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Innovative Recycling of Asbestos Waste: Reinventing Brake Pad Materials to Boost Automotive Components

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Abstract

When a brake shoe makes contact with the brake drum, a friction substance called a brake lining is connected to the surface of the brake shoe to generate frictional force. Previously, asbestos was the most commonly utilized material for brake linings. Alternative materials, however, have been developed in response to the health dangers involved with inhaling asbestos dust. Non-asbestos fibers, for example, have seen significant use in braking components. Semi-metallic, non-asbestos organic (NAO), low-metallic NAO, and ceramic brake pads are the four basic varieties offered. It is critical to determine which type is best for your vehicle. Paper, elastomerics, graphitics, and sintered metals are among the friction materials used. A variety of other materials, including ceramics, advanced fibers, and other metal alloys, are also used. Prior to its ban, asbestos was widely utilized as a friction substance. Natural minerals found in rock formations are used to make asbestos fibers. These minerals exist as strong, flexible fibers that can be split into individual strands and thin threads. These threads can be woven into high-temperature and chemical-resistant textiles.The goal of this study is to recycle old asbestos materials into practical commercial products with unique properties. Asbestos waste powder will be incorporated into particle-reinforced aluminum composites. The sintering processes improve mechanical strength and wear resistance by forming a metallic structure. Waste asbestos materials, whether in the form of fine powder or bigger particles, can be used to make new goods. Asbestos' intrinsic brittleness makes it appropriate for powder sintering to produce tile formations or acoustically orientated materials. This recycled waste product has applications such as layer creation in 3D printing and reinforcement in composite manufacturing processes. In addition, fracture surface analysis was performed as part of the technique.

1. Introduction

Tribological characteristics were experimentally determined using Chase friction test equipment in accordance with IS2742 part-4. Notably, the findings from the experiments revealed intriguing trends. Fly ash particles incorporated into the friction composites exhibited consistent behaviors in terms of fade and recovery, along with a notably lower wear rate. On the other hand, friction composites based on steel slag demonstrated superior recovery behavior. The analysis of the brake pads through scanning electron microscopy (SEM) unveiled the development of plateaus, pits, fractures, and a range of other distinctive features on the pad surfaces.[1] Characterization of the brake pads encompassed an examination of their physical, chemical, mechanical, and thermal properties, carried out in accordance with established industrial standards. The investigation of the tribologicalbehaviors involved the utilization of the Chase testing machine, adhering to the SAE-J661-2012 protocol. Furthermore, the worn surfaces of the brake pads were subjected to scanning electron microscope analysis, aimed at deciphering the predominant wear mechanism at play.[2]

Remarkably, the friction material with a 10 wt% aramid content emerged as the frontrunner in terms of overall performance, while the composite devoid of fibers exhibited the least favorable outcome. The assessment of worn surfaces was facilitated through scanning electron microscopy, coupled with energy-dispersive X-ray analysis, affording insights into the structural and compositional transformations induced by the wear process.[3] The first configuration comprised ventilated brake discs crafted from cast iron, coupled with brake pads composed of semi-metallic material. These pads adhered to ECE R90 standards. In the second setup, ventilated brake discs made of cast iron were paired with brake pads crafted from a NAO (non-asbestos organic) composite material, synthesized in our laboratory.[4]

The study focuses on Aluminum Metal Matrix Composites (AMMC), a widely employed composite type that caters to emerging industrial requirements. The investigation centers on the mechanical properties of AMMC, specifically those produced through the stir casting technique, and involves the incorporation of boron carbide and silicon carbide as reinforcements within aluminum alloy 6061.[5] An interesting observation was the notable reduction in the radial thrust cutting force component associated with the rotary tool. Specifically, the radial thrust cutting force exhibited a 30-40% decrease when compared to that of a fixed circular insert. This reduction in cutting force has important implications for the overall machining process, including improved precision and reduced stress on both the tool and the workpiece.[6] Metal-matrix composites hold significant potential in aiding automotive engineers in addressing the multifaceted challenges posed by contemporary and future demands for environmentally friendly, fuel-efficient, secure, and low-emission vehicles. These versatile materials possess the capacity to be meticulously tailored to align with the specific design prerequisites of either automotive power-train or chassis components. Despite certain technological and infrastructural obstacles currently impeding their widespread adoption, there exists a conviction that these barriers can be surmounted. As a consequence, the integration of metal-matrix composites into high-volume vehicle manufacturing appears plausible.[7]

Investigation serves as a comprehensive exploration into the potential recycling and utilization of AAW, laying the groundwork for future endeavors aimed at examining its feasibility within braking applications. The study not only sheds light on the intrinsic properties of AAW but also hints at the avenues for sustainable innovation within the realm of friction materials, ultimately contributing to advancements in braking technology and environmental responsibility.[8] The results and observations gleaned from the experimentation underscore specific instances of optimized mechanical properties. Notably, the specimen featuring 25% wt% SiC, manufactured under an injection pressure of 90 MPa, exhibits optimized tensile strength. Conversely, the specimen comprised of 5% wt% B_4C, produced under an injection pressure of 90 MPa, showcases optimal impact strength.[9] Research delves into an array of aspects encompassing the physical, mechanical, chemical, and tribological properties of a series of friction materials enhanced with rubber from discarded tires. The evaluation process involves subjecting these materials to a battery of standard European industry tests (ECE R-90) to discern their tribological behavior.[10]

