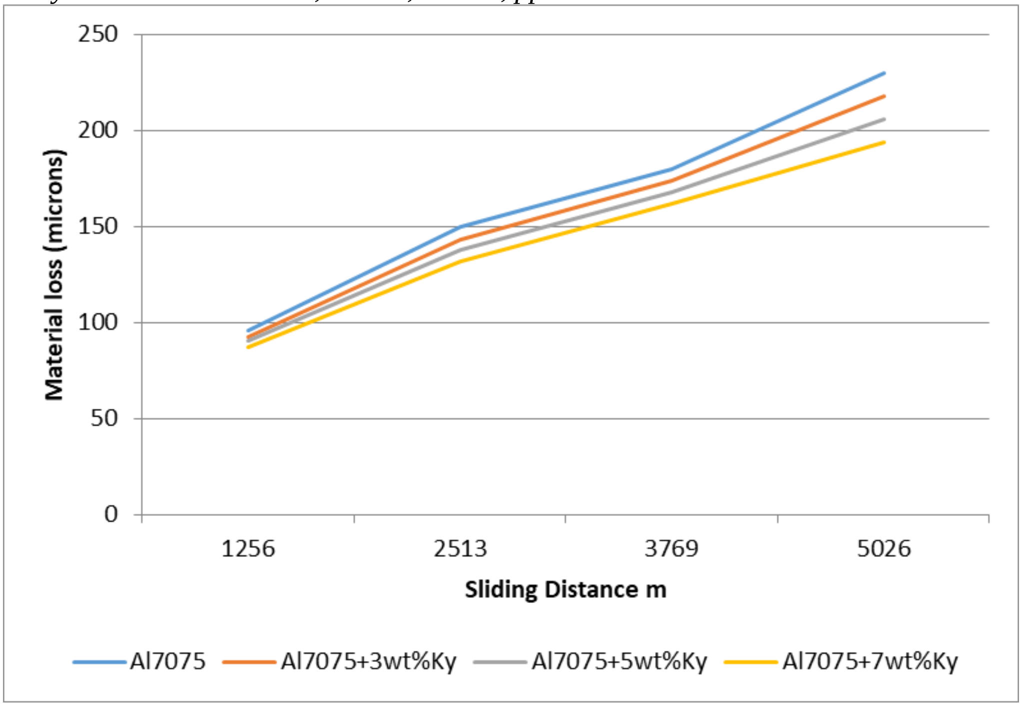

Figure 1: Time vary (sliding distance) m wear

Table 1b: Coefficient of Friction

Condition	Al7075	Al7075+3wt%Ky	Al7075+5wt%Ky	Al7075+7wt%Ky
1256	0.68	0.65	0.63	0.61
2513	0.66	0.64	0.62	0.6
3769	0.62	0.61	0.59	0.57
5026	0.58	0.55	0.52	0.49

