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The Ignition Phenomenon and Mechanism of Welding Spatters Under Different Current Intensities

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Abstract: The ignition of combustible materials by electric welding spatters represents a significant cause of fires in welding operations, and the current intensity is a sensitive factor that affects the ignition capacity of welding spatters. In this work, the influence of different current intensities on the physical properties and ignition capacity of welding spatters on common combustible materials was investigated, and the ignition mechanism of electric welding spatter was also explained by means of the hot-spot theory. The results indicated that the splash range, the total generated quantity, the maximum diameter, and the temperature of electric welding spatters increased with the enhancement in current intensity. Furthermore, a higher current intensity was associated with a greater likelihood of producing irregular spatter particles. The probability of ignition of electrode welding spatters was found to be sensitive to their physical properties, exhibiting a non-linear increase with increasing current intensity. At a current intensity of 360 A, a surge in both the physical properties and ignition capacity of the spatters was observed, which is attributed to the coupling of a reduction in the critical hot-spot radius and an unstable pulsation in the arc.

Keywords: hot-spot ignition; hot particles; electric welding spatters; spatter fires

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1. Introduction

In the environment of daily life and in the building industry, electric welding can be seen everywhere. Electric welding is realized by using an electrode to melt the places at which metal parts need to be connected through the arc at high temperature. The welding process produces a large amount of welding spatters, which undergo a process of transformation from liquid to solid, and the temperature of the spatters can reach up to 2000 °C. These hot metal particles are an important fire ignition pathway by which wild land and urban spot fires are started, and once they drop, they are difficult to control. If there are flammable or combustible materials beneath the welding position, high-temperature welding spatters will cause combustion and even lead to the occurrence of fires [1]. This is despite the fact that in all countries arc welding operations are explicitly prohibited from placing flammable and explosive materials in the welding area [2]. However, every year, there are many cases of welding fire accidents caused by welding workers neglecting safety and operating in violation of the regulations. In 2022, a welding fire accident occurred at a chemical company in Anyang Coal Chemical Industry Park, Tongye Town, Yindu District, Anyang City, Henan Province, China, resulting in three deaths and a direct economic loss of about USD 491,500. In 2015, a fire broke out in the raw material warehouse of China's Shandong Dashun Lingqi Cashmere Textile Co., resulting in a direct economic loss of approximately USD 366,550. According to incomplete statistics, there are thousands of fire accidents caused by welding faults in China every year, resulting in a large number of casualties and property losses.

In recent years, the research on fires caused by electric welding construction work has primarily focused on the analysis of accidental cases of electric welding fires and the evaluation of safety protection measures. However, there has been a paucity of research conducted on the ignition capacity of electric welding spatters and its relationship with current intensity. Challen et al. were the first to propose safety and health precautions in the electric welding process, noting that the process can result in electrocution accidents, fires and explosions, smoke poisoning, and burning eyes. They identified four common hazards and proposed measures to prevent them from occurring [3]. The American Welding Council published *ANSI Z49.1: 2005 Safety in Welding and Cutting*, which addresses all aspects of safety and health in welding operations, with a particular emphasis on fire prevention [4]. On this basis, the National Fire Protection Association also provides general requirements to help ensure that those involved with hot work are addressing fire and explosion hazards, prevention, and safety practices in areas in which combustible materials could spark or ignite from the hot work being performed. It also offers clear guidance on managing the activities and safety requirements of welders. This standard is recorded in *NFPA 51B: Standard for Fire Prevention during Welding, Cutting, and Other Hot Work* [5]. China has also issued the *JB/ZQ 3687-1986 Welding Code for Manual Arc Welding*, which establishes normative requirements for manual arc welding operations [6]. The aforementioned studies and codes merely suggest control measures from the perspective of safety and protection and do not investigate the ignition capacity of electric welding spatters or the factors influencing it.

The research on the ignition of combustibles by molten metal has undergone multiple demonstrations. Early scholars generally believed that the ignition capacity of welding spatters was directly related to temperature. Urban explored the ignition process of hot metal particles from three aspects: generation, simultaneous transport, and thermal chemical change of the particle [7]. Omar et al. employed an infrared thermal camera to measure the thermal behavior of welded joints and spattered spatters and obtained data regarding the size, velocity, spatter angle, and distribution of the welded spatters [8]. Miles et al. investigated the ignition capacity of high-temperature metal particles by heating spherical steel spatters of 0.80–1.91 mm to 500–1300 °C and found a significant relationship between the ignition capacity of the metal particles and the particle size [9]. In addition to linking the intuitive phenomenon of spatter ignition with temperature parameters, scholars have also established a series of mathematical methods to describe the influence of temperature on the spatter's ignition capacity. Urban et al. heated different sizes of steel spatters, aluminum spatters, copper spatters, and other metal particles to different temperatures, analyzed the ignition capacity of high-temperature metal particles on fibrous combustibles, obtained the hyperbolic rule of the ignition boundary size and temperature, and established the corresponding mathematical prediction model, which further explored the ignition mechanism of the high-temperature particles [10]. Environmental factors and ignition methods have also been included in the analysis of the ignition capacity of welding spatters; however, various analyses suggest that temperature remains the dominant factor. Liu explored the effect of temperature on the ignition capacity of electric welding spatters in a fire scene test of electric welding ignition by using an infrared thermal camera to analyze the temperature change of the welding position [11]. Lyu et al. classified the events of cellulose ignition by arc spatters into three types: no ignition, ignition smothering, and combustion ignition and explored the relationship between arc spatter ignition behavior and temperature [12]. These studies explored the laws of ignition of combustible materials by hot particles, with a particular emphasis on the relationship between ignition behavior and particle temperature, but lacked an analysis of the electrical aspects.

