JJMIE

Volume 15, Number 1, March. 2021
ISSN 1995-6665
Pages 123 - 132

Jordan Journal of Mechanical and Industrial Engineering

Mould Pollution Control Model of Aluminum Alloy Equipment Considering Ultraviolet Radiation Intensity

Wenbo Yang[1*], Gang Li[2]

[1]General Affairs Office, Yantai Vocational College, Yantai 264670, China
[2]Department of Food and Biochemical Engineering, Yantai Vocational College, Yantai 264670, China

Received July 18 2020 Accepted March 13 2021

Abstract

Due to the particularity of the aluminum alloy equipment material, it is extremely susceptible to mold corrosion and corrosion in the case of external environmental pollution, affecting the performance of the equipment. Taking the aluminum alloy equipment contaminated by mold as the research object, the control model of mold contamination was constructed under different ultraviolet irradiation intensity. This includes separating and purifying from corrosion samples of aluminum alloy, and obtaining test culture strains, measuring the change of pH value in the corrosion medium, and then studying the growth characteristics of Aspergillus niger in pure Chagas medium. Through electrochemical testing and surface morphology analysis, the growth and corrosion behavior of mold on the surface of aluminum alloy were studied. It is essential to change the irradiation intensity and irradiation time of ultraviolet ray to study its control effect on aluminum alloy mold corrosion. The experimental results show that the sterilization effect is the most effective and economical when the UV intensity is 84000 μW/cm2 and the irradiation time is 30 min.

Keywords: Ultraviolet radiation intensity; aluminum alloy equipment; mold contamination; control model; corrosion behavior;

1. Introduction

Due to its high strength and low density, aluminum alloys are widely used in fields with strict quality and strength requirements, such as aviation, aerospace, and navigation. As a newly developed road traffic operation tool, high-speed rail often uses lightweight and high-strength 7-series aluminum alloy as the supporting material due to its high speed. As the high-speed railway technology continues to mature, the convenience of China's high-speed rail has envied the world and has developed into the first of China's "four new inventions". Since the Industrial Revolution, the endothermic greenhouse gases and highly polluted gases such as carbon dioxide emitted by humans into the atmosphere have increased year by year, and the greenhouse effect and pollution of the atmosphere have also increased. Due to the significant differences in the global climate and environment, factors such as rain and sand during operation cause severe corrosion of key parts of the train, which seriously affects the safety and service life of high-speed trains [1]. Especially in recent years, the degree of global air pollution has been increasing, and the CO_2 content in the high-altitude atmosphere has increased significantly, which also provides sufficient favorable conditions for the growth and reproduction of mold spores, such as nitrogen and carbon sources [2]. As mold spores continue to grow and reproduce on the surface of aluminum alloy equipment, it will gradually cause different degrees of pollution and corrosion on the metal surface. For a long time, it will reduce the mechanical strength and service life of aluminum alloy equipment. Aluminum alloy equipment is inevitably exposed to the atmosphere during the operation, so the surface of the aluminum alloy equipment must be effectively protected to reduce the changes in the mechanical properties of the aluminum alloy equipment caused by mold contamination.

Ultraviolet is a general term for electromagnetic waves with a wavelength of 0.01 to 0.40 microns. According to the size of the wavelength, it can be divided into three bands: UVC also known as short-wave sterilization ultraviolet (100 to 280 nanometers), UVB also known as medium wave erythema effect ultraviolet (280 to 315 nanometers) and UVA also known as long-wave black spot effect ultraviolet (315 to 400 nanometers). Energy-saving lamps and fluorescent lamps have the same light emitting principle, and the spectrum is generated by the excitation of mercury atoms. Low-pressure mercury lamps mainly produce two kinds of ultraviolet rays with wavelengths of 254 nm and 185 nm, which can be used for air disinfection, sterilization, drinking water disinfection and photochemical reactions. The ultraviolet sterilization lamp is the same as the fluorescent lamp in construction, accessories, and wiring methods. The only difference is the construction material of the tube wall. The lamp material used in the ordinary lamp tube is ordinary glass. It is difficult for ultraviolet light to pass through. Phosphor powder emits visible light after absorption; most of the ultraviolet sterilization lamp wall uses quartz glass [3]. The principle of ultraviolet ray

* Corresponding author e-mail: yangwb163yxdz@163.com

sterilization is mainly to destroy the nucleic acid substance of the mold, causing it to fail to reproduce, destroying its protein structure, causing its functional metabolism to malfunction, and thus unable to carry out normal metabolism and causing the death of the mold. Because the effective structure of mycotoxins is protein, ultraviolet light can also cause the functional structure of mycotoxins to be destroyed, thus achieving the purpose of eliminating toxicity.

Ultraviolet rays are widely used in medicine as a new type of disinfection and sterilization method, and the results of research at home and abroad show that ultraviolet rays can be widely used in urban tap water disinfection. There are also experiments to verify that ultraviolet rays have a certain killing effect on fungi. In practical applications, the sterilization effect of ultraviolet rays mainly depends on the irradiation intensity. The irradiation intensity represents the amount of energy contained in ultraviolet rays, so the irradiation intensity can directly affect the sterilization effect of ultraviolet rays. The main reasons that affect the intensity of ultraviolet radiation are the following, such as the choice of lamp, if the quartz tube is not qualified, it is difficult to achieve a specific intensity, and the resistance of the ballast itself can also affect the intensity of irradiation [4]. Secondly, the ultraviolet sterilization effect is also affected by the irradiation distance. The irradiation effect of the ultraviolet lamp is directly related to the distance between the irradiated object and the ultraviolet lamp. The farther away from the ultraviolet lamp, the lower the irradiation intensity, and the closer the distance, the higher the irradiation intensity. And the most important point that affects the ultraviolet sterilization effect is the irradiation time. The length of the irradiation time will also have a huge impact on the irradiation effect. Finally, the influence of the irradiation environment, the temperature and environmental factors have a great impact on the irradiation effect. Generally, the lower the irradiation temperature is, the worse the sterilization effect of ultraviolet irradiation is. Increasing the irradiation temperature will improve the irradiation effect. According to the data of UV sterilization research, use UV to remove the mycotoxins from the aluminum alloy equipment, which provides a theoretical basis for the control of mold pollution in the aluminum alloy equipment.

