PALM

Hardness and Wear Resistance of Electroless Nickel-Teflon Composite Coatings

by Ronald N. Duncan

Teflon is one of the most lubricious materials presently available. Unfortunately, it is also quite weak and has poor resistance to wear. The combination of the polymer, however, with a strong, supporting matrix of electroless nickel, helps overcome these problems and provides a composite with excellent frictional properties.

Typically, Teflon composites contain 10 to 30% by volume of polytetrafluoroethylene (PTFE) particles in an electroless nickel matrix containing 5 to 10% by weight phosphorus. The particles have a nominal diameter of 0.3 to 0.4 μm and are uniformly distributed throughout the matrix. Accordingly, unlike impregnated coatings, as the composite is worn, a fresh supply of PTFE is exposed, maintaining a low coefficient of friction. This is typically 0.1 to 0.2 for nonlubricated conditions.

The addition of soft particles to an electroless nickel deposit, however, can significantly reduce the coating's hardness. In some cases, this can also lower its wear resistance. This paper will describe the results of tests conducted to quantify this reduction in hardness, and will discuss its effect upon the wear and load bearing characteristics of the coating.

PROCEDURE

In order to evaluate coatings with different Teflon contents, specimens were plated in solutions made with different concentrations of a commercial PTFE and surfactant dispersion. In some cases, experimental dispersions containing different surfactants or surfactant concentrations were also used. All the dispersions were added to an electroless nickel plating solution of the type producing deposits containing 10.5 to 11.5% phosphorus by weight.

Most of the solutions were operated in a 50-liter polypropylene tank, with pumped solution agitation. Some of the experimental solutions were plated in 1- or 4-liter glass beakers, heated on a hot plate and agitated with a magnetic stirring bar. Air agitation was not used with any of the baths. In general, the solutions were operated at 90°C and 4.8 to 5.0 pH.

The specimens plated for microhardness testing were single edge razor blades made of 1080 steel. Those for abrasive wear tests were standard commercially available mild steel panels. The coating thicknesses were typically 20 to 25 μm, although occasionally coatings as thick as 80 μm, or as thin as 12 μm were tested.

After plating, one half of most of the hardness specimens and all of the panels were heat treated, usually at 350°C for two hours. Higher temperature treatments were not investigated because PTFE begins to degrade at temperatures approaching 400°C.

TESTING

The Teflon content of the different coatings was determined by dissolving a known weight of each deposit in nitric acid, and then filtering the particles out of the solution on a weighed, 0.1 μm membrane. The phosphorus content of the electroless nickel matrix was also determined by conventional colorimetric analysis. This was typically 9.5 to 10% by weight.

Prior to hardness testing, the specimens were coated with a thick layer of copper to help support the coating. Microhardness testing was conducted generally in accordance with ASTM Standard B-578-87, using a Vickers diamond indentor. The load used for each test was varied to provide the largest practical indention, which could be supported within the coating's thickness. Normally this was 50 grams, but for some of the thinner deposits, the load had to be reduced to 20 or 25 grams. While tests made with different loads are not totally comparable, they are similar enough to allow different coatings to be compared.

The Taber wear tests were conducted in accordance with industry standards, i.e. the panels were abraded with CS-10 bonded wheels, under a 1000 gram load, for six 1000-cycle periods. The wheels were cleaned and redressed before each segment. The panels were weighed to the nearest 0.1 mg, before and after each increment, so that their weight loss and Taber Wear Index could be determined.

RESULTS

These tests confirmed that the hardness of composite coatings is dependent upon the volume of PTFE present. Increasing the Teflon content of the deposit decreases its hardness in both the as-deposited and heat treated conditions. This effect is summarized in Fig. 1.

In the as-deposited condition, the hardness of coatings with 14 to 16% PTFE is typically 350 to 400 VHN, while those containing about 25% particles is only about 275 VHN. After heat treatment at temperature above 300°C, this can be increased to 625 to 700 VHN and 400 VHN respectively.

The results of the Taber Wear tests showed a trend similar to that of the hardness tests. As shown in Table I, as the Teflon content of the deposit increased, so did the amount of material abraded away. At 25% PTFE, the loss of the heat treated composite is only slightly less than that of regular electroless nickel, which has not been heat treated.

DISCUSSION

The addition of Teflon particles to electroless nickel reduces hardness and wear resistance because it reduces the effective load bearing area of the coating. For example, at a PTFE content