In addition to studying the temperature and certain related parameters, the types of ignition materials have also become one of the research objectives for numerous scholars. Chen et al. set variables such as height, stacking method, and thermal conductivity of the ground surface, respectively, to study the effect of spattered welding spatters generated during electric welding on the ignition characteristics of wood chip, cotton, polyurethane foam boards, and polystyrene foam boards [13]. Zhao et al. analyzed the ignition capacity of welding spatters on three kinds of exterior wall insulation materials by changing the morphology of the exterior wall insulation materials, the relative position, and the insulation materials [14]. Numerical simulation is also a powerful tool for fire research, especially in its ability to intuitively express the dynamic changes in the system temperature field, providing a basis and ideas for further theoretical discussions. Wang investigated in detail the ignition phenomenon and mechanism of flying fire particles such as electric welding on exterior wall insulation materials such as polyurethane foam by establishing a physical model [15]. Li et al. conducted a heating test on brass particles to simulate the ignition capacity of high-temperature particles generated by welding, fireworks, grinding, and other processes on combustible materials. The ignition process of the hot particles was also qualitatively analyzed through a numerical simulation, and the effects of the diameter of the hot particles, the input power, and the activation energy of the reaction on the ignition behavior were investigated [16]. On the other hand, the microstructure and structural characteristics of the welding spatters have also been found to be one of the strong influencing factors. Lei studied the ignition situation, spatter shape, and size of welding spatters falling on polyurethane foam board, glazed ceramic tile, sawdust, and skimmed cotton, respectively. The macro- and microcharacteristics of welding spatters were summarized [17]. Tian studied the ignition capacity and microstructure characteristics of short-circuit splashed welding spatters, including the experiment of critical parameters of short-circuit splashed welding spatters igniting α-cellulose [18]. These studies provided an initial exploration of the ignition capabilities of welding spatters but used a relatively limited type of ignition material and were slightly restricted in their mechanistic studies.

Some scholars have noticed that electrical parameters also have an impact on the ignition capacity of welding spatters. Lu et al. studied the effect of voltage change on the quantity, size, and distribution of welding spatters, and the ignition properties of electric welding on cotton cloth, paper, and polyurethane foam were simulated. It was found that the critical voltages of paper, polyurethane foam, and cotton cloth ignited by welding spatters were 45 V, 40 V, and 37.5 V [19]. Fabio et al. studied the safe use of electricity by personnel under various welding conditions [20]. Coldham et al. reviewed electrical fault parameters that can lead to arcs and WUI ignition events and introduced a method to predict the probability of ignition [21]. These studies explored the influence of electrical factors on the spatter in the welding process but ignored the relationship between the current intensity and the ignition capacity of the spatter. Environmental indicators are also one of the factors that affect the ignition capacity of hot particles. It has been found that wind speed, ambient temperature, ambient relative humidity, particle trajectory, and distance will all affect the ignition capacity [22–24].

Summing up the above research on the igniting ability of welding spatters, we found that the selection of igniting materials placed below the welding position was relatively simple, and the welding current intensity was small (all below 100 A), resulting in an insufficient reflection of actual welding operation conditions. And these studies did not consider the influence of welding current intensity on the ignition capacity of welding spatters and did not explain its influence law from the perspective of theory. In this work, the physical properties and ignition capacity of welding spatters under different current intensities were investigated through a large number of spatter splashing tests, and the influencing factors of the ignition capacity of the welding spatters were explained combined with the hot-spot theory. It can provide a methodological basis for preventing fires caused by welding spatters and support the investigation and analysis of welding spatter fire accidents.

2. Materials and Methods

2.1. Material

The electrode material was structural steel (3.2 × 350 mm), and the coating was titanium calcium. The weldments were made of steel bars (diameter: 13 mm, length: 1.3 m).

The common combustible materials for testing are shown in Table 1. The current output range of the welding machine (Tayor Welding Machine Co., Ltd, Shanghai, China. model: ZX7-400I) was 20–400 A, and the temperature measurement range of the infrared thermal camera (Fluke Testing Instruments (Shanghai) Co., Ltd, Shanghai, China. model: Fluke Ti400) was −20–1200 °C. Since the thickness of the cotton cloth and the newspaper was close to 0, the method of multilayer laying was adopted to make their thicknesses have the same macroscale as that of other materials, as shown in Figure 1.

Table 1. Types of ignition materials.

Ignition Material	Size	Density	Ignition Point	Laying Method
Cotton	450 × 300 mm	0.16 kg/m^2	520 °C	Laying 2 layers
Foam board	300 × 450 × 40 mm	15 kg/m^3	250 °C	Laying 1 layer
Wood chip	460 × 350 × 30 mm	300 kg/m^3	280 °C	Laying 1 layer
Newspaper	540 × 380 mm	0.051 kg/m^2	160 °C	Laying 8 layers

Figure 1. Ignition materials and their laying method. (**a**) Cotton. (**b**) Foam board. (**c**) Wood chip. (**d**) Newspaper.

2.2. Experimental Procedures

The test platform is shown in Figure 2. The welding position was adjusted to a vertical distance of 0.2 m from the ground, and five concentric circles were drawn at intervals of 100 mm with the vertical projection of the welding position as the center for marking the drop range of the welding spatters. The current intensity of welding machine was adjusted to 150 A, 220 A, 290 A, and 360 A, respectively, and a splash test was conducted with the welding machine using welding rods of structural steel. Spatter drops originated from the metal, and an infrared thermal camera was used to measure and observe the temperature of the electrode welding spatter as it descended. A video camera was employed to document the welding process and observe the test phenomena. After the completion of each group of welding operations, a period of observation was allowed to elapse, during which the welding spatters and the ambient temperature were monitored. This was in order to ascertain the range of the spatter's splashing. Each current intensity was subjected to three repetitions of the test. The diameter of the collected spatters was determined by means of a digital vernier caliper. In order to test the ignition capability of the welding spatters, foam boards were positioned beneath the welding position, and the current intensity was adjusted to 150 A, 220 A, 290 A, and 360 A for ignition tests. The same infrared thermal camera and video camera were employed to document the combustion phenomenon of each experimental material under varying current intensities. Upon completion of the aforementioned series of tests, the aforementioned steps were repeated for cotton cloth, wood chips, and newspaper.