2. Factors affecting mould contamination of aluminum alloy equipment

Environmental pollution is one of the important reasons that cause aluminum alloy equipment to be susceptible to mold corrosion. The discharge of the three wastes from industrial enterprises leads to the problems of high carbon emissions and pollution of river water bodies, which significantly increases the content of carbon dioxide and other acidic substances in the atmospheric cycle, and provides sufficient conditions for the growth and reproduction of mold [5]. Lightweight aluminum alloy equipment itself has poor corrosion resistance. The presence of microorganisms on the metal surface is usually not valued by the crew inspection personnel. Mold contamination and corrosion are subtly affecting the strength, life and mechanical properties of aluminum alloy equipment. Before conducting relevant mold pollution control experiments, it is necessary to analyze the influence of various external environmental factors on the formation of mold corrosion of aluminum alloy equipment, which helps to ensure the objectivity and authenticity of the subsequent research results. Factors such as atmospheric pollution, corrosion of aqueous solutions, various types of organic media, ambient temperature, and stress on the metal equipment itself will have an important impact on the mold contamination behavior of aluminum alloy equipment. See Figure 1 below:

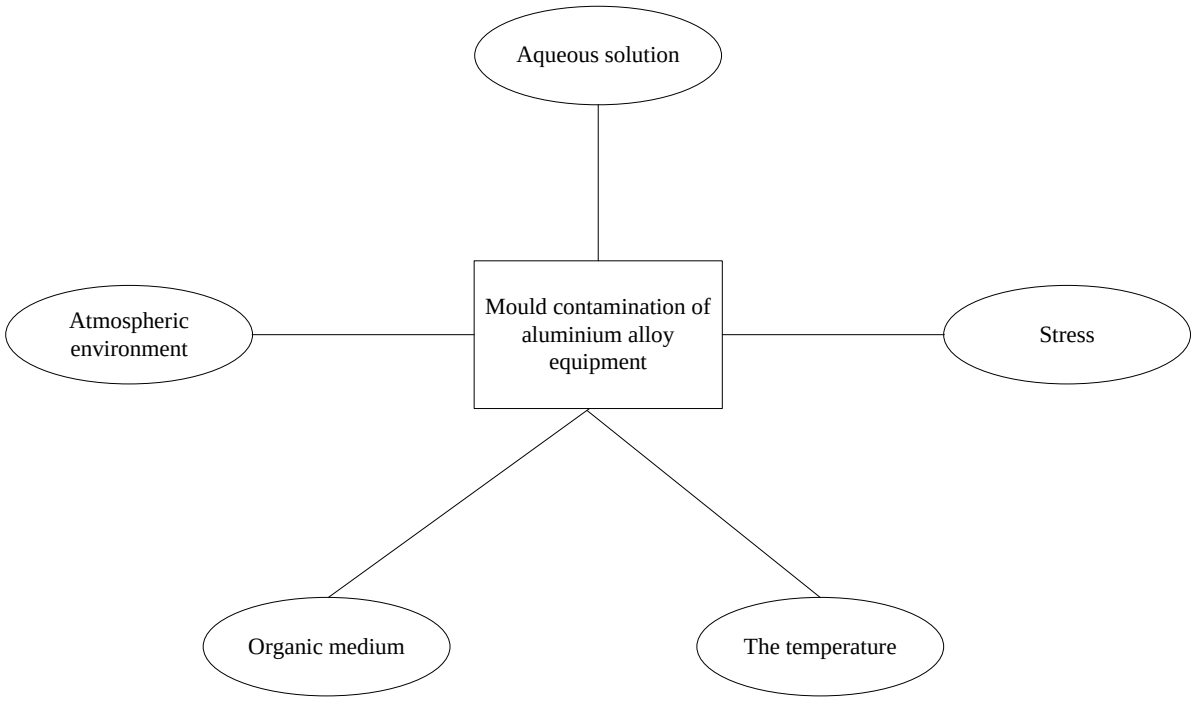


Figure 1. Various environmental factors affecting mold contamination of aluminum alloy equipment

O_2 in the atmosphere will not have a beneficial effect on the mold corrosion of aluminum alloy equipment, but with the increase of air pollution, the content of CO_2 and other acidic substances and nitrogen oxides in the air increase, which is the mold spores attached to the metal equipment providing a favorable food source and an appropriate living environment. In a relatively humid atmospheric environment, the acidic substances produced by the combination of CO_2 and nitrogen oxides with water will also cause certain corrosion effects on aluminum alloy equipment [6]. Some aluminum alloy equipment or depressions will contain some acidic substances, chlorides and fluorides, which will not only cause a certain degree of corrosion to the aluminum alloy equipment itself, but the volatilization of organic matter will also cause pollution and corrosion to other aluminum alloy equipment. Aluminum alloy equipment that has been corroded and contaminated by chemical substances is more susceptible to microbial attack, accelerating the rate of damage to the surface coating of aluminum alloy equipment. Lipid carbon oxides in the atmosphere and in the equipment are prone to form acidic hydrolysates, which are strongly polluting and corrosive. These materials provide convenient conditions for the survival and reproduction of mold spores, and constitute double pollution for aluminum alloy equipment. And destruction, long-term reduction of the mechanical strength and mechanical properties of aluminum alloy equipment [7]. The temperature change of the outside of the aluminum alloy equipment and the ambient temperature and the atmospheric stress are also one of the important causes of mold contamination and corrosion on the surface of the aluminum alloy. The temperature change of the aluminum alloy equipment before and after the work is large, and the severe temperature difference will make the surface of the aluminum alloy equipment. The organizational structure of the aluminum alloy has changed, and the mold attached to the surface of the aluminum alloy equipment will use this structural change to accelerate the pollution and erosion of the aluminum alloy equipment surface. The results of surface corrosion morphology and elemental analysis of aluminum alloy equipment are shown in Figure 2.

There are many kinds of molds, and the growth and reproduction are rapid. They can promote their own growth by degrading various organic substances. The organic acids in the metabolites can cause a certain degree of damage to metals, non-metals, and coatings. A large number of reports show that molds have been detected in the corrosion products of carbon fiber metal materials used in outer space, aircraft fuel tanks, and aluminum alloy materials for ships, and mold corrosion has become one of the major safety hazards in the engineering field [8]. In order to provide theoretical support and technical guidance to engineering safety, it is of great significance to systematically study the mold corrosion mechanism and protection technology.

