A FINITE ELEMENT BASED TECHNIQUE FOR SIMULATING SLIDING WEAR

V. Hegadkatte\textsuperscript{1}, N. Huber\textsuperscript{2}, O. Kraft\textsuperscript{1,2}

\textsuperscript{1}Institut für Zuverlässigkeit von Bauteilen und Systemen, Universität Karlsruhe (TH), Kaiserstr. 12, D-76131, Karlsruhe, Germany.

\textsuperscript{2}Institut für Materialforschung II, Forschungszentrum Karlsruhe GmbH, Postfach 3640, D-76021, Karlsruhe, Germany.

\*Presenting Author
Vishwanath.Hegadkatte@imf.fzk.de

ABSTRACT

Micro-machines are known to fail prematurely due to excessive wear by virtue of their inherent high operating frequencies and high surface to volume ratio. In order to predict wear and eventually the life-span of such complex systems, several hundreds of thousand operating cycles have to be simulated. Due to the complexity of wear, the existing wear models are insufficient to reliably predict wear based on the material properties and the contact information. As a first step, a technique has been developed which involves post processing of the results from a finite element (FE) contact simulation with a simple wear model to compute wear. The technique can be used to simulate wear in a pin-on-disc set-up in order to improve and verify the wear models.

KEYWORDS: Wear, Wear Modelling, Wear Simulation, Pin-on-Disc, Micro-machines

INTRODUCTION

Wear is one of the major reliability issues of micro-machines. Commonly used experimental methods, like Pin-on-Disc, Scratch test or Atomic Force Microscopy (AFM) are not sufficient for a quantitative prediction of the progress of wear and eventually the life span of micro-machines. The strategy discussed in this paper makes use of a simple existing wear model, which is implemented within a FE based wear simulation tool. This technique allows for simulating pin-on-disc wear experiments with the goal to achieve a better understanding of the phenomena of the wear process. The approach applies both to the macro- and especially to the micro-scales. However, of special interest to the micro-scale applications is that the high contact pressures and sliding velocities encountered in micro-machines would result in high amount of wear in the relevant micro-tribological experiments. There exists hardly any possibility to improve the finishing of complex shaped micro parts, e.g. micro-gears, for adjusting the tolerances and the surface quality, which is another reason for the importance of a simulation tool that could predict the influence of the production process and its achievable tolerances on the lifetime of a micro-machine. The Wear-Processor can be used to develop a wear model and subsequently identify the included parameters by simulating micro-tribological experiments conducted within the parameter space of a certain micro-machine. With the wear simulation tool to be discussed in this chapter, we attempt to close the gap between in-situ wear measurements, standard tribological experiments and the actual operation of the micro-machine [1].

1. Operation of the Wear Processor

The wear simulation tool, henceforth known as the Wear-Processor is shown in Figure 1.1. The entire processes inside the dashed line represent the Wear-Processor. The contact geometry is explicitly modeled and appropriate material and friction properties are assigned. Also the appropriate boundary conditions are applied on the interacting bodies. The simulation of wear begins with the solution of the general contact problem of wear begins with the solution of the general contact problem (Contact Pressure)

\[ u_{\text{total}} = u_{\text{static}} + u_{\text{wear}} \]

where \( D \) is the local wear depth in the current step.

Figure 1.1: Flow chart of the Wear-Processor.
is the total linear wear up to the $j$th wear step, $h_{j-1}$ is the total linear wear up to the $(j-1)$th wear step and $\Delta s_j$ is the increment of sliding distance for the $j$th (current) wear step, $p$ is the contact pressure at each surface node and $k_D$ is the dimensional wear coefficient.

2. Simulation of wear in a pin-on-disc set-up

In principle, because of the generality of this method, wear on components for any material combination can be simulated as far as experiments are available. In this section, for a first demonstration, the Wear-Processor is applied for simulating wear on a loaded spherical pin sliding over a disc (“pin-on-disc”) as shown in Figure 2.1(a). The FE model is built using a very small slice of the pin and the disc in the contact region from that part of the pin-on-disc, which is within the dashed circle in Figure 2.1(a).

The progress of wear over the number of revolutions (proportional to the sliding distance) on the pin and the disc surfaces is shown in Figure 2.1(b). It can be seen that the slope of the wear curve for the pin is steadily decreasing, owing to the fact that the contact conforms and so the pressure continuously decreases (running-in).

CONCLUSION

A post processing scheme has been proposed with which wear in 3D contacting geometries can be simulated. The results from the wear simulation and the experimental observations are qualitatively in good agreement. Such a simulation tool is the first step to develop guidelines for material selection and micro-machine design. Part of that is to formulate requirements on the materials and production technology, so that a given life span can be achieved. The simulation tool determines the loss of material at the surface. Our goal is to further develop the tool to solve 2D transient wear problems, like e.g. in a micro gear. This will allow to study the continuous change of the kinematics of micro-machines as well as to obtain a more realistic stress analysis during their operating life time. Thus, the life span can be predicted more accurately both by the failure due to kinematics and the breakdown due to drastically risen loads resulting from wear.

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REFERENCES
