

Fig. 10A - SEM photo of typical ground paper plate after 4000 applications

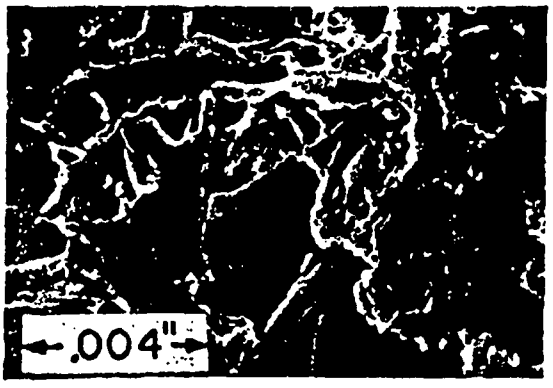


Fig. 10B - SEM photo of ground paper plate after 4000 clutch applications; note absence of particulates within paper structure

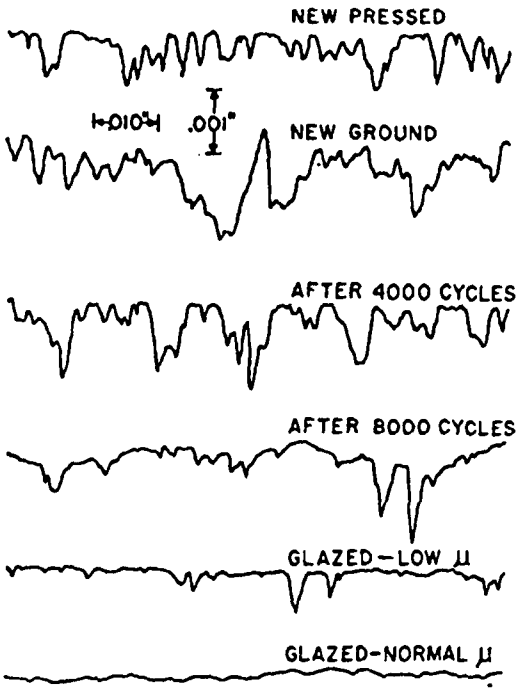


Fig. 11 - Comparison of new and used paper surface profiles

samples wore rapidly for the first several applications, then gradually tapered off such that no additional wear was detectable after 200 applications. When the apply time was increased to 0.4 s, apparently the samples both wore and swelled. After additional testing, surface examination of some samples showed greater contact areas, but with an increased average paper thickness.

Indirect measurements of the wear then had to be employed, such as profile mapping several areas of the clutch plate and noting changes in the peak-to-valley height distributions with added testing. These calculations showed an equilibrium wear rate for the 0.4 s apply time of 0.1×10^{-9} in^3/ft-lb. The apply time was extended further in increments until a complete engagement was made at 2.2 s. The volume of paper material worn, per unit of work, was found generally to increase and at an increasing rate as the engagement time increased. The specific wear rate was 1.6×10^{-9} in^3/ft-lb for the full engagement. However, the wear sometimes was confined to one area of one side of a plate. The cause of this had not been determined, but it appears that the paper material wears in a manner such as to produce a constant contact pressure. With some localized swelling, the paper wear presumably also becomes highly localized until the paper material becomes stabilized dimensionally. Despite the nonuniformity of wear, the wear rate per unit of work done was found to increase dramatically as the engagement time increased and the sliding velocity decreased.

After this wear testing, paper clutch plates of both the pressed type and the ground type may be quite similar in visual appearance, profilometer traces, and squeeze film behavior. SEM photographs of a ground paper plate after 4000 clutch applications are shown in Fig. 10A. Note the similarity of this used, ground paper sample with the new, pressed paper sample of Fig. 2. The relative absence of particulates within the paper structure should be apparent in Fig. 10B.

Representative profilometer traces of this and other clutch surfaces are shown in Fig. 11. Note the change of scale from Fig. 1, particularly the horizontal scale, which was made to provide a better visualization of surface flatness. The sample with 8000 cycles was tested under more severe conditions, resulting in a slightly wavy surface. This seems to cause a slightly lower dynamic friction at the higher sliding velocities, presumably due to the more favorable hydrodynamic action of a wavy surface. Two glazed appearing plates were included in Fig. 11 to illustrate the fact that "glazing" does not necessarily produce substantial friction changes. The sample with the low friction was found to have near-normal friction after a solvent extraction of the retained oil and reimpregnation with fresh oil. Both samples exhibited a smeared, almost scaled surface appearance under the SEM, with periodic pores of a few thousandths diameter. These surface scales could be expected to reduce greatly the permeability of the surface layer and possibly produce a lower friction level in the squeeze and squash film phases. However, when examined under an

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