3. Materials and methods

As the research methods and mechanisms of microbial corrosion have matured and formed a system, the problem of mold corrosion has gradually become more prominent. The current evaluation methods for mold corrosion mainly investigate the tolerance of aluminum alloy materials to mold in the mold environment by simulating the mold growth environment. According to the different materials and equipment use environment, the commonly used test standards in China are military equipment environment, military communication equipment environment, civil aircraft loading environment, ship electronic equipment environment and electrical and electronic product environment. The damage caused by molds to materials is divided into two situations, directly eroding the material and decomposing the material as their own nutrients, resulting in the deterioration of the physical properties of the material and direct or indirect corrosion and degradation of the bottom layer and surrounding materials through their own metabolism. For electronic devices, they can also be used in components and the formation of a biological bridge between them can cause circuit failure [9, 10]. Comprehensive mold testing standards for multiple environments, the impact of mold on materials is divided into five levels, as shown in Table 1:

Table 1. Classification of the degree of mold influence

Degree of mold	Coverage area	Level	Mold growth
Not moldy	0	1	No mold
Trace mold	1~10%	2	Scattered and rare mould on the surface
Mildly moldy	11-30%	3	Mycelium distribution on the surface, not covered with culture medium
Mildewed medium	31-70%	4	There are a lot of mould on the surface, and the properties of the material change
Serious mildew	71-100%	5	Mould grows on the surface with a certain thickness and the material deteriorates rapidly

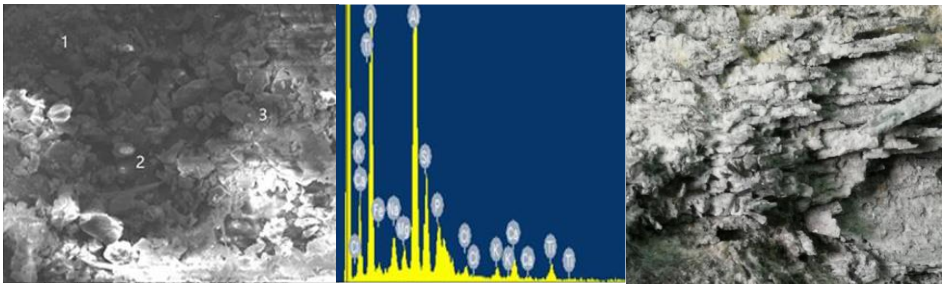


Figure 2. Corrosion morphology and element analysis of aluminum alloy equipment surface

In the mold test, in order to simulate the mold growth environment, the mold species were directly inoculated on the sample, hung in the mold experiment box, and cultivated for at least 14h to detect changes in the material structure and performance. In the determination of mold environmental test results, the naked eye and magnifying glass are often used to observe the growth of mold and the macroscopic changes of materials [11-13]. In laboratory research, the method of mold corrosion research is similar to that of bacterial corrosion. The corrosion mechanism is analyzed by surface morphology analysis and electrochemical testing technology.

3.1. Experimental materials

3.1.1. Experimental reagents and drugs

The main drugs used are shown in the Table 2:

Table 2. Experimental drugs and reagents

Drug name	Purity	Manufacturer
Sodium chloride	AR	Sino pharm Chemical Reagent Co., Ltd
Potassium chloride	AR	Sino pharm Chemical Reagent Co., Ltd
Dipotassium phosphate	AR	Sino pharm Chemical Reagent Co., Ltd
Sodium nitrate	AR	Sino pharm Chemical Reagent Co., Ltd
Magnesium sulfate	AR	Sino pharm Chemical Reagent Co., Ltd
Sucrose	AR	Sino pharm Chemical Reagent Co., Ltd
Agar	AR	Beijing aoboxing Biotechnology Co., Ltd
Epoxy resin	AR	Feicheng Deyuan Chemical Co., Ltd
Absolute ethanol	AR	Sino pharm Chemical Reagent Co., Ltd
Acetone	AR	Sino pharm Chemical Reagent Co., Ltd
Glutaraldehyde 25% solution	AR	Tianjin kemio Chemical Reagent Co., Ltd
Pickling solution	-	Wuhan huakete New Technology Co., Ltd
Caustic lotion	-	Wuhan huakete New Technology Co., Ltd

3.1.2. Laboratory equipment

The main instruments and equipment used in this experiment are shown in Table 3:

Table 3. Experimental instruments

Equipment name	Model	Manufacturer
Electrochemical workstation	CS350	Wuhan Kesite Instrument Co., Ltd
Electronic balance	BS224S	Sartorius, sartorius, Germany
Electronic analytical balance	AL 104	Mettler-Toledoinstr(shanghai)Ltd
pH meter	PHS-3C	Shanghai Precision Scientific Instrument Co., Ltd
Portable pressure steam sterilizer	CMSX-280	Beijing Yongguang medical instrument factory
Constant temperature and water-proof incubator	GH4500	Tianjin taist Instrument Co., Ltd
Ultraviolet lamp	Philips TUV 64 T5 HO 4P-SEA	-

Ultraviolet irradiation device: three 30W ultraviolet sterilization lamps are hung on the upper part of the ultraviolet sterilization chamber, the wavelength is 254 nm, and the ultraviolet irradiation intensity at 20 cm below the lamp tube is 5mW/cm^2 [14]. The inside of the sterilization chamber is covered with aluminum foil to reflect ultraviolet rays and prevent energy from leaking out of the chamber. Before UV irradiation, the UV lamp is preheated for 30 min to ensure the stability of the irradiation. When the UV illuminance meter (calibrated at 254 nm) is placed at the target position, the UV irradiation intensity can be measured there, and the UV irradiation dose can be changed by changing the irradiation time.

3.1.3. Experimental materials and experimental equipment

The material used in this experiment is made of 7075 aluminum alloy sheets. The mass fraction of each component is: Si: 0.4%, Fe: 0.5%, Cu: 1.2-2.0%, Mn: 0.3%; Mg: 2.1-2.9 %; Cr: 0.18-0.28%; Zn5.1-6.1%; Ti: 0.2%; Al: balance. Electrochemical test electrodes and morphological characterization samples are all cut with a size of 10mm×10mm×3mm. The electrode is soldered to the copper wire by soldering. The electrode and the test piece are encapsulated with black epoxy resin. The working surface size 10 mm×10 mm, all electrodes and test pieces are polished with 180, 600, and 1200 mesh sandpaper before use, washed with water and absolute ethanol and dried, then stored in a desiccator. Use absolute ethanol and acetone cotton balls when using wipe to remove oil and impurities on the surface [15, 16]. The experiment uses micro-arc oxidation test pieces for the samples with an oxide layer thickness of 20 μm and 60 μm. Similarly, the copper wire is welded, and the black epoxy package is used to retain a working surface. High temperature steam sterilization before the experiment to prevent the introduction of other bacteria Species of bacteria or fungi.

