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EFFECT OF SURFACE ROUGHNESS ON CORROSION RESPONSE OF STAINLESS STEEL POLISHED BY ELID GRINDING METHOD

Jin Nagata [1], Jun Komotori [1], Kazutoshi Katahira [2], Hitoshi Ohmori [2]

[1] Department of Mechanical Engineering, Keio University, 3-14-1, Hiyoshi,
Kohoku-ku, Yokohama 223-8522, Japan
[2] The Institute of Physical and Chemical Research (RIKEN)

ABSTRACT

To clarify the corrosion resistance of a stainless steel having on ELID ground surface, electrochemical corrosion tests were carried out using a three electrode electrochemical cell connected to a computer driven potentiostat. After corrosion tests, morphologies of corroded surface and the corrosion products were analyzed by a Scanning Electron Microscope (SEM) equipped with an Energy Dispersive X ray analyzer (EDX). Excellent smooth surfaces can be achieved by the ELID grinding process when using extremely fine abrasives. The value of surface roughness (Ra) for the ELID ground sample is almost the same as that of the sample polished by using an alumina suspension. The corrosion properties of the ELID ground samples with smooth surface are superior to those of alumina polished specimen. This is attributed to the ELID grinding, producing a very thin and stable oxide layer which displays a superior corrosion resistance compared to that of the alumina polished samples. Consequently, the ELID process appears to offer significant future promise for use in bioimplant and other engineering components subjected to corrosion process.

KEYWORDS

Surface roughness, Corrosion response, Stainless steel, ELID grinding method

1. INTRODUCTION

The ELID (Electrolytic In-Process Dressing) grinding process, which incorporates in-process dressing of metal bonded superabrasive wheels, was applied for efficient and precision grinding of hard materials such as ceramic, optical glass and hard metals[1][2]. This method is a relatively new process using a rigid metallic bond with the assistance of a special pulse electrolytic in-process method. The wheel is electrolytically dressed during the grinding process for continuous protruding abrasives from the grinding wheel. Until now, mirror surface machining of optical and electronic components mainly have been performed by polishing and lapping, but these methods provide poor machining accuracy and very low efficiency. Excellent smooth surfaces can be achieved by ELID with the use of extremely fine abrasives.

To apply this process for bio-implant materials, it is very important to study the corrosion resistance of the materials finished by the ELID grinding process. However, few works[3][4] have been published on corrosion of the ELID ground materials. In this study, corrosion resistance of a stainless steel having different surface characteristics was examined with special focus on the effect of surface roughness on corrosion response.

2. EXPERIMENTS

2.1 Materials and surface treatment

The chemical composition of the material (type 316 stainless steel) used in this study is given in Table1. The configuration of the test specimen is shown in Fig.1. Prior to surface finishing, all the specimens were carefully degreased using acetone, and dried with hot air. The test specimens were then subjected to two surface finishing processes; (1) ground by the ELID grinding method, and (2) ground and polished by emery paper (400 to 2000 grit) and alumina suspension (0.3μm). The rotating speed of the wheel for ELID grinding was 100 rpm and applied pressure was 150kPa. Three types of cast iron diamond wheels were used with different sizes of abrasives (#325, #2000 and #8000 wheel). Fig.2 shows the construction of the proposed ELID grinding system. Fig.3 shows the schematic illustration of the ELID-grinding mechanism in order to maintain ultraprecision finish grinding with fine abrasives.

2.2 Corrosion test

Electrochemical corrosion tests were carried out using a three electrode electrochemical cell connected to a computer driven potentiostat. The potentials were referred to as a saturated calomel electrode (SCE). Approximately 500

Table1 Chemical composition of type 316 stainless steel (wt%)

C	Si	Mn	P	S	Ni	Cr	Mo	Fe
0.05	0.30	13.1	0.39	0.26	10.59	16.36	2.01	Bal.

