

# ***Research on the Application of New Composite Flame Retardant Materials in Safety Protection of Chemical Engineering***

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**Abstract:** Chemical engineering production processes are characterized by high temperature and high pressure conditions, flammable and explosive media, and continuous operational procedures. Fire and explosion hazards have long served as the core risks restricting the safe production of the chemical industry. Conventional flame retardant materials suffer from low flame retardancy efficiency, inadequate weather resistance, and poor compatibility with chemical equipment, which fail to meet the safety protection requirements of complex working conditions in modern chemical engineering. Taking new composite flame retardant materials as the core research object, this paper systematically sorts out the application status of such materials in the field of chemical safety protection, and deeply analyzes practical problems existing in material research and development, engineering adaptation, field application and operation and maintenance. Targeted optimization and improvement strategies are proposed in accordance with the operational characteristics of chemical production and relevant safety specifications. The research findings can effectively enhance the stability and reliability of the flame retardant protection system for chemical engineering, and provide theoretical support and practical references for fire risk prevention and control and the upgrading of safety production systems in the chemical industry.

## **1. Introduction**

The chemical industry may suggest that it functions as a core pillar of the national economy, covering the significant findings of multiple key links including raw material processing, reaction synthesis, transportation and storage. Moreover, the large-scale application of various flammable, explosive and corrosive chemical raw materials and finished products could indicate that production sites remain in a long-term high-risk state<sup>[1]</sup>. Furthermore, the evidence may suggest that fire accidents feature sudden occurrence, strong destructiveness and wide diffusion, causing direct losses such as equipment damage, production suspension and casualties. In light of these significant results, the data could demonstrate that secondary disasters including environmental pollution and industrial chain disruption are further induced. Safe production shows enterprises need core safety. As the core carrier of passive safety protection in chemical engineering, the performance of flame retardant materials may suggest that the significant findings of on-site fire risk prevention capacity and accident disposal effect are directly determined. However, the evidence could indicate that

traditional single flame retardant materials are prone to performance degradation under chemical working conditions with extreme temperature differences, chemical corrosion and long-term pressure bearing. Therefore, the key results might demonstrate that traditional materials appear incapable of satisfying the refined and high-level safety protection standards of modern chemical engineering. Given that the evidence demonstrates that multi-component compounding and process optimization are applied, new composite flame retardant materials could indicate that multiple important advantages including excellent flame retardancy, structural stability and working condition adaptability are integrated. Materials show composites replace traditional ones. Notwithstanding the results of prior findings, the study may suggest that new composite flame retardant materials have gradually replaced traditional materials in significant chemical engineering protection scenarios<sup>[2]</sup>. Additionally, the important findings could demonstrate that practical demands of chemical safety prevention and control appear critical to the study of new composite flame retardant material applications. Nevertheless, the evidence might indicate that the investigation of practical application deficiencies and the optimization of the protection system could demonstrate significant engineering value. Thus, the key results may suggest that consolidating the significant safety defense line of chemical engineering and reducing the incidence of safety accidents appear to be the core objectives. Research shows deficiencies need addressing for safety.

## **2. Application Status of New Composite Flame Retardant Materials in Chemical Engineering**

### **2.1 Continuous Improvement in the Popularity of Flame Retardant Protection on Equipment Surfaces**

Chemical production equipment may suggest that long-term service environments present significant challenges, given that high-temperature heat sources, flammable gases, and corrosive media could indicate substantial operational risk<sup>[3]</sup>. Moreover, the findings demonstrate that metal equipment shells and non-metallic sealing components appear highly susceptible to combustion and deformation under open flame erosion, which could indicate further spread of fires. Furthermore, the evidence may suggest that new composite flame retardant materials, featuring strong adhesion and high compactness, demonstrate that protective coatings are widely applied to core production equipment such as reaction kettles and conveying pipelines. In light of these results, the significant data could indicate that these materials appear to form a stable flame retardant isolation layer on equipment surfaces, blocking heat conduction and contact paths between flammable media and fire sources. Materials effectively delay high-temperature aging and equipment damage<sup>[4]</sup>. However, the results may suggest that large and medium-sized domestic chemical enterprises have gradually completed the important upgrading and replacement of flame retardant protective layers for old equipment. Therefore, the significant findings could demonstrate that the coverage rate of new composite flame retardant coatings and plates appears to increase year by year, which may suggest that passive fire protection capacity of basic equipment could show critical improvement. Notwithstanding these results, the evidence may indicate that the key findings demonstrate that a critical barrier for initial fire prevention and control in chemical production sites appears to have formed through these significant protective measures. Coverage rates show equipment protection improves annually.

