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The Effect Of Surface Topography On Cavitation Erosion Of Mild Steel

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ABSTRACT

The variations of the altitude density function (ADF) about surface profile of mild steel were investigated during the process of electrochemical polishing (ECP), and its cavitation erosion behavior and corrosion behavior in 0.5 mole/L NaCl aqueous solution were studied by magnetostrictive vibratory device for cavitation erosion and electrochemical device, respectively. The results showed that variation tendencies of ADF with polishing time was flat-steep-flat, and there was narrow Gauss distribution in ADF at the special period of ECP time form 4 seconds to 8 seconds, which had a fine performance of cavitation erosion resistance and electrochemical corrosion resistance.

KEYWORDS

Mild steel;
Electrochemical polishing;
Altitude density function;
Cavitation;
Corrosion.

INTRODUCTION

The performances of wear erosion resistance and electrochemical corrosion resistance for metal materials depend to a great extent upon the surface quality. Some research results have shown that surface geometrical topography of material also has an effect on the above performances. ECP can change surface roughness, therefore, it has been widely used for improving surface quality of materials.

The assessment of metal surface topography is an important part for the research of surface quality of materials. There are many methods to assess the surface topography of materials; one of them is the statistic parameter of geometrical topography of describing surface roughness, which is altitude density function (ADF) used for describing the state of altitude distribution about surface profile.

With the wide use of ECP, it has made more progress in the investigations of surface topography. In the aspect of surface roughness, H.Ramasawmy[1] studied the topography of surface profile processed by electro discharge machining after ECP; J.J.Zhou[2] studied the surface profile interval. In the aspect of surface statistic properties, M.Zhang[3] investigated the probability density function of the altitude distribution; L.X.Chen[4] researched the statistic features of surface profile. These researches revealed the surface topography characteristics after ECP from different sides; however, it has not been reported for the variation of surface topography during the process of ECP. In order to understand the details of surface topography during process of ECP and to determine reasonable ECP time for getting excellent surface quality, it is necessary to explore the variation behavior of surface topography during its process. This paper investigated the variation trend of ADF during the process of ECP and the performance of cavitation erosion resistance and corrosion resistance about different surface profile of mild steel.

EXPERIMENTAL

The experiments were carried out under the conditions of neutral solutions. The test material was Q235A mild steel, its chemical composition was listed in TABLE 1, the area of sample was 10*20 mm^2, and the original surface was processed by means of grinding. The pulse electrical source (frequency 0-2 kHz) was used as the apparatus of ECP, and copper served as the tool cathode. The images of surface morphology were observed by optical microscope (X400). The surface profile curves were measured by the profiler (Surfcorder SE-3H), in which the test length was 2 mm. The technology parameters of ECP were: the current density was 80 A·cm^{-2}; the polar gap was 0.1 mm; the concentration of solution was 15%$NaNO_3$; the experiment temperature was at 293 K; the polish time was respectively 4s, 8s and 20s.

TABLE 1: Chemical composition of Q235A

Element	C	Mn	Si	S	P
W %	0.14~0.22	0.30~0.65	≤0.30	≤0.050	≤0.045

The electrochemical impedance spectroscopy (EIS) were measured with EG&G potentiostat/galvanostat M273A instrument and frequency response analyzer M5210 in the solution of 0.5 mole/L NaCl; the platinum electrode and saturated calomel electrode (SCE) were used as the counter and reference electrodes; working electrode were made by Q235A mild steel of original surface and polished for 4s, 8s and 20s respectively. Cavitation tests were performed according to ASTMG32-85 standard test method[5] by using ultrasonic equipment.

RESULTS AND DISCUSSIONS

Surface profile topography

The photographs of optical microscope and plots of surface profile topography are obtained by the experiments under the conditions mentioned above, shown in figure 1 and 2, respectively. The (a) is the surface profile of non polishing, showing the topography of original surface; the (b) and (c) are the surface profile of polishing for 4 and 8 second, representing the surface of during the process of ECP; the (d) is the surface profile of polishing for 20 second, which expressed the surface of full ECP. It is shown that the surface profile of polishing for 8 second has a fine surface quality.