The main strain that causes mildew in aluminum alloy equipment is Aspergillus niger. According to the literature, when the irradiation intensity is 350 μW/cm^2 and the irradiation time reaches 30 minutes, the killing rate of Aspergillus niger strain can reach 97%. The irradiation distance is 1.5 m, because the device should be applied on the conveyor belt, and the conveyor speed is 0.2 m/s. According to the calculation, the irradiation time needs to be 7.5 seconds. According to the irradiation effect, the irradiation intensity is multiplied by the irradiation intensity. It is known from time that the required irradiation intensity is 84000 μW/cm^2. Ultraviolet lamps with such high irradiation intensity are relatively rare and the cost of use is high, so alternative measures are needed. According to an article published in the Chinese Journal of Disinfection [17, 18], the ultraviolet sterilization intensity has the following relationship with distance:

$$E = \frac{97.72}{L^{1.828}} \quad (1)$$

In the above formula, E is ultraviolet intensity, L is the distance from the ultraviolet lamp. This formula is derived under the irradiation condition of an ultraviolet lamp with a power of 30 W and a standard irradiation intensity of 100 μW/cm^2. If the UV lamp is hung at a distance of 10 cm from the sample, the irradiation intensity is about 6515 μW/cm^2. If the power is changed to 150 W for standard UV lamps with a radiation intensity of 440 μW/cm^2, the illumination intensity at 10 cm should be approximately 28665 μW/cm^2. At this time, if three lamps

are used for simultaneous illumination, the 84000 μW/cm^2 radiation intensity required for the calculation can be met. The designed irradiation device is shown in Figure 3:

The transmission speed of a general conveyor belt is 0.2 m/s, and the distance of 7.5 seconds for a simulated conveyor belt transmission is 1.5 m. The above irradiation device is set, and cardboard is arranged around it to isolate ultraviolet rays. The main material used for the irradiation device is a thin plastic plate, and then use wide tape to make a hard box with a length of 150 cm, a width of 100 cm, and a height of 12 cm, and then install an ultraviolet lamp. The three lamps are distributed according to one lamp every 25 cm, the installation position of the lamp is at the position of 10, so that the designed purpose can be achieved.

3.2. Fabrication and identification of mold medium

3.2.1. Making medium

The mold medium used in the experiment was Cha's medium. The medium composition was: $NaNO_3$ content 3 g/L, KCl content 0.5 g/L, $MgSO_4 \cdot 7H_2O$ content 0.5 g/L, K_2HPO_4 content 1 g/L, $FeSO_4$ content It is 0.01 g/L, sucrose content is 30 g/L, and agar content is 20 g/L. The medium used in each experiment is now used. The prepared culture medium, culture dish, ten 10 mL colorimetric tubes and 150 mL distilled water are sterilized under high temperature and high pressure. The process is as follows: open the sterilization pot, adjust the voltage to 225 V, wait for the water in the pot to boil and close the air valve until the pressure in the pot reaches 1.5 MPa, the temperature is 120°C, adjust the voltage to 115 V, keep the temperature in the pot between 121°C-126°C for 15 to 20 min, then cut off the power supply and wait for the pot to boil When the internal pressure drops to 0 MPa, open the air valve, wait until the temperature drops to room temperature, and then place the reagent on the sterilization test bench. Take 30 mL of sterilized culture medium and pour it into the culture dish respectively, place it under the ultraviolet lamp for cooling, dilute the spore content of the bacteria with distilled water to 10^6/mL, inoculate it into the culture dish with agar culture medium, place it in the 28°C incubator for culture, and use it after 2 h.

There are two kinds of test media used in this experiment, one is pure agar-free medium without adding bacteria, and the other is agar-free medium inoculated with bacteria at a volume ratio of 2%. Take a small piece of bacteria on the petri dish after dilution, dilute it with distilled water to a spore content of 10^6/mL and inoculate it into the test medium. All glassware used is sterilized by the above method. The electrodes and salt bridges used are sterilized under an ultraviolet lamp for 30 minutes before use, and the laboratory operation room is sterilized with an ultraviolet sterilization lamp for 30 minutes before use.

3.2.2. Mold identification

The Aspergillus niger used in this experiment was taken from moldy food, and the corrosion samples of aluminum alloy were continuously separated and purified in the medium until a single mold colony appeared in the medium, as shown in Figure 4.

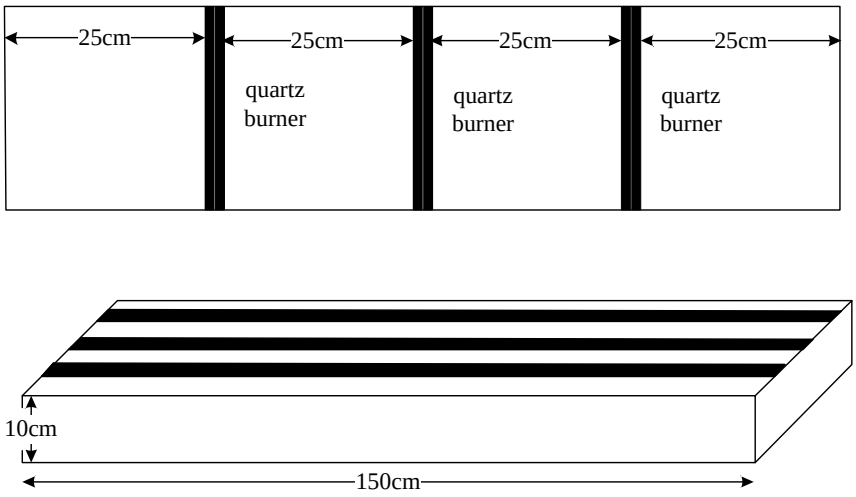


Figure 3. UV irradiation device.

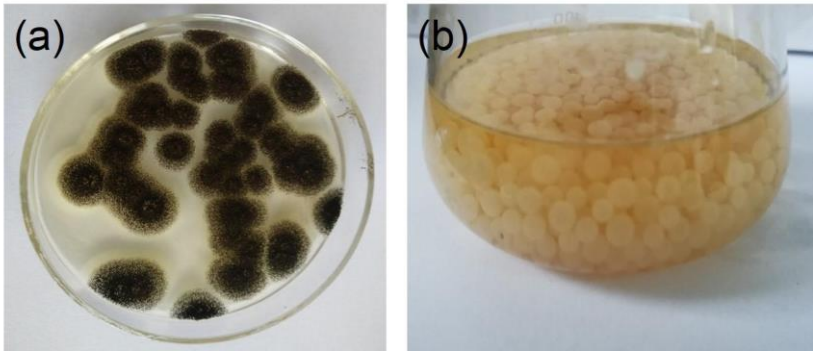


Figure 4. The isolated and purified mold colonies.

