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INFLUENCE OF TREAD GROOVE WIDTH OF RUBBER ON FRICTION COEFFICIENT

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ABSTRACT

The present work studies the influence of rubber tread width and direction of motion on the friction coefficient displayed by the sliding of rubber against ceramic flooring. Experiments were carried out to measure the friction force exerted by rubber of different tread width considering the motion direction.

Based on the experimental findings, it was found that the effect of sliding direction on friction coefficient displayed by the tested rubber sliding against ceramics was significant due to the amount of rubber deflection. Besides, in the presence of water film, the ability of the groove to store the fluid was responsible for the variation of the values of friction coefficient. Sand particles strongly affected the contact, while water facilitates the motion of sand particles so that their effect was much pronounced. Oil decreased the adhesion between rubber and ceramic and consequently rubber deformation decreased.

Friction coefficient displayed by the tested rubber sliding against dry ceramics significantly increased up to maximum then decreased with increasing groove width. In the presence of water, friction coefficient decreased down to minimum then increased with increasing groove width. Surfaces contaminated by sand particles showed the same trend of friction coefficient observed for water. The values of friction coefficient were much higher than that shown for water sliding. Friction coefficient, displayed by the tested rubber sliding against water and sand contaminated ceramics represented relatively lower values than that observed for sand contaminated sliding. When the oil was covering the sliding surfaces, friction coefficient increased up to maximum then decreased with increasing groove width.

KEYWORDS

Friction coefficient, rubber, ceramic, tread groove width, direction of motion.

INTRODUCTION

It is well known that an acceptable value of friction should be obtained to keep the foot from slipping off the flooring and increase the safety of walking. Little attention was exerted to measure the friction coefficient of rubber footwear soles sliding against dry and contaminated flooring. The effect of scratching the rubber braking pads, to increase their deformation, on friction coefficient was investigated, [1]. The experimental observations showed that, at dry sliding of bare foot against the tested pads, the friction increase was due to the extra deformation exerted by the pad, where the tread shape allowed for that deformation. The reduction in the friction coefficient displayed by bare

foot and rubber footwear soles sliding against the brake pedal rubber pads of different hardness in dry, sand contaminated, water and oil lubricated conditions was discussed, [2]. At dry sliding, friction coefficient slightly decreased with increasing the hardness of the rubber pad. For the transverse direction of sliding, friction coefficient displayed relatively lower values than that observed for longitudinal sliding. In the presence of sand particles between the foot and the rubber pad, friction coefficient significantly increased with increasing hardness. Bare foot sliding against water wetted pedal pads displayed relatively higher friction coefficient than that shown for surfaces contaminated by sand particles. For oil lubricated pedal pad, friction coefficient significantly increased with increasing the hardness of rubber pad, at longitudinal and transverse sliding directions respectively. Rubber footwear soles, slid against the tested pedal pads, displayed lower friction values than that observed for bare foot at dry sliding. In the presence of sand particles on the sliding surfaces, friction coefficient significantly increased, while decreased for water wetted pads with increasing hardness of the tested pad. Friction coefficient of rubber footwear soles sliding against oil lubricated pedal pad increased with increasing the hardness of the rubber pad.

The effect of rectangular and cross treads introduced in the rubber mats on friction coefficient when sliding against footwear was investigated, [3].It was found that friction coefficient displayed slightly decreased with increasing tread groove at dry, detergent wetted and oily sliding due to the decreased contact area accompanied to the increased groove width of the rubber. At water wetted sliding friction coefficient remarkably increased with increasing the tread groove. Oily sliding displayed very low values of friction coefficient. As the tread width decreased, the friction values decreased due to the decrease of the contact area at dry, detergent wetted and oily sliding. At sliding against water wetted flooring, friction coefficient significantly increased with increasing both of the width of the tread and the groove due to the easier water escape from the contact area, where the groove volume was relatively higher. Friction coefficient displayed by cross tread rubber sliding against dry, detergent wetted and oily sliding showed drastic decrease with increasing tread groove. In general, rubber friction is divided into two parts; the bulk hysteresis and the contact adhesive term, [4]. These two contributions are regarded to be independent of each other, but this is only a simplified assumption.

Friction measurement is one of the major approaches to quantify floor slipperiness. Investigations on friction measurement have been focused on liquid contaminated conditions. It was expected that wet surfaces had significant lower friction coefficient values than those of the dry surfaces, [5]. The friction coefficient difference between the dry and wet surfaces depended on the footwear material and floor combinations. Friction measurements under liquid contaminated conditions were very common. The squeeze film theory explains the effects of the liquid on the measured friction. Measurements of the static friction coefficient between rubber specimens and ceramic surfaces were carried out at dry, water lubricated, oil, oil diluted by water and sand contaminating the lubricating fluids, [6 - 9]. It was observed that, dry sliding of the rubber test specimens displayed the highest value of friction coefficient. For water lubricated ceramics, the value of the friction coefficient decreased compared to dry sliding. For oil lubricated ceramic, friction coefficient decreased with increasing the height of the grooves introduced in the rubber specimens. As for ceramic lubricated by detergent and contaminated by sand, friction coefficient increased significantly compared to the sliding on ceramics lubricated by water and soap.

The effect of the treads width and depth, of the shoe sole on the friction coefficient between the sole and ceramic floor interface, was discussed, [10]. It was found that, at dry sliding, friction coefficient slightly increased with increasing tread height. Perpendicular (relative to the motion direction) treads displayed the highest friction coefficient due to their increased deformation, while parallel treads showed the lowest values. In the presence of water on the sliding surface, significant decrease in friction coefficient was observed compared to the dry sliding. For detergent wetted surfaces, friction coefficient drastically decreased to values lower than that displayed by water. Parallel treads showed the highest friction coefficient, while perpendicular treads displayed the lowest friction values as result of the formation of the hydrodynamic wedge.Oily smooth surfaces gave the lowest friction values as result of the presence of squeeze oil film separating rubber and ceramic. Emulsion of water and oil shows slight friction increase compared to oil lubricated sliding. As the tread height increased, friction increased due to the easy escape of the lubricant from the contact area. Tread groove designs are helpful in facilitating contact between the shoe sole and floor on liquid contaminated surface, [11, 12]. The effectiveness of a tread groove design depends on the contaminant, footwear material and floor. Tread groove design was ineffective in maintaining friction on a floor covered by vegetable oil. Tread grooves should be wide enough to achieve better drainage capability on wet and water detergent contaminated floors.

The effect of rubber flooring provided by rectangular and cylindrical treads on the friction coefficient was investigated, [13, 14]. It was found that, at dry sliding, friction coefficient slightly increased with increasing treads height. Perpendicular treads displayed the highest friction coefficient due to their increased deformation, while parallel treads showed the lowest values. In the presence of water on the sliding surface significant decrease in friction coefficient was observed. For detergent wetted surfaces, friction coefficient drastically decreased to values lower than that displayed by water. Parallel treads showed the highest friction coefficient, while perpendicular treads displayed the lowest friction values as result of the formation of the hydrodynamic wedge. Oily smooth surfaces gave the lowest friction value as result of the presence of squeeze oil