Variation of the ADF with the time of ECP

The ADF is used for describing the frequency degree of appearance of the altitude of surface profile at the different regions on the surface, it is shown as follows[6].

$$\phi(z) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{z^2}{2\sigma^2}\right) \quad (1)$$

Where z is the altitude of surface profile and is the standard deviation. The experimental curves and fitted curves of ADF of surface profile are made by means of the computer software [4]. The experimental and fitted plots of ADF of the original surface and polished surface are shown in figure 3, in which (a) denotes original surface (non-polishing), (b) and (c) describe the variation features of surface during the process of ECP (polishing for 4s and 8s respectively),

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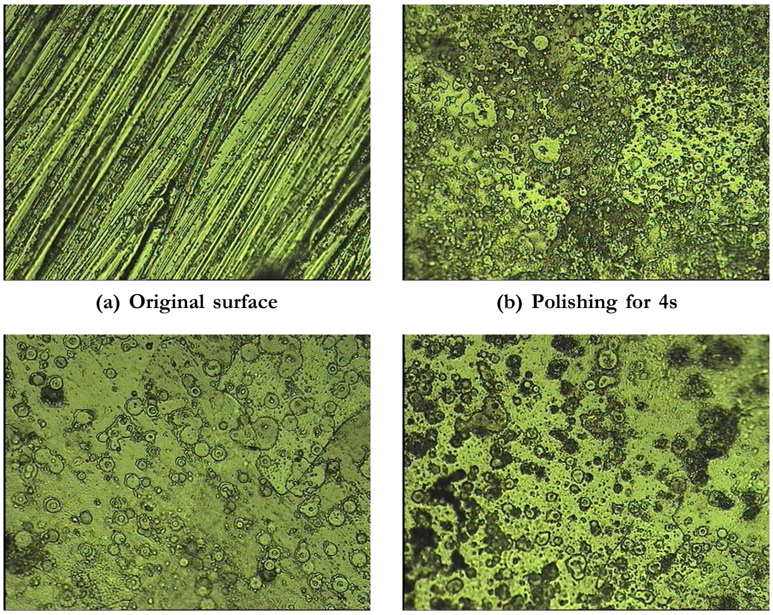

(a) Original surface (b) Polishing for 4s

(c) Polishing for 8s (d) Polishing for 20s

Figure 1: Photographs of surface morphology at different polishing time

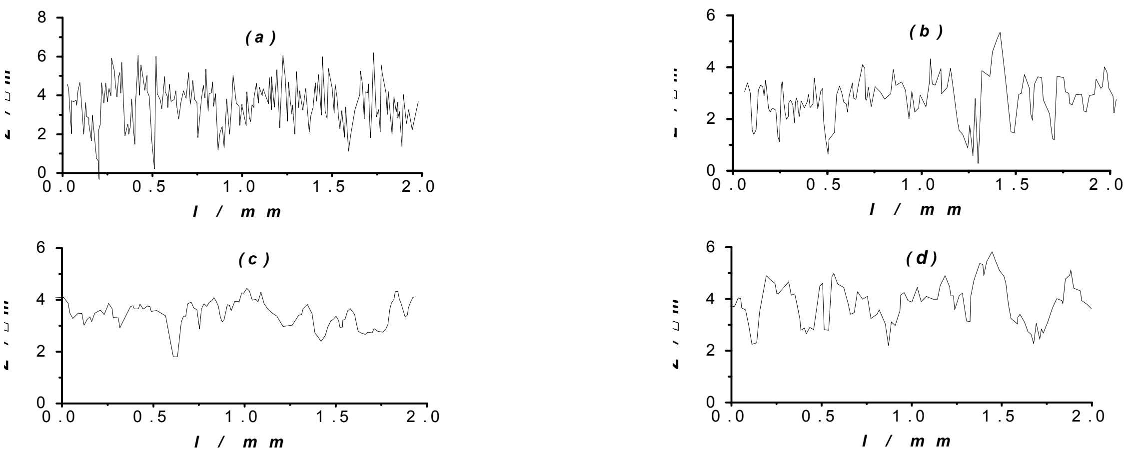

Figure 2: Plots of surface profile at different polishing time

(a) Original surface (b) Polishing for 4s (c) Polishing for 8s (d) Polishing for 20s

