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Lewis Research Center



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Scanning-Electron-Microscope Used in Real-Time Study of Friction and Wear

The Problem:

The wear of solid surfaces in sliding contact begins with contact between the high points or asperities on each of these surfaces. The macroscopic wear behavior is really a summation of microscope events. In addition, the wear process is a dynamic process in the sense that mechanisms change with load, speed and time so that static or post-testing examination of work surfaces is not adequate for many cases. The need, therefore, is for a method or methods of studying friction and wear phenomena at the microscopic level: and under dynamic conditions.

The Solution:

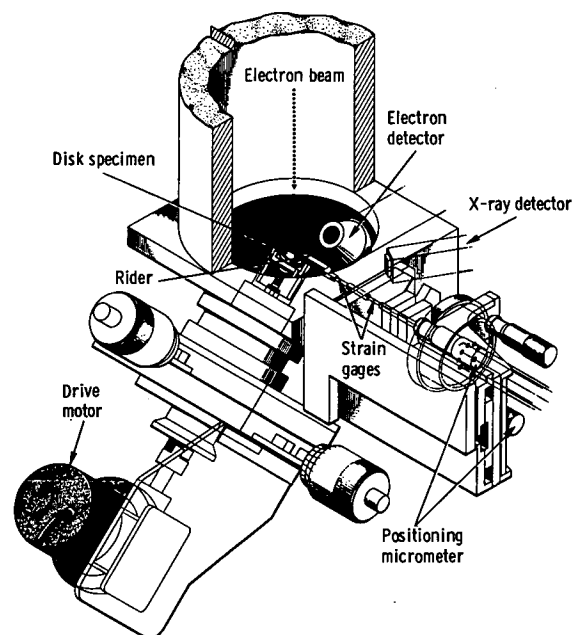
A small friction and wear apparatus built directly into a scanning-electron-microscope (SEM) to provide both dynamic observation and a microscopic view of the wear process.

How It's Done:

The friction and wear experiments were conducted in the vacuum chamber of the SEM. The SEM is a field emission electron source type which provides for real time viewing on a closed circuit television system at 15 complete frames per second.

The friction and wear apparatus used is shown schematically in the figure. A disk specimen 1.9 cm (0.75 in) in diameter is mounted on an adapter to the rotary specimen feedthrough. The surface of the disk is inclined at approximately 83° with respect to the electron beam to permit the interface to be viewed from a near side view. A variable speed electric motor and gear train provides rotation of the disk from 0.1 to 10 rpm. The rotation can either be clockwise or counterclockwise to provide for observation of either the prow or the wake of the rider disk contact. In addition, a side view of the wearing process can be observed, without, however, the capability of friction force measurements.

The rider specimen is 0.1 cm (0.039 in) in diameter with an 0.05 cm (0.02 in) radius on the end. A 20° taper is machined on the shank down to the radius in order to reduce the shadowing of the interface.



Detailed drawing of friction apparatus mounted on scanning electron microscope.

The rider is mounted in an arm which can be moved in and out as well as up and down and laterally by means of a bellows and gimbal system. The gimbal system is a precision optical orientor mounted on a translational stage. The stage and the optical orientor are micrometer controlled allowing very precise positioning of the rider on the disk under the scanning beam.

The arm in which the rider is mounted contains two flex bands of beryllium-copper on which strain gages are attached. One band mounted parallel to the disk surface is used to measure the normal load applied to the contact. The other band and strain gage are mounted perpendicular to the disk surface and monitor the friction force. In addition, another strain gage is mounted on the bottom of

(continued overleaf)

the load band and can measure the force of adhesion between the rider and disk. The normal loading is accomplished by magnets mounted on the optical orientor ring which pull the arm downward to the disk surface.

The load sensing gage output is amplified and displayed on a digital millivolt meter which, with suitable calibration, provides for a direct reading of the load being applied. The friction force gage is read out either on a strip chart recorder or oscilloscope to provide for the observation of the friction trace which is more transient in nature.

The entire friction test is viewed on the television monitor of the SEM and the video signal is recorded on video tape, together with audio comments. The tape can be played back in slow motion and stop action to facilitate interpretation. In addition, kinescopic motion pictures can readily be made from the video tape.

The addition of a friction and wear apparatus to the scanning-electron-microscope with real time scanning provides for in situ experimentation and the observation of the friction and wear process at a very basic level. The system developed for this purpose provides the following:

1. Precise specimen positioning necessary for keeping the contact region in the field of view at increased magnifications,
2. A low-angle view, relative to the disk surface, of the actual sliding interface,
3. SEM viewing of the prow, the wake, or side of the rider-disk contact region with continuous friction measurements in prow or wake positions,
4. A loading system providing for continuous loading from 1 to 75 grams force,
5. A continuously variable speed control from 0.1 to 10 rpm, which, depending on the radial distance of the contact from the disk center, provides surface sliding speeds from 0.94 to 0.003 cm (0.37 to 0.001 in) per second, and
6. Dynamic data recording of visual information on video tape.

Friction and wear tests conducted using this system have indicated that considerable information can readily be gained. When used in conjunction with a dispersive x-ray analyzer, the following types of information are observable:

1. The friction coefficient and the correlation of the variation with the actual wear process at any point in real time.
2. The type of wear, such as adhesive or abrasive wear, and changes in wear behavior with time, speed, or load,
3. Identification of the primary wearing surface and source of wear particles,
4. The size, shape, distribution, and agglomeration characteristics of the wear particles and their influence on the wearing process, and
5. Metallic transfer between the sliding surfaces.

Notes:

1. Further information is available in the following report:

NASA TN-D-7700 (N74-25975), Dynamic-Scanning-Electron-Microscope Study of Friction and Wear

Copies may be obtained at cost from:
Aerospace Research Applications Center
Indiana University
400 East Seventh Street
Bloomington, Indiana 47401
Telephone: 812-337-7833
Reference: B75-10064

2. Specific technical questions may be directed to:
Technology Utilization Officer
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Reference: B75-10064

Patent Status:

NASA has decided not to apply for a patent.

Source: W.A. Brainard and D.H. Buckley
Lewis Research Center
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