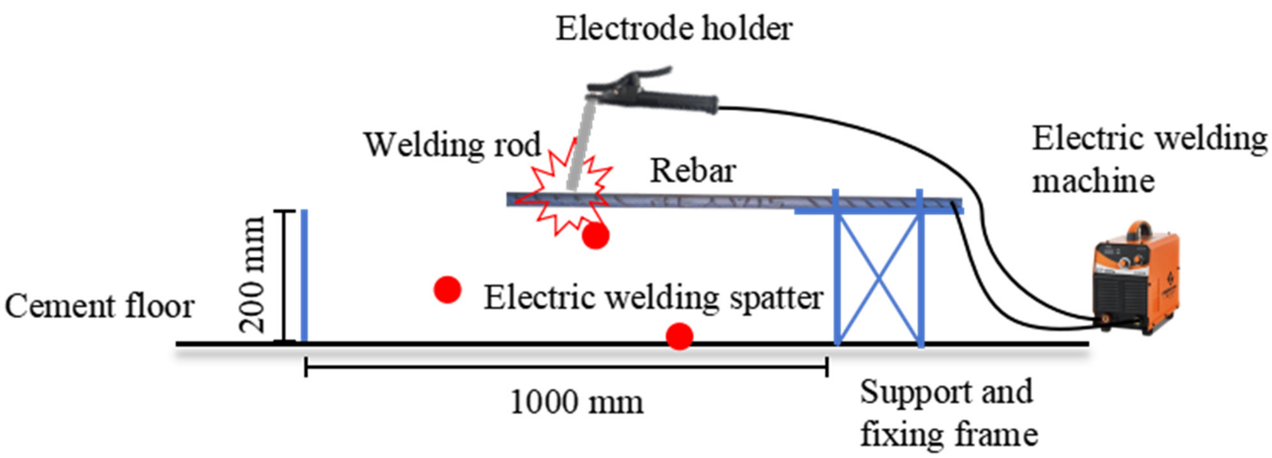


Figure 2. Schematic diagram of the experimental platform.

The ambient wind speed in the experiment was approximately 0.1–1.5 m/s; the ambient temperature was 23.8–25.8 °C; the humidity of the air was 46.2–60.7%; and the floor of the experimental site was a concrete floor.

3. Results and Discussion

3.1. Physical Properties of Welding Spatters at Different Current Intensities

The physical properties of welding spatters represent a significant causal factor in the occurrence of fires. In the case of welding fires, the physical factors directly related to the ignition and spread of the fire are the splash range of the spatters, the diameter of the spatters, the shape of the spatters, and the temperature of the spatters.

The splash range of the spatters is defined as the distance from the vertical projection of the welding position when the welding spatter falls to the ground and remains stationary after moving in a parabolic motion during welding operations. The quantity and the splash range of the spatters under different current intensities were counted separately, and the average of the three groups of repetitive experiments was calculated. The results are shown in Figure 3.

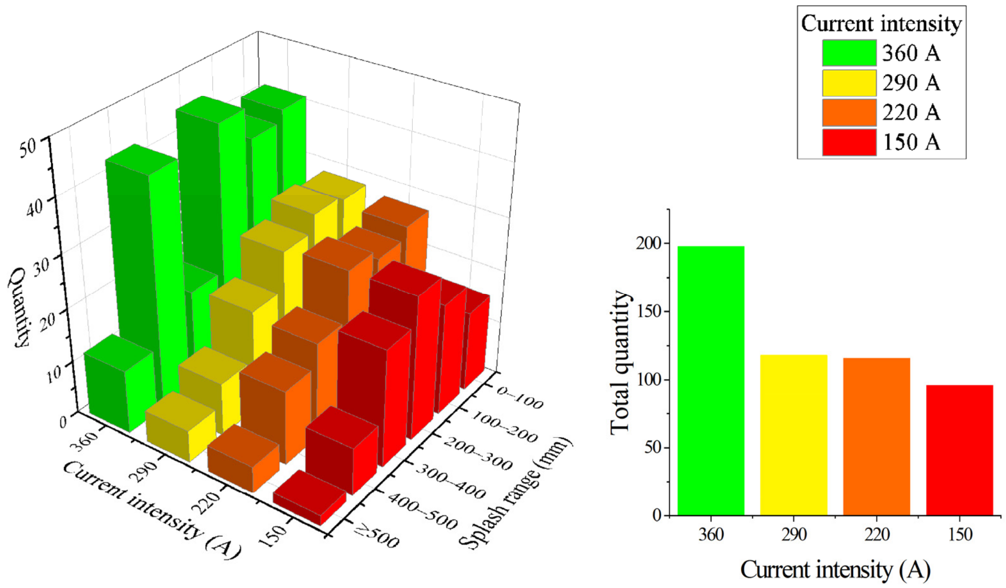


Figure 3. The quantity and the splash range of the spatters under different current intensities.

The distribution of welding spatters was random, yet the majority of spatters were concentrated within the 0–400 mm range, with a relatively low quantity observed beyond the 500 mm range. The quantity of spatters within the ranges of 0–100 mm, 100–200 mm, and 500–600 mm demonstrated a correlation with increasing current intensity. The quantity of spatters within the 200–300 mm and 400–500 mm ranges was approximately equivalent at currents of 150 A, 220 A, and 290 A. However, when the current increased to 360 A, the quantity of spatters significantly increased. Within the range of 300–400 mm, the quantity of spatters was not significantly related to the current intensity and was relatively small compared to the other five ranges. The probability of welding spatters splashing within the range of 0–300 mm was greatest for current intensities of 150 A, 220 A, and 290 A, while they tended to splash further away at a current intensity of 360 A. Additionally, it can be observed that the quantity of dropped welding spatters increased with rising current intensity, reaching a significant increase at 360 A.

The diameter of the welding spatters was measured by a digital vernier caliper, with the maximum diameter recorded during measurement. The distribution of the diameter of spatters under varying current intensities is shown in Figure 4.

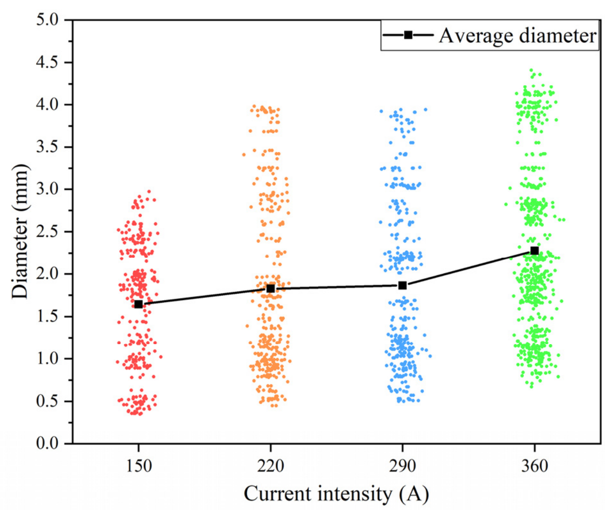


Figure 4. The distribution of the diameter of welding spatters.

