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The Latest Research Status and Prospect of Water Mist Fire Suppression Technology

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Abstract: *Water mist fire suppression technology is of great value in new energy fires, special industrial environments, and interdisciplinary applications. In the new energy scenario, it is widely used and effective in lithium batteries, solar energy, wind energy, and biomass energy with the advantages of environmental protection. For example, lithium battery fire cooperates with gas fire extinguishing agents, solar panel fire prevention, and wind energy needs special injection. Biomass can cope with a variety of fires. There are progress and shortcomings in combustible dust, coal mines, and medical facilities in special industrial environments, such as rapid response to dust environment. The characteristics of bright atomization in underground coal mines, fire extinguishing, and water saving of medical facilities, but there are problems such as cost. Nanotechnology uses specific materials to improve fire extinguishing efficiency, and artificial intelligence relies on intelligent control to achieve precise operation of the system. In the future, the technology will develop in multiple dimensions, expand its application fields, technological innovation, interdisciplinary cooperation, and so on. However, it is still necessary to overcome the difficulties of various scenes to achieve accurate and efficient fire prevention.*

Keywords: *water mist fire extinguishing technology; new energy fire; special industrial environment; nanotechnology; artificial intelligence*

1. Introduction

Under the background of the rapid development of science and technology and the continuous advancement of industrialization, the new energy industry is booming. The special industrial environment is increasingly complex and diverse, posing unprecedented challenges and higher fire prevention and control technology requirements. As a new and potential fire extinguishing technology, water mist fire extinguishing technology has unique physical and chemical characteristics and mechanisms. It has gradually become the focus of research and application. New energy facilities or equipment have special energy storage and conversion methods. When a fire occurs, it presents complex characteristics such as fierce combustion, rapid spread, strong thermal radiation, and possible production of toxic and harmful gases. For example, the chain reaction caused by thermal runaway in a lithium battery fire can have serious consequences. In the special industrial environment, whether it is a combustible dust environment, coal mine roadway, medical facilities, etc. They all have their own unique fire risks and working conditions. In this context, the in-depth study and application of water mist fire extinguishing technology is significant. It is related to the safe and stable development of the new energy industry and plays a key role in fire prevention and control in special industrial environments. In addition, the rapid development of frontier disciplines such as nanotechnology and artificial intelligence. It provides new opportunities and possibilities for the innovation and breakthrough of water mist fire extinguishing technology. Interdisciplinary integration research is expected to further enhance the performance and application scope of water mist fire extinguishing technology. O as to better adapt to the complex and changeable fire prevention and control requirements, To lay a solid foundation for ensuring the safety of life and property, and the sustainable development of society.

2. Water mist fire extinguishing technology in new energy fire response

When the new energy facility or equipment is on fire. It has the characteristics of violent combustion, rapid spread, strong thermal radiation and possible production of toxic and harmful gases. Taking the lithium battery fire as an example, the electrolyte inside the lithium battery is usually flammable and volatile. The internal chemical reaction will release a lot of heat and flammable gases, causing the fire to expand rapidly. Moreover, the high temperature generated by the lithium battery fire may trigger a chain

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reaction of adjacent batteries. The whole energy storage system or electric vehicle is in a serious fire crisis. This kind of fire will not only cause devastating damage to the equipment itself, but also endanger the lives of the surrounding personnel. It will also have a negative impact on the environment. Water mist fire extinguishing technology has many application advantages in new energy fires. It is environmentally friendly, its main component is water, and there is no large amount of chemical residues after fire extinguishing, which is in line with the concept of sustainable development of new energy industry; The damage to the equipment is small, and no secondary damage is caused; It has strong adaptability and can adjust the parameters of water mist spray pressure, flow rate and droplet size according to different new energy fire scenarios. Effectively control the fire.

Water mist fire extinguishing technology has been widely used in new energy fires and the effect is remarkable. In terms of lithium-ion battery fires, Lin Zhang et al. [1] used a new synergistic fire extinguishing method of gaseous fire extinguishing agents (C CFO, CO_2 and HFC-227ea) and water mist. The experimental results show that the synergistic effect is better than that of a single fire extinguishing agent, and the combination of C/Cfo and water mist has the best fire extinguishing and cooling effect. The combination of CO CO and water mist has good economic benefits and good fire extinguishing and cooling effects. At the same time, Matt Ghiji et al. [2] studied the thermal behavior of electrolytes and found that water mist can quickly suppress the flame in a specific geometry. In the new energy battery laboratory, Wang Jilei et al. [3] solved the potential safety hazard of the test.The high-pressure water mist fire extinguishing system is applied to the laboratory and the environmental chamber of the test system. The actual test shows that it has a good fire-extinguishing effect on battery fires and reduces casualties and property losses. It has important reference and promotion significance. In the comprehensive pipe gallery cable fire, Wu Yaqian [4] used a high-pressure water mist as a means of fire extinguishing. Experiments show that it can effectively inhibit the spread of cable fire, and has the functions of cooling and preventing re-ignition, and different flow coefficients have different effects. Through the study of the numerical model, it is concluded that the optimal working condition of fire extinguishing in the electric cabin of the utility tunnel is that the nozzle pressure is 20 MPa, the flow coefficient is 1.0, and the layout spacing is 2.6 m.