### **2.2 Gradual Perfection of Flame Retardant Protection Systems in Storage Areas**

Chemical storage areas may suggest that centralized accommodation of liquid and solid flammable materials creates significant density and categorical complexity<sup>[5]</sup>. However, the

evidence could indicate that large-scale chain combustion accidents remain highly likely once fire breaks out, making such areas key objects of chemical engineering safety protection. Furthermore, the findings might demonstrate that new composite flame retardant materials have been deeply integrated into the protection construction of storage areas, covering significant scenarios including partition walls, fireproof ceilings, shelf protective layers, and ground flame retardant cushions. In light of these results, the data could suggest that new composite materials possess superior moisture resistance, corrosion resistance, and aging resistance compared with traditional flame retardant building materials. Composite components show storage spaces divided into fire prevention zones. Moreover, the significant findings may indicate that these composite flame retardant components could effectively block horizontal and vertical diffusion paths of fires, thereby providing key protection across chemical storage facilities. Therefore, the results might suggest that the large-scale application of such materials appears to greatly reduce the probability of chain fire accidents, supporting important advances in safety protection<sup>[6]</sup>. Additionally, the evidence could demonstrate that these developments may promote the standardized and refined development of safety protection systems, establishing significant improvements in chemical storage area management. Given that findings show composite materials perform consistently, results suggest chemical storage protection may continue advancing. Notwithstanding these results, the key evidence could indicate that chemical storage facilities might further demonstrate standardized safety outcomes through continued integration of composite flame retardant materials into protection construction.

### **2.3 Continuous Expansion of Application Scenarios for Emergency Fire Sealing Works**

Concealed positions in chemical engineering, including pipeline supports, cable through-layer holes, and equipment interface gaps, may suggest that these areas serve as the main diffusion channels for fire smoke and open flames, constituting the weak links of traditional flame retardant protection<sup>[7]</sup>. However, the significant findings could indicate that tiny protection defects appear to lead to the failure of the overall fire prevention system. Moreover, the evidence may suggest that new flexible composite flame retardant sealing materials demonstrate outstanding plasticity, high fitting degree, and excellent adaptability to complex special-shaped structures, establishing that these materials are widely used in emergency fire protection scenarios such as hole sealing, gap filling, and cable protection. In light of these key results, the data could indicate that these materials are compatible with pipelines, cables, and equipment interfaces of different specifications, and might demonstrate that dense fireproof sealing layers form after curing, realizing integrated functions of fire resistance, smoke insulation, and heat isolation. Safety standards show requirements increasingly refined. Furthermore, the significant evidence may suggest that the continuous upgrading of safety management and control standards for chemical engineering could indicate that technical requirements for fire sealing of concealed positions have been increasingly refined<sup>[8]</sup>. Given that the findings demonstrate expanded application scenarios, the results might indicate that new composite flame retardant materials appear to effectively compensate for the protection deficiencies of traditional flame retardant materials in subtle and concealed positions. Additionally, the key evidence could suggest that these developments demonstrate that the overall fire prevention framework may show continued improvement across complex chemical engineering environments. Materials address gaps traditional methods miss.

### **3. Problems Existing in the Application of New Composite Flame Retardant Materials in Chemical Engineering**

#### **3.1 Insufficient Comprehensive Stability of Materials under Extreme Working Conditions**

Modern chemical production involves high temperature and high pressure, strong corrosion and temperature fluctuation<sup>[9]</sup>. The operating temperature and pressure of equipment in certain fine chemical and coal chemical production process significantly exceed normal industrial range. Therefore, extremely high requirement on weather resistance and structural rigidity of flame retardant material in these fields is put forward for strong corrosion and temperature fluctuation in chemical working conditions. Most new composite flame retardant materials are compounded with organic and inorganic substances. If the proportion of organic additives is excessively high in certain formula systems, the additives will be volatilized, the components will be aged and the structure will be loosened during continuous high-temperature operation for a long time. These phenomena will directly decrease the degree of tightness of flame retardant protective layer and weaken the heat insulation and fire resistance of flame retardant protective layer gradually<sup>[10]</sup>.

#### **3.2 Deficiencies in Adaptability between Materials and Working Conditions of Chemical Equipment**

Metal, fiberglass reinforced plastic, composite plastic and other equipment is widely used in chemical engineering. Equipment made of different materials have different surface tension, thermal expansion coefficient and adhesion performance, and need different fitting flexibility of flame retardant material. The mass-produced new composite flame retardant materials are still using general formula system, and lack of customized research and development for the equipment materials. When used in special parts such as non-metallic flexible equipment and thin-walled pipelines, the fitting effect is poor and the deformation adaptability is weak, and the protection layer falls off and cracks when the equipment vibrates.

#### **3.3 Non-standard Construction and Operation & Maintenance Systems Impair Protection Effectiveness**

The protective effect of new composite flame retardant material is not only related to the inherent material property, but also related to the standard construction method and routine operation and maintenance management. Unified construction specification applicable to new composite material hasn't been formed in chemical industry. Most construction team still adopt conventional construction process to construct new composite flame retardant material and can't effectively control the following parameter of new material: material ratio, coating film thickness and cure temperature as well as maintenance time of new material. Meanwhile, random manual construction may lead to the following construction defect: construction quality is not standardized and protective layer is uneven; new material can't be cured sufficiently and hollow layer appear. All these will damage the overall stability of protection system.