Fig. 4 (a) is the mold colony on the solid medium, and Fig. 4 (b) is the mold pellet formed by shaking culture in the liquid medium, and the PCR method was used to identify Aspergillus niger. Inoculate a single colony of Aspergillus niger onto the liquid culture medium and place it on a shaker for shaking culture. The temperature in the shaker is 30°C and the rotation speed is 150-180 r/min. After shaking culture for 2 h, due to the uniform winding of Aspergillus niger, the shape of the colony of Aspergillus niger in the liquid culture medium is crystal clear and spherical. Filter with double-layer filter paper. After the pellets of Aspergillus niger are slightly dry, store them in -20°C in the refrigerator. The pre-processing steps before doing PCR are as follows:

1. Grind the pellets of Aspergillus niger frozen at -20°C in liquid nitrogen to a fine powder, divide the powdered Aspergillus niger into 1.5 m1 centrifuge tubes, 100 mg per tube, add 0.6 mL DNA extract Draw buffer, water bath at 65°C for 30-35 min.
2. Place the centrifuge tube in a centrifuge at 12000 r/min at 4°C for 10 minutes, take the supernatant and transfer to a new 1.5 m1 centrifuge tube.
3. Add an equal volume of extract (phenol: chloroform: isoamyl alcohol=25: 24: 1) to the supernatant in the centrifuge tube and invert gently 5-7 times.
4. Add 1/10 volume of 3 mol/L sodium acetate solution and 0.6 times volume of isopropanol, gently invert 5-7 times, and let stand at -20°C for 30 min.
5. Centrifuge at 12000 r/min for 5 min at 4°C. Discard the supernatant and add 200 gL of TE buffer to dissolve the precipitate. TE buffer is mainly used to dissolve nucleic acids and store DNA and RNA stably.
6. Add 1 μL of ribonuclease (RNase A), RNase A can hydrolyze RNA, but it has no effect on DNA. Able to get DNA sequence. Compared with the standard gene library, the mold used in this experiment was Aspergillus niger.

3.3. Electrochemical test

The electrochemical test was carried out in pure agar medium. In this experiment, a three-electrode system was used, with 7075 aluminum alloy as the working electrode, a saturated calomel electrode as the reference electrode, and a platinum electrode as the counter electrode. The CS350 electrochemical workstation was used for open circuit potential. Electrochemical impedance and polarization curve test.

Because mold is an oxygen-consuming microorganism, in the liquid environment, it will grow on the surface of the liquid. When assembling the test device, place the electrode working surface close to the liquid surface. The open circuit potential (Open Circuit Potential, OCP) each test time is 15min, record the relationship between the potential of the working electrode and the reference electrode with time.

Electrochemical impedance (Electrochemical impedance spectroscopy, EIS) is a very important method in corrosion testing. During the detection, a small amplitude sinusoidal potential current is applied, which is basically non-destructive to the corrosion product film and the surface of the material. According to the impedance diagram, some dynamics of corrosion can be obtained Parameters, and be able to reason about corrosion dynamics and establish a reasonable equivalent circuit diagram. In this experiment, a 10 mV AC disturbance voltage was applied to the working electrode, the scan frequency range was 10^4 Hz-10^{-2} Hz, and the test was performed at room temperature. The physical picture is shown in Figure 5:

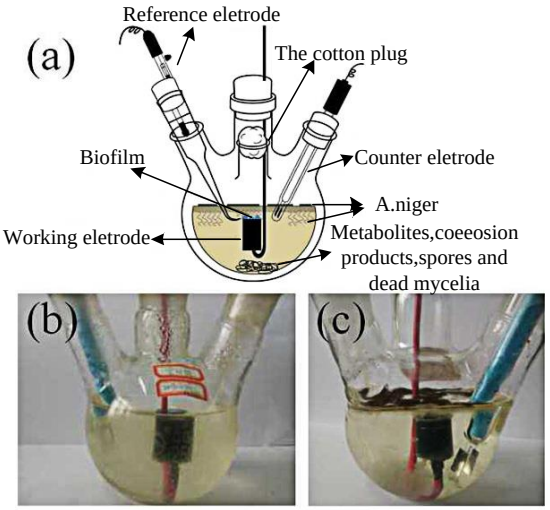


Figure 5. Electrochemical device diagram.

In the above figure, Fig. 5 (a) is a simulation figure, Fig. 5 (b) is a device without mold, and Fig. 5 (c) is a device with mold added. All the electrochemical tests in this experiment were carried out at Coster Electrochemical Workstation (CS350). The open circuit potential is the self-corrosion potential, which can reflect the change of the corrosion state of the material surface. In the study of microbial corrosion, the formation, destruction or shedding of biofilms can be preliminarily judged based on the change in open circuit potential. However, the strength of the material corrosion cannot be judged solely by the change in open circuit potential. It can only be used as an auxiliary information. It should be combined with other analytical methods to analyze the electrochemical process of microbial corrosion. Electrochemical impedance (Electrochemical impedance spectroscopy, EIS) is a conventional electrochemical test method for corrosion research. Applying a small amplitude AC signal (10 mv) to the system during the test will not change the surface state of the working electrode. The same working electrode can be continuously monitored, and the corrosion can be judged according to the change in the size and shape of the impedance arc. Time trends. EIS is measured at a stable open circuit potential with a frequency range of 10^5 Hz to 10^{-2} Hz. The electrochemical impedance data was fitted using Zview2 software (Scribner Inc). Polarization curves (Potential dynamic polarization curves) are also measured at a stable open circuit potential. The scanning range set in this experiment is one 200 mv to 300 mv, and the scanning speed is 0.5 mv/s. The polarization curve was fitted by Cview2 software (Scribner Inc).