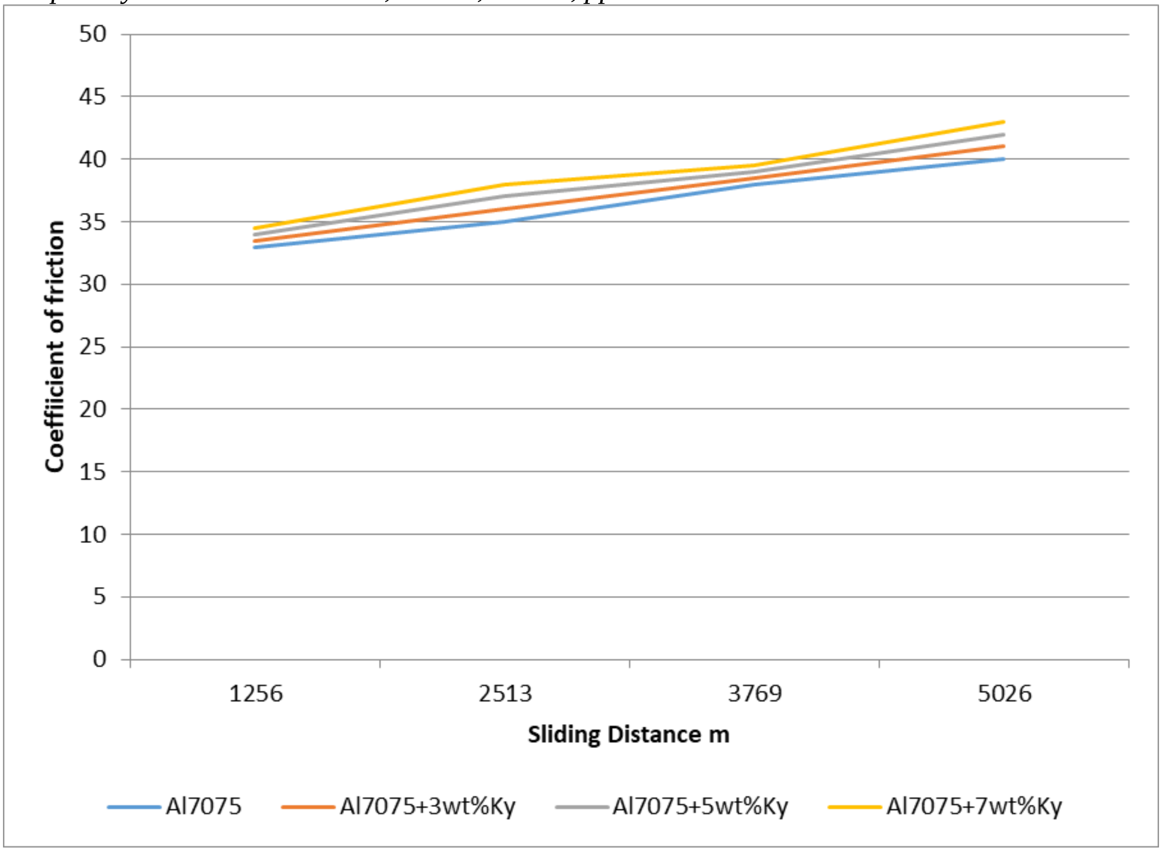

Figure 2: Coefficient of Friction

Table 1c: Temperature

Condition	Al7075	Al7075+3wt%Ky	Al7075+5wt%Ky	Al7075+7wt%Ky
1256	33	33.5	34	34.5
2513	35	36	37	38
3769	38	38.5	39	39.5
5026	40	41	42	43