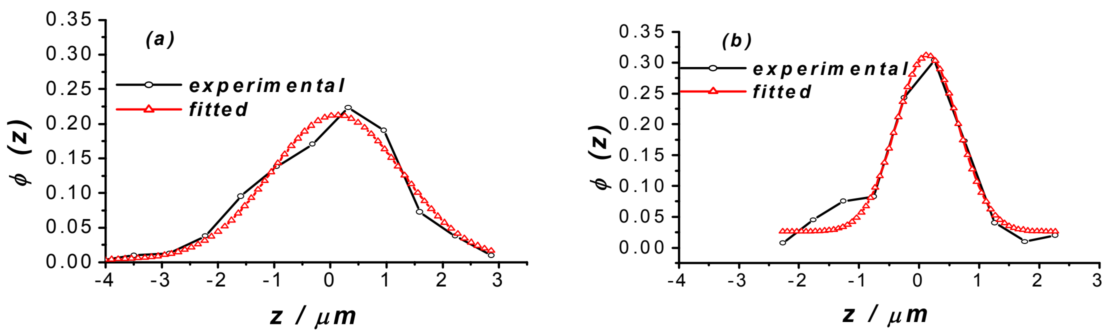

Figure 3 (a) and (b)

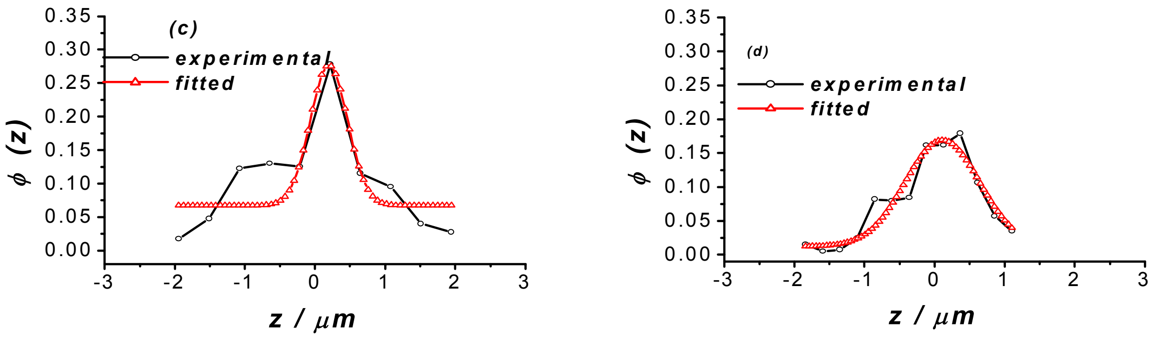

Figure 3: Variation of ADF in the process of ECP
(a) Original surface (b) Polishing for 4s (c) Polishing for 8s (d) Polishing for 20s

and (d) shows the features of surface after full ECP (polishing for 20s).

It can be seen from figure 3 that the distribution of ADF of the original surface is flat shown in (a). When ECP time is 4 s and 8 s, the distributions of ADF become steep that shown in (b) and (c), the distribution range of altitude probability density becomes narrow, and follows the Gauss distribution. When the time of ECP is 20 s (full ECP), the distribution of ADF is over again flat shown in (d). These indicate that the roughness of surface profile varies with the time of ECP. There is a fine surface quality in the special stage of ECP (4-8 s).

Corrosion resistance of the surface polished for different time

The electrochemical impedance spectroscopy (EIS) of the original surface under the static (quies-