4. Results and discussion

4.1. Mold growth test

In order to improve the mechanical properties of 7075 aluminum alloy metal materials, other added metal components, such as Cu, Zn, Mg, Si, etc. combine with A1 to form an intergranular phase. During the corrosion process, as the metal elements are eluted, the physical and chemical properties of the material surface change the unevenness to make the material prone to corrosion. A large number of studies have shown that metal oxides such as

nano-ZnO, CuO and AgaO can affect the growth state of microorganisms, and are widely used in biomedical biomimetic materials, daily skin care products and antibacterial materials. Trace elements such as iron, silicon, zinc, copper, iodine, selenium, and manganese can affect the growth of microorganisms. The 7075 aluminum alloy selected for the experiment contains three metal ions, Cu^{2+}, Zu^{2+}, and Mg^{2+}. Aspergillus niger is a fungal microorganism that metabolizes a large amount of organic substances containing hydroxyl, carboxyl, and amine groups during life cycle activities. Organic acids are dissolved into the medium, resulting in changes in the pH value of the environment. By recording the changes in the pH value of the medium during the test, the growth of Aspergillus niger in pure Cha's medium for 7 h can be investigated. As shown in Figure 6:

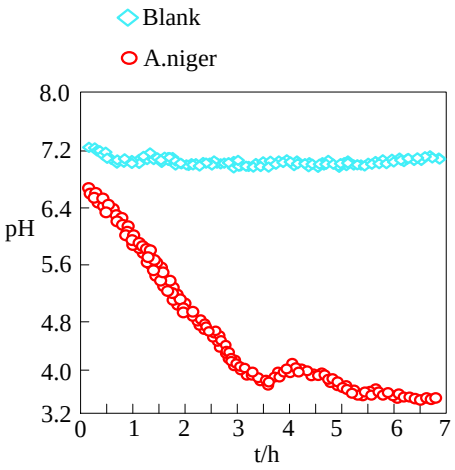


Figure 6. PH value of the test system in 7 h.

In the blank group, the pH value of the medium is basically unchanged, and is maintained at about 7.2. In the culture medium added with bacteria, the pH value decreased significantly, the rate of decrease increased after 1 h, the pH value was only 3.8 on the 3 h, and remained stable after a slight decrease on the 3.5 h, indicating that the fungus was in the medium and 28°C after the 1 h. It grows rapidly and secretes a large amount of organic acids. On the 3 h, it reaches a stable growth period. The growth and mortality of molds reach a balance, and the number of molds in the medium reaches the maximum. According to the change trend of pH value, Aspergillus niger grew in pure medium for 3 h and reached a stable growth period. Therefore, the growth morphology of the 7075 aluminum alloy surface after inoculated with mold for 1, 2, and 3 h is recorded in the form of a picture, as follows in Figure 7:

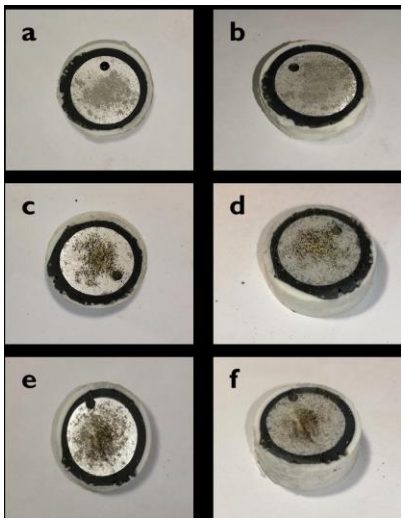


Figure 7. The growth of mold on the surface of aluminum alloy.

In the above figure, figures a and b show the growth of mold on the aluminum alloy surface for 1 h, figures c and d show the growth of mold on the aluminum alloy surface for 2 h, and figures e and f show the growth of mold on the aluminum alloy surface for 3 h. As can be seen from the above figure, on the 1 h, the mold can be evenly distributed on the surface of the aluminum alloy, and there are only a small number of conidia on the mycelium. On the 2 h, the conidia of the mycelia increase significantly, and the spores start to multiply, and they continue to conid mycelium to achieve a period of rapid growth, and by the 3 h the spores are also basically evenly distributed on the surface of the aluminum alloy. The results in the figure intuitively prove that Aspergillus niger can grow and reproduce rapidly under the conditions allowed by environmental nutrition, thereby affecting the surface structure of the aluminum alloy through life activities. The microscopic appearance of molds growing on different hours is shown in Figure 8:

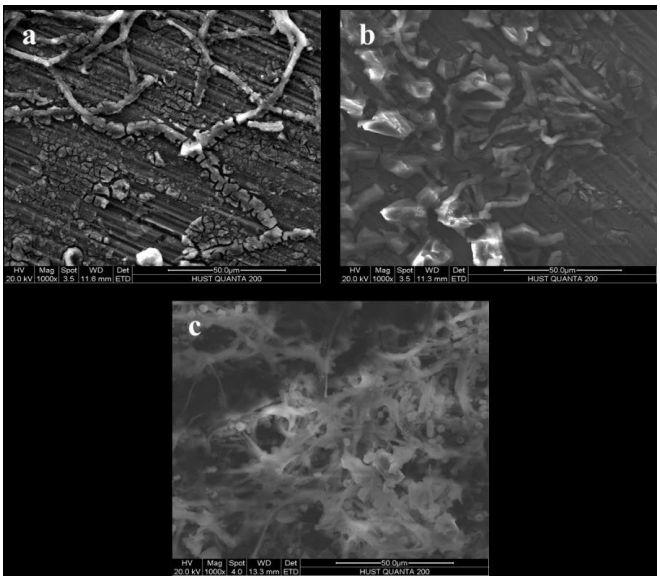


Figure 8. SEM image of mold on aluminum alloy surface.

In the above figure, a is the microscopic morphology of Aspergillus niger attached to the surface of the aluminum alloy for 1 h. There are accumulations of corrosion products on the surface of the aluminum alloy, which are distributed along the direction of mycelial growth and present a branched structure. Picture b is the surface microscopic morphology of the fungus growing for 2 h. The distribution of corrosion products is similar to the distribution in picture a, but scattered spores are distributed around the corrosion products. The results are the same as in the macro picture. To increase the growth rate. The mold grows on the surface of the aluminum alloy for 3 h. As shown in Figure c, the mycelium contains many spores distributed in it, and the mycelia and corrosion products intersect and accumulate on the surface of the aluminum alloy.

4.2. Study on the control law of ultraviolet radiation intensity on mold

Ultraviolet radiation is an effective method to control the corrosion of microorganisms. It can destroy the life activities of microorganisms or prevent the microorganisms from contacting with the matrix material by ultraviolet rays to inhibit the damage caused by the microorganisms to the matrix material. Ultraviolet rays can effectively inhibit the growth of fungi. In this section, three effective ultraviolet irradiation intensities will be selected for comparison. After 30 minutes of irradiation, the application effect of ultraviolet rays in mold corrosion will be studied. The open circuit potential of aluminum alloy in the mold medium with three different ultraviolet irradiation intensities is shown in Figure 9.

Except for the blank group that has not been irradiated with ultraviolet rays, the open circuit potential of other ultraviolet irradiation systems is relatively stable. The open circuit potential of the lowest ultraviolet intensity of 40,000 μW/cm^2 showed a negative trend shift with little tendency on the 1 h and 1.5 h, and a stable positive shift in the later period. It remained stable afterwards; the open circuit potential of 60,000 μW/cm^2 did not change, and remained basically stable; the open circuit potential of 84000 μW/cm^2 intensity continued to rise and remained stable, indicating that the stability of the oxide film on the aluminum alloy surface after UV irradiation can be improved. Which can effectively protect the aluminum alloy from corrosion caused by mold.