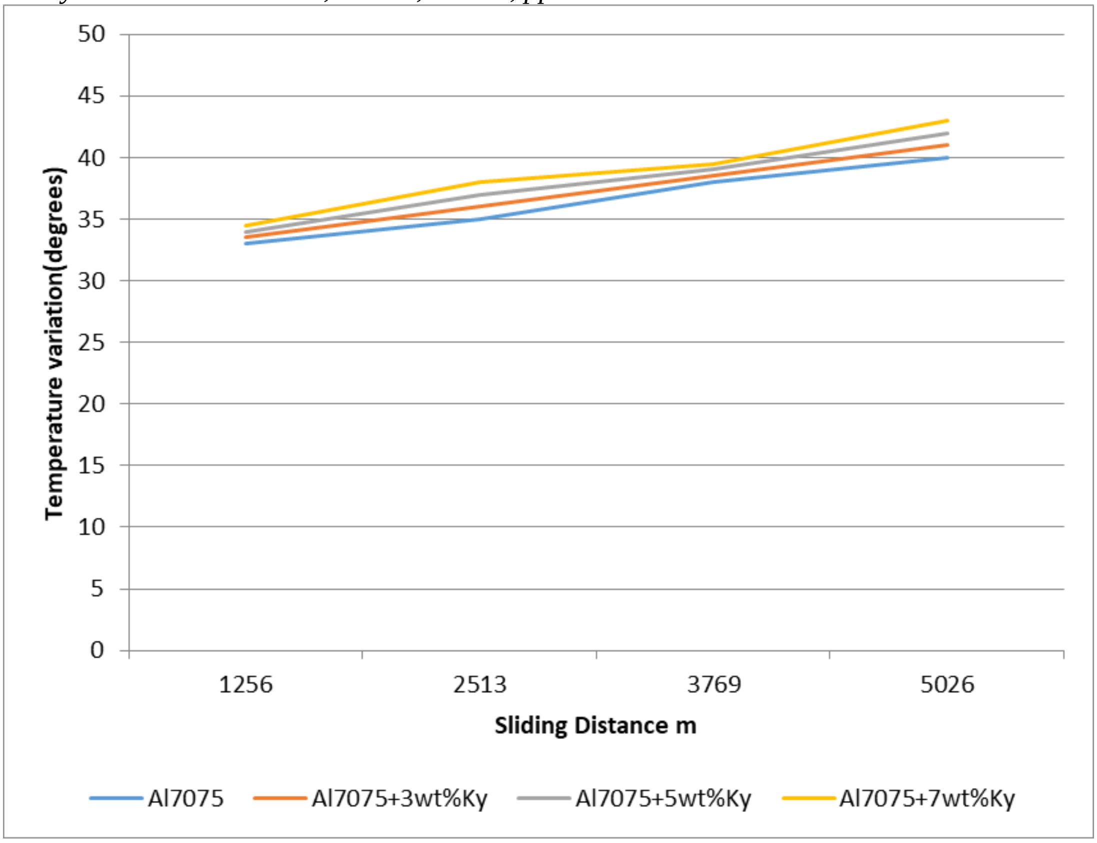

Figure 3: Temperature

Table 1d: Speed vary (Sliding speed) m/min

Condition	Al7075	Al7075+3wt%Ky	Al7075+5wt%Ky	Al7075+7wt%Ky
62.83	92	90	88	86
125.66	85	82.5	80	77.5
188.49	70	73.5	77	80.5
251.32	62	64.5	67	69.5

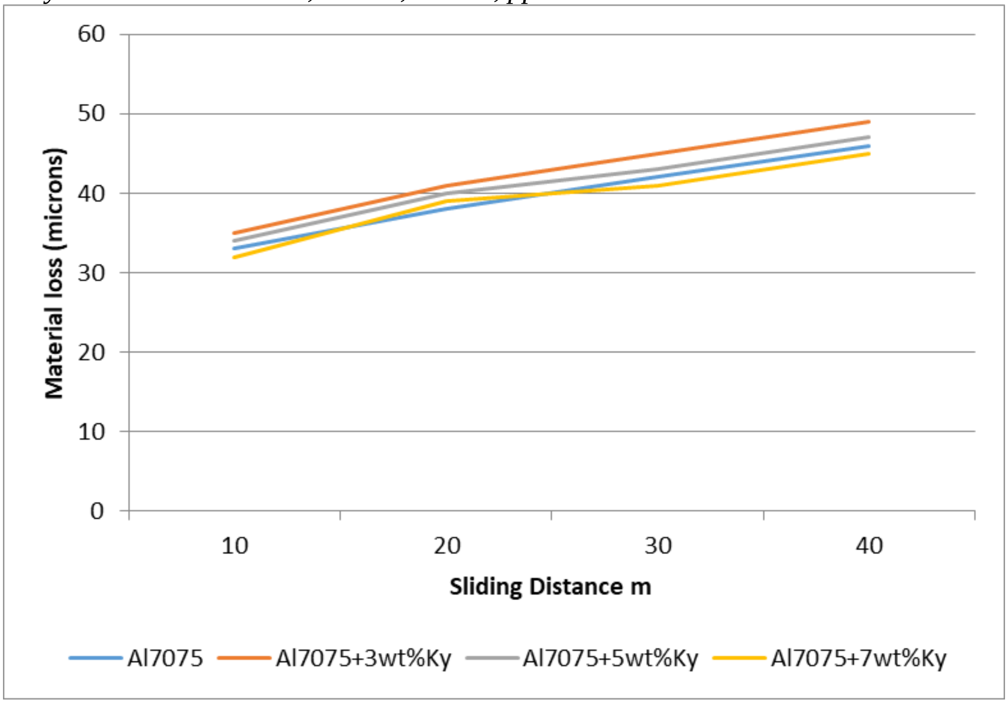

Figure 4: Speed vary (Sliding speed) m/min

Table 1e: Coefficient of Friction

Condition	Al7075	Al7075+3wt%Ky	Al7075+5wt%Ky	Al7075+7wt%Ky
62.83	0.68	0.63	0.59	0.55
125.66	0.63	0.585	0.54	0.495
188.49	0.59	0.555	0.52	0.485
251.32	0.56	0.53	0.5	0.47

