Electric Vehicle Fire Suppression: Emerging Challenges and Research Gaps

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The rapid adoption of electric vehicles (EVs) is transforming the global mobility landscape. While EVs contribute significantly to sustainability goals, they also introduce new fire safety challenges - particularly related to lithium-ion battery systems. Unlike conventional vehicle fires, EV fires are driven by complex electrochemical reactions that are not yet fully understood or easily controlled. This presents significant implications for emergency response, infrastructure safety and regulatory development.

One of the most critical challenges lies in the absence of a definitive extinguishment method for EV fires. Current firefighting practices largely rely on water due to its cooling effectiveness. However, battery packs are typically sealed, limiting the ability of water to reach the internal cells where thermal runaway occurs. As a result, large volumes of water are often required without guaranteeing complete extinguishment. This creates uncertainty for responders, especially when determining whether to continue suppression efforts, allow controlled burning, or adopt containment strategies.

The complexity is further compounded by limited understanding of thermal runaway propagation. Battery behaviour varies depending on chemistry, design, and damage conditions, making it difficult to predict how a fire will evolve. Firefighters must rely on external indicators such as smoke, sound, and temperature, which do not fully reflect internal battery conditions. This gap highlights the need for improved diagnostic tools and operational guidance to support real-time decision-making during incidents.

Another major concern is the risk of reignition. Even after visible flames are extinguished, residual energy within damaged cells may trigger secondary fires hours or even days later. Currently, there is no universally accepted standard for determining when an EV fire is fully under control. This uncertainty affects not only firefighting operations but also post-incident handling, including towing, storage, and public safety management.

Globally, firefighting approaches remain inconsistent. While some organisations emphasise aggressive cooling with water, others incorporate strategies such as controlled burning, submersion, or containment. The lack of a harmonised doctrine creates variability in response and may lead to inefficiencies or increased risk. For countries like Malaysia, developing a standardised national approach that integrates international best practices while addressing local conditions is essential.

In addition, the design of EV battery systems poses operational challenges. Battery packs are typically located beneath the vehicle and encased in protective structures, restricting access during firefighting. This limits the effectiveness of suppression efforts and prolongs incident duration. Greater collaboration between manufacturers and emergency services is needed to improve accessibility and provide clear emergency response guidance.

The risks are significantly amplified in enclosed environments such as basement car parks, tunnels, and charging facilities. In these settings, limited ventilation, heat accumulation, and toxic gas build-up can escalate the hazard. Existing building fire safety systems are often not designed to handle EV-specific risks, underscoring the need for updated infrastructure standards and emergency planning.

Finally, there remains a lack of comprehensive data, training, and policy integration. The relatively low number of documented EV fire incidents limits the availability of empirical data, while current training programmes are still largely based on conventional vehicle fires. Establishing a national reporting system and enhancing firefighter training will be critical steps toward improving preparedness and response capability.

As EV adoption continues to grow, addressing these gaps will be essential to ensuring safe and resilient transport systems. The challenge lies not only in extinguishing the fire, but in managing the unique risks associated with battery systems—from initial response to long-term safety considerations.

References:

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