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Wear 258 (2005) 1525–1530
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Effect of the specimen geometry on wear – combination of polyacetal (POM) and carbon steel for machine structures

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Received 2 March 2004; received in revised form 3 November 2004; accepted 29 November 2004
Available online 17 January 2005

Abstract

Engineering plastics which have been shown to have good mechanical properties are now frequently used as materials for various machine elements. Engineering plastics are combined with other engineering plastics and metallic materials for machine construction. These machine elements are fabricated with contact surface forms, such as convex, concave, and plane surfaces. Therefore, when designing machines with a combination of materials containing engineering plastics, it is useful to know the wear and friction characteristics for various contact surface forms. In the present research, polyacetal (POM), an engineering plastic, and carbon steel, a metal often used for machine structures, were chosen as materials to study wear and friction. Wear tests were performed in the combination of a convex surface and a plane, and in the combination of a plane and a plane. As a result, some features of the wear and friction characteristic are clarified. (1) The worn mass when the flat specimen made of POM is rubbed by the POM pin specimen is larger than when with the pin specimen made of carbon steel. (2) When the flat specimen made of POM is rubbed by the POM or the carbon steel pin specimen, the same grade of wear is observed regardless of the pin specimen material. (3) The worn length of the steel spherical pin specimen on the steel flat specimen becomes close to the initial radius of the curvature of the pin specimen when the sliding distance is large. The initial condition of the spherical tip pin specimen on the flat specimen evolves toward a condition of the flat tip pin specimen on the flat specimen. So, the comparison between the two geometries is non-relevant. Such problem did not occur in POM pin specimen.

Keywords: Coefficient of friction; Coefficient of wear; Polyacetal; Carbon steel for machine structure; Specimen geometry; Spherical surface; Flat surface

1. Introduction

Engineering plastics are thermoplastics. The strength per unit weight, i.e. the specific strength, is greater than commonly used metallic materials, and the material cost is relatively lower. For these reasons, engineering plastics have recently replaced metallic materials in many machine parts.

Many research works have been carried out on the industrial use of thermoplastics or polymers. Some representative papers [1–8] in such scope are listed in the section of references. Briscoe and Tabor have written a generalized text [9]. And our previous report [10] has shown that the wear of engineering plastics is strongly influenced by their thermal properties. When such a new material is used for machine elements, the partner material may be a metallic material, or the same engineering plastics. Moreover, the contact surfaces formed in machines can be constructed by various surface combinations, such as a convex surface and a concave surface, a convex surface and a convex surface, a plane and a convex surface, etc.

In this research project, polyacetal (POM), as an engineering plastic, and carbon steel, as a partner material, were chosen for experiments on wear and friction characteristics. In addition, plane and convex surfaces were used as the contact surface form to investigate the effect of the specimen geometry on wear.

Many research papers (for example, [11–13]) regarding the material and tribological properties of POM have been

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doi:10.1016/j.wear.2004.11.015

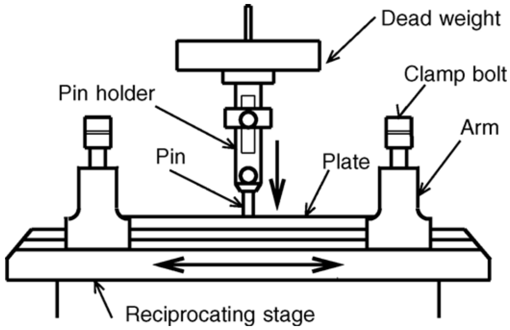

Fig. 1. Pin-on-flat wear-testing machine with reciprocating friction.

reported. However, the research work treating the effect of the specimen geometry is needed.