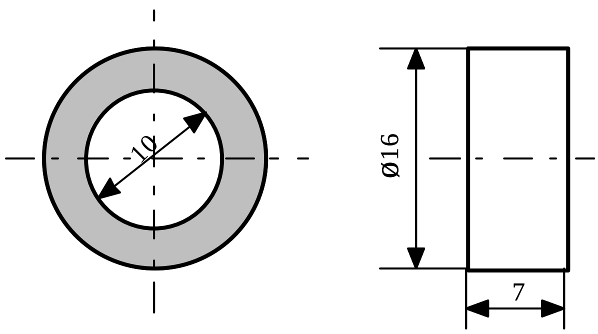

Fig.1 Specimen configuration

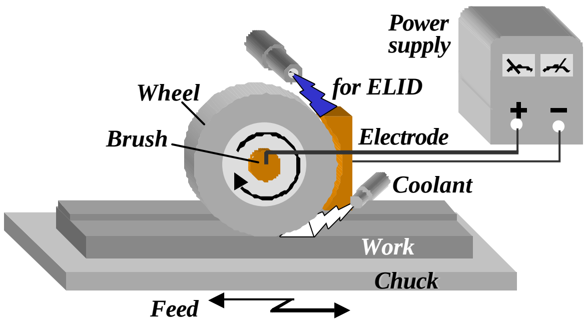

Fig.2 Principle of ELID grinding system[1]

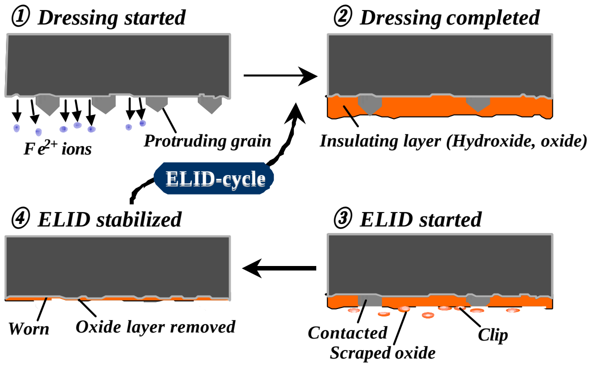

Fig.3 Schematic illustration of ELID-grinding mechanism[1]

ml of 3 wt% NaCl solution was used for potentiodynamic cyclic polarization testing. The corrosion potential (E_{corr}) of the sample was recorded without applying an external potential for 10 minutes. After holding the sample at the corrosion potential for 10 minutes, potentiodynamic cyclic polarization scans were commenced at a scan rate of 10mv/min. When the observed current density reached 1mA/cm^2, the anodic scan was stopped, the sample was then scanned in the cathodic direction, at the same scan rate, until the current density reached 0mA/cm^2. After corrosion tests, morphologies of corroded surface and the corrosion products were analyzed by a Scanning Electron Microscope (SEM) equipped with an Energy Dispersive X ray analyzer (EDX).

3. RESULTS

3.1 Surface characterization

Fig.4 shows a typical view of samples ground by the ELID grinding technique before corrosion test. A very smooth surface was observed for the specimen ground with a #8000 wheel (#8000 series). Detailed observations were also carried out using SEM. The surface ground with a #325 cast iron diamond wheel (#325 series) exhibited very distinct patterns due to the grinding grooves. In the case of the #8000 series, however, an excellent smooth surface finish was achieved.

