Tribological Modeling for Mechanical Designers

Ludema/Bayer

EDITORS

STP 1105

STP 1105

Tribological Modeling for Mechanical Designers

Kenneth C Ludema and Raymond G. Bayer, editors

ASTM
1916 Race Street
Philadelphia, PA 19103

Library of Congress Cataloging-in-Publication Data

Tribological modeling for mechanical designers / Kenneth C Ludema and Raymond G. Bayer, editors.
(STP ; 1105)
Papers from a symposium held in San Francisco on May 23, 1990, and sponsored by ASTM Committee G-2 on Wear and Erosion.
Includes bibliographical references and indexes.
ISBN 0-8031-1412-5
1. Tribology--Mathematical models--Congresses. I. Ludema, K. C II. Bayer, R. G. (Raymond George), 1935- . III. ASTM Committee G-2 on Erosion and Wear. IV. Series: ASTM special technical publication ; 1105.
TJ1075.A2T725 1991
621.8'9'015118--dc20 91-8238
CIP

NOTE

The Society is not responsible, as a body, for the statements and opinions advanced in this publication.

Peer Review Policy

Each paper published in this volume was evaluated by three peer reviewers. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM Committee on Publications.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of these peer reviewers. The ASTM Committee on Publications acknowledges with appreciation their dedication and contribution of time and effort on behalf of ASTM.

Printed in Baltimore
October 1991

Foreword

This publication, *Tribological Modeling for Mechanical Designers,* contains papers presented at the symposium of the same name held in San Francisco, CA on 23 May 1990. The symposium was sponsored by ASTM Committee G-2 on Wear and Erosion. Professor Kenneth C Ludema of the University of Michigan in Ann Arbor, MI and Raymond G. Bayer of IBM in Endicott, NY presided as symposium chairmen and are editors of the resulting publication.

Contents

Overview

Purpose

The symposium for which the following papers were written was organized out of the recognition that those tens of thousands of mechanical designers who design consumer products need far better information than they now have when they design mechanical components for wear life. They have equations (tables, graphs, guidelines, etc.) for the analysis of stresses, for vibration modes and natural frequencies, for rates of heating and cooling, and for most other phenomena - but very little for the wear life of products.

The needs of designers may best be seen in the dichotomy between the mechanical sophistication of machines and devices, and the fact that these devices are most often discarded because of mechanical wear. Tribological adequacy seems to be one of the last considerations in the design process if it is explored at all, and probably for good reason - it is very complicated. Tribological design requires knowledge of materials (including lubricants), surface making processes, running-in procedures and assembly procedures. The designer is handicapped because neither friction nor wear are intrinsic properties of material in any form, but rather are highly dependent on the mechanical system and how it is run. Most designers have been caught in attempting to upgrade products only to find that the new product fails too often. Some then attempt a test program, only to find that there is no correlation between test results and the functioning of production items.

Progress in wear modeling

The impetus for developing useful information on the wear properties of material comes mostly from those in research, referred to here as research tribologists. Their first priority Is to maintain research activities and write scholarly papers. By the nature of their work tribologists select relatively impractical materials and experimental parameters, and interact mostly with others who do the same. However, some tribological concepts have diffused into general design practice. The most common are equations for designing fluid film bearings. Further mature concepts have made their way into the design of rolling element bearings, belts, gears, pumps, etc. such that predictions can easily be made of functional product life. Whereas many mechanical devises can be built up with such components, many consumer products can not, because they must sell at the lowest cost. The majority of designers are connected with consumer products.

This is the third symposium on modeling for wear resistance, each with different sponsors. The first was held at Columbia University in New York City, December 17-19, 1986 (1) and the second was held at Argonne National Laboratories (2). These were attended mostly by researchers, and by invitation. These were serious efforts and much good information was exchanged. It may be seen from the proceedings of these symposia that each of the specialties in tribology communicates in very different and esoteric language, compared with the needs of designers.