2. Experimental apparatus and procedures

The experimental apparatus is a pin-on-flat wear-testing machine with a reciprocating motion that was described in our previous report [14]. It is briefly outlined here. The structure of this wear-testing machine with reciprocating friction is shown in Fig. 1. A flat specimen and a pin specimen are fixed to a reciprocating stage or to a pin specimen holder by setting screws. The diameter of the pin specimen is 4 mm. A normal load can be applied by a weight on the pan positioned above the pin specimen holder. The sliding speed was a constant velocity of 11.06 mm/s. The normal load was changed with a maximum value of 19.6 N. The maximum sliding distance was 200 m. The wear test was performed repeatedly under such conditions, and friction and wear characteristics were investigated.

The specimen surfaces are degreased by alcohol before experiment and free dust or free wear fragments are blown off from the specimen surfaces before and after the experiment.

Friction force was measured with a strain-gauge detector installed on the wear-testing machine. The worn mass was obtained by the mass difference before and after the experiment measured with a precision electronic balance. Since the worn mass of the pin specimen was close to the resolution of an electronic balance in many cases, the worn mass of the flat specimen was primarily measured. However, in the experiment with the combined steel specimens, the worn mass of both the pin specimen and the flat specimen were measured.

3. Materials and geometry of specimens

The specimen materials used are carbon steel utilized for machine structures (carbon content 0.45%), and POM, a general-purpose engineering plastic. POM is reinforced by introduction of oxygen into the principal carbon chain. Since POM excels in mechanical properties and wear characteristics, it is used as a material for the fuel device-elements of automobiles. The flat specimens and the pin specimens (tip radius of curvature 2 mm) are made of these two materials.

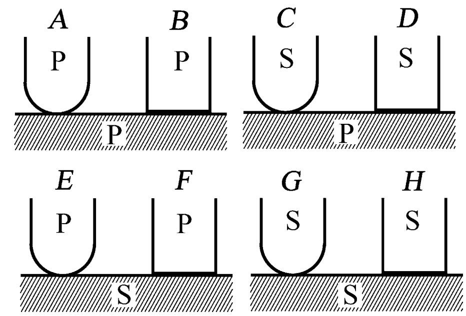

Fig. 2. Combinations of specimen material, and pin specimen geometry.

Two kinds of pin-tip specimens are used. One has a spherical tip (contact surface form) and the other has a flat tip. Therefore, eight kinds of combinations between the pin specimen and the flat specimen are obtained, as shown in Fig. 2. Notations “P” and “S” in the figure indicate that it is a specimen made of POM, and carbon steel, respectively.

Spherical and flat tip of the pin specimen is made by precision machining. Their surface roughness is as follows: spherical pin tip (both POM and steel) is approximately 1 μmRa (average roughness). POM flat specimen surface is as injection molded (0.2 μmRa). Steel flat specimen surface is finished by grinding and the surface roughness is approximately 0.5 μmRa.

In the following description, the designations of “A” – “H” indicate the eight kinds of contact situations which can be obtained through the specimen material combinations and the pin specimen geometry (Fig. 2).

4. Experimental results

The effects of the applied normal load on the coefficient of friction and the coefficient of wear for the spherical tip

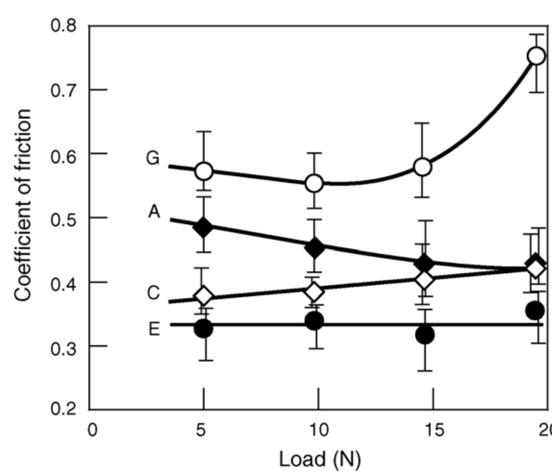

Fig. 3. Effect of normal load on coefficient of friction when pin specimen has a spherical tip surface.