To quantify the surface conditions, the surface roughness (Ra) was measured by using a Laser Scanning Microscope. Comparison of surface roughness for the specimen with different surface finishings is given in Fig.5. This result indicates that the surface roughness of the #8000 series is the same as that of the alumina polished specimen (alumina

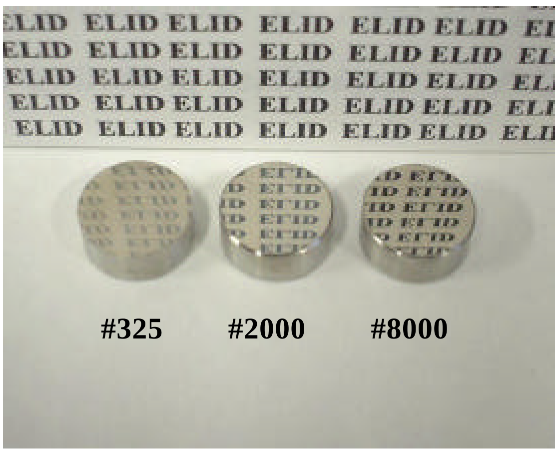

Fig.4 View of the resultant specimen (ELID series)

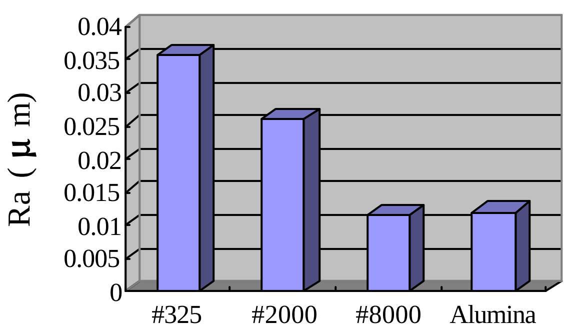

Fig.5 Comparison of surface roughness for the specimen with different surface finishings

series) ; these values are less than that of other ELID ground specimens.

3.2 Corrosion test

3.2.1 ELID ground specimen

Potentiodynamic polarization tests were carried out for the ELID ground specimen (Fig.6). During the anodic sweep of the test, the passive current densities of the specimens ground with the #2000 and the #8000 wheel, occurred in the applied potential range of 0.1 to 0.4 V vs S.C.E. The passive current density (I_{pass}) for #8000 series was higher than values observed for the #2000 series. No passive current density was observed for the #325 series with a relatively rough surface.

Pitting potential (E_{pit}) for the #8000 series was higher compared to the #325 and the #2000 series. Here, Epit is defined as the potential in which current density rapidly increased. This means that the corrosion property is superior with the scale of abrasives decreased. Fig.7 shows SEM micrograph of a pit observed after corrosion test. The corrosion pit generated along the grinding grooves. These results support the idea that the corrosion reaction is affected by the surface roughness.

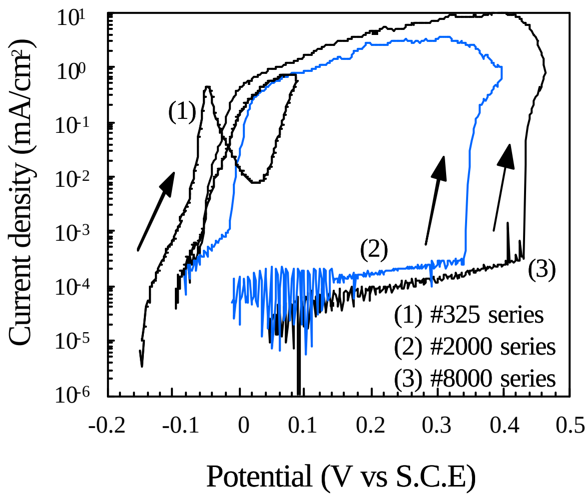

Fig.6 Anodic polarization curves of stainless steel for ELID ground specimen

Fig.7 SEM micrograph of the corrosion pit

3.2.2 Alumina polished specimen

Additional potentiodynamic polarization tests were carried out for the alumina polished specimen. Fig.8 shows the polarization curves, together with the results for the ELID ground specimens. This result indicates that the corrosion property of the #8000 series is more superior than that of the alumina polished specimen. Besides, the value of the surface roughness on the ELID ground specimen is the same as that on the alumina polished specimen.

