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By N. E. Miller and D. E. Engelhaupt

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The Bendix Corporation
Kansas City Division
P. O. Box 1159
Kansas City, Missouri 64141

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By N. E. Miller and D. E. Engelhaupt

The Bendix Corporation, Kansas City Division*

Equipment has been developed to electromechanically polish metal spheres. Mechanical polishing is accomplished by the action of three cup-shaped laps which rotate against the sphere. An abrasive slurry containing an electrolyte is continuously applied to the sphere and laps. Electrochemical etching is accomplished by applying a positive potential to two of the laps and a negative potential to the third.

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Preparation of metallographic samples can be difficult when low wear rates are obtained during mechanical polishing. An effective technique for low wear rate samples is electromechanical polishing in which mechanical polishing is used with simultaneous electrochemical etching. Electromechanical polishing normally is done on flat samples. However, equipment (shown schematically in Figure 1) has been developed to polish spheres electromechanically.

Mechanical polishing of spherical specimens is accomplished by the action of three cup-shaped laps that rotate against the sphere. The axes of the three laps are equally spaced around the sphere in the horizontal plane. Abrasive slurry flows onto the top of the sphere; the used abrasive slurry drains from the bottom. One of the laps rotates about a fixed axis and controls the position of the sphere. The other two laps are supported on pivot balls and are loaded against the sphere surface by air pressure. The two air-loaded laps are self-aligning. Flanges on the air-loaded laps counterbalance the weight of the laps and part of the weight of the sphere, so that all three laps impose the same load on the sphere. The sphere moves relative to the laps. By periodically stopping the rotation of one of the laps, wear is distributed uniformly over the sphere surface. Using this technique, sphere roundness of less than $0.5 \mu\text{m}$ is obtained routinely.

The abrasive slurry contains an aqueous electrolyte and is applied at room temperature so that the sphere and laps are continuously covered with electrolyte. The laps are conductive but are fitted with an insulating sheath around the outside diameter to direct the current through the sphere. The faces of the laps are covered with an inert polishing cloth which separates the conductive laps from the sphere. Anodic electrochemical etching is accomplished by applying a positive potential to two of the three laps and a negative potential to the third lap. Anodic etching of the sphere takes place at the lap with the negative potential. The use of two laps for the positive potential reduces the current density where etching is not desired and improves process control.

The electrochemical sphere polishing machine was used to polish 25-mm-diameter molybdenum alloy spheres. The spheres were machined from bar stock and were rough lapped before polishing. For polishing 25-mm-diameter spheres, the two air-loaded laps were rotated at 18.8 rad/s and the rigid axis lap was rotated at 1.9 rad/s. Rotation of one of the air-loaded laps was interrupted for 0.8 s out of every 2.5 s to obtain uniform wear. The air load on the laps was 10.5 N. The laps were made of 304 stainless steel with a paper-filled phenolic sheath. The outside lap diameter was 21.6 mm, and the inside diameter was 16.5 mm. The lap faces were cut at a 45-degree angle with respect to the lap axis and were covered with fiberglass cloths. An alkaline electrolyte of potassium carbonate in distilled water (500 g/L

concentration) was mixed with two sizes of aluminum oxide abrasive ($0.3\ \mu\text{m}$ and $0.05\ \mu\text{m}$) in a volume ratio of 4:1:1 and dripped continuously on the sphere and laps. As shown in Figure 2, the wear rate increased linearly with the applied direct current. At currents above 100 mA, electrochemical etching occurred much faster than mechanical polishing, and considerable grain relief resulted. Below 100 mA, mechanical polishing controlled formation of grain relief, and a highly polished surface was obtained; the grain orientation of the bar stock from which the sphere was machined was not detectable.

Potassium carbonate was selected as the electrolyte because of its high solubility and conductivity, which permits a lower cell voltage ($\leq 24\ \text{V}$). This electrolyte minimizes chemical etching of the sphere in the absence of polishing current and minimizes corrosion of the associated equipment.

ILLUSTRATIONS

Figure

1 Electromechanical Sphere Lapping Machine

2 Effect of Etch Current on Wear Rate

Figure 1. Electromechanical Sphere Lapping Machine

Figure 2. Effect of Etch Current on Wear Rate