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ON THE MECHANISM OF SHOE VERSUS WALKING-SURFACE FRICTION

TRACK OR CATEGORY

Materials Tribology

AUTHORS AND INSTITUTIONS

Kenneth G. Budinski, Steven T. Budinski, Bud Labs USA

INTRODUCTION

Falls on walking surfaces is a significant cause of visits to hospital emergency rooms and a significant concern from the liability aspect [1]. The purpose of this study is to investigate the mechanisms of friction of footwear versus various walking surfaces. The objective of the work is guidance in selecting materials and surface conditions for both footwear and walking surfaces that are less prone to slipping (higher footwear/walkway friction). These studies were conducted under clean and dry conditions in room air. Standard tests used on footwear [2,3,4,] were reviewed for use the more traditional inclined plane, sled test and pin-on-disk [5] were selected for use. The coefficients of friction under breakaway (COFb) and kinetic (COFk) conditions were used as test metrics. The mechanism studies addressed rubber properties, real area of contact, microtopography and rolling friction.

LABORATORY FRICTION TESTS

Friction differences between footwear - Fourteen same size shoes and same weight were tested using the inclined plane test for system friction on the same walking surface: prefinished oak flooring. The breakaway COFb's varied from 0.21 to 1. Why such a disparity?

Friction differences between rubbers – Sled friction tests were conducted on five rubbers (CBR, PUR, SBR, PCR and PCR/EPDM) sliding on variety of test surfaces: Ground steel, phenolic laminate, oak flooring, PTFE). There was not a significant difference between the five rubbers on all surfaces, but the polyurethane (PUR) friction was slightly higher against all test surfaces. Smooth steel versus the rubbers produced the highest average COF: 0.52 and the fluorocarbon (PTFE) counterface produced and average COF of about 0.3 on all rubbers. Type of rubber did not seem to have a significant effect on system friction.

Effect of type of walkway surface on friction – Six shoes from the footwear differences test were tested on the inclined plane test to determine the role of the walkway material. The six test shoes ranges from the slipperiest rubber, to leather, to coarse -tread ski boots. The test walkways were, rough concrete, smooth concrete, smooth ceramic tile, textured ceramic tile, oak flooring, vinyl flooring, carpet tile. The concrete surfaces and the carpeting produced the highest friction with each shoe. However one shoe had high friction against all of the test surfaces. It was also determined that a leather sole was slippery against all of the walkway types, and that aged rubber behaved like smooth leather. It was also determined that concrete, smooth or textured, will wear the shoe and that has to be part of the friction mechanism. It takes energy to produce remove material from the footwear rubbing contacts. The shoe sole material that produced high friction on all test surfaces was a thermoplastic elastomer.

FRICTION MECHANISM TESTS

The role of shoe tread design on friction – A major difference between the footwear tested was the pattern on the soles; they ranged from large cleats on the ski boot to no texture on the leather shoe. Tread difference will obviously affect real area of contact with walkways so test were conducted to measure the real are of contact of six differ shoes and determine if their real area of contact correlated with inclined plane COF difference. They did not. The real area of contact was determined by walking on a surface plate covered with a thin film of chalk. The area of chalk removed was measured as the real area of contact. The most significant leaning of this study was that there was no sliding between the shoe and the walking surface under real walking conditions. This suggested that as reported in some Russian literature, [6] walking is really rolling and rolling friction laws apply.

Rolling friction tests - A walkway was modified such that the force of one walking step was measured using four different shoes. The COF measured with this setup verified that walking is rolling since the coefficients of friction with all four shoes against the same steel surface were statistically the same and that the COF was about 0.1. The low value suggests that rolling is happening at the contact surface, not sliding. Walking is rolling, with the knee appearing to be the axel of a lower leg "wheel" and the shoe is at the end of a spoke (the lower leg) on the wheel.

Mechanisms that prevail during sliding – Sliding and slips can occur when shoe contact is other than normal rolling or standing. Sliding friction testing applies. Correlations were attempted between sliding friction tests conducted with different shoes versus various counterfaces . Rubber hardness did not correlate with shoe friction versus wood flooring, but it was observed that the most popular rubber Durometer hardness was about 60. Inclined panes test of six shoes on smooth steel did not correlate with real area of contact. Inclined plane tests of five shoes versus fixed abrasive papers indicated that sharp roughness on a walking surface greatly increases COF. And 10 µm sandpaper was just as effective as 150 µm sandpaper in producing COF greater than 1. Pin on disk tests of a spherical rider versus plastics with widely different surface roughnesses showed that a smooth steel rider had low friction on both smooth and rough counterfaces and when the rider was change to rubber, the friction force was high and the same on both smooth and rough plastic. Thus walkway roughness probably has no effect unless it is hard and sharp and can produce wear of the contacting shoe.

DMA tests and rubber wear tests suggested that the stiffness and viscoelastic properties of common shoe rubbers like SBR and PCR are significantly different and when they are abraded the resulting wear surfaces are very much different and the with protrusion or tree-bark patterns and these are likely responsible for the reason why, type of rubber plays a role in fiction against any walking surface. The aged rubbers used in the shoe friction tests verify this. They lost their elastomeric properties and were slippery against all walkway surfaces tested.

CONCLUSIONS

1. Footwear wears continually on all hard and rough surfaces like concrete and the microtopography of these worn surfaces depends on the type of rubber and this microtpography and the elastomeric properties of the footwear material determine the conformance of the footwear to the walking surface. The better the conformance, the greater the slip resistance (friction). Intimate conformance of surfaces often require shear when motion is attempted and shear requires more energy (friction) than sliding. This is the mechanism of footwear walking surface friction.

(**Basis**: rubber vs steel COF's, rubber wear tests, rubber DMA tests and optical microscopy of worn rubber)

2. Footwear tread design and real area of contact does not affect friction versus smooth hard walkway surfaces.

(**Basis**: real area of contact tests and COF tests of 7 different shoes versus smooth stainless steel)

3. Normal walking produces a rolling action between footwear and walkway and rolling friction laws apply. Slipping occurs when normal rolling contact turns to sliding contact.

(**Basis**: real area of contact test showed no slip, walking COF tests show COFs that are in the rolling range: less than 0.1).

4. Rubbers/elastomers age with time and this significantly alters their mechanical and physical properties (especially elastic and viscoelastic) and they can become slippery like leather to all walkway surfaces. Rubbers used for the contacting surfaces of footwear probably need aging studies to determine safe life.

(**Basis**: COF and resilience studies on aged rubber-soled footwear)

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KEYWORDS

Friction: Friction mechanisms, Friction: static, Contact: Contact mechanics