As shown in Figure 4, the average diameter of the welding spatters exhibited a gradual increase with rising current intensity, accompanied by a convergence of the diameter distribution toward a larger range. The diameter of the welding spatters under the above four currents was mainly concentrated in range of 1.00–2.00 mm, and the quantity of spatters smaller than 1.00 mm decreased significantly with increasing current intensity. At a current of 360 A, the formation of spatters larger than 4.00 mm was observed, accompanied by a notable increase in the quantity of spatters.

The physical properties of the welding spatters can reflect the formation process of the spatters. The shape of the welding spatters can be classified into six categories based on observations from multiple experiments. These categories include regular spherical (the outer layer of the welding spatter is in the shape of a regular sphere), double spherical (two spherical welding spatters are stuck together), goat-horn shape (the welding spatter consists of one larger sphere and two smaller spheres closer together), irregular spherical (the welding spatter is in the shape of an irregular sphere, and the surface is very rough), droplet (one end of the welding spatter is larger than the other end, and the whole spatter is in the shape of a droplet), and concavity (the shape of the welding spatter is concave inward), as shown in Figure 5.

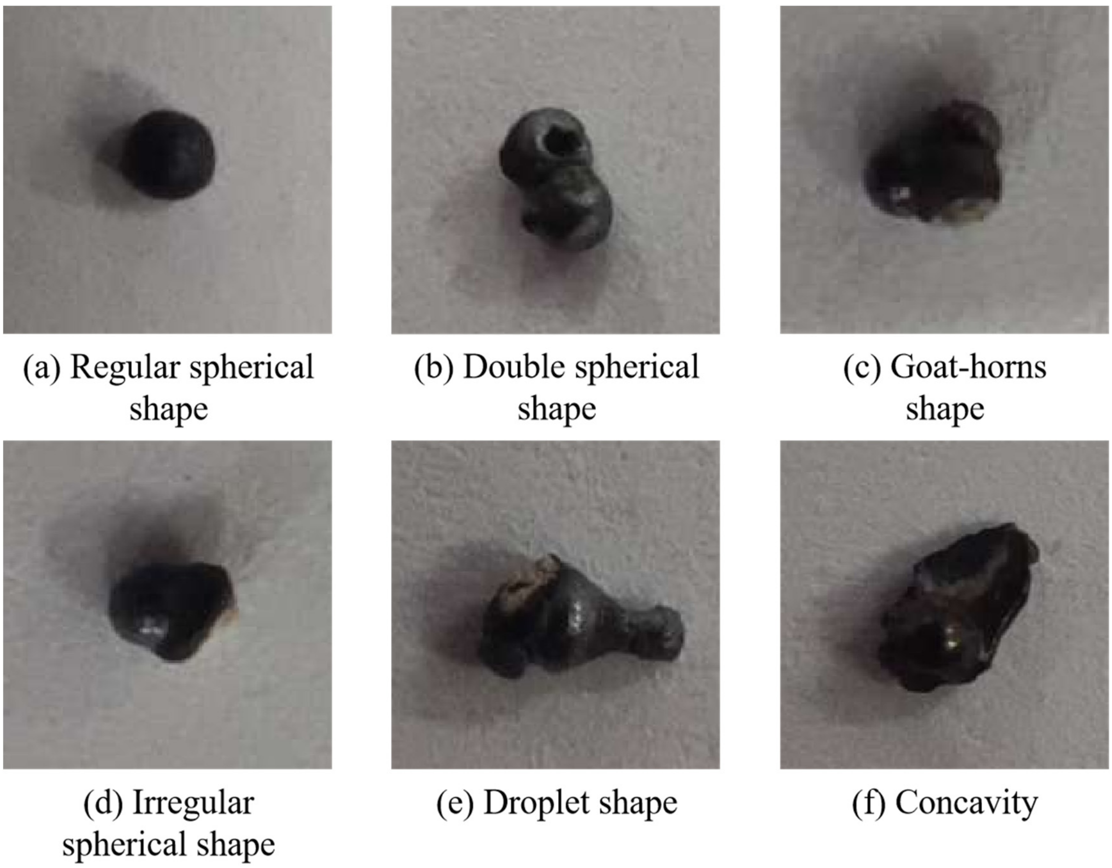
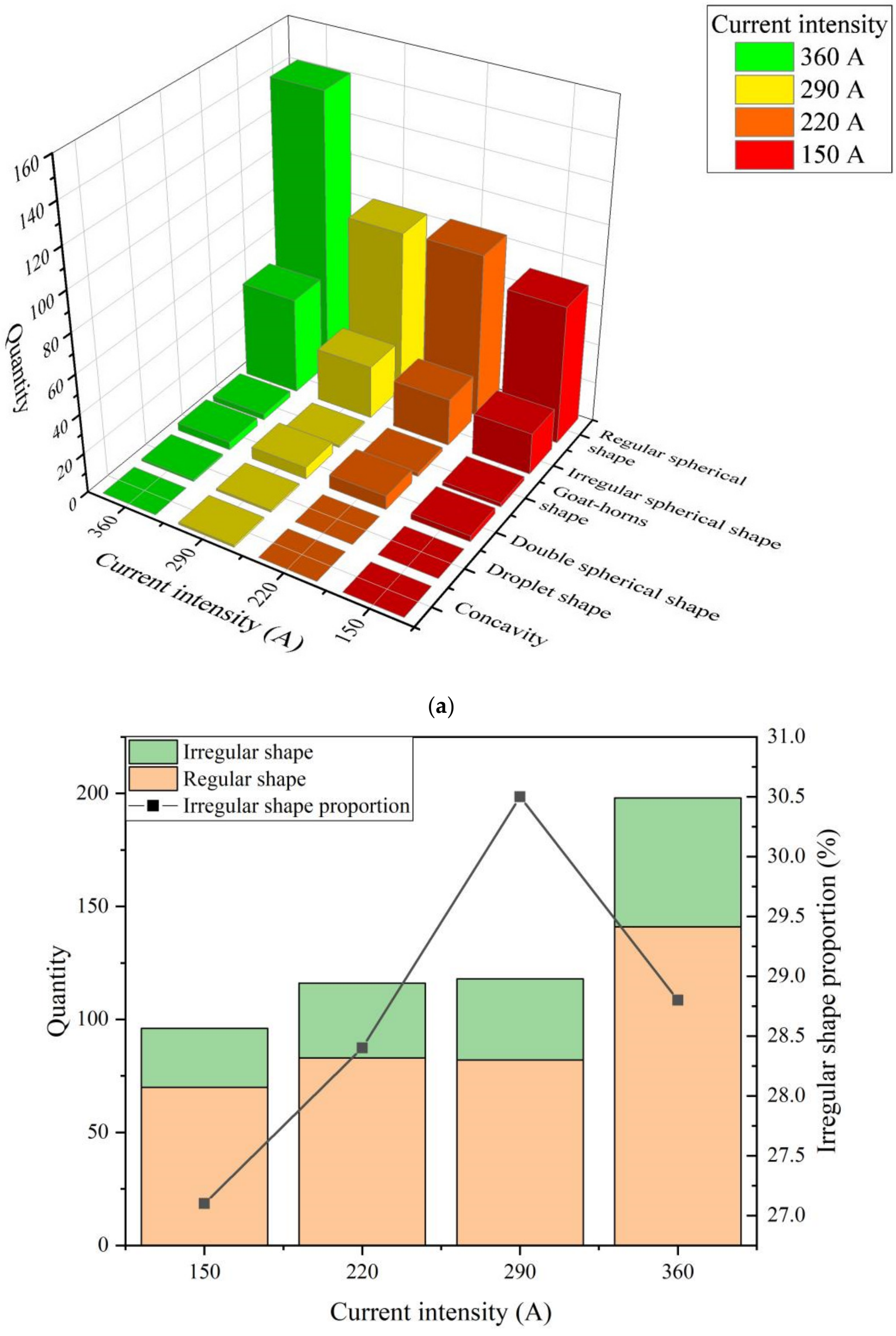


