Serbian Tribology Society

SERBIATRIB '15

14th International Conference on Tribology

University of Belgrade, Faculty of Mechanical Engineering

Belgrade, Serbia, 13 – 15 May 2015

RESEARCH ON TRIBOLOGY PHENOMENA IN EVERY DAY LIFE

Dušan STAMENKOVIĆ[1,*], Milan NIKOLIĆ[1], Ljubislav VASIN[1], Milan BANIĆ[1], Aleksandar MILTENOVIĆ[1]

[1]Faculty of Mechanical Engineering Niš, Serbia

*Corresponding author: dusans@masfak.ni.ac.rs

Abstract: *Friction exists all around us: human skin is frequently one of the interacting surfaces in relative motion, shoe-floor friction, vehicle movement of the road, friction between skis and snow, and so on. Friction presents the main mechanism for generating driving force in car starting and accelerating, and generating breaking force. People can't walk without friction between footwear and floor. Basketball player can't play without enough friction between ball and hands skin. Drivers need friction between steering wheels and hands skin and between shoes and command pedals. Athletes, football players and other sportsmen need friction inside shoes between socks and shoe interface material. These are some examples but there are much more and this paper presents an overview of different studies in area of every day tribology.*

Keywords: *tribology, slip resistant, footwear-floor, skin tribology, tire-road.*

1. INTRODUCTION

Tribology phenomena exist in many processes around us such as humane walking/running/jumping, movement of vehicles in traffic, industrial manufacturing, cleaning the house floor, hands washing, and other. We differentiate the positive and negative effect of friction. Rubbing both hands together to generate heat is example of positive friction that everyone does in winter.

It is significant to control/manage the friction process. In some cases we want to increase the friction force and in another cases it is necessary to degrease the friction force. In order to control the friction we have to investigate many tribology parameters in many different situations.

Overview of different studies in area of every day tribology are presented in this paper, and authors determine the directions of own future research.

2. FRICTION AROUND US

Crunch of door hinges is the result of friction. Everybody knows that lubricating of hinges will reduce the friction and door will not creak anymore. Electrical brush running on metallic commutator represents one very old application of friction contact. Joints such as hips and knees in human body are the examples of friction elements.

Friction exists in situation where elements are in mutual contact under the contact pressure and there is movement of the one relative to the other. Very represented cases are vehicle movement on the road i.e. friction in the contact of tire and road and humane walking i.e. friction in the contact of footwear and floor. These are the extern friction phenomena, but there are internal phenomena. In vehicle motor there are many friction elements and in humane body there are many tribological processes.

2.1 Friction in contact of tire and road

Starting, movement and/or control of the vehicle are being implemented only due to friction that occurs at the contact of the tire and the road. Traction is the friction between wheels and road that allows a vehicle to move forward. Therefore, knowledge of the characteristics of this process is most relevant in terms of traffic safety, energy efficiency, economy, etc. According that, the most important task is more accurate predicting the behaviour of the friction characteristics of the contact tire-road, in real condition [8].

The basic friction characteristics of the tire-road interface are properties of the individual components of the tribosystem such as: road surface, tires, contaminants (between the tire and the road) and atmosphere (temperature, humidity, radiation affecting the state of the contaminant). The most important aspect of the road surface relative to its friction characteristics is the surface texture. Road surface texture is expressed in form of macro-texture and micro-texture. Surfaces are normally designed with sufficient macro-texture to obtain a suitable water drainage rate in the tire/road interface.

Runway surface friction is directly relevant to the braking action which will be available to an aircraft decelerating after touch down. A major problem with micro-texture of runway airport is that it can change with the accumulation of rubber deposits in the touchdown area which can largely mask micro-texture. Devices which detect surface friction are termed “Continuous Friction Measuring Equipment”. Their primary application is the determination of reference friction levels on dry and wetted surfaces.

