ELASTOHYDRODYNAMICS 96 (TRIBOLOGY AND INTERFACE ENGINEERING SERIES) pdf

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The new Series Editor is Professor Brian Briscoe of Imperial College London, currently Editor-in-Chief of Tribology International, and to reflect these developments the series has been renamed Tribology and Interface Engineering.

Tribology of metal cutting is, in some ways, the ugly beast that content providers â€” metal cutting researchers, tool and machine tool companies, market researchers and sales personnel, major manufacturing corporations and others â€” have wanted to keep in the closet. Global competition has forced the closet door open; really, it has eliminated the door itself. What used to be relatively simple and written as a set of postulates in texts on the subject is now uncomfortably complex. Historical Background The term tribology comes from the Greek word tribos, meaning friction, and logos, meaning law. The contact between two materials, and the friction that one exercises on the other, causes an inevitable process of wear. What those contact conditions are, how to strengthen the resistance of contact surfaces to the resulting wear, as well as optimizing the power transmitted by mechanical systems and complex lubrication they require, have become a specialized applied science and technical discipline which has seen major growth in recent decades. When it comes to metal cutting, tribology is thought of as something that has to be studied in order to reduce the tool wear and thus increase tool life. Although this is true x Preface in general, it does not exhaust the application of tribological knowledge in metal cutting. Unfortunately, the published books and articles on the subject do not treat the subject in a systematic way. Rather, the collection of non-correlated facts on tool materials, cutting regimes, tool life and its assessment, cutting fluids, tool coatings, etc. Having read the known works and related materials, one does not feel thoroughly equipped to analyze and improve the tribological conditions in various metal cutting operations. To proceed further and to comprehend the content of this book properly, one should clearly realize that the ultimate objective of metal cutting tribology is the reduction in the energy spent in metal cutting. Increased tool life, improved integrity of the machined surface, higher process efficiency and stability are the results of achieving this goal. Enormous sums of money are spent on research in tribology. The objective of this research is understandably the minimization and elimination of losses resulting from friction and wear at all levels of technology where rubbing of surfaces is involved. It is claimed, research in tribology leads to greater plant efficiency, better performance, fewer breakdowns and significant savings. Most of this wasted energy is spent at the toolâ€”chip and toolâ€” workpiece interfaces due to unoptimized tribological processes. This fact can be easily appreciated if one realizes that nearly all the energy spent in the cutting process is converted into thermal energy. Therefore, the temperature of a certain zone in the cutting system is a relevant indicator of the energy spent in this zone. This is because the energy spent generates heat, thus the higher temperature of a particular zone indicates greater energy spent in this zone. Therefore, most of the energy required by the cutting system is spent at the toolâ€”chip and toolâ€”workpiece interfaces. Unfortunately, this simple fact has been overlooked for years, so the deformation zone attracts much more attention from researchers in the field with less attention to the tribological aspects of metal cutting. Naturally, this energy spent at the discussed interfaces lowers tool life, affects the shape of the produced chip, and leads to the necessity of using different cooling media that, in turn, lowers the efficiency of the machining system as more energy is needed for cooling medium delivery and maintenance. The situation in metal cutting is entirely different from that in the design of tribological joints in modern machinery. In the latter, a designer is rather limited by the shape of the contacting surfaces, materials used, working conditions set by the outside operating requirements, use of cooling and lubricating media, etc. In metal cutting, practically any parameters of the cutting system can be varied in a wide range. Modern machine tools do not limit a process designer in his selection of cutting speeds, feeds or depth of cut. The nomenclatures of tool materials, geometries of cutting inserts and tool holders available at his disposal are very wide. The selection of cooling and lubrication media, and their application techniques are practically unlimited. Although the chemical composition of the work material is normally given as set by the designer, the properties of this material can be altered over a wide range by heat treatment, forging and casting conditions. The only problem in the selection of optimal tribological cutting parameters is the lack of knowledge on the metal cutting tribology. Therefore, study and optimization of the tribological conditions at these interfaces have a great potential in terms of reduction of the energy spent in cutting, increased tool life, reduction and elimination of coolants, etc. The optimization of tribological processes in metal