Morphology and Efficiency of the Deposition Function in the Deterministic Electrochemical Repairing Method

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Abstract. Deterministic electrochemical repairing method is effective technique for the rapid fixing of damaged parts in the military equipment, and its critical content is to achieve a steady deposition function. In order to take into consideration both the repairing efficiency and fixing accuracy, three shapes of deposition functions were developed through the square nozzles, the rectangular nozzles and the round nozzles. Meanwhile, for the three kinds of nozzles, each kind had several sizes, which aimed to further improve the scope of application of the deterministic electrochemical repairing method. Furthermore, the deposition functions were detected through measuring the morphology and efficiency of the deposition spots obtained by the deterministic electrochemical repairing system with the varied deposition times of 0.5h, 1.0h, 1.5h and 2.0h, respectively. The experimental results indicated that morphology of the deposition functions were consistent with those theoretical results, and their corresponding efficiency was steady, which were propitious to obtained better repairing efficiency and higher fixing accuracy. The developed effective deposition functions can promote the practical application of deterministic electrochemical repairing method in the precision assurance of military equipment.

1. Introduction

Deterministic electrochemical repairing method is effective technique for the rapid fixing of damaged parts in the military equipment [1], which is developed from the computer controlled optical surfacing (CCOS) [2, 3] based on the Preston theory and the brush plating [4, 5] based on the electrochemical deposition. Through controlling the deposition region and the deposition time accurately, maintenance of the damaged parts in the military equipment can be improved.

The critical content of the deterministic electrochemical repairing is to achieve a steady deposition function, which is the foundation to calculate the dwelling time through combining with the objective surface data. Morphology and efficiency of the deposition function are two most important factors to judge its feasibility. Firstly, surface morphology of the deposition function should be regular, which is favorable to calculate the dwelling time and improve the fixing accuracy. Secondly, fixing efficiency of the deposition function should be steady, which indicated that the fixing thickness should be linear with the deposition time. These two critical factors were investigated in this study.

In order to take into consideration both the repairing efficiency and fixing accuracy, three shapes of deposition functions were developed through the square nozzles, the rectangular nozzles and the round nozzles [6-8]. Meanwhile, for the three kinds of nozzles, each kind had several sizes, which aimed to further improve the scope of application of the deterministic electrochemical repairing method [9, 10]. Furthermore, the deposition functions were detected through measuring morphologies and efficiencies...
of the deposition spots obtained by the deterministic electrochemical repairing system with the varied deposition times of 0.5h, 1.0h, 1.5h and 2.0h, respectively.

2. Experimental apparatus
Schematic diagram of the deterministic electrochemical repairing system used in this study is shown in the Figure 1. The specimen was treated as the cathode in the electrochemical deposition system. The developed nozzle was fixed on the platform. The electrochemical deposition solution was sucked from the container by the peristaltic pump to lumen of the nozzle and recycled back to container through the vacuum pump from the external cavity of the nozzle.

Figure 1. Schematic diagram of the deterministic electrochemical repairing system.

Nozzle head is critical part in the deterministic electrochemical repairing system. Three shapes of nozzles were developed in this study, as shown in the Figure 2, which consisted of the square nozzles, the rectangular nozzles and the round nozzles. Due to the complex shapes, these nozzles were obtained by the additive manufacturing [11, 12]. For the four square nozzles in the Figure 2(a), their sizes were 9mm*9mm, 11mm*11mm, 13mm*13mm, and 15mm*15mm, respectively. For the four rectangular nozzles in Figure 2(b), their sizes were 9mm*12mm, 11mm*16mm, 13mm*20mm, and 15mm*24mm, respectively. For the four round nozzles in Figure 2(c), their sizes were Φ9mm, Φ11mm, Φ13mm, and Φ15mm, respectively. These nozzles were fixed on the experimental apparatus in the Figure 1.

(a) Square nozzles                        (b) Rectangular nozzles                 (c) Round nozzles

Figure 2. The developed nozzles by the additive manufacturing.

3. Results and Discussions
Deposition functions were obtained by taking the Q235 steel plate as the specimen in the Figure 1, and the deposition times for each nozzle were set 0.5h, 1.0h, 1.5h and 2.0h, respectively. The deposition spots on the electrochemical deposited specimens are shown in the Figure 3. It could be observed that shapes of these deposition spots were consistent with cross-sectional shapes of the nozzles in Figure 2. The four deposition spots in the upper line were obtained by the four round nozzles in the Figure 2(c).
The four deposition spots in the middle line were obtained by the four rectangular nozzles in Figure 2(b). The four deposition spots in the bottom line were obtained by the four square nozzles in Figure 2(a). Meanwhile, it could be found that there were many burrs in boundary region of the deposition spots, especially when size of the deposition spot was small. The major reason for this phenomenon was that there was a small amount of residual liquid in these boundary regions, although the residual liquid was mainly eliminated by the Marangoni effect through the volatile component in the solution.

For the purpose of further investigating efficiency of the deposition function, cross-sectional lines of the deposition spots in the Figure 3 were detected by the surface profilometer. For the deposition spots obtained by four square nozzles in Figure 2(a), the cross-sectional lines were selected along one edge, and the results are shown in the Figure 4. Meanwhile, with regard to the deposition spots gained by four rectangular nozzles in the Figure 2(b), the cross-sectional lines were selected along the longer edge, and the results are shown in the Figure 5. Furthermore, for the deposition spots achieved by four round nozzles in the Figure 2(c), the cross-sectional lines were selected along one diameter, and the results are summarized in the Figure 6. It could be judged from the results that the maximal thickness of the deposition spot was almost proportional to the deposition time along with same electrochemical deposition parameters. Shapes of the cross-sectional lines in the Figures 4, 5, and 6 were quite close to the near-Guassian function, which were consistent with the proposed results in the former literature [1, 10]. The near-Guassian function was favorable to improve the repairing efficiency and fixing accuracy in the deterministic electrochemical repairing method, because the centralized repairing energy was more efficient and effective to fix the defects on the damaged part.
Figure 4. Cross-sectional lines of the deposition functions for the square nozzles.

(a) 9mm*9mm  (b) 11mm*11mm  (c) 13mm*13mm  (d) 15mm*15mm

Figure 5. Cross-sectional lines of the deposition functions for the rectangular nozzles.

(a) 9mm*12mm  (b) 11mm*16mm  (c) 13mm*20mm  (d) 15mm*24mm
Figure 6. Cross-sectional lines of the deposition functions for the round nozzles.

4. Conclusions
Morphology and efficiency of the deposition function in the deterministic electrochemical repairing method were investigated in this study. Three shapes of deposition functions were developed through the square nozzles, rectangular nozzles and the round nozzles. Morphology of the deposition functions were consistent with theoretical results, and the corresponding efficiency were steady. The developed effective deposition functions promote application of deterministic electrochemical repairing method.

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