WEAR RESISTANT PERFORMANCE OF ION IMPLANTED ALLOY STEELS

Arnold H. Deutchman and Robert J. Partyka

Ion Beam Materials Processing Corporation
2200 Lane Road, Columbus, Ohio 43220
U.S.A.

ABSTRACT

A series of alloy steel samples were implanted with nitrogen atoms and tested for wear resistant performance in a pin-on-disk wear test geometry. Samples six square centimeters in area were lapped, degreased, and implanted at room temperature in a vacuum of $7 \times 10^{-6}$ Torr at doses ranging from $1 \times 10^{17}$ atoms/cm$^2$ to $5 \times 10^{17}$ atoms/cm$^2$ at an energy of 40 keV. The samples were mounted in a pin-on-disk wear test apparatus, subjected to a 10 psi normal force and run unlubricated for up to 300,000 feet of linear travel. Doses in the $1 \times 10^{17}$ to $5 \times 10^{17}$ atoms/cm$^2$ range produced a repeatable 3X decrease in sample wear rate for the first 50,000 feet of travel. Samples both gas carburized and then implanted showed an additional repeatable 2X decrease in wear rate for the first 50,000 feet of travel compared to non-carburized, implanted samples. In addition to laboratory wear sample test data, results from implanted steel dies used in a plastics extrusion production environment, and preliminary results from ion implanted tungsten carbide tools are reported.

INTRODUCTION

The ion implantation of nitrogen into carbon, alloy, and tool steels has been shown to increase the resistance of these materials to abrasive and adhesive wear in both lubricated and unlubricated wear situations. Wear reduction factors from 2 to 10 times that of the untreated base metals have been reported from pin-on-disk type sliding wear tests (1,2,3,4). These observed increases in wear resistance have been attributed to an increase
in the hardness of the steel surfaces which could be brought about by the introduction of mobile interstitial nitrogen and the formation of iron nitrides. In order to study the hardness and wear resistant properties of the very shallow surfaces layers produced by ion implantation, testing of implanted samples in a controlled laboratory environment, and testing of implanted components in an actual industrial production environment was completed.

A series of alloy steel samples were implanted and tested in a pin-on-disk wear test system. The samples were run in an unlubricated state in order to duplicate the actual conditions found in most plastic and some metal extrusion applications. The optimum implanted doses and energy previously reported in the literature (5) were verified, and the process of ion implantation was next applied to actual industrial components. A series of various components including steel dies and drills and tungsten carbide dies and drills were implanted and tested under actual factory production conditions. The tests showed component life increases ranging from 2X to 10X and also led to an estimate of the maximum operating temperatures for nitrogen implanted steel and tungsten carbide tools and dies.

LABORATORY SAMPLE TESTING

Sample Preparation and Implantation

Six sets of three samples each were prepared for laboratory pin-on-disk testing. Each 2 X 1/2 X 3/4 inch sample was machined from the same 4140 alloy steel bar stock. The Rockwell hardness of the alloy steel was approximately R_C = 44. All eighteen wear samples were lapped with #400 and #600 silicon carbide grit and then polished to a semi-lustrous finish with crocus cloth. The samples were then degreased in trichloroethylene and ultrasonically rinsed in methanol.

Three individual treatment protocols were studied. In the first protocol three samples were implanted with a dose of 1 X 10^{17} atoms/cm^2 and performance tested against three unimplanted samples. In the second protocol three samples were implanted with a dose of 5 X 10^{17} atoms/cm^2 and performance tested against three unimplanted samples. And in the third treatment protocol six samples were gas nitrided and three of the six were also implanted with a dose of 5 X 10^{17} atoms/cm^2 to study possible synergistic effects. All nitrogen implantations were done with the samples mounted in a water cooled aluminum fixture held at room temperature in Ion Beam Materials Processing Corporation's five cubic foot ion implantation system shown in Figure 1. All nitrogen implantations were done at an energy of 40 keV and with a