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Influence of vermiculite on performance of flyash-based fibre-reinforced hybrid composites as friction materials

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ABSTRACT

Flyash-based fibre-reinforced hybrid phenolic composites filled with vermiculite were fabricated and characterized for their physical, thermal, mechanical and tribological performance. The performance were evaluated in terms of their friction-fade, friction-recovery, maximum disc temperature rise and wear behaviour on a Krauss friction tester conforming to the Regulation-90 as per the Economic Commission for Europe (ECE) norms. The fade behaviour has been observed to be optimally dependent on the flyash–vermiculite combination whereas the recovery remained broadly unaffected at ~112 ± 14%. Addition of vermiculite has contributed to the reduction in the maximum disc temperature rise whereas it enhanced the frictional amplitude, i.e. $\mu_{max}-\mu_{min}$. The wear behaviour remains closely related to the trend observed in fade. The addition of vermiculite has caused an increase in the post-braking onset of degradation temperature of the surface composition as compared to the pre-braking composition. The analyses of friction and wear performance of the composites were carried out and major factors influencing the tribo-performance were identified. Worn surface morphology investigation using scanning electron microscope has revealed that the addition of vermiculite alters the compositional interactions at the braking interface leading to flyash–vermiculite combination specific topographical attributes responsible for tribo-performance evolution.

1. Introduction

In the current decade material scientists and formulation designers have been putting continuous efforts to develop new class of friction composites which would be more commercially viable and environmentally sustainable via reduced resource depletion [1,2]. In this direction use of flyash in friction materials as filler, that are aplenty, being a coal combustion by-product from thermal power plants, with multifunctional attributes such as high thermal stability with a good amount of metal oxides in its composition has recently been contemplated by several researchers [3–6]. However, the problem of complexity in choosing and optimizing the nature and content of disparate ingredients in friction material composition on one hand and the fuzzy nature of performance outcomes with the slightest variation in the operating parameters/braking variables on the other has posed a real challenge [7–11].

Potentially, flyash being pozzolanic in nature with high-temperature resistance and being able to exhibit a better integrity/compatibility with the resin may lead to enhanced tribo-performance of flyash-filled composites in friction braking applications [3–6,12–14]. Additionally, performance-to-cost ratio stimulates the adoption of such an ideology of flyash incorporation into friction materials. Malhotra et al. [3] and Mohanty and Chugh [4] have explored the possible functional efficiency pertaining to performance of flyash based friction composites. These investigations independently have claimed that flyash contributes to enhancement of thermal resilience and frictional stability on one hand and bulk utilisation of flyash without much compromise in the performance attributes on the other. Conceptually, the designing of friction-formulation rests upon the systematic strategy of progressive building-up of the composition via incorporation of ingredients following a step-by-step dilution of the resin/resin-filler mixture, an aspect which has already been initiated and reported in our earlier publications [5,6]. These publications report the successful incorporation of flyash into phenolic matrix with a small amount of aramid fibre incorporation to enhance the pre-form strength as a ternary composite followed by the optimization and subsequent evolution of a quaternary composite with

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