The primary emphasis of the study is placed on scrutinizing the tensile and impact strength characteristics of these composite materials. Of particular significance is the utilization of the Taguchi technique, a robust methodology, to optimize key process parameters. Paper offers a comprehensive overview of the impact of reinforcement addition on various aluminium alloy matrices, spotlighting their advantages and limitations. The discussion encompasses critical concerns such as the occurrence of agglomeration phenomena, the nature of fiber-matrix bonding, and challenges associated with the uniform distribution of particles within the matrix. [11-13] Aluminum matrix fly ash (AMFA) cenosphere composites were successfully produced through the implementation of the stir casting technique. Notably, the selected fly ash cenospheres constituted a significant proportion, exceeding 60%, of the overall fly ash particle composition. These cenospheres were characterized by their narrow size distribution and diminutive dimensions, ranging from 2 to 30 µm.[14-15] As the proportion of waste wire dust (WTD) in the brake pad composition increases, the mean coefficient of friction and porosity also exhibit an increment. Simultaneously, the hardness and density of the brake pads decrease. Importantly, the specific wear rate, a critical indicator of material performance, is influenced by the WTD content.[16]

The mechanical and tribological behavior of these Al 7075-B_4C composites was then comprehensively evaluated. Various tests were conducted, encompassing hardness, tensile, compression, and flexural strength assessments, as well as an exploration of wear characteristics.Notably, the incorporation of B_4C particles led to improved wear resistance, with a noteworthy trend of reduced wear rates in the composite materials compared to the matrix alloy. The research findings elucidated the formation of a mechanically mixed layer on the composite surface, comprising oxygen and iron, which acted as an effective insulating barrier, mitigating direct metal-to-metal contact and consequently enhancing wear resistance.[17-18] The experimental tests yielded a wealth of data, which were subsequently analyzed and distilled into a correlation model. This model effectively encapsulates the relationship between various precipitation hardening parameters and the resulting fatigue strength of the AA 6061-SiCp composite.[19-20]

The investigation into wear mechanisms is enhanced by employing Scanning Electron Microscopy, which enables the detailed analysis of surface features and wear patterns. Notably, the majority of the slag-based fillers exhibit superior wear resistance compared to composites reinforced with Al2O3. Among the different slag fillers, blast furnace slag demonstrates the highest tribological performance.[21] Polymer surface coatings exhibit remarkable substrate adhesion, flexibility, and resistance to corrosion. In contrast, the annual generation of 400,000 tons of boron wastes poses a significant challenge. To address this, we have successfully developed polymer composites utilizing epoxy resins, incorporating as much as 50 wt. % of boron wastes. Our investigation encompassed evaluating the dynamic friction and wear properties, Shore D hardness, and surface roughness of these composites.[22] By delving into the characteristics, behaviors, and performance attributes of friction waste materials, this research endeavors to contribute to our fundamental understanding of their properties and utilization. The subsequent sections of this article will expound upon the methodologies, experimental procedures, and analytical techniques employed to comprehensively evaluate the friction waste materials under consideration. As we embark on this journey of exploration, the outcomes and insights garnered from this study hold the promise of not only shedding light on the untapped potential of these materials but also paving the way for innovative solutions and sustainable practices in diverse industrial applications.

2. STIR CASTING PROCESS

The aluminum alloy (AL2021) was molten within a clay pot using a graphite crucible in an oven fueled by fire. The formulation of the composite was created in a 10 kg-capacity oven. Post-turbine extraction, external mechanical agitation was applied through an electric motor, maintaining a consistent speed of around 350 rpm. The dynamometer oversaw movement and speed during this process.

Upon reaching the commencement point at 600°C, fly ash was added, having been preheated to a similar temperature. The introduction of preheated particles ensured a controlled feed rate of approximately 1 g/s, with agitation set at 220 rpm and melting temperature at 740°C. To counteract Mn loss from oxidation, 1% Mg was incorporated at 730°C before the powder addition. The manual powder addition mechanism facilitated the introduction of particles into the molten metal crucible. A baffle was implemented to ensure uniform mixing of the composite. Subsequent to this, a degassing process was carried out, aimed at preventing hydrogen entrapment. The use of sulfuric acid as a cleansing agent, along with nitrogen, helped eliminate hydrogen from the molten metal. Degassing transpired for approximately 20 minutes at 760°C.Following manual stretching, the composite was poured into a rotating centrifugal mold. In total, four composite samples were prepared, each containing distinct percentages of reinforcements.