Information on the runway surface condition includes the runway surface friction characteristics which are assessed according to the aerodrome maintenance programme, the presence of water, snow, slush, ice or other contaminants on the runway. The device for detect surface friction on the runway airport is presented on Figure 1.

Figure 1. Device for detect surface friction on the runway airport [12]

The most important problem for tire/road interface is hydroplaning (Fig. 2). When the rain is so heavy that there is a layer of water on the road, it can result in an effect called hydroplaning, where the car tire is skimming or gliding across the water surface with no contact with the road and with extremely low friction.

Figure 2. Effect called hydroplaning [13]

It may also occur in certain circumstances when running in a combination of water and wet snow. In this situation solution is to add treads to the tire that will channel the excess water out from under the tire (Fig. 3). In this way, the tire can get in better contact with the wet road surface, thus greatly increasing friction and traction.

Figure 3. Tires with wider treads

But, the disadvantage of having treads automobile tires is that under normal, dry driving conditions, the treads increase rolling

friction and in that way reduce energy efficiency and driving comfort.

Providing a specific value for the friction coefficient of tire rubber is impossible because there is not only one value. Friction is dependent on a complex system of parameters such as normal force, sliding velocity, surface roughness, lubrication, temperature, etc. Knowledge of the characteristics of friction between the tires and the road has an important role in the design of ABS and control system of the drive. Modelling of the friction in the contact of the tire and road is an area of intense research in recent years.

Design of ABS and anti-slip protection as the control systems of cars, as well as the legal obligation to apply the winter and summer tires show progress in the knowledge of friction and tribological operating conditions.

2.2 Contact of footwear and floor

In Germany in 2011 about 180.000 cases occurred due tripping or slipping. More than half of the accidents are caused due to slippage during walking. For the cost consequences due to falls caused by sliding the German Association of the Accident Insurance spent about 2 billion Euros.

Slips and trips are the most common cause of injury at work [9]. On average, they cause over a third of all major injuries and over 40 % of all reported injuries. HSE (Health and Safety Executive) statistics suggest that most of these accidents are slips, most of which happen when floor surfaces are contaminated (water, talc, grease, etc). There are the following influencing factors: floor, contamination, footwear, pedestrian factors, cleaning and environment.

Designers and producers of flooring must take into account safety and security of people in their walking on public pedestrian areas.

The guide [2] discusses the range of floor surfaces available for indoor sports facilities and offers guidance on selection. It covers the various requirements of different sports and the extent to which some surfaces may be considered as “multi-sport” surfaces, together with design, cost and construction implications. Contact of human leg with the floor surface can cause a range of injuries like bone fracture, strain from repeated foot impact, twisting of joints from restricted foot movement, and other.

For the most sports the degree of friction between the player's shoes and the floor surface needs to be high enough to prevent slipping, but not so high as to restrict foot movement either in a continuous direction or when turning, or prevent the controlled sliding of the foot that is required in some sports.

The surface deformation, shock absorbency, and the energy returned to the player and the ball are critical characteristics: they influence the risk of injury to an athlete, the extent of fatigue and the fundamental playing qualities of a surface. Previously, the general terms “sprung floors” or “semi-sprung floors” has sometimes been used for floors that have such characteristics.

Wood is one of the most widely used materials in the construction of sports floor surfaces. Vinyl, linoleum, rubber and composites are widely used materials for sports floor surfaces. They are usually in sheet form with a foam backing that achieves a “point elastic” or “mixed elastic” floor.

There are four categories of flooring systems in standard BS EN 14904. These are: Point elastic, Mixed Elastic, Area Elastic and Combined Elastic (Fig. 4).

The selection of sports floor products can be problematic. There are strong traditions in some sports to use particular manufacturers or types of flooring. Commercial pressures encourage manufacturers to continually update and develop their product ranges. The development of reliable testing methods and universally agreed performance standards has been a slow process that is often perceived as over complex [2].