Figure 5. Shapes of welding spatters.

The effect of varying current intensities on the shape of the welding spatters is shown in Figure 6. It can be seen from Figure 6a that the predominant shapes observed were regular and irregular spherical shapes, followed by double spherical shapes. The remaining types exhibited a markedly lower quantity of spatters. The concave shape demonstrated the lowest quantity of spatters and was observed only once at a current of 290 A. As shown in Figure 6b, regular spherical-shaped spatters were more prevalent at any current, and the percentage of irregularly shaped spatters increased with increasing current intensity. At a current of 360 A, the percentage of irregularly shaped spatters decreased due to the rise in the total quantity of spatters produced. However, the number of irregularly shaped spatters remained significantly higher.



(**b**)

Figure 6. Shape of welding spatters under different current intensities. (**a**) Shape distribution of the welding spatters under different current intensities. (**b**) Shape distribution of regular and irregular spatters under different current intensities.

The infrared measurements of the temperature of the welding spatters under different current intensities are shown in Figure 7. It can be observed that the overall temperature of the welding spatters increased with increasing current intensity, which was particularly evident at low current intensities. Figure 8 illustrates the variation in temperature of the welding spatters over time at different current intensities. The natural cooling time of the spatter temperature was prolonged with increasing current intensity. After 50 s under a current intensity of 150 A, the temperature of the spatter was equal to the ambient temperature, while this cooling took 70 s under a current intensity of 360 A. The temperature of the welding spatters exhibited the greatest decrease in the first 30 s, followed by a slower rate of decline.