In addition, to further verify the effectiveness of using ultraviolet rays to remove mycotoxins in aluminum alloy equipment, the method in this paper and the method in literature [1] were used to carry out the inactivation test of mold spores under the same length of time. The comparison results are shown in Figure 10.

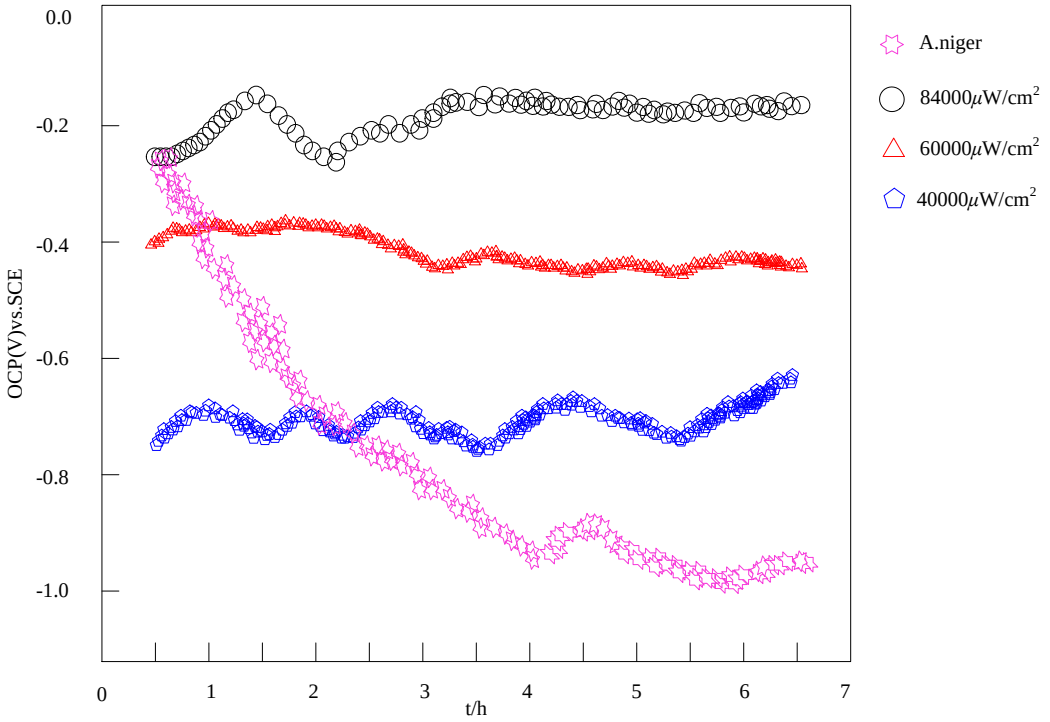
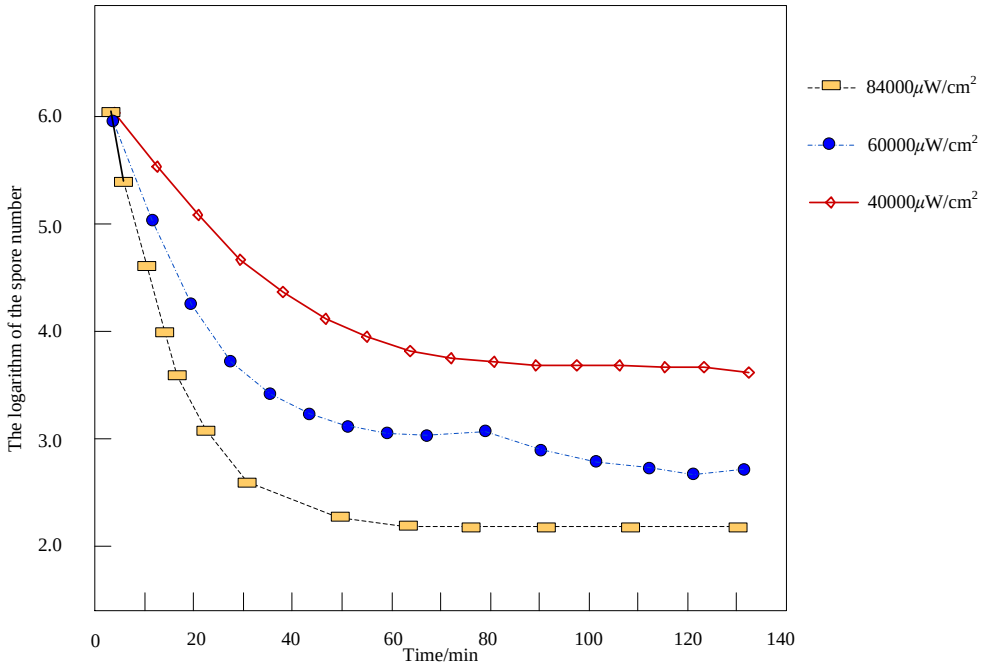
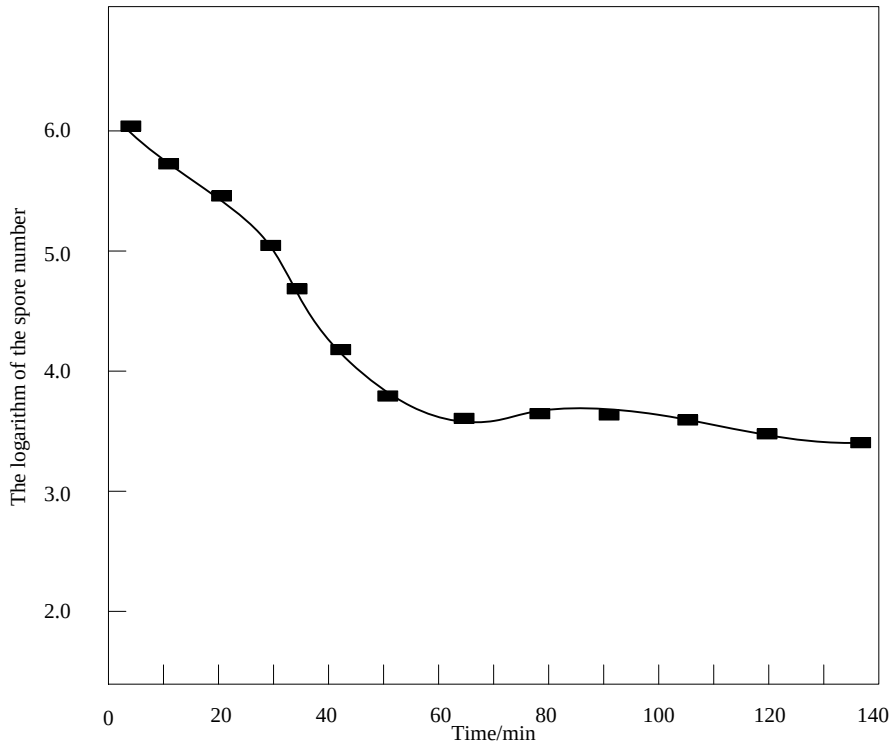


Figure 9. Open circuit potential of aluminum alloy under different ultraviolet irradiation intensity.