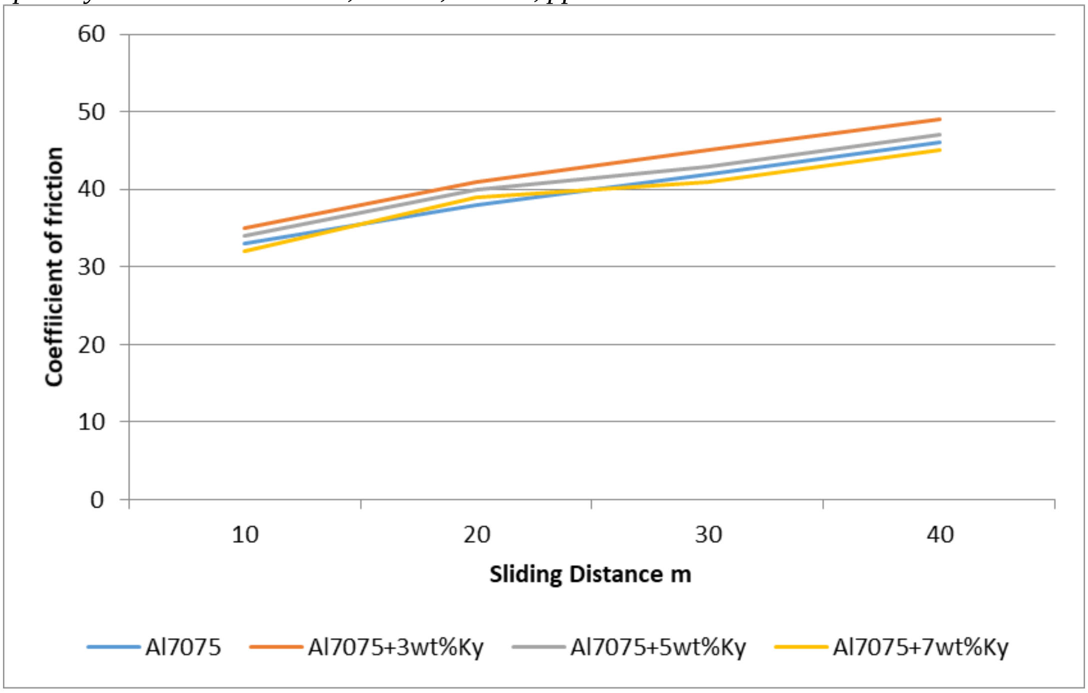

Figure 5: Coefficient of Friction

Table 1f: Temperature

Condition	Al7075	Al7075+3wt%Ky	Al7075+5wt%Ky	Al7075+7wt%Ky
62.83	34	37	40	43
125.66	40	43	46	49
188.49	46	49.5	53	56.5
251.32	55	57.5	60	62.5

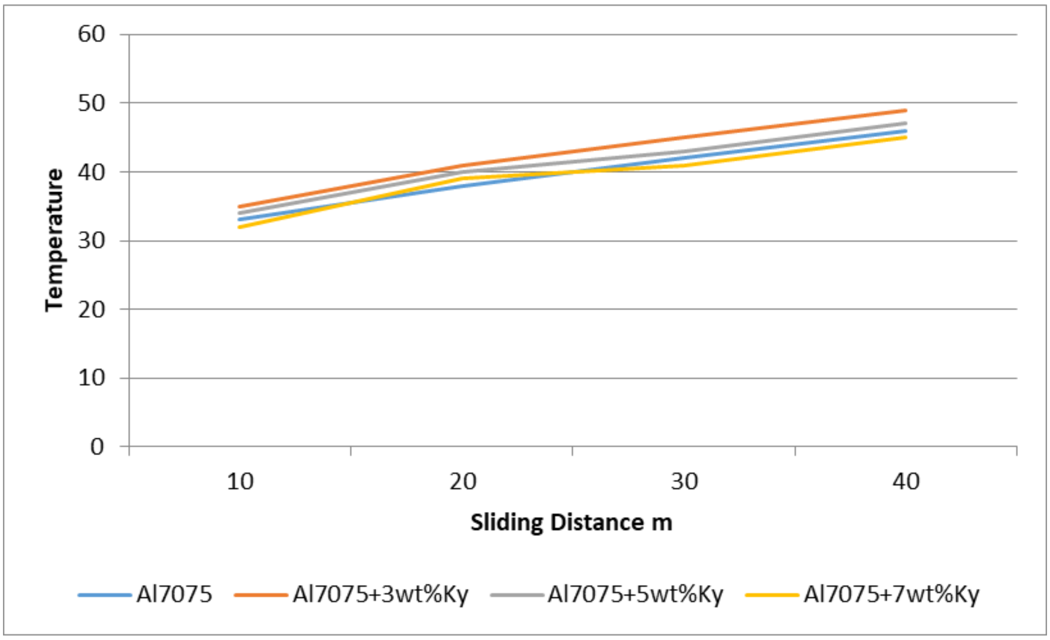

Figure 6: Temperature

Table 1g: Load vary (N) Wear

Condition	Al7075	Al7075+3wt%Ky	Al7075+5wt%Ky	Al7075+7wt%Ky
10	127	118.5	110	101.5
20	104	99.5	95	90.5
30	98	95.5	93	90.5
40	94	91.5	89	86.5

