

and Origin of Wear Particle from Boundary Lubrication with a Zinc Dialkyldithiophosphate," *Wear*, Vol. 93, 1984, pp. 117-126.

36 Ives, L. K., "An Extraction Replica Method for the Study of Surface Films," ASLE Reprint No. 84-AM-1A-3, 1984.

37 Begelinger, A., de Gee, A. W. J., and Salomon, G., "Failure of Thin Film Lubrication," *ASLE Trans.*, Vol. 23, 1980, pp. 23-34.

38 Jahanmir, S., Abrahamson, E. P., II, and Suh, M. P., "Sliding Wear Resistance of Metallic Coated Surfaces," *Wear*, Vol. 40, 1976, pp. 75-84.

39 Weast, R. C., *Handbook of Chemistry and Physics*, CRC Press, Cleveland OH, 1973, B-192.

40 Baldwin, B. A., "Effect of Temperature on Simulated Valve Train Wear," *ASLE Trans.*, Vol. 36, 1983, pp. 445-454.

41 Jahanmir, S., Suh, N. P., and Abrahamson, E. P., II, "Microscopic

Observations of the Wear Sheet Formation by Delamination," *Wear*, Vol. 28, 1974, pp. 235-249.

42 Sakurai, T., Ikeda, S., and Okabe, H., "The Mechanism of Reaction of Sulfur Compounds with Steel Surface During Boundary Lubrication," *ASLE Trans.*, Vol. 5, 1962, pp. 67-74.

43 Sakurai, T., and Sato, K., "Study of Corrosivity and Correlation Between Chemical Reactivity and Load Carrying Capacity of Oils Containing Extreme Pressure Agents," *ASLE Trans.*, Vol. 9, 1966, pp. 77-87.

44 Allum, K. G., and Ford, J. F., "The Influence of Chemical Structure on the Load Carrying Properties of Certain Organo-Sulfur Compounds," *J. Inst. Petrol*, Vol. 51, 1965, pp. 145-161.

45 Forbes, E. S., "The Load Carrying Action of Organo Sulfur Compounds," *Wear*, Vol. 15, 1970, pp. 87-90.

DISCUSSION

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Dr. Jahanmir has presented a very important contribution to the wear mechanism of ZDDP.

The surface chemical films created by the friction is shown here to be important in determining the amount of wear.

Two types of behavior appear: one is the antiwear, one is the prowear. The data presented here show clearly that in the two cases, the chemical composition is different and the role of sulfur is particularly relevant.

Wear rate of one specimen can be attributed

— to the wear rate of the film itself, due to the shearing process

— and to the wear rate due to formation of these films (like corrosion process). Mechanical properties of the film may be important and hardness measurement can provide valuable information. But adherence properties of the film is a very important property and I am very interested in the fact that with the film with the high sulfur content, a diffusion layer is present which certainly increases the adherence of the film. The comment of the author will be appreciated.

You present some high resolution Auger results, related to P and S, given precious information on the nature of the films. This point is very important. Could you please give more details on results and spectra.

NOTE: The closure by Dr. Jahanmir will be published in the January 1988 issue of the JOURNAL OF TRIBOLOGY.

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