2.3 Skin tribology

The human skin is very interesting, but very important for tribology research. In daily life, the human skin is constantly in interaction with other materials, like wood, stone, silk,

cotton, glass, skin, plastics, metals, etc. Interaction of human finger and mobile phone touch screen is everyday very illustrative example of skin friction.

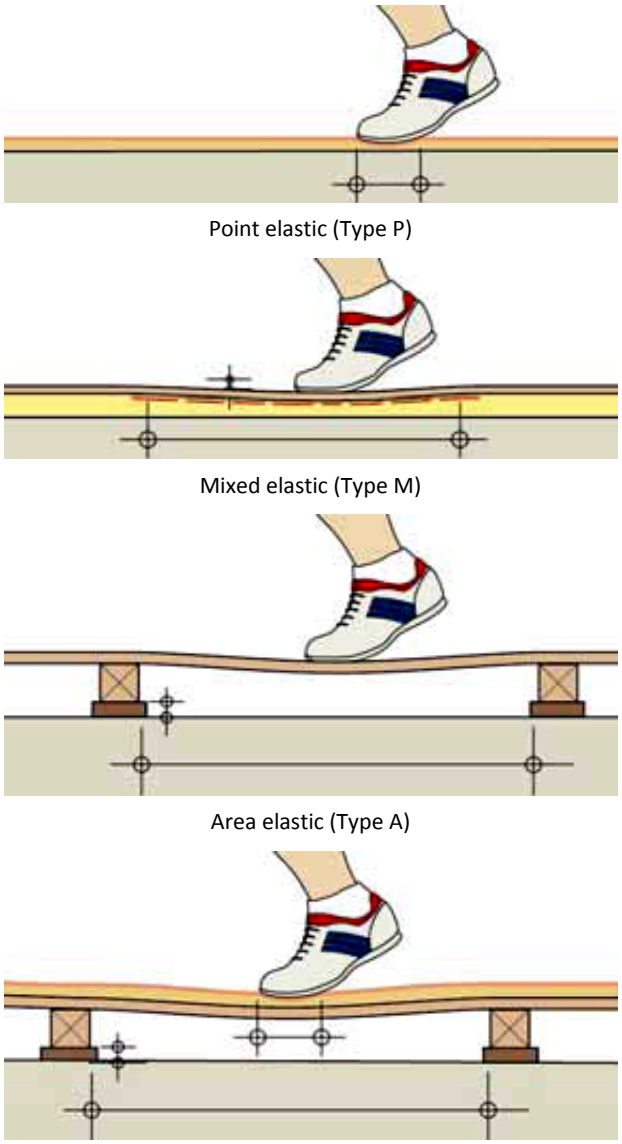

Figure 4. Categories of flooring systems according the BS EN 14904

Skin friction can be treated as a system with various parameters as feature of the contact material, characteristic of the skin area, parameters of the contact situation between the materials and environmental condition. The new device presented in paper [5] is a portable handheld device made for measuring the friction between the human skin in vivo and some material (Fig. 5).

The interactions of skin with a variety of materials and some aspects of skin tribology have been studied in [4-6]. The coefficient of static friction for different body regions varies over a wide range between 0.05 to 3.86 and according that it is concluded that the coefficient of friction in skin-product interaction depends greatly upon the operational conditions, the environmental conditions, materials properties and other [5].

Figure 5. The portable handheld device [5]

Author of research on skin tribology [5] has recommended: “An objective for researchers could be to identify the variables that influence skin friction. Moreover, skin friction could turn out to be a very interesting subject for product developers and in other practical fields. A useful addition to skin friction could be predictive models for touch and feel, for instance. This would give product developers the opportunity to put skin friction knowledge into practice in consumer products. Another very interesting option, though not without difficulties, could be a predictive model for skin injuries. This, however, would be complicated and requires specialised knowledge of skin and medicine”.