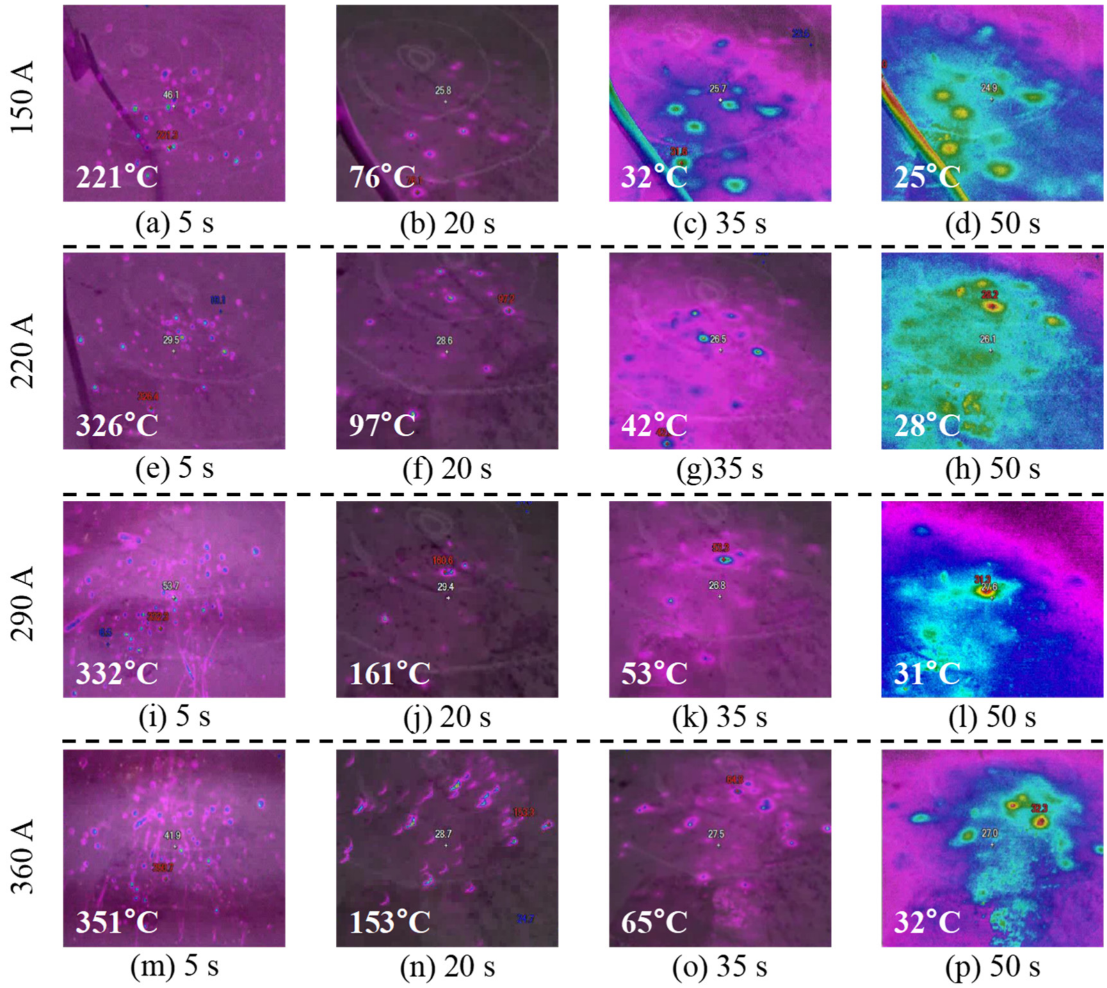


Figure 7. Infrared measurements of the temperature of the welding spatters under different current intensities.

Upon examination of the aforementioned phenomena, a discernible correlation between the physical properties of the welding spatters and the current intensity becomes evident. The quantity, the range of splashes, and the temperature of the spatters all increased with increasing current intensity. Moreover, an elevated current intensity increased the probability of producing irregular and large-diameter welding spatters. In particular, all the properties of the spatters appeared to exhibit a pronounced increase at a current intensity of 360 A. This is due to the fact that increasing current intensity leads to an enhancement in the welding temperature and melting rate of the weld material, which enables a larger amount of weld material to be melted, resulting in a greater quantity and larger diameter of spatters, for a similar overall cooling time. Furthermore, the elevated current at 360 A gave rise to an unstable pulsation of the arc, which augmented its melting effect, resulting in a notable increase in the quantity of spatters and the formation of larger-diameter and irregularly shaped welding spatters. The pulsation of the arc also induced splashing of the spatters, which was directed to a more distant area.

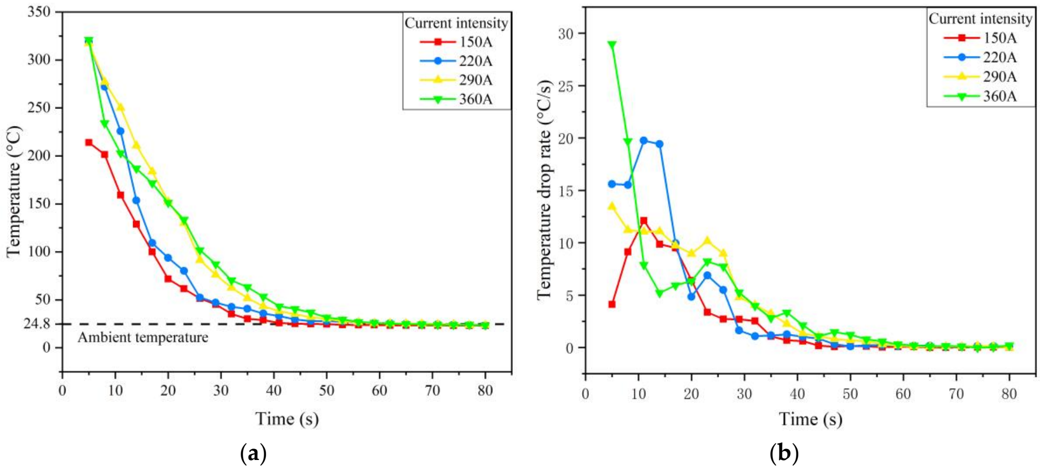


Figure 8. Temperature variation of the welding spatters with time at different current intensities. (**a**) Temperature curves under different current intensities. (**b**) Cooling rate curves under different current intensities.

3.2. Igniting Ability of Welding Spatters at Different Current Intensities

The capacity of the welding spatters to ignite the foam board under varying current intensities is shown in Figure 9. Upon impact with the foam board, the spatters emitted an open flame, igniting the surrounding foam material. Subsequently, the high-temperature spatters burned in a downward trajectory, resulting in the formation of a crater-like burn mark. However, the range of sinking caused by each spatter after falling was relatively limited. As the current intensity increased, the welding spatters on the foam board exhibited a significantly enhanced ignition capacity. In addition, the foam board underwent shrinkage in certain areas as a consequence of the high-temperature heat flow generated during the welding process. When the current intensity exceeded 220 A, the foam board was incinerated.

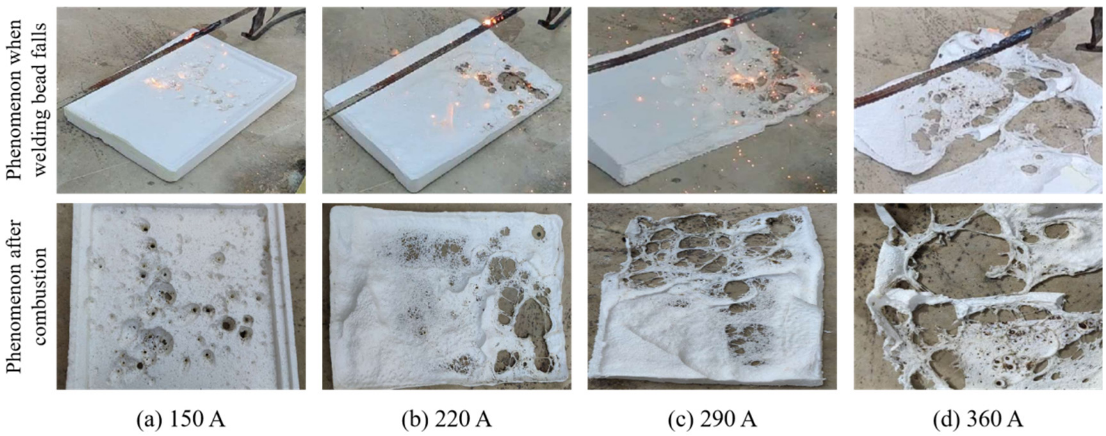


Figure 9. The ability of the welding spatters to ignite the foam board under different current intensities.

