Fire-retardant Composite Conveyor Support Structures for Underground Mines

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ABSTRACT

Historically, the Australian mining industry has consistently reported the highest number of compensation claims related to lower back pain, attributed, at least in part, to the strenuous manual labour involved. The adoption of advanced materials such as Glass Fibre-Reinforced Polymer (GFRP) composites, renowned for their high specific strength and stiffness, emerges as a viable strategy to alleviate the physical strain on miners. Traditionally, metallic conveyor support frames in underground mines are conventionally used due to the ease of assembly and regulatory requirements. However, in challenging environments where manual transport is necessary, these heavy steel structures become cumbersome for workers to carry and pose safety risks.

The application of GFRP composite conveyor support structures in underground mines could enhance workers well-being by reducing fatigue during manual handling, transportation, and installation. Nonetheless, the use of non-metallic structures in mining is restricted by stringent regulations, especially in environments prone to spontaneous combustion, such as underground mines with suspended coal particles. The susceptibility of GFRP composites to fire raises concerns about smoke and toxic gas production during combustion. Therefore, the challenges of employing composite materials extend beyond load-bearing requirements to meet fire-resistant and anti-static (FRAS) regulations outlined in DPI Technical Reference Guideline MDG 3608—"Non-metallic Materials for Use in Underground Coal Mines and Reclaim Tunnels".

This study explores a prototype modular conveyor support frame made of halogen-free fire-retardant GFRP composites, examining its fire resistance, load-bearing capabilities, and fatigue performance. Flammability tests demonstrated compliance with FRAS requirements, achieving a UL94 V-0 rating and a 42% limiting oxygen index (LOI) value. Quasi-static load-bearing tests applied realistic conveyor loads to the prototype, revealing stable hysteresis behaviour without structural compromise. Under maximum design load, the frame exhibited minimal deflection, well within the EUROCOMP design code allowances. Finite element (FE) analysis closely aligned with experimental results, showing strains and deflections within acceptable limits. Numerical investigations into bearing stresses around bolt holes indicated safety margins well below failure thresholds. Additionally, dynamic fatigue loading tests revealed the prototype's resilience, withstanding over a million cycles without significant deterioration in load-carrying capability.

These comprehensive findings highlight the promising potential and feasibility of employing fire-retardant GFRP composites as lightweight conveyor support structures in underground mines.