3. RESEARCH ON SLIP RESISTANCE OF PUBLIC PEDESTRIAN AREAS

Footwear suppliers use a variety of terms to describe their products, as like as “slip-resistant”, “anti-slip”, “improving grip performance”, etc. Slip-resistant industrial footwear should normally be tested according to European standards, but many manufacturers and suppliers do not give helpful additional information, such as the degree of slip resistance and the types of work environment for which their products are most suited.

Terms that are often in use are floor slip resistance and footwear slip resistant. Slip resistance properties have been widely measured as a form of coefficient of friction at the sliding interface between the shoes and floors.

Because of the nature of complexity and factors involved, the measured coefficient of friction quantities show inconsistencies even as the same shoe-floor combinations are employed. This fact is recognized as a great concern when different friction testers, sensors and/or protocols are used worldwide.

3.1. Test methods for assessing floor slip resistance

Research carried out by Health and Safety Laboratory (HSL), in conjunction with the UK Slip Resistance Group (UKSRG) and the British Standards Institution, has shown that commercially available, portable scientific test instruments can accurately assess the slipperiness of flooring materials [9]. There are two different methods and devices: pendulum test and surface roughness measurement.

The pendulum tester (Fig. 6), known as the portable skid resistance tester or the British pendulum, is the subject of a British Standard, BS 7976. The method is based on a swinging, imitation heel (using a standardised rubber soling sample), which sweeps over a set area of flooring in a controlled manner. The Pendulum test is a key method for on-site testing of floor slip resistance. The level of floor slip potential is determined on the base of the deflection angle of the pendulum (Table 1).

Table 1. Slip potential classification, based on pendulum test values

Level of slip potential	Pendulum test values
High slip potential	0 ÷ 24
Moderate slip potential	25 ÷ 35
Low slip potential	36 +

An indication of slip resistance in water-contaminated conditions may be obtained by measuring the surface roughness of flooring. Roughness measurements may also be used to monitor changes in floor surface characteristics, such as wear. Research has shown that measuring the *Rz* parameter (Average maximum height of the profile according ISO 4287) allows slipperiness to be predicted for a range of common materials [9]. Figure 7 presents the surface roughness meters.

Figure 6. Pendulum tester [14]

Figure 7. Surface roughness meters [9]

The classification of floor slip potential according to measured surface roughness is presented in Table 2.

Table 2. Slip potential classification, based on *Rz* roughness values

Level of slip potential	*Rz* surface roughness
High slip potential	Below 10 µm
Moderate slip potential	10 ÷ 20 µm
Low slip potential	20 + µm

Many European flooring manufacturers use ramp tests to classify the slipperiness of their products. Such tests are generally carried out using German National Standard test methods DIN 51097 and DIN 51130. DIN 51097 uses barefoot operators with a soap solution as the contaminant, and DIN 51130 uses heavily-

cleared safety boots with motor oil contamination.

3.2. Slip resistance testing of outdoor floor foil

Outdoor floor foil is a self-adhesive foil that can be applied for advertising on different pedestrian surfaces. This product must be slip resistant. Testing of slip resistant of outdoor floor foil has been conducted at Faculty of mechanical engineering in Nis.

Measuring of the static friction force is performed between the shoes sample and the floor sample on specially designed device tribometer. Within the conducted tests, one smooth and other rough (with relief) rubber were used for shoes soles samples. For floor sample was used concrete block for pedestrian areas, which is covered with self-adhesive foil. Surface roughness of concrete block with self-adhesive foil is measured and average maximum height of the profile *Rz* was 27.1 µm. Testing samples are shown in Figure 8.