The third symposium, the ASTM Symposium of May 23,1990 reported here, sought to meet the needs of designers. Authors were invited to show how the great chasm between research language and designers needs could be bridged. Perhaps the extent of the chasm may be seen in that only two authors from industry submitted papers. The great majority of the papers were written by research tribologists. The latter were written from the perspective of a physicist, a chemist, several in materials engineering, on specialist in solid mechanics and five mechanical engineers. The latter are "near" the design process, but do not often design consumer products.

Overview of the papers of the symposium

To a great extent the authors report that they have a long way to reach in order to reach designers. Designers have an equally long reach, but they have no better idea than do research tribologists which direction to reach. Our authors made a valiant effort to propel us toward sensible wear models. Most authors agreed on the nature of the problem and some offered specific improvements in the understanding of wear. In particular, some of the points made were the following, with editorial comment:

1. Research papers in tribology contain information that is rarely applicable to practical problems. The reasons may include:
    a. Terminology is a major point of confusion in the field. This is probably a consequence of the presence of several very different academic disciplines in the field.
    b. Research papers focus on very few of the operating variables and phenomena in real machines that control wear. Research papers range from the "near applied" to the fundamental, the latter often from the point of view of the atomic and molecular structure through the sliding interphase region.
    c. Attempts to harmonize the methods in the various specialized areas in tribology are largely philosophical and not well directed.
    d. Research results as presented seem to imply that the dual phenomena of friction and wear are uncoupled from each other and from considerations of the mechanical properties of the machinery holding the sliding pairs.
    e. Research results rarely provide information on the changes that occur at interfaces (debris formation and migration, eg.) over time.
2. The greatest advances in tribology have been made in capital products and machinery that are expected to last for a long time. The design of consumer products involves minimum cost for material and manufacture, which involves variables (surface roughness, materials variation, etc.) that have been inadequately studied.
3. Several wear models do exist but these are extremely limited in scope and applicability. Unfortunately, the limits of applicability of these models are rarely published. In fact, the literature would suggest, by virtue of the lack of comment, that the available models are universal in application. This is particularly misleading in designing wear tests when only those variables that appear in simple models are thought to be the controlling variables in all sliding systems.

4. Designing for wear resistance outside of the scope of the current limited models should be done primarily by empirical methods in the next decade. This is so because it is not reasonable to expect the many relevant and disparate variables in wear to be rationalized in the next decade, whether in the form of broadly applicable equations, models, algorithms or handbook entries. The same applies to wear tests as well as to the selection of materials.

   The empirical method includes:

   a. Gathering data from practical sliding elements over a reasonable range of controllable variables. The entire system, including the machinery surrounding the sliding surfaces, must be thoroughly characterized.
   b. A data base of research results, for equally well characterized laboratory systems should be (and is being) gathered
   c. Bench wear tests should be done but only after the results of the bench test are known to correlate very well with the results from the practical system being simulated.
   d. Special attention should be paid to wear debris and other residue - the manner in which sliding systems retain or flush out debris, which will depend on, among other things, specimen shape, vibration characteristics and duty cycles. Efforts should be made to trace the chemical and mechanical "pathways" by which the debris and residue was formed, transformed or ejected.

A significant fraction the efforts of research tribologists should be devoted to such empirical work.

Overall, tribology is seen to be a very broad and complicated topic. There is a major problem in communication across the field which should be addressed in the next decade. Research tribologists should devote some of their efforts to making their results useful, but designers should indicate what they need from research tribologists. Many more symposia on wear modeling must be held.

1. Approaches to Modeling of Friction and Wear, Proc. Workshop on the Use of Surface Deformation Models to Predict Tribology Behavior , Eds. FF. Ling and C.H.T. Pan, Springer-Verlag
2. Proc. of the International Workshop on Wear Modeling, June 16 and 17, 1988, Eds, F.A. Nichols, A.I. Michaels and L. Northcutt, DOE-Conf.-8806370, June 19,1989).

Ken Ludema
University of Michigan,
G.G. Brown Building
Ann Arbor, MI 48109-2125

ISBN 0-8031-1412-5