Study on Dry-ice Particle Jet Assisted Decontamination Technology

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Abstract. Dry-ice particle jet technology, which has the characteristics of no pollution, easy production and high impact, has been widely used in the cleaning of automobile, aviation, printing, electronics and nuclear industry. In this paper, a set of dry-ice jet spraying decontamination device was built. Two types of artificial pollutants, paint and oil contamination were smeared onto the workpieces. The effect of dry-ice particle jet spraying on the paint and the oil contamination was studied comprehensively. In addition, the wettability of the workpieces before and after dry-ice particle jet spraying was tested. The results of this study enrich the technology of industrial cleaning and promote the practical applications of the dry-ice particle jet spraying technology.

1. Introduction

With the rapid development of aerospace, railways, electric power and other fields, more stringent requirements are put forward for the quality of surface cleanliness of workpiece. Traditional surface cleaning technologies mainly include chemical cleaning[1], mechanical polishing[2,3], electrochemical polishing[4-6]. However, the aforementioned methods have many disadvantages. The use of cleaning agent in chemical cleaning has serious damage to human health. Moreover, the extensive use of chemical reagents may cause not only the waste of water resources, but also secondary pollution to the environment. The disadvantages of mechanical polishing are high noise and a large amount of powder remaining on the polished surface, resulting in the need for secondary polishing and cleaning to meet the requirements of the equipment. For the electrochemical polishing technique, the use of strong acid and alkali may cause irrecoverable damage to the device and human body. In addition, the wasted liquid needs to be purified before discharging, which lead to the further increase of the cleaning cost. Thus, it is of great significance to study a low cost, high efficiency and no pollution cleaning technology to further improve the quality of surface cleanliness of workpiece.

In order to solve the aforementioned problems, we proposed a dry-ice particle jet spraying technology to remove the pollutants on the workpiece. The influence of the dry-ice particle jet spraying on the pollutants was studied and the relevant characterizations were used to prove the effectiveness and practicability of this method.
2. Experimental

2.1. Experimental process
The schematic of dry-ice particle jet is shown in figure 1, including a dry-ice particle sprayer, air compressor and gasholder. The work parameters of the air compressor were rated power 22 kW, rated pressure 0.4 MPa, and rated flow 3.6 m\(^3\)/s, respectively. The diameter and length of dry-ice particles was 1 mm and 1-3 mm, respectively. The dry-ice mass flow rate was 15 g/s. The inclination angle of spraying nozzle was 45° and the distance between the spraying nozzle and workpiece was 10 cm.

![Figure 1 Schematic of dry-ice particle jet system.](image)

2.2. Experimental process
In this work, the contact angles of the stainless-steel surface before and after dry-ice particle jet spraying were detected by an optical contact angle measuring system (SL200KS, KINO, China). The decontamination processes were recorded by a digital camera (DSC-RX10 III, Sony, Japan).

3. Results & discussion

3.1. Experimental process
Figure 2 shows the removal process of the sprayed paint by dry-ice particle jet spraying. Firstly, black paint was smeared on the stainless-steel plate as a cleaning test sample. The size of the stainless-steel plate was 60 × 60 cm and the thickness was 1 mm. The paint was one of the thermoplastic acrylic resin aerosol materials, which had good adhesion strength with the stainless-steel plate. The surface of the stainless-steel plate was sprayed by the paint for three times and the interval of each spray was 5 min. As a result, the thickness of the paint was 50 μm. After that, the samples were dried at 80 °C for 2 hours to cure the paint. During the dry-ice particle jet assisted decontamination processes, we can see that the black paint fell off easily. After spraying for 500 s, the black paint with an area of 1800 cm\(^2\) was remove thoroughly.
Generally, the oil contamination with high adhesion on the workpiece surface is difficult to be removed by non-chemical cleaning method. Thanks to the high impact of dry-ice particle jet, it can be used to remove the oil contamination on the workpiece surface. Here we studied the oil removal by dry-ice particle jet spraying. Artificial oil contamination, which was mainly composed of lubricating oil and ash layer (15 g ash layer was mixed into 5 mL lubricating oil uniformly), was evenly coated on the surface of the workpiece with an area of $3.14 \text{ cm}^2$. Figure 3 shows the cleaning processes of oil contamination removal by dry ice particle jet at the spraying pressure of 0.4 Mpa, spraying angle of 45°, and spraying distance of 10 cm. The oil contamination can be removed by dry ice particle jet in only 0.1 s.
3.2. Surface wettability and chemical compositions before and after decontamination by dry-ice particles jet spraying

The contact angle of water on the workpiece with black paint was about 74°, while the contact angle of water on the workpiece reduced to ~34° after dry-ice particles jet spraying, indicating that the surface cleanliness was significantly improved, as shown in figure 4.

![Figure 4](image)

Figure 4 Images of 5 μL water droplet on the workpieces before (a) and after (b) paint removal by dry-ice particle jet spraying.

4. Conclusions

In this work, dry-ice particle jet assisted decontamination technology was proposed to remove the paint and oil contamination on the workpiece surface. This method showed excellent cleaning effect, and the pollutants were easily fell off under the impact of dry-ice particle jet. A painted workpiece with area of 1800 cm² was cleaned thoroughly after dry-ice particle jet spraying for 500 s. In addition, it took only 0.1 s to remove oil contamination on a workpiece with area of 3.14 cm². The wettability test demonstrated that the contact angle of water on workpiece decreased significantly after dry-ice particle jet spraying. Furthermore, the chemical composition results showed that almost no contaminant was found on the workpiece surface after dry-ice particle jet spraying.

References

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