cutting results in the following: Considering the energy transmitted through the tribological interfaces in metal cutting, one can select a tool material for a given application to assure the chosen performance criterion such as tool life, quality of the machined surface, efficiency, etc. Because the tool geometry largely defines the state of stress in the deformation zone, stresses, temperatures and relative velocities at the toolâ€”chip and toolâ€”workpiece interfaces, the optimized tribological parameters can be directly used in the selection of proper tool geometry. The machining residual stresses are determined by the tribological process taking xii Preface place at both the toolâ€”chip and toolâ€”workpiece interfaces. Therefore, one can control both the superficial and in-depth machining residual stresses over a wide range in terms of their sign, magnitude and distribution by controlling the tribological processes at the mentioned interfaces. The proper selection and application of a particular medium is only possible when true tribological mechanism of its action is known. The composition and chemistry of cutting fluids can be designed based on the Rebinder effect rather than on other properties cooling and lubricating as considered today of a particular cutting fluid. Uniqueness of this Publication There is a concern that some of the present cutting tool and process designers, manufacturing engineers and engineering students may not be learning enough about metal cutting tribology. Although containing some vitally important information, books to date do not provide methodological information on the subject that can be helpful in making critical decisions in process design, the design and selection of cutting tools, and the implementation of proper machine tool. The most important information is scattered over a great number of research and application papers and articles. Commonly, isolated experimental findings for particular test conditions are reported instead of methodology. As a result, the question: Therefore, a broad-based book is needed. The purpose of this book is twofold: First, it aims to summarize the available information on metal cutting tribology with a critical review of work done in the past and thus help specialists and practitioners to separate facts from myths. As shown, the major problem in metal cutting studies is the physically incorrect model used today. Other known problems are just consequences of the implementation of this model. In other words, one fundamental misconception has caused a chain reaction of implementation issues. Second, it intends to present, explain and exemplify a number of novel concepts and principles in the tribology of metal cutting such as the energy partition in the cutting system, physical efficiency of the cutting system and its practical assessment, versatile metrics of cutting tool wear, optimal cutting temperature and its use in the optimization of the cutting process, the physical concept of cutting tool resource, and embrittlement action of the cutting fluids. The major distinguishing feature of this book is that the practical ways of modeling and optimization of the cutting process are considered using two simple in- and postprocess parameters, namely, the cutting temperature and chip compression ratio that can be measured with sufficient accuracy not only at a research lab but also in the shop floor. Preface xiii This makes this book not just another book on the subject, but a practical guide for a wide variety of readers from machining shop practitioners to scientists in the field of metal cutting. For the first time, it attempts to present metal cutting tribology as a science that really works. Emphasis is placed on the practical application of the results in everyday practice of machining, cutting tool and machining process design. The application of these recommendations will increase the competitive position of the users through machining economy and productivity. It will help them to design better cutting tools and processes, enhance technical expertise and levels of technical services. Intended Audience The book is intended for four types of readers: How this Book is Organized The chapters that follow and their contents are listed below: Chapter 1 Generalized model of chip formation This chapter covers the history, merits and major drawbacks of the single-shear plane model. It is argued that the single-shear plane model is inadequate to explain the real cutting process. It lists and discusses the following principle drawbacks of the single-shear plane model: The chapter concludes that any progress in the tribology of metal cutting and in the prediction ability of metal cutting theory cannot be achieved if the single-shear plane model is still at the very core of this theory. Based on the introduced definition of the metal cutting process as a purposeful fracture of the layer being removed, it presents the realistic generalized model of chip formation xiv Preface suitable to analyze the tribological processes in metal cutting. The chapter reveals the influence of various factors on the chip structure and thus the tribological conditions. Chapter 2 Energy partition in the cutting system This chapter clarifies the energy aspects of metal cutting tribology. It is argued that although many tribological physical, chemical, etc. It considers for the first time the complete