The capacity of the welding spatters to ignite newspaper under different current intensities is shown in Figure 10. When the welding current was 150 A, only the larger spatters that fell on the newspaper exhibited an instantaneously open flame, which was subsequently extinguished. In contrast, the smaller spatters were less effective at igniting the newspaper and only produced a superficial charring effect on the surface of the newspaper. The combustion process of the newspaper was gradual, accompanied by a minimal amount of smoke, and the majority of burning marks on the newspaper were charring traces. As the current intensity increased, the welding spatters on the newspaper exhibited a significantly enhanced ignition capacity, and the combustion rate also accelerated. At a current intensity of 360 A, the newspaper was fully ignited and incinerated, and the spatters were capable of penetrating through eight layers of the newspaper, resulting in the formation of a pronounced open flame.

Figure 10. The ability of the welding spatters to ignite the newspaper under different current intensities.

The capacity of the welding spatters to ignite the cotton under different current intensities is shown in Figure 11. It can be observed that no open flame was present at the moment of spatter deposition, and only slow charring occurred when the current intensity was low. As the combustion area gradually increased, an open flame emerged on the cotton cloth. However, the flame was swiftly extinguished, accompanied by a modest quantity of smoke, and the burning speed was relatively slow. With increasing current intensity, the welding spatters demonstrated a markedly enhanced ignition capacity. At a current intensity of 360 A, the cotton exhibited the first stabilized presence of an open flame, accompanied by the production of a considerable quantity of white smoke.

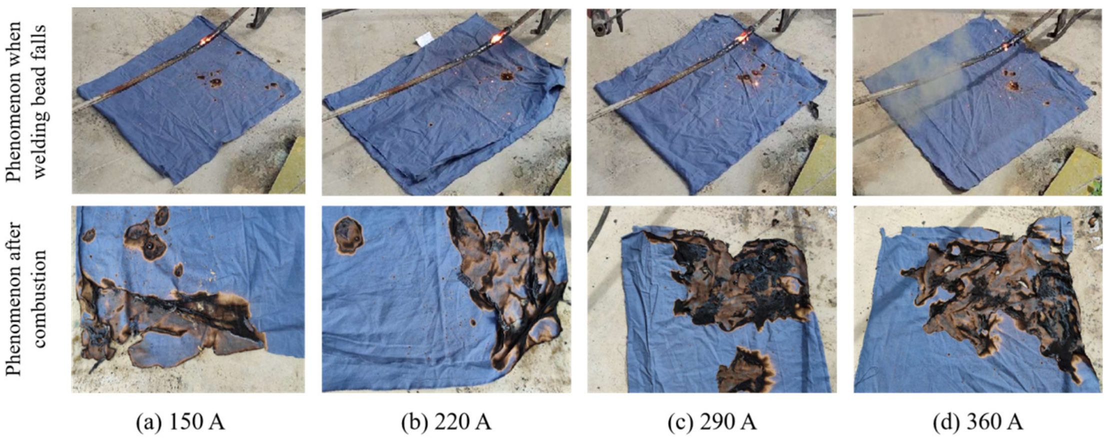


Figure 11. The ability of the welding spatters to ignite the cotton under different current intensities.

The ability of the welding spatters to ignite wood chips under different current intensities is shown in Figure 12. Upon impact with the surface of the wood chips, the spatters were capable of producing an initial open flame, which persisted for approximately 20 s before extinguishing, following by a transition to charring and smoldering. As the current intensity increased, the duration of the open flame gradually increased, and the surface of the wood chips was more deeply charred by smoldering. At a current intensity of 360 A, the wood chip layer was capable of being burned through.

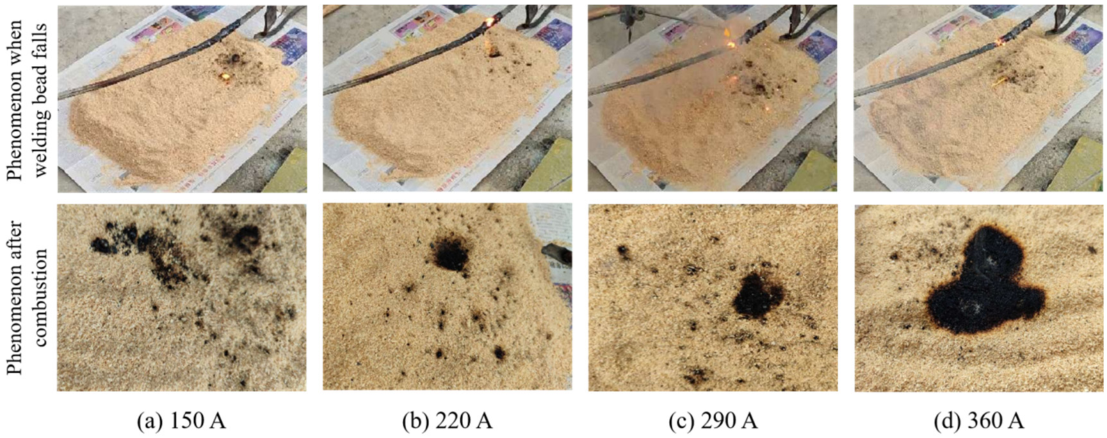


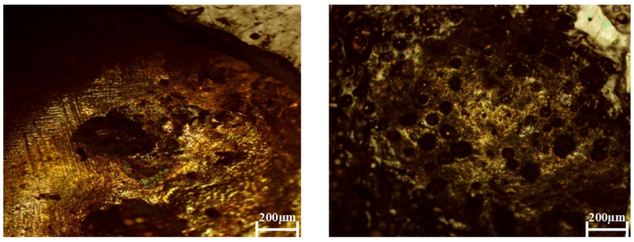
Figure 12. The ability of the welding spatters to ignite wood chips under different current intensities.

It can be observed that all the combustible materials exhibited an open flame subsequent to the descent of the spatter. The foam board and wood chips initially generated an open fire following the descent of the welding spatters. Subsequently, they underwent a transformation, whereby they become involved in melting combustion and charring smoldering, respectively. In contrast, the newspaper and cotton cloth initially exhibited the phenomenon of charring and smoldering after the drop of the spatters, which then produced an open flame. The experimental phenomenon revealed a decreasing order of ignition capacity of welding spatters to ignite various materials, namely, newspaper, foam board, cotton, and wood chips.