In addition, Water mist fire extinguishing technology is widely used in solar energy, wind energy, biomass energy, and other new energy fields, and presents different characteristics and characteristics. With effect. In the field of solar energy, the cooling effect of water mist can effectively reduce the temperature of panels and prevent the spread of fire [5]. Because solar panels are usually installed outdoors, the environment is relatively open, and water mist can evaporate quickly. It will not cause excessive water damage to the panels. Therefore, in the process of fire extinguishing, it is necessary to ensure that the spraying of water mist will not have a long-term adverse impact on the photoelectric conversion efficiency of the panel. Aim at that solar electrical equipment fire, can extinguish the fire on the premise of not damaging the equipment, has small fog drop, is not conductive and can be effectively cooled, It is only necessary to solve the problems of waterproofing, water accumulation and drainage of equipment.

In the field of wind energy, wind turbine fires are caused by high unit locations, narrow internal space and poor ventilation conditions. When water mist is used to extinguish fire, it is necessary to spray remotely and precisely and close the ventilation and smoke exhaust system [6]; In the fire of electrical control cabinet, water mist can protect equipment by cooling and will not cause secondary damage such as short circuit. However, pay attention to the spray angle and intensity.

In the field of biomass energy, water mist can extinguish biomass fuel storage fires through cooling and suffocation. However, the high bulk density of biomass fuel may hinder its exertion, so it is necessary to increase the injection intensity and coverage [7]; During the fire of biomass fuel processing, the fine water mist can inhibit the dust explosion fire and reduce the temperature and concentration of the dust. However, the timing and intensity of the injection should be accurately grasped.

3. Research on water mist fire extinguishing technology in special industrial environment

Remarkable progress has been made in the research of water mist fire extinguishing technology in special industrial environments.

In a combustible dust environment, Meng Xiangbao et al. [8] pointed out that dry powder fire extinguishing agents can cause pollution, difficult cleaning, and possible damage to the equipment in a combustible dust environment. An automatic fire extinguishing system with high-pressure water mist for a combustible dust environment was designed. The designed high-pressure water mist automatic fire extinguishing system shows excellent performance. The average response time of the flame sensor and

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controller is only 4 ms and 12 ms respectively, and the average generation time of high-pressure water mist is only 96 ms. Such a rapid response and speed of fog generation can be extremely effective in containing the spread of flame.

For the underground roadway environment of coal mines, scholars [9] adopt the method of combining experiments, numerical simulation, and theoretical analysis. The Movement of nitrogen water mist in a simulated tunnel and its characteristics of fire prevention and control were studied. The atomization conditions and particle size distribution of nitrogen water mist were successfully defined. The movement status, fire prevention, and cooling characteristics in the simulated roadway, as well as the effects of different ventilation and particle size conditions are deeply grasped. The effect of factors on fire extinguishing effect.

In a medical facility environment, people are mostly at a disadvantage when evacuating in a medical facility, so in the event of a fire, Evacuation will be difficult and lead to serious consequences. Extinguishing a fire with a conventional fire hydrant may damage the equipment due to excessive water usage. To solve this problem, Yu-Jen Chen et al. [10] considered water consumption as a key factor while considering fire extinguishing performance. In this study, three standard wood cribs (7.5 MW) were extinguished using newly developed mobile high-pressure equipment and a nozzle A with a K value of 3.7. Its performance is superior to the equipment used by the National Fire and Disaster Research Institute. At a pressure of 49.3 KGF/cm ² and a flow rate of 26 LPM, the extinguishing times were 68s,76s, and 60s, respectively, and there was no re-ignition within two minutes. Calculations show that the system requires only 33 liters of water to extinguish the fire, which is 27% less than an indoor fire hydrant, but it is still effective. And has no electric leakage phenomenon under the operating pressure and flow rate.

Water mist fire extinguishing technology has its own advantages and disadvantages in different special industrial environments. It presents green, low-carbon, safe, environmental protection and fire extinguishing performance in special industrial environments such as power platforms, oil depots and some situations in buildings. Has excellent characteristics, a wide application range under the background of carbon peak, And can further enhance the fire extinguishing effect by means of additives or in coordination with other technologies, For example, the improved knapsack water mist fire extinguishing system also has better performance in specific aspects; However, it also has some shortcomings in some application scenarios, such as power platforms and oil depots. It has the problems of high cost of system installation and maintenance and high requirement for water quality. But also the initial state of the knapsack wat mist fire extinguishing system and the reignition phenomenon of the wat mist in the gasoline pool fire, shows that there are some limitations in its fire extinguishing performance.