(a)The results of inactivation of mold spores in this method



(b)The results of inactivation of mold spores under the method of literature [1]

Figure 10. Comparison results of inactivation of mold spores

Analyzing Figure 10(a), we can see that in the case where the ultraviolet irradiation intensity is 84000 μW/cm^2, the logarithm of the spore number tends to be stable after about 30 minutes of irradiation. Considering energy saving and other aspects, it is concluded that when sterilizing aluminum alloy equipment under ultraviolet irradiation, the irradiation intensity can be selected to be 84000 μW/cm^2 and the irradiation time is 30min. The sterilization effect is the most effective and economical. Analysis of Figure 10(b) shows that the method in literature [1] has a poor bactericidal effect on mold spores. The logarithm of the number of spores stabilizes when the experimental time reaches 50 minutes, and its bactericidal effect is significantly lower than that of the method in this paper.

5. Conclusion

In this paper, combined with electrochemical testing, surface morphology and composition analysis, the corrosion behavior of Aspergillus niger on the surface of aluminum alloy was studied, and the corrosion protection performance of mold on the surface of aluminum alloy under different ultraviolet irradiation intensity was explored. It is concluded that considering energy saving and other aspects, when sterilizing aluminum alloy equipment by ultraviolet irradiation, the irradiation intensity is 84000μW/cm^2 and the irradiation time is 30min. The sterilization effect is the most effective and economical.

References

[1] Zhou W., Zhang Z.G. (2019). Analysis on Corrosion Effect of Mold Pollution on Aviation Aluminum Alloy Equipment. Environmental Science and Management, 44(1):87-92.

[2] Chen G.J., Wang H.Q., Chen Y.M., et al. (2019). Contrastive Study on Indoor Temperature-humidity Threshold Value for Mould Germination Risk on the Hygroscopic Wall. Journal of University of Souht China (Science & Technology), 33(2):1-7.

[3] Jin Z.Q, Wang S.X. (2018). Synergistic Effects of Microwave, Ultraviolet and Ozone Combination on Mold Spores and Aflatoxin. Journal of Northwest A&F University (Natural Science Edition), 46(4):147-154.

[4] Yue X.Y., Zhang H., Chen W.F., et al. (2018). Temporal and Spatial Distribution Characteristics of Mold Communities during Storage of Corn as Studied by Denaturing Gradient Gel Electrophoresis. Food Science, 39(4):307-311.

[5] Yadong L., Jae H.K., Gu X.H. (2018) Developing Methodology for Service Life Prediction of PV Materials: Quantitative Effects of Light Intensity and Wavelength on Discoloration of A Glass/EVA/PPE Laminate. Solar Energy, 174(1): 1726-1733.

[6] Yang S. (2019). Simulation of Absorbing Frequency Dynamic Regulation of Metal Material Absorber. Computer Simulation, 36(6): 251-254.

[7] Xu Z.X., Hua W.Y., Xiong L.J., et al. (2020). Novel Design of Volume of Detention Tanks Assisted by a Multi-Source Pollution Overflow Model towards Pollution Control in Urban Drainage Basins. Environmental Science and Pollution Research, 27(11):12781-12791.

[8] Tian C.M., Zhang Y.F., Yang H., et al. (2018). To Analysis of the Irrandiance and Monitoring Results of The Same Ultraviolet Lamp with Different Ultraviolet Lamp. Henan Journal of Preventive Medicine, 29(5):321-323.

[9] Zhang W.W., Sun Y.H., Wei H.Y., et al. (2019). Germicidal effects of ultraviolet on condensed milk barrel and its dynamic. Food & Machinery, 35(4):108-112.

[10] Jin Z.Q., Wang S.X. (2018). Synergistic Effects of Microwave, Ultraviolet and Ozone Combination on Mold Spores and Aflatoxin. Journal of Northwest A&F University (Natural Science Edition), 46(4): 147-154.

[11] Mahmoud I.A., Fahmyaly M., Mohib A., et al. (2019). Integration of Benchmarking with Overall Equipment Cost Loss for Industrial Process Improvement. Jordan Journal of Mechanical and Industrial Engineering, 13(1):49-59.

[12] Kumar A., Ram M. (2018). Mathematical Modelling for Reliability Measures to Sugar Mill Plant Industry. Jordan Journal of Mechanical and Industrial Engineering, 12(4):269-279.

[13] Zgeye S M. (2019). A Comparative Study on Beam Divergence Angle and Wave Length between Semiconductor Laser and Helium-Neon Laser. American Journal of Mechanical and Industrial Engineering, 4(5):69.

[14] Ning N., Zhang J.K., Yang S. (2018). Effect of Photo Reactivating Light Intensity on the Photo Reactivation of Escherichia Coli. Liaoning Chemical Industry, 47(9):866-868.

[15] Hao K.Y., Chen X.Y., Li Y.W., et al. (2018). Correlative Analysis of Ultraviolet Radiation and Air Quality in Linzhi. Environmental Science & Technology, 41(7):103-106.

[16] Chen Y. (2018). Measurement and Analysis of Measurement Error of Ultraviolet Radiation Illuminance Caused by Ambient Reflection. Inner Mongolia Environmental Sciences, 30(2):163+165.

[17] Li L.W., Chen Y.Y., Li K.L., et al. (2018). Experimental Measurement and Analysis of the Irradiance of Different Types of Ultraviolet Germicidal Lamps. China Light & Lighting, (11):18-22.

[18] Umarov A.V., Khamzaev H.E., Mirsalikhov B.A. (2020). Temperature Dependence of the Heat Capacity of Polymeric Compositions Based on Polyethylene (LDPE) with a Metal Oxide Filler. American Journal of Mechanical and Industrial Engineering, 5(1):1.