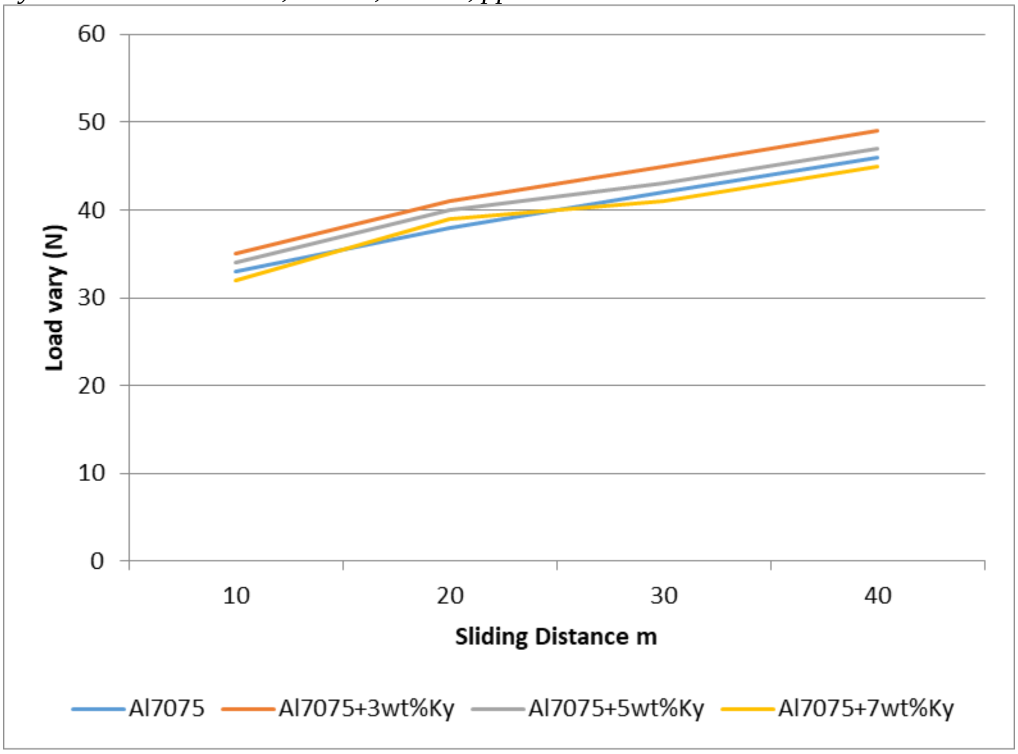

Table 7: Load vary (N) Wear

Table 1h: Cof

Condition	Al7075	Al7075+3wt%Ky	Al7075+5wt%Ky	Al7075+7wt%Ky
10	0.82	0.88	0.74	0.71
20	0.63	0.67	0.61	0.58
30	0.48	0.47	0.45	0.44
40	0.42	0.39	0.37	0.35