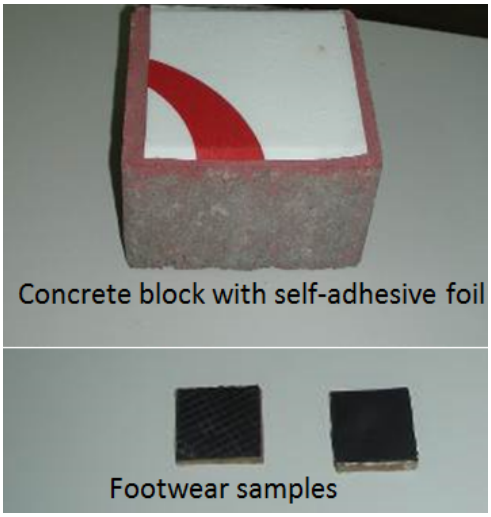

Figure 8. Testing samples

Measuring system (force sensor, test samples and weight) is shown in Figure 9. The static friction force is the force value registered in that moment of the sliding start, i.e. in the beginning of the sliding shoes sample per stationary floor sample.

The measurement was carried out with variations of the normal force (weight). i.e. contact pressure of the three load levels (48 kPa, 86 kPa, 140 kPa).

Figure 9. Measuring system

The contact surfaces were examined in two different regimes: dry and wet condition. Static friction coefficient values established in testing are presented in Table 3.

Table 3. Static friction coefficient values established in testing

Floor sample (foil on concrete)	Static friction coefficient
Smooth rubber dry	0.729
Smooth rubber wet	0.659
Rough rubber dry	0.643
Rough rubber wet	0.534

Measuring results (values of static friction coefficient are higher than 0.5) suggest that slip resistant of outdoor floor foil is satisfactory.

3.3. Basic principles of floor slip resistant research

Although the measurements of friction coefficient were commonly adopted to evaluate slip potentials of footwear and floor, it has been found that there are different approaches in the interpretation of measurement results [11]. The research that is planned to perform at Faculty of mechanical engineering in Nis should to be focused on establishing the method of determine the slip resistance of pedestrian areas considering the basic tribology parameters. In order to achieve this goal, current concepts of slip resistance measurement should be analyzed by a tribological point of view.

Friction is a system property and tribological systems must be modelled carefully in order to perform a valid test. In a friction test the resulting tribometric

characteristics data must be understood as tribological systems characteristics associated with the following group of parameters:

- **Structural parameters**, which characterize the components (materials, lubricant, and environment) involved in the friction and wear process and their physical, chemical, and technological properties;
- **Operational parameters**, that is, the loading, kinematic, and temperature conditions and their functional duration;
- **Interaction parameters**, which characterize, in particular, the action of the operating parameters on the structural components of the tribological system and define its contact and lubrication modes.

Structural parameters include triboelements, interfacial element such as lubricant or dirt particles, and environmental medium such as air or moister.

The basic operational parameters in tribology [1] are:

- Type of motion (sliding, rolling, spin, and impact and their possible superpositions; the kinematics can be continuous, intermittent, reverse, or oscillating);
- Load (F_N), defined as the total force (including weight) that acts perpendicular to the contact area between triboelement (1) and (2), as shown in Figure 10;
- Velocity (v), to be specified with respect to the vector components and the absolute values of the individual motions of triboelements (1) ad (2);
- Temperature of the structural components at stated location and time, that is, the initial (steady state) temperature and the friction-induced temperature rise;
- Time dependence of the set of operational parameters (F_N, v, T, for example, load cycles and heating or cooling intervals;
- Duration of operation or test.

However, one of the most important aspects on slip resistance properties is that they are stochastic. That is, one flooring material could be more slip resistant than another under one set of conditions, but less slip resistant under another ones [3]. This could be due not only to the shoe material types and changes of surface geometry caused by wear, but also to the surface contaminants. According that, tribological characteristics of footwear-floor contact should be analyzed in each specific condition.