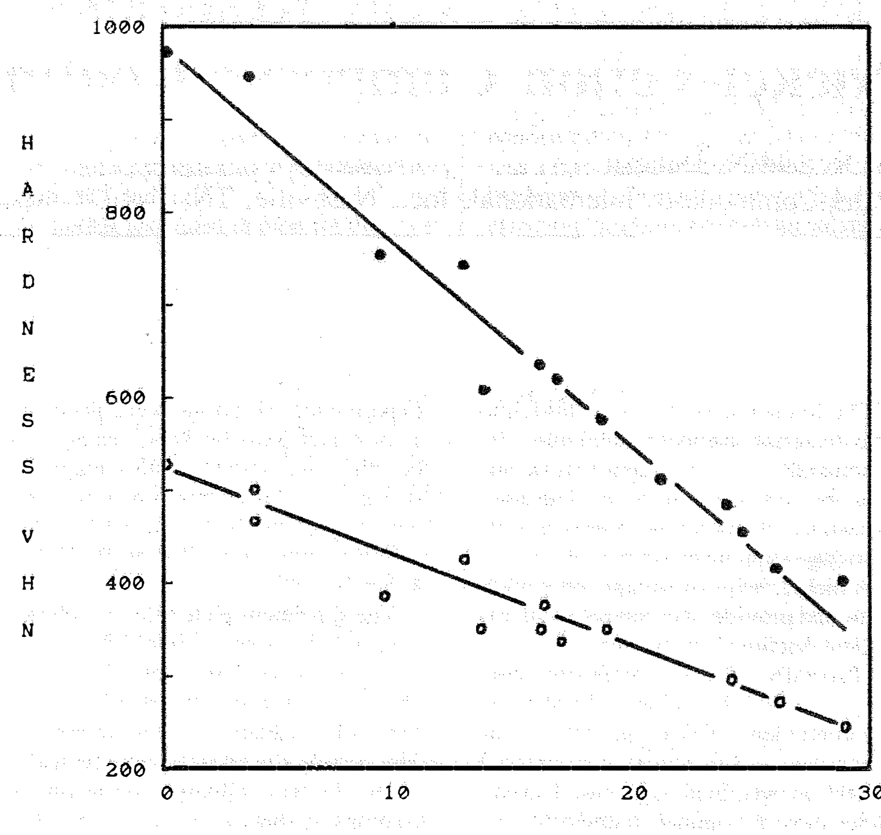

Fig. 1. Effect of Teflon content on the hardness of composite coatings.

of 15%, the cross sectional area of the deposit is reduced by 25%. With 25% particles, the reduction is nearly 60%.

The polymer has little strength and thus, structurally, Teflon composites begin to resemble a sponge. Even though the electroless nickel matrix may have its normal hardness, as soon as a load is applied to it, it begins to crush, allowing the indentor to penetrate deeper and wider. Similarly, there is less metal available on a wear surface to resist the action of an abrasive, and so the coating is torn away more rapidly.

In different wear regimes, increased wear may not always occur. In adhesive wear, especially in applications of marginal lubrication, the loss of hardness and strength may be offset by the increased lubricity provided by the Teflon. In this case, wear may actually be reduced.

CONCLUSION

The hardness and wear resistance of Teflon composite coatings can be greatly reduced by the presence of PTFE particles. Accordingly, oftentimes it may be necessary to compromise to obtain a balance of lubricity and hardness. With paper handling machinery, it might be desirable to select a coating containing 15% PTFE instead of 25%, and a lesser degree of lubrication, in order to retain hardness and reduce wear. With molds, however, it may be necessary to permit increased wear in order to obtain the better release properties of high Teflon composites.

Table I. Effect of Teflon Content on the Wear Resistance of Composite Coatings

Teflon Content,%	*Hardness, VHN*	*Taber Wear Index mg/1000 cycles*
0	980	12
9.5	750	12.5
14	600	13.5
25	450	16

Specimens heat treated at 350°C for two hours.

Ronald N. Duncan

BIOGRAPHICAL SKETCH

In Memory of Ron Duncan

Ron Duncan served as Vice President of Palm International, Inc., where he led the company's technical and educational initiatives. Prior to joining Palm, he was Director of Research at Elnic, Inc., focusing on electroless nickel formulation and materials research.

Before entering the metal finishing industry, Ron spent 12 years in the oil sector with Exxon and Caltex Petroleum Corporations, tackling materials and corrosion challenges. His work took him across the globe—including the United States, Middle East, Europe, South America, and Africa—where he developed a reputation for his deep expertise and practical problem-solving.

Ron held a BE in Mechanical and Metallurgical Engineering from Vanderbilt University. He was a Registered Professional Engineer and a certified Corrosion Specialist through NACE. A leader in technical standards, he chaired NACE task groups T-1G-19 and T-6A-53, contributing to authoritative reports on electroless nickel and other metallic coatings. He also served on the AESF's Electroless Committee.

Throughout his distinguished career, Ron authored more than fifty technical papers on corrosion, coatings, and electroless nickel. His work appeared in Materials Performance, Plating and Surface Finishing, Metals Progress, Products Finishing, and Finishers Management, as well as in numerous industry conferences. He was the principal author of the electroless nickel chapter in Volume 5 of the Metals Handbook and was honored with the AESF Gold Medal in 1996 for the best paper published in Plating and Surface Finishing.

Ron also directed the Electroless Nickel School, a comprehensive four-day seminar presented by Palm, which educated professionals in all aspects of electroless nickel technology.

Ron Duncan passed away on December 15, 2006. He is deeply missed by his family, colleagues, and the broader surface finishing community. His legacy of innovation, mentorship, and integrity continues to inspire all who had the privilege of working with him.