2.1 Tensile Test

Materials intended for engineering applications are typically chosen based on their specific properties, including attributes like tensile strength, yield strength, and modulus of elasticity. Among the various techniques available for evaluating mechanical properties, tensile testing stands out as the prevailing method. In the context of this study, a tensile test was conducted employing a universal testing machine (UTM). The hybrid composite specimens denoted as A, B, and C were formulated in accordance with ASTM standardsB-557M.

Table 2. Composites tensile property

Composite	Ultimate Strength(MPa)	Yield Strength(MPa)
C1	69.20	61.78
C2	79.83	65.51
C3	126.56	79.08
C4	140.97	84.57

From the above graph, it can be concluded that Composite 4 had the highest force value for the same stroke values, followed by Composite 3. It also shows a comparison of force, stroke, tension, and strain for all four composites. Composite 4 had the maximum values for breaking load, maximum displacement, and percentage elongation. Composite 4 had a higher breaking load and percentage elongation than composite 2, while composite 2 had a greater displacement than composite 1. While composite 4 contained an aluminum alloy, only the tensile strength of this composite was superior to that of the other composites.

2.2 Hardness Test

Hardness refers to the resistance of a material to local deformation. An impression or scratch on the surface of a hard material and the ability to indent or cut the material. Hardness of the four airtight testers. In the Brinell hardness test, the pieces of force were pressed onto the flat surface of the specimens with a force from 500 kgf to 1000 kgf. The induction was performed using a microscope. Reading on three points.

Table 3. Hardness Survey Results

Composite	Trial-1 BHN	Trail-2 BHN	Trail-3 BHN	Average BHN
C1	91.2	93.3	92.1	91.9
C2	88.7	83.5	79.5	83.9
C3	81.4	82.6	79.2	81.06
C4	79.5	79.0	80.8	79.7

A hardness test was performed on the four samples, and the results are shown in Tables 5 and 10. From the graph plotted for various trials to analyze the hardness of the specimens, it is clear that C4 has a higher hardness, which is by two in the presence of SiC, fly ash, and CNT in larger proportions. The presence of reinforcements in the microstructure plane increased the hardness of the composites.

2.3 Wear Test

A wear test was used to test the material to determine the loss of material during the dynamic condition of the component. It is a process of removing either one or both sides of the material surface to enhance the life of the materials. An abrasive wear tester was used to perform the wear test. The abrasive machine consisted of a laterally movable test piece holder and rotable cylinder. The abrasive cloth of 60 Grade is wound over the cylinder and fixed. The cylinder diameters were 150 and 500 mm in length. It had a rotational frequency of approximately 40 ± 1rpm. An equivalent revolution was made 84 times.

Table4.Wear rate of metal matrix composites

Samples	Load in N	Sliding Velocity m/s	Sliding Distance m	Wear Rate mm^3/m
	10	1	1000	0.02467
1	10	1	1000	0.02684
	10	1	1000	0.02478
	10	3	2000	0.03406
2	10	3	2000	0.03456
	10	3	2000	0.03265
	10	5	3000	0.048
3	10	5	3000	0.04662
	10	5	3000	0.04782
	15	1	2000	0.0282
4	15	1	2000	0.02866
	15	1	2000	0.02971

Samples 1, 2, and 3 were used for the abrasion wear tests. Each sample was tested using three parameters: the load, speed, and distance. The applied loads were 10, 15, 20 and 25N. The sliding distances were taken as 1000,2000 and 3000m. Sliding velocity as 1, 3 and 5 m/s. The maximum wear results were obtained in the samples at 3. The maximum 0.04782m/s. The wear surface was study SEM, the Result will explain in the below SEM Images

Fig.1 and 2: Wear Surface Analysis

The SEM images are shown in the fig.1 and 2. The SEM Image was carried out 100x and 20 magnification. SEM was performed using the ZESSIS instrument. The SEM images clearly show the wear tracks. The SEM image was obtained using abrasive wear. The wear surface is removed from the image. The causes of porosity level it will be reason of adhesive wear properties.

Conclusion

Composite 4 exhibits the most noteworthy values in terms of tensile strength, displacement, and percentage elongation when compared to other composite materials. Moreover, the final strength and yield strength of Composite 4 surpass those of its counterparts. Impact testing revealed an absorbed energy of 2 Joules for all four samples.The increased hardness of Composite 4 can be attributed to the higher proportions of Asbestos waste and fly ash. This enhanced hardness trend is observable due to the incorporation of these components. Additionally, Composite 4 demonstrates heightened flexural rigidity owing to the varying composition of the reinforcement.Conducting wear tests yielded a notable outcome, with sample 3 demonstrating the maximum wear. Further analysis of the wear SEM image substantiates its abrasive wear characteristics, ultimately resulting in a ductile response from the composite material.As a result, this study successfully repurposes brake pad waste material as a reinforcement element for automobile components, particularly in Composite 4, showcasing its potential and utility in enhancing material properties.

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