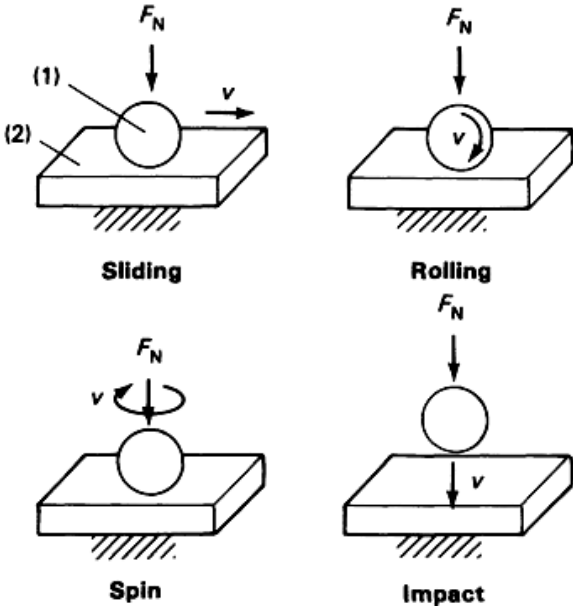

Figure 10. Kinematics of trybosystems [1]

4. CONCLUSION

In the most of cases the lack of static friction force in footwear-floor contact is the reason for falls and injuries. There are many different standards and methods for assess the slip resistance, but there are no obligation to apply for the producers of footwear and floor.

Evaluation of slip resistance should be based on understanding of basic tribological characteristics between the shoes and floors.

According the importance of this problem and experience in earlier studies in the field of static friction, at Faculty of Mechanical Engineering in Niš will be initiated the investigation with the goal to determine tribological properties of footwear-floor contact, especially for public pedestrian area.

Plan of the research will consist of:

- Multi-disciplinary theoretical and experimental studies of factors

influencing people slip and fall while walking;

- Research and systematization of the existing standards in the EU in the field of slip resistance properties of footwear and flooring;
- Identification of test procedures for determining the tribological characteristics of shoes and pedestrian areas and setting new technical requirements regarding the production of footwear and flooring;
- Research on influence of footwear-floor friction on human musculature during sudden change of speed and direction of movement;
- The application of expert knowledge and experience in the university and laboratory equipment available in the testing and verification of tribological characteristics of the industry product.

REFERENCES

[1] *ASM Handbook, Volume 18: Friction, Lubrication and Wear Technology*, 1992.

[2] *Floors for Indoor Sports, Design – Guidance Note*, Sport England, 2006.

[3] I.-J. Kim, H. Nagata: Research on slip resistance measurements – a new challenge, Industrial Health, Vol. 46, pp. 66-76, 2008.

[4] E. Van Der Heide, X. Zeng, M.A. Masen: Skin tribology: Science friction?, Friction, Vol. 1, No. 2, pp. 130-142, 2013.

[5] N. Veijgen: *Skin Friction: A Novel Approach to Measuring in vivo Human Skin*, PhD Thesis, University of Twente, Enschede, 2013.

[6] S. Derler, L. Gerhardt: Tribology of skin: Review and analysis of experimental results for the friction coefficient of human skin, Tribology Letters, Vol. 45, pp. 1-27, 2011.

[7] S. Muler, M. Uchanski, K. Hedrick: Estimation of the maximum tire-road friction coefficient, Journal of Dynamic Systems, Measurement, and Control, Vol. 125, pp. 607-617, 2003.

[8] D. Stamenković, M. Đurđanović, M. Nikolić: Prilog istraživanju problema kontakta pneumatika i kolovoza, in: *10th International Conference on Tribology – SERBIATRIB '07*, 2007, Kragujevac, Serbia, pp. 297-300.

[9] *HSE: Assessing the slip resistance of flooring, A technical information sheet published by the Health and Safety Executive*, 2012.

[10] D. Stamenković: Science in safety, the bearing tribology has on slips, trips and falls, Health & Safety International, February/March 2014.

[11] D. Stamenković, M. Nikolić, M. Milošević, M. Banić, A. Miltenović, M. Mijajlović: Tribological aspect of rubber based parts used in engineering, Tribology in Industry, Vol. 36, No. 1, pp. 9-16, 2014.

[12] http://www.airport-suppliers.com/supplier

[13] http://www.tallervirtual.com/como-actuar-ante-el-aquaplaning/

[14] http://www.highwaysmaintenance.com/skidtext.htm