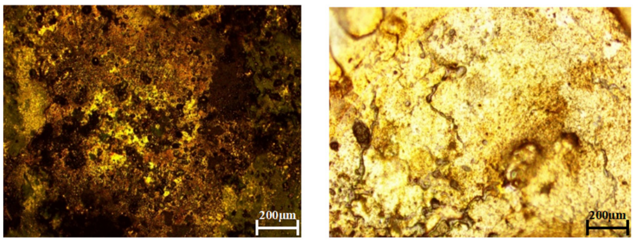
In contrast with the prevailing hypothesis, this pattern is not demonstrably correlated with the ignition point of the combustibles. Although the foam board and wood chips have comparable ignition points, they exhibited disparate ignition difficulties. This is due to the fact that the propensity of high-temperature particles to ignite combustible materials is directly correlated with the intrinsic structural characteristics of the combustible materials. In conditions of identical heat dissipation, the foam board exhibits a greater specific surface area in contact with oxygen, allowing for complete air contact and facilitating ignition. Furthermore, the contact between a larger welding spatter and a foam board results in the melt and collapse of the foam board, thereby significantly enhancing the ignition potential of the welding spatter. Conversely, wood chip possesses a higher moisture content, necessitating greater heat for combustion. Additionally, the moisture content can influence the bulk density of wood, consequently reducing the specific surface area of wood in contact with air and further impairing the ignition ability of melt spatters on wood chips. The thickness of both the newspaper and the cotton was relatively minimal. However, the smoother surface of the newspaper and the lower surface friction resulted in a greater likelihood of the welding spatters rolling on the surface of the newspaper, thereby facilitating a continuous transfer of heat to the newspaper surface.

The effect of the current intensity on the ability of welding spatters to ignite is also noteworthy. The physical properties of the spatters produced under different current intensities resulted in differences in the phenomenon of ignition of combustible materials and the ignition capacity. The probability of ignition of the spatters was influenced by the splash range, the diameter, and the shape of the spatters. The temperature and cooling time of the spatters exerted a direct influence on the ignition phenomenon and the ignition capacity of the spatters. A larger spatter diameter and a more irregular spatter shape can lead to an increase in the contact area between the spatters and the combustible materials, thereby enhancing the thermal conductivity of the spatters. Moreover, relatively regular and small-sized welding spatters are more likely to roll on the surface of combustible materials, thus expanding the contact range and ignition probability of the welding spatters. However, regular and small-sized spatters only appear at a lower current intensity, and their temperatures are also lower, which results in a reduced ignition capacity compared to that of large-sized welding spatters, which are more difficult to diffuse.

The ignition capacity of the welding spatters on all types of combustibles materials increased with increasing current intensity. Furthermore, at a current intensity of 360 A, all the materials exhibited a unique ignition phenomenon, resulting in more obvious sparks, open flames, and smoke. The combustion intensity the destructiveness of the combustible material also increased. This phenomenon may be associated with the cooling process of the welding spatters and the hot-spot theory [9,25]. An examination of the phase diagram of the welding spatters following its cooling revealed that the cooling process of the welding spatters varied depending on the current intensity, as shown in Figure 13.



(a) 150 A (b) 220 A



(c) 290 A (d) 360 A

Figure 13. Microscopic image of the spatter magnified 50 times under different current intensities.

The cooling of the welding spatters is insufficient in the initial seconds following their descent, resulting in the release of air and then the formation of pores and cracks on the surface of the welding spatters. Furthermore, upon contact with the ground, the welding spatters will also splash and remelt with air, dust, and various impurities, resulting in a secondary expansion of the splashed spatters on the ground after cooling. These factors make the spatter an inhomogeneous particle with numerous pores, which reduces the density and specific heat capacity of the spatter. Figure 12 shows that the quantity and size of pores on the spatter decreased with increasing current intensity. This is due to the fact that the rate of cooling of the welding spatters increases with the rising of current intensity, as shown in Figure 8b. At a current intensity of 360 A, the cooling rate of the spatters was so rapid that the surface of the spatter cooled and closed before the pores were formed, resulting in a noticeably smoother surface. This also indicates that the density and specific heat capacity of the welding spatters produced at a higher current intensity are higher. In hot-spot theory, an increase in density and specific heat capacity will result in a reduction in the critical hot-spot radius of the hot particles, which describes the minimum particle radius required for hot-spot particles to ignite a certain combustible material. This will make the ignition conditions less demanding on the size of the welding spatters, thus increasing the probability of successful ignition. However, further detailed calculations are required to ascertain how the hot-spot theory specifically affects welding spatters.

4. Conclusions

In this paper, the effects of different current intensities on the physical properties and ignition phenomenon of welding spatters were experimentally investigated, and the influencing mechanism of the current intensities was analyzed by combining with the hot-spot theory. The conclusions are as follows: (1) The quantity, the splash range, and the temperature of the welding spatters increase with increasing current intensity, and it is more likely to produce irregular and large-diameter welding spatters under a high current intensity. (2) The ignition capacity of welding spatters to ignite combustible materials is contingent upon the intrinsic structural characteristics of the substance and the current intensity. The capacity of welding spatters to ignite newspaper, foam board, cotton, and wood chips gradually weakens. Additionally, the ignition capacity of the spatters is improved with increasing current intensity, leading to a higher burning rate and more intense combustion of the combustible materials. (3) The critical hot-spot radius is an important factor affecting the ignition capacity of the spatters. It decreases with increasing current intensity, thus enhancing the probability of ignition of the spatters. The improvement in the ignition capacity of welding spatters is non-linear, which is the result of coupling the hot-spot theory and the physical properties of the spatters. (4) The physical properties and ignition capacity of the welding spatters showed a surge at current intensity of 360 A, which is due to the unstable pulsation of the arc and a significant decrease in the conditions to reach the critical hot-spot radius. Therefore, excessive welding current intensity is one of the causes of spatter fires. Welding operations should ensure mandatory safety requirements for current intensity.

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