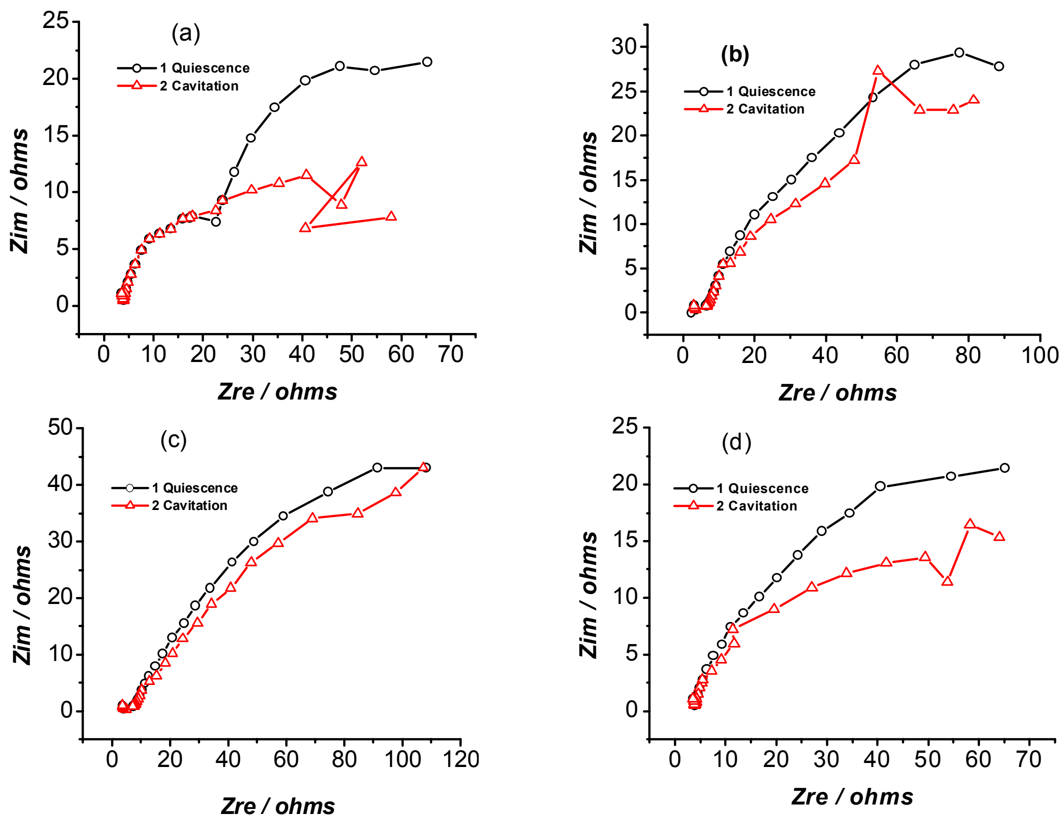

Figure 4: EIS of mild steel in different surface
(a) Original surface (b) Polishing for 4s (c) Polishing for 8s (d) Polishing for 20s

cence) and cavitation condition is shown in figure 4 (a). It can bee seen that the transmission resistance of the surface is 140Ω under the static condition, and is 70Ω under the cavitation condition, which reduces 70Ω compared with the surface under the static condition The result shows that the cavitation erosion resistance of the original surface is poor.

Figure 4 (b) shows the EIS of the surface polished for 4s in static and cavitation condition. Under the static condition the transmission resistance is 160Ω and under the cavitation condition the transmission resistance is 120Ω. Compared with the surface under static condition the transmission resistance decreases 40Ω than that of the surface under cavitation condition which indicates the cavitation erosion resistance of the surface polished for 4s improves.

The EIS of the surface polished for 8s in static and cavitation condition are shown in figure 4(c). The transmission resistance of the surface under static condition is 200Ω, and is 170Ω under cavitation condition, which reduces 30Ω compared with that of the surface under static condition. The results show the cavitation erosion resistance of the surface polished for 8s further improves.

The EIS of the surface polished for 20s (or called longer polishing time) under static and cavitaiton condition are shown in figure 4 (d). The transmission resistance of the surface changes to 150Ω under static condition, and changes to 100Ω under cavitation condition. The transmission resistance of the surface under cavitation condition decreases that indicates the cavitation erosion resistance of the surface polished for 20s not improves but reduces.

CONCLUSIONS

During the process of ECP, ADF for surface profile of mild steel varies with polishing time, and the tendency in variation of ADF is flat-steep-flat. The roughness of surface of mild steel varies with the time of ECP. In the primary stage, the convex peaks on the surface change gradually to small, it changes to the smallest in the middle stage. The roughness increases again at the later stage. There are fine surface smoothness and excellent cavitation erosion resistance at the polishing time from 4 s to 8 s. The surface becomes rougher which result in increase of corrosion and cavitation for the longer polishing time (20 s).

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