4. Innovative application of nanotechnology and artificial intelligence in water mist fire extinguishing

Nanotechnology has a wide range of innovative applications in water mist fire extinguishing. By adding that nano material. It can enhance the fire extinguishing effect of water mist, improve the fire extinguishing speed, improve the fire extinguishing mechanism, and adapt to different environmental conditions. It provides a new way to improve the efficiency and safety of fire extinguishing.

At present, nano-materials that can enhance the fire extinguishing effect of water mist mainly include nano-SiO2 composite thickener, graphene and FeO. The nano-SiO_2 composite thickener can improve the fluidity of water mist aerosol [11], and can be made into an aqueous fire extinguishing agent with adhesive properties. It can form a stable covering layer on the solid surface to prevent re-ignition and has excellent performance in wood fire extinguishing tests. And that preparation is simple and convenient, and the cost is low.PPS/G/FeO fibers made of a mixture of low content graphene and FeO are applied in the field of protective clothing [12],Although it is not directly used in water mist fire extinguishing, it provides a potential research direction. In addition, in other fire extinguishing-related fields, such as luxury cruise ship water mist fire extinguishing systems, there is no specific nanomaterial. However, it provides a direction for exploring application scenarios [13]; Although the water mist fire extinguishing system in the archives storehouse does not mention specific nanomaterials, it has the basis of application specifications [14]; Nanomaterials enhance the fire performance of polyurethane foam, although not for water mist fire extinguishing, but also for its reference ideas [15].With the continuous progress of nanotechnology, it is expected that more nanomaterials will be used in water mist fire extinguishing to improve the effect and ensure fire safety.

In addition, the research of artificial intelligence in water mist fire extinguishing technology has shown significant progress and broad potential. In terms of intelligent control and monitoring, an

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intelligent control system based on SIEMENS S7-200 smart series PLC and Kunlun Tongtai TPC1262Hi touch screen, It can realize system water level, pressure alarm and fault alarm, operation record, linkage programming control, state monitoring, equipment management, parameter It has diversified functions such as number setting and remote monitoring [16]. Data are collected by temperature, smoke, flame, pressure, leakage, and other sensors, and transmitted to the upper monitoring layer through the network. As to accurately acquire and process the environmental information of the fire extinguishing site and achieve the goal of accurate control and real-time monitoring. In terms of improving fire extinguishing efficiency, sensors are used to collect data such as temperature, smoke concentration and flame size at the fire scene. It uses artificial intelligence algorithm to analyze in depth, and then automatically adjusts the spray intensity, spray angle and other spray parameters of water mist. Effective optimization of fire extinguishing effect, such as water mist automatic fire extinguishing system based on flame sensor, can fuse multi-sensor information. According to this, the basic parameters of the system are designed and the water pump is controlled to achieve efficient fire extinguishing operation. In terms of system linkage, artificial intelligence can effectively promote the coordinated operation of water mist fire extinguishing systems and other firefighting systems. Predicting the possibility of fire occurrence based on data analysis, starting each system in advance and carrying out pre-intervention; It automatically adjusts the linkage control strategy according to the actual situation of the fire, such as giving priority to the use of water mist in the early stage of the fire and cooperating with ventilation and smoke exhaust. When the fire increases, it will cooperate with automatic sprinkler and gas fire extinguishing systems; Optimize the system layout and sprinkler settings according to the building structure and fire spread situation; rely on intelligent sensors to achieve remote monitoring and operation; At the same time, it can also provide decision-making assistance for firefighters and cooperate with fire-fighting robots. It improves the linkage effect of the system and the comprehensive ability to deal with the fire in an all-round way.

5. Comprehensive development trend and the prospect of water mist fire extinguishing technology

Water mist fire extinguishing technology shows significant development characteristics and trends in multiple dimensions, as follows:

(1) Continuous expansion of application fields

In the underground scene of coal mine, it is feasible and urgent to establish relevant norms. This will effectively promote the full release and precise implementation of its fire prevention and extinguishing efficiency. In the fields of construction, ship, spacecraft and so on, this technology has gained wide attention, and the practical application effect is considerable. Take the field of ships as an example, although specific devices have emerged. However, its deep potential in the field of marine application still needs to be deeply excavated and carefully carved. The research path of water mist fire extinguishing technology in the field of civil aviation has been clear. Such as the exploration of the new generation of airborne fire extinguishing technology, the analysis of the characteristics of special environments (high plateau, etc.), the design optimization of application facilities, and high efficiency. The key technologies of the system and the research on the generation and control mechanism of low-pressure water mist have been anchored. In addition, the demand for its application in construction and industrial subdivisions such as cooking areas and commercial buildings is also rising steadily.

