

**Effects
of
Mechanical
Stiffness
and Vibration
on Wear**

Raymond G. Bayer
editor



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Foreword

This publication, *Effects of Mechanical Stiffness and Vibration on Wear*, contains papers presented at the Symposium of the same name, held in Montreal, Quebec, Canada on 18 May 1994. The symposium was sponsored by ASTM Committee G-2 on Wear and Erosion. Raymond G. Bayer, Consultant, presided as the symposium chairman and is the editor of the resulting publication.

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Overview

This Special Technical Publication, (STP) is one of a extensive series of publications on wear, erosion, and friction that have been sponsored by ASTM Committee G-2 on Wear and Erosion. Typically these publications have been used to document the papers presented at the symposia that the committee has held on various testing and testing related aspects of these subjects. The G-2 committee has used a continuing program of symposia and workshops to advance the state of the art of wear, erosion, and friction testing and to identify needed activities in these and related areas. The associated STPs provide a means of documenting the current state of the art and serve as a convenient reference for those interested in the subjects of wear, erosion and friction testing. Originally suggested by A. W. Ruff, the effects of mechanical stiffness and vibration on wear in test devices and applications was considered by the committee to be an appropriate subject for this program. The symposium, entitled "Effects of Mechanical Stiffness and Vibration on Wear in Test Devices and Applications," was held May 18, 1994, in Montreal, Quebec, Canada, in conjunction with G-2's spring meeting.

The fact that vibrations can cause and modify wear is generally recognized, as is the fact that such vibrations are influenced by the mechanical stiffness of a test apparatus or machine. Such factors are often cited as possible contributors to the scatter in wear test results obtained with different machines or between laboratories or as reasons for the lack of correlation between laboratory tests and field performance. While this is the case, there is not a well developed literature associated with the effects of vibrations and stiffness on wear. Scattered information and papers can be found in various tribological and related publications, but there appears to be a lack of publications focusing on such effects, particularly as they relate to testing. Because of this and the potential significance of vibrations and stiffness in wear testing, the committee decided it would be worthwhile to hold a symposium and publish an STP on the effects of these two factors on wear behavior. It was hoped that this would attract papers that would provide an overview of current activity and knowledge in this area and serve as a nucleation point for committee activity. If successful in doing this, it was felt that the resulting STP would be a significant contribution to the literature on effects caused by these two factors and serve as a useful and needed reference.

These goals were achieved. A good mix of papers was received, resulting in a reference STP that contains an overview of the fundamentals aspects, examples of the influence of stiffness and vibration on wear, and illustrations of current experimental and analysis techniques used in the investigation of these effects. The reference of these papers also serve as an extensive bibliography on the subject. In addition a subcommittee has been formed in G-2 to address the effects of vibration in wear tests. The initial focus of that activity is on methods to characterize the stiffness of wear testers.

A general overview of how vibrations can modify contact situations is presented in the paper by Soom. In it he discusses how vibrations can modify loads and motions in the contact region and the implications of these modifications on wear and friction behavior. For example he discusses how vibrations can either reduce or increase wear and friction, and how vibrations and stiffness effects can produce changes similar to those associated with physical and chemical modifications of surfaces. In their paper Bryant and Lin provide a

specific example of some of the general concepts discussed in the Soom paper and illustrate some of the methods that can be used in the study of the effects of vibration. With respect to the latter the paper describes an interesting photoelastic method used to study the real area of contact and how it changes with vibrations. In this paper the authors show how the wear of carbon electrodes can be reduced as a result of vibrations modifying the real area of contact and influencing thermal mounding behavior. Thermal mounding is a wear mechanism frequently identified with the wear of brakes, brushes, and seals. The third paper also illustrates some of the general concepts involved. In this case the subject is concerned with induced vibrations superimposed on fretting motions. In this paper Vingsbo and Schon differentiate between self-induced and machine-induced vibrations. Self-induced vibrations are those that result from and are related to the contact conditions. Machine-induced vibrations are those that result from the properties of the machine containing the contact, that is, the wear test apparatus. A technique to measure these induced motions, which involves the comparison of transducer outputs, is described in the paper. A method for controlling system-induced vibrations in wear test equipment is also demonstrated.

The subject of machine-induced vibrations is further treated in the papers by Norton and Ault and their students and by Hagi and Gafitanu. In the former both a general method of analysis and an experimental approach is used to evaluate the effects of various design parameters on the dynamic loads of bearings in a four-bar linkage. These techniques are used to investigate the influence of coupler stiffness on bearing loads, which are found to be significant. The good agreement found between the experimental and analytical results indicates the usefulness of such analytical models in these types of studies. In the latter paper a methodology is presented for increasing spindle life in grinding machines by optimizing the preload conditions on the spindle bearings to minimize vibrations. In it a general methodology is proposed and applied to the spindle of a commonly used grinder. In this methodology an analytical method is used to relate bearing preload, static and dynamic stiffnesses, vibration level, and life. For the particular spindle analyzed, these relationships were also investigated experimentally. Good agreement was obtained between the analytical predictions and experimental results.

In the paper on orthopedic biomaterials, Waldman et al. provide an example of the characterization of a wear test in terms of the vibrational characteristics of the device. The motivation for their investigation was an attempt to understand the reason for scatter in the reported wear data for these biomaterials. Their results support the contention that vibrations can be a factor. They concluded that there was sufficient correlation between vibrational characteristics and dominant wear mechanisms that vibrational characterization of wear testers should be pursued. The last paper of the STP also provides another illustration of how vibrations can influence wear behavior. In this case Li discusses the effects that ultrasonic vibrations can have on tool life. This paper is concerned with an investigation of the interrelationships between machining parameters, vibrations, and tool wear. In this study it was found that vibrations decreased crater wear but increased flank wear. Models for these two effects are also presented in the paper.

Examples of the use of displacement sensors, transducers and spectral analysis to study vibrations in wear situation can be found in the papers by Bryant and Lin, Vingsbo and Shon, Hagi and Gafitanu, Norton et al., and Waldman et al.

This collection of papers clearly indicate the significance of vibrations to wear behavior and the potential effect they can have on wear test results. These papers also indicate that there are available analytical and experimental techniques that can be used for the study and characterization of vibrations and stiffnesses in wear tests. While this is the case, most current wear testers are not characterized in this fashion and such characterizations are generally

absent from standard wear test procedures. It would appear, therefore, that what needs to be done is to start characterizing wear testers in terms of their vibration and stiffness characteristic and to correlate these with the wear behavior obtained in such devices. Such activity would help to decrease the scatter associated with wear data, as well adding to our fundamental understanding of wear behavior.

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Symposium chair and editor.

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