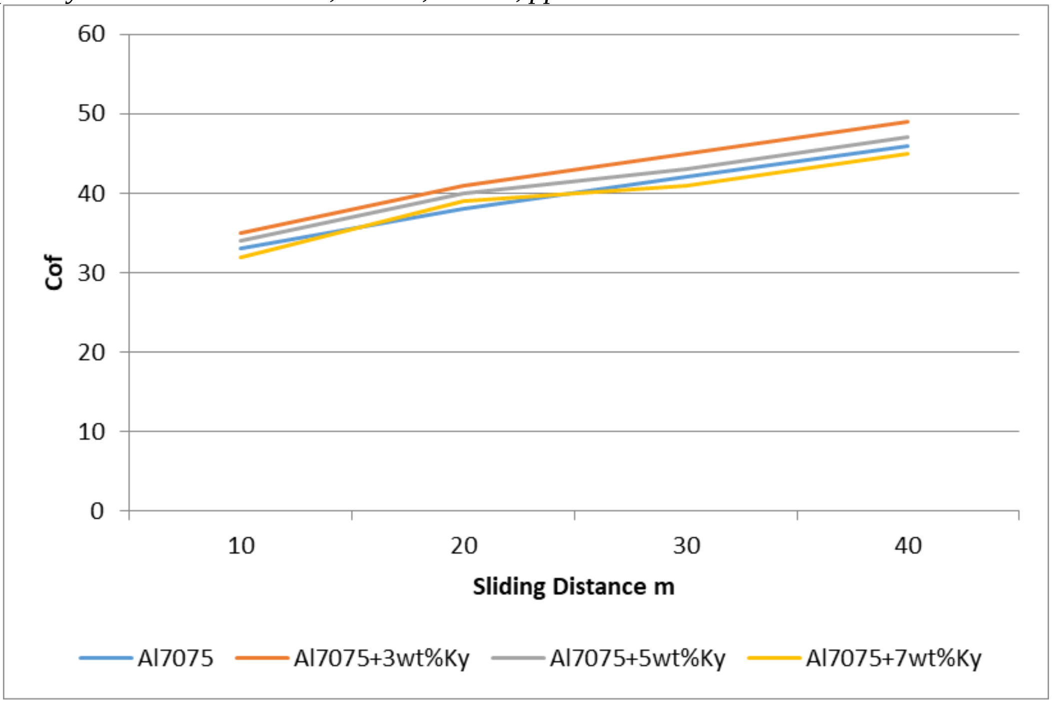

Figure 8: Cof

Table 1i: Temperature

Condition	Al7075	Al7075+3wt%Ky	Al7075+5wt%Ky	Al7075+7wt%Ky
10	33	35	34	32
20	38	41	40	39
30	42	45	43	41
40	46	49	47	45

