

# WEAR PROCESSES IN MANUFACTURING

*SHYAM BAHADUR AND  
JOHN H. MAGEE, EDITORS*

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# ***Wear Processes in Manufacturing***

*Shyam Bahadur and John Magee, editors*

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# Foreword

This publication, *Wear Processes in Manufacturing*, contains papers presented at the symposium of the same name held in Atlanta, Georgia on May 6, 1998. This symposium was also held in conjunction with the May 7–8 standards development meetings of Committee G-2 on Wear and Erosion, the symposium sponsor. The symposium was chaired by Professor Shyam Bahadur, Iowa State University; John H. Magee, Carpenter Technology, served as co-chairman. They also both served as STP editors of this publication.

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# Overview

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The importance of tribological phenomena in engineering has long been recognized. The evidence for this lies in the extensive studies on tool wear performed over many decades. The same is the case with studies related to the friction and lubrication in deformation processing as evidenced by a number of conferences and related publications. In spite of this, the interaction between the tribologists and manufacturing researchers has not been great. The objective of this symposium was to provide a forum for these researchers for a mutually beneficial interaction.

There are many manufacturing processes in which wear and friction play dominant roles. In the present era of increased productivity, processing at high speeds contributes to the rapid wear of tools. The current emphasis on quality also demands tighter tolerances, which requires, among other things, the use of tools with less wear. In forming processes the wear of tools and dies occurs because of the stresses needed to deform material and the difficulty of lubrication in high contact stress situations. In processes performed at high temperatures, lubrication is a serious problem because of the lack of suitable lubricants and the difficulty of maintaining a lubricant film between the contacting surfaces. The absence of good lubrication results in adverse consequences such as rapid tool wear, surface damage such as galling, and increased power requirement. The recognition of tool wear as the limiting factor for high speed machining and as the factor contributing to the impairment of surface integrity has caused tool companies to invest heavily in the development of wear-resistant tools for machining. There are processes such as grinding which use two-body abrasion mechanism for material removal. Similarly, superfinishing operations use three-body abrasion for achieving the desired surface finish. Finally, minimizing erosive wear damage on critical components is often the key to a successful manufacturing process.

The collection of papers published in this volume may be grouped into the following categories. These categories are: abrasion in ceramic grinding, wear of cutting tools, friction in vibratory conveyers, and erosion in manufacturing. A brief summary of the papers in each category is provided below.

## **Abrasion in Ceramic Grinding**

There were two papers presented in this category. One of the papers presented the two-body belt abrasion test for assessing quantitatively the grindability of new ceramic compositions. The test establishes a belt grindability index as the measure of grinding ease reported using the units of wear factor. A project funded by the US Department of Energy demonstrated that this test provided repeatable results which correlated well with the actual grinding behavior. The test is similar to one of the several abrasion testing geometries mentioned in the ASTM Standard G-132.

Using a similar test setup, another paper investigated the effect of variables such as belt speed, load, cutting fluid, and specimen rotation on the material removal rates in grinding. The cutting fluids investigated were mineral oil, water-glycol mixture, and biodegradable soybean oil. This paper presented the results of surface damage in grinding under different conditions and emphasized the detrimental effect of temperature rise in grinding.

### **Wear of Cutting Tools**

In this category, a maximum number of papers were presented. One of the papers presented the tool life study for face milling inserts under various cutting conditions, with and without coolant. The material used for machining was 4140 steel and the milling inserts were C5 grade. One of the main conclusions of the study was that coolant does not always enhance the tool life. Optical and scanning electron micrographs showing the tool wear were presented and the wear mechanisms were identified.

Another paper presented tool wear results from the machining of austenitic 303 and 304 stainless steels with varying carbon, nitrogen, and copper contents. It was demonstrated that tool life increased by increasing the copper and nickel contents and by decreasing the carbon and nitrogen contents. The results of this study are important from a practical standpoint because machining of austenitic stainless steels poses special problems particularly in regards to early tool failure.

There are three papers in this section that deal with the effect of coatings and/or other treatments on cutting tools. One of these investigated the wear behavior of cemented carbide and TiC-coated cemented carbide tools in turning operations under different cutting conditions. The data from these tests together with the data from literature is used in constructing the wear maps. The latter are drawn with cutting speed and feed rate as the machining parameters. This kind of information is useful in selecting the cutting conditions for extended tool life. Another paper investigated the machining of a high strength steel alloy with grooved inserts, coated with plasma and chemical vapor deposition (PVD and CVD) processes, for different combinations of cutting speeds and feeds. Apart from the generation of machining data, the focus in this study was on the wear mechanisms, failure modes and tool lives of the inserts. The authors found that surface finish improved with a mixed carbide grade of insert (WC + TaC), and multilayered CVD coating produced a better surface finish. The third paper dealt with the investigation of coatings, substrates and substrate treatments that would increase the life of cemented carbide slitter knives used to slit magnetic media from wide rolls into narrow product form. The treatments tried in this work were ion implantation, implantation of boron, titanium nitride PVD and CVD coatings, and diamond-like carbon (DLC) coating. It was concluded that the coatings failed because of inadequate adhesion between the coating and the substrate. The plasma enhanced CVD titanium nitride coating gave good results but it was not considered economical.

A paper in this section deals with the tribology of wood machining such as tool wear, tool-wood frictional interactions, and wood surface characterization. The studies included the identification of friction and wear mechanisms and modeling, wear performance of surface-engineered tool materials, friction-induced vibration and cutting efficiency, and the influence of wear and friction on the finished surface. Various wood species were investigated from soft pine to hard maple and the results revealed significant variations in the coefficient of friction, an important parameter when modeling chip formation.

### **Friction in Vibratory Conveyor**

In this paper, the problem of feeding connectors using vibratory conveyors to machines that assemble input/output (I/O) pins to the metallized ceramic substrate, as used in the computer industry, was studied. The motion of a single I/O pin on an in-phase, linearly oscillating conveyor using the classical model of friction was modeled and the results were compared with those from the experimental observations. The implications of these theoretical and experimental results are discussed in terms of the practical application of in-phase vibratory conveyors in manufacturing.



## **Erosion in Manufacturing**

One of the papers studied the wear of pipe materials as used in a pilot plant which transports DRI (Direct-Reduced-Iron) pellets at high temperatures in the manufacture of steel. Included in this study were also the new candidate materials for pipes. The materials tested were 304 stainless steel, high chromium white castings, hard coatings based on high chromium-high carbon alloys, cobalt alloys and aluminum oxide. The samples from both the pilot plant and laboratory showed that erosion was the dominant mechanism of wear. The next paper introduced an electrochemical technique to assess erosion in aqueous and other systems that involve an electrolyte as the erosion fluid. The potential and the usefulness of this technique to measure slurry erosion, fretting corrosion and cavitation were also discussed.

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