## **4. Optimization Countermeasures for Application Problems of New Composite Flame Retardant Materials**

### **4.1 Optimize Material Formula System to Enhance Stability under Extreme Working Conditions**

Considering the extreme working conditions such as high temperature, corrosion and temperature fluctuation in chemical engineering, the following improvements should be made on the components of new formula of composite flame retardant materials: Highly volatile and easily aged organic additives should be replaced by high-temperature resistant and corrosion-resistant inorganic modified components. The content ratio of inorganic flame retardant fillers, binders and modifiers should be adjusted to improve the internal microscopic structure of materials, enhance the combination compactness and stability of components and reduce the volatilization of components and aging of structure in high-temperature environment. Special anti-corrosion modified ingredients should be added in case of acid-base corrosive working conditions to improve the surface erosion resistance, alleviate the damage of chemical corrosive medium to protective layer and ensure the structural integrity of materials during long-term operation.

Material modification experiments and working condition simulation tests should be carried out repeatedly to simulate and verify the variation laws of material performance changes under different temperature, pressure and corrosion environment, and select the optimal formula system applied to extreme chemical working conditions. The cross-linking modification technology should be used to enhance the thermal stability of materials and reduce the impact of thermal expansion and contraction caused by alternating temperature changes so as to prevent the shedding and delamination of protective layers. The optimal formula system should be selected to enhance the mechanical strength and impact resistance after molding, and improve the vibrating operation state of chemical equipment. The long-term stable operation of flame retardant protective layers under complex working conditions can ensure that the excellent fire and heat insulation performance are sustained.

### **4.2 Develop Customized Material Systems to Strengthen Working Condition Adaptability**

Considering the different equipment materials and diversified process scenarios in chemical engineering, we shall develop new composite flame retardant materials according to classified equipment, and form classified material product system. Based on different physical properties of equipment made of metal, fiberglass reinforced plastics, plastics and other materials, we shall control bonding system and flexibility parameters of materials to improve fittingness of materials and various substrates, enhance the stability of adhesion of protecting layer and solve the problem of easy shedding of protecting layer on thin-walled component and flexible equipment. We shall control flexibility and toughness of materials based on characteristics of equipment deformation, and make protecting layer adapt to slight deformation of equipment made and avoid damaging defect of rigid protecting structure.

We shall establish hierarchical adaptive application system of flame retardant materials according to classification standard of chemical process risk levels. We shall develop special high-strength and super weather-resistant high-grade flame retardant composite materials for typical high-risk scenarios such as high-risk reaction and high-temperature refining, and meet the requirement of extreme working condition for protecting equipment. For typical scenario including storage and auxiliary equipment, we shall control formula of flame retardant materials with economical performance to eliminate redundant performance and control application cost.

Scenario-oriented and customized material research and development and application can

achieve accurate matching of requirement of working condition and performance of protecting layer, and enhance application cost-effectiveness and practicability of materials without sacrificing the application of chemical engineering satisfying requirement of safety protection standard of engineering.

### **4.3 Establish Standardized Construction and Operation & Maintenance Systems to Ensure Protection Effectiveness**

Based on the performance characteristics of new composite flame retardant materials and chemical engineering construction scenarios, special standardized construction specifications should be constructed, and clear technological parameters for whole process material proportioning, base layer, coating construction and curing maintenance are defined. Detailed construction specifications should be formulated for different construction scenarios such as equipment surface, hole sealing and storage components, and unified construction specifications should be constructed for manual operation to eliminate quality defects caused by arbitrary construction. Construction personnel should strengthen professional skill training, enhance understanding of material performance and construction technology, improve construction refinement level and ensure the quality and standardization of flame retardant protection system from the construction technology view.

Establish a regular and refined operation and maintenance management system for flame retardant protection. Inspection of composite flame retardant protective layer should be included in the daily safety inspection system of chemical equipment, focusing on the protection conditions of inspected areas and equipment with high-risk working conditions, so as to repair the damaged, aged and shed protection layer in time. Based on industrial technical standard, a performance detection system for new composite flame retardant materials should be constructed, and special detection indicators such as aging resistance, corrosion resistance and bonding strength should be introduced to evaluate material performance attenuation during long-term service. Protection files should be established to record construction parameters, detection results and rectification conditions, and achieve the whole life cycle management of flame retardant protection system, so as to continuously consolidate the safety protection line of chemical engineering.

## **5. Conclusion**

With the advantages of excellent flame retardancy and good adaptability, new composite flame retardant materials have been extensively used in core links of chemical engineering such as equipment protection, storage fire prevention and hole sealing. New composite flame retardant materials have an important role in enhancing the level of fire prevention and control and decreasing the safety accident probability in chemical engineering. However, new composite flame retardant materials still have obvious problems in stability during extreme working condition, scenario adaptability and standardization of construction and operation & maintenance, which affect the long-term and stable operation of protection system. Based on the current application status sorting out and key problems analysis, this paper puts forward the optimization approaches from three aspects of material formula optimization, customized research and development and standardization of construction and operation & maintenance, which can effectively solve various practical problems in chemical application of new composite flame retardant materials. In the future, it is intended to further integrate intelligent working condition monitoring technology and material modification technology, continuously improve the overall performance and adaptability of composite flame retardant materials, and provide more technical support for the safe production in chemical engineering.

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