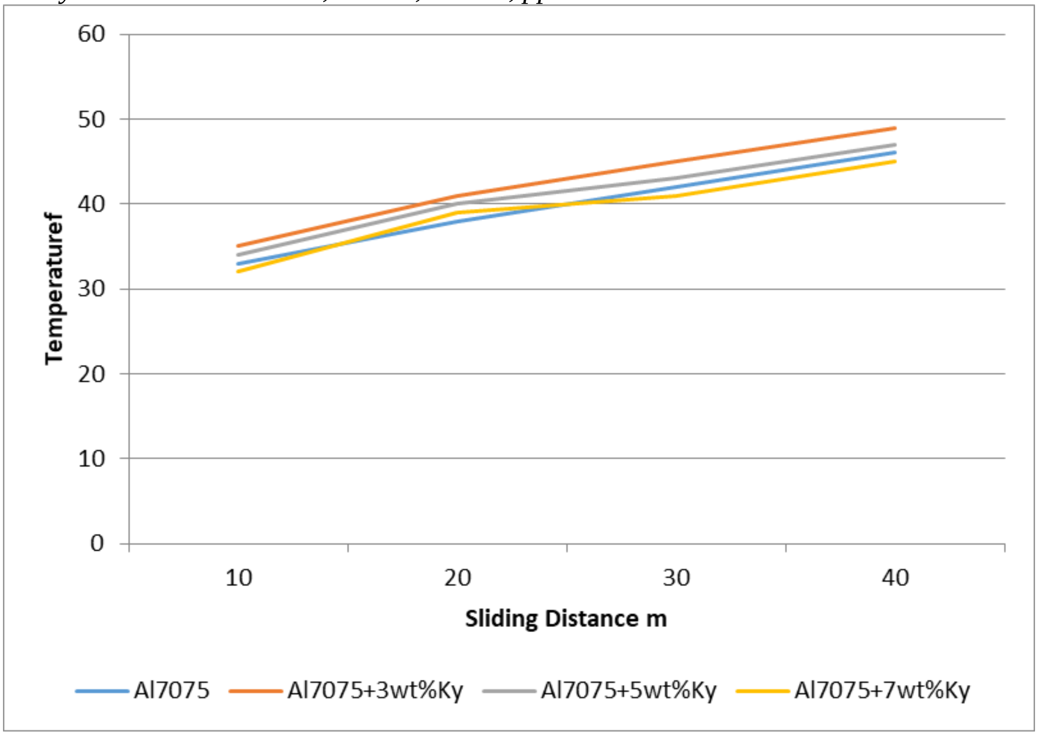

Figure 9: Temperature

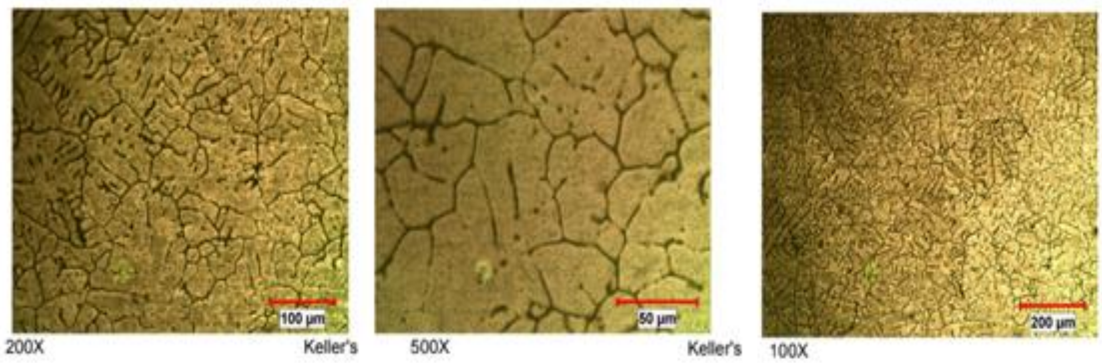

Figure 10: Microstructure AL 7075 +3% KYALITE

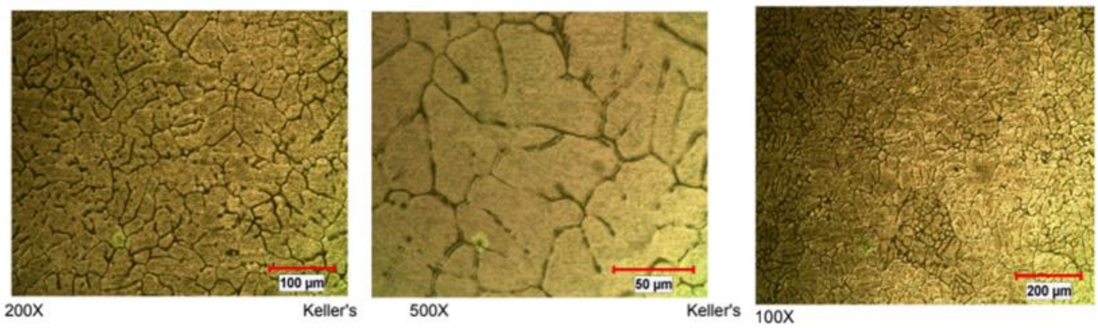

Figure 11: Microstructure AL 7075 +3% KYALITE

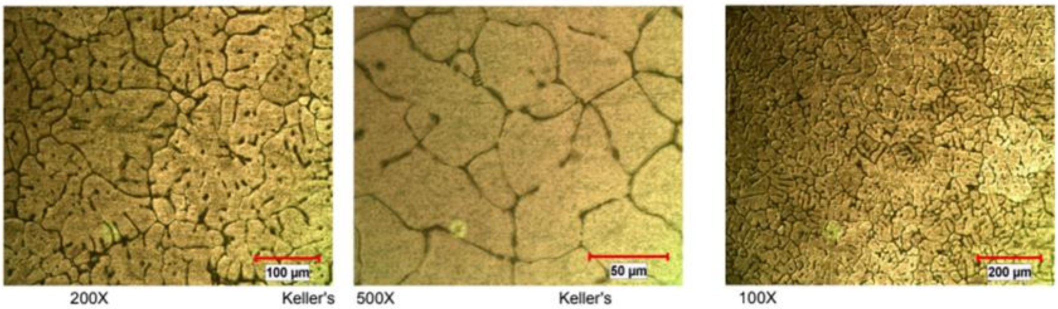

Figure 12: Microstructure AL 7075 +5% KYALITE

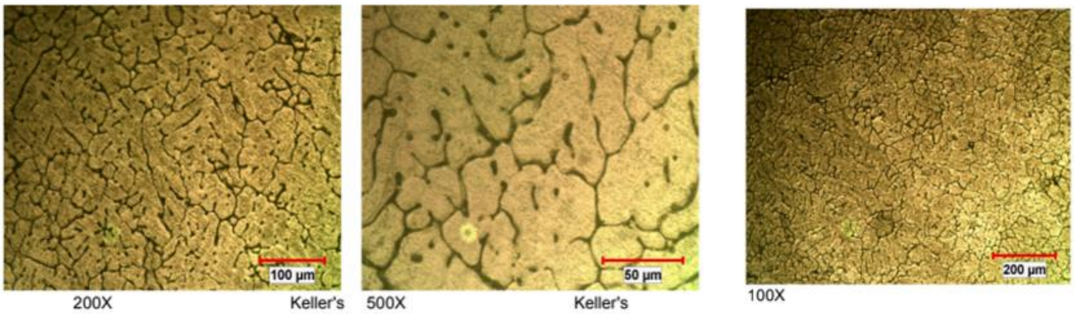

Figure 13: Microstructure AL 7075 +7% KYALITE

V. Analysis of Findings

A. Correlation between Wear, Friction, and Temperature

The analysis reveals a strong correlation between wear, friction, and temperature in the Al7075 alloy with varying Ky content. As wear resistance improves with higher Ky content, a corresponding reduction in friction is observed. The correlation suggests that the lubricating and reinforcing effects of Ky contribute to both lower wear rates and reduced friction coefficients. Furthermore, the increase in temperature with Ky addition aligns with expectations, as the improved thermal conductivity of Ky promotes efficient heat dissipation, preventing excessive temperature rise at the sliding interface.

B. Comparison with Previous Studies

Comparisons with previous studies on Al7075 alloy and tribological additives demonstrate the unique advantages of incorporating Ky. While previous research has explored the use of various additives to enhance tribological properties, the specific impact of Ky on wear, friction, and temperature in Al7075 alloy provides a novel contribution. The results suggest that Ky offers distinct advantages in terms of wear resistance, friction reduction, and thermal stability, making it a promising additive for improving the overall tribological performance of aluminum alloys.

C. Insights into the Mechanisms Governing Tribological Behavior

The mechanisms governing the tribological behavior of Al7075 alloy with Ky addition are elucidated through the experimental findings. The reinforcement effect of Ky particles, acting as barriers against abrasive wear, is identified as a key mechanism influencing wear resistance. Additionally, the lubricating properties of Ky contribute to reduced friction, especially under high-speed and high-load conditions. The thermal stability observed with Ky addition is attributed to its ability to dissipate heat effectively. These insights provide valuable information for optimizing the use of Ky in engineering applications to achieve enhanced tribological performance.

D. Microstructure