4. DISCUSSION

Table2 summarizes the values of E_{corr}, E_{pit} and I_{pass} observed from the potentiodynamic polarization tests (Fig.6 and Fig.8). Remarkable differences in the values between the #8000 series and the alumina series are observed. To clarify the reason for this, a surface analysis was performed by using SEM and EDX. Fig.9 shows the results. The ELID ground sample had a high value of carbon and oxygen. This implies that the surface of the ELID ground sample was covered with some kind of oxide film ; existence of the film leads to an excellent corrosion property on the ELID ground specimen.

With ELID grinding, in the small clearance between the two poles, electrolysis occurs upon supply of a chemically soluble grinding fluid and an electrical current. It could be suggested that chemical reactions between oxygen and the heated specimen, due to the ELID grinding, results in the existence of oxide film.

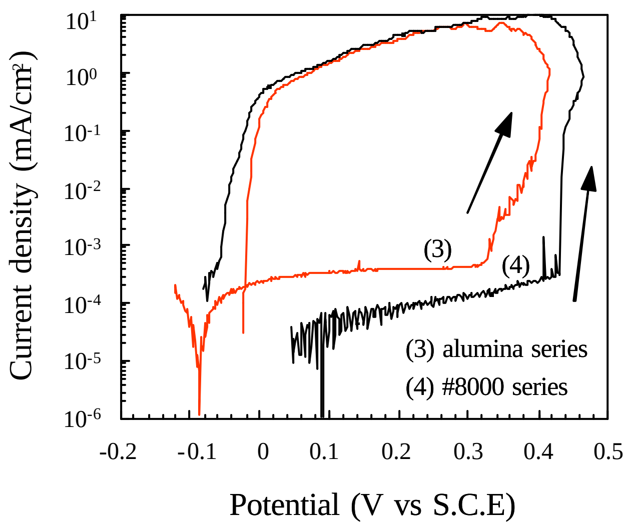

Fig.8 Anodic polarization curves of stainless steel for the specimen with different surface finishings

Table2 Polarization test results on surface finished stainless steel

	Ecorr (mV vs S.C.E)	Epit (mV vs S.C.E)	Ipass (10^{-4} mA/cm^2)
#325 series	-142	52	-
#2000 series	-23	330	2.00
#8000 series	43	427	0.86
alumina series	-131	310	3.32

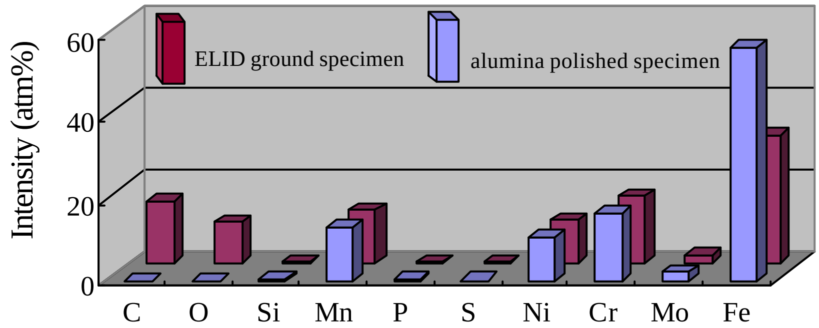

Fig.9 EDX pattern of the ground surface

5. CONCLUSION

In the present study, to clarify the effect of surface roughness on corrosion response of type 316 stainless steel, the ELID grinding method was used as the surface finishing process. Two surface finishing processes were evaluated: (1) the ELID grinding method, (2) alumina polishing method. Results are summarized as follows.

(1) Excellent smooth surfaces can be achieved by the ELID grinding process when using extremely fine abrasives. The value of surface roughness (Ra) for the ELID ground sample is almost the same as that of the polished sample by using an alumina suspension.

(2) The corrosion properties of the ELID ground samples with smooth surface are superior than those of the alumina polished specimen. This is attributed to the ELID grinding, producing a very thin and stable oxide layer which displays a superior corrosion resistance compared to that of the alumina polished samples.

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