(2) Steady progress in technological innovation

In the application dimension of additives, alkali metal salts and other additives have been proved to significantly improve fire extinguishing efficiency. Part of the high-efficiency compound additive formula has been successfully locked. It is worth noting that there are significant differences in the fire-extinguishing performance of different additives. The concentration of water mist containing additive is also affected by the variation of hydrogen addition. Under the macro background of carbon peak, water mist fire extinguishing technology is a typical example of low-carbon green technology. It shows a strong development trend in the aspects of deepening technological innovation, expanding application territory, and coordinating with other energy-saving and emission-reduction technologies. Direction and potential.

(3) Challenges need to be solved urgently.

Different application fields pose different challenges to water mist fire extinguishing technology. In the field of wood structure construction, there are limitations in the fit between the simulated environment and the real fire scene. Moreover, the selection of key parameters such as droplet diameter, spray flow rate, nozzle density, and so on is facing difficulties. There are many drawbacks and loopholes in the traditional fire extinguishing technology, which hinders the promotion of water mist fire extinguishing

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technology. Moreover, the adaptability in specific complex scenarios needs to be enhanced. Because of the high complexity of the space structure and the uncertainty of the fire extinguishing effect, It is a significant obstacle to the design and application of a water mist fire extinguishing system. When expanding the scope of application in the construction and industrial fields, It is faced with the problem of a lack of standards and specifications and the need to adjust the system according to the characteristics of different scenarios. Under different conditions, the fire suppression effect of water mist is affected by many factors, and the selection of spray mode is also quite challenging. The hangar scene puts forward strict requirements for the precise control of fire extinguishing time and gas concentration.

(4) The optimization path is clear.

Additive combination optimization can start from two aspects physical additives and chemical additives. At the level of physical additives, efforts can be made to reduce surface tension and improve stability and durability; At the level of chemical additives, the focus is on enhancing the efficiency of decomposing active gases and capturing free radicals. And deeply consider the synergistic effect between additives. In the specific implementation process, scientific methods such as orthogonal design and effect analysis can be used. Organically combining experimental research and theoretical calculation means, According to the characteristics of different fire scenarios and fuel types, the appropriate additive combination scheme is determined.

(5) Cross-domain collaboration is booming.

At the level of technology research and development, it cooperates with mechanical engineering, material science, and other fields. It aims to improve the performance of the nozzle and innovate the additive category. In the aspect of experimental research, we should actively carry out joint experiments of interdisciplinary integration. Computer simulation and practical application scenarios are closely combined to achieve complementary advantages and mutual verification. Industry application dimension, in aviation, cruise, and other fields to carry out in-depth special research and development to meet the characteristics and needs of the industry. From the perspective of international cooperation, countries can fully share research results and practical experience. And then in technology research and development, application and promotion, standard formulation, and other aspects of cohesion. Jointly drive the water mist fire extinguishing technology to a higher level of advancement and expansion.

6. Conclusion

Water mist fire extinguishing technology is rich in many aspects, such as new energy fire response, special industrial environment adaptation, and interdisciplinary innovative application. The research results and significant development trends. In the field of new energy fire, water mist has the advantages of environmental protection, low damage, and strong adaptability. It has been widely used in lithium batteries, solar energy, wind energy, biomass energy, and other scenarios with remarkable results. A variety of collaborative fire extinguishing research and practical cases provide strong support for its in-depth application in the new energy industry. Under special industrial environments, water mist fire extinguishing technology has made progress in combustible dust, coal mines, medical facilities, and other environments. Although each has its advantages and disadvantages, it provides a direction for subsequent improvement. Nanotechnology opens up a new path for improving the fire-extinguishing effect of water mist through specific nanomaterials. Artificial intelligence realizes the efficient and accurate operation of fire extinguishing systems with the help of intelligent control and system linkage. Looking forward to the future, water mist fire extinguishing technology will continue to expand its application field. Especially in coal mines, civil aviation, and other fields, the deepening application is worth looking forward to; Technological innovation is steadily advancing, and additive innovation is expected to further improve fire extinguishing efficiency; In the aspect of overcoming challenges, it is necessary to study the optimization strategy in depth for each scenario; The optimization path is clear, and the efficiency can be improved from the optimization of additive combination and other aspects; Cross-domain collaboration is booming, which will promote the technology to a higher level through multi-disciplinary cooperation and international exchanges. However, it is still necessary to realize that water mist fire extinguishing technology still faces many challenges in different scenarios. For example, the determination of key parameters in each scenario, the enhancement of system adaptability, and the improvement of standards and norms require the concerted efforts of all parties. Continuous exploration and innovation to achieve more accurate and efficient application of water mist fire extinguishing technology in the field of fire prevention and control. To contribute continuously to the construction of a safe and reliable production and living environment.

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