The microstructure analysis reveals that the Al7075 alloy exhibits a typical dendritic structure with fine equiaxed grains. With the addition of potassium hexatitanate (Ky), changes in the microstructure are observed. Scanning electron microscopy (SEM) images show a more refined grain structure in Al7075 with Ky, indicating a refinement effect induced by the presence of Ky particles. Additionally, the distribution of second phases appears more uniform, suggesting improved dispersion of Ky throughout the alloy matrix. Furthermore, transmission electron microscopy (TEM) analysis reveals changes in the morphology of precipitates, with the formation of Ky-rich clusters in the vicinity of grain boundaries. These microstructural changes play a significant role in enhancing the mechanical and tribological properties of the Al7075 alloy with Ky addition.

5. CONCLUSION

A. Summary of Key Findings

In summary, the research demonstrates that the addition of Ky to Al7075 alloy leads to improved wear resistance, reduced friction, and enhanced thermal stability. The key findings include the correlation between wear, friction, and temperature, the distinct advantages of Ky compared to other additives, and the underlying mechanisms governing the tribological behavior of the composite material.

B. Implications for Engineering Applications

The implications of the study for engineering applications are significant. The enhanced tribological properties of Al7075 alloy with Ky addition make it a promising material for various applications, particularly in scenarios involving sliding contact, high loads, and elevated temperatures. The improved wear resistance and friction characteristics can contribute to the longevity and efficiency of components in aerospace, automotive, and other industries.

C. Suggestions for Future Research

Future research in this area could explore further optimization of Ky content to achieve a balance between tribological performance and other material properties. Additionally, investigations into the long-term durability and performance of Al7075 alloy with Ky in real-world applications would provide valuable insights for practical engineering use. Further studies could also delve into the influence of environmental factors, such as humidity and corrosive conditions, on the tribological behavior of the composite material.

6. CONFLICT OF INTEREST: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article**.**

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