model of energy partition and flows in the metal cutting system. The chapter introduces the concept of physical efficiency of the cutting system as the ratio of energies spent on the separation of the layer being removed from the rest of the workpiece and the total energy required by the cutting system to exist. It demonstrates that physical efficiency can be determined knowing the stressâ€”strain curve of the work material, cutting regime and by measuring the cutting force. In a simple and physically grounded manner, the work of plastic deformation done in cutting is correlated with a measurable, post-process characteristic of the cutting process such as the chip compression ratio. The significance of chip compression ratio in the study and optimization of the cutting processes is revealed. Using these results, a practical analysis of the physical efficiency of particular cutting systems is presented and the influence of various parameters and properties on this efficiency is discussed. Two distinctive ways of increasing the physical efficiency of the cutting system are proposed. The first is based on the energy theory of failure and utilizes the interference of the coherent deformation and thermal waves to reduce the required mechanical energy. The second is based on the correlation between the state of stress imposed by the cutting tool in the layer being removed and the fracture strain of the work material. A systemic and systematic approach to the analysis of the tribological conditions at the toolâ€”chip and toolâ€—workpiece interfaces based on the generalized model of chip formation is presented, with the definition and determinations of basic tribological characteristics at these interfaces. The contact stresses, velocities and temperatures are considered. It explains why the similarity method, as compared to numerical methods, is much less sensitive to the particular model used in the thermal analysis of metal cutting. Preface xv The influence of various properties and parameters of the metal cutting process on its tribological characteristics is revealed. The stable and measurable tribological characteristics of metal cutting to be used in the meaningful selection of the parameters and characteristics of the cutting process are identified. Chapter 4 Cutting tool wear, tool life and physical resource This chapter argues that the existing measures and metrics of tool life and cutting tool evaluation suffer from severe drawbacks. The proper metrics for the assessment of cutting tool wear are presented and evaluated. It offers new effective characteristics of tool wear like the dimension wear rate and the relative surface wear rate. It introduces and explains the concept, physical background and significance of the optimal cutting temperature the first metal cutting law and its consequences as the temperature at which the combination of minimum tool wear rate, minimum stabilized cutting force and highest quality of the machined surface is achieved. The validity of the formulated law is illustrated for a vast variety of cutting conditions, work materials and cutting operations. Practical methods for the determination of optimal cutting temperature are offered. The influence of various parameters and characteristics of the cutting process such as the cutting speed, feed, depth of cut, parameters of cutting tool geometry, workpiece material and its diameter on tool life are quantified. Finally, it presents, explains and exemplifies a breakthrough concept of physical resource of the cutting tool in terms of the limiting energy passed through the cutting wedge. Chapter 5 Design of experiments in metal cutting tests This chapter challenges the existing standards, procedures and policies in metal cutting tests, particularly in the tool-life testing often conducted in tribological studies of the metal cutting process. It explores the methods of design of experiments DOEs in metal cutting. Particular attention is paid to the preprocess stage as the most important yet least formalized stage of DOE, where the most crucial decisions affecting the test outcome are made. It explains the basic terminology and requirements to the input and output parameters in DOE particularly to metal cutting. The complete system of metal cutting tests starting from the screening of the

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DOE is presented, which is implemented at the first stage of testing where the essential parameters are to be identified to the group method of data handling, where the problem of optimization of essential parameters is dealt with. A new sieve DOE is introduced, based upon the Plackettâ€"Burman design ideas, an oversaturated design matrix and the method of random balance. The proposed sieve DOE allows the experimentalist to include at the first phase of the experimental study as many factors as needed and then to sieve out nonessential factors and their interactions by conducting relatively small number of tests. The basic properties and qualities of GMDH are discussed and practical example of its application in tool life testing is presented. A detailed example of the introduced DOEs using deep-hole machining testing is provided. Chapter 6 Improvement of tribological conditions This chapter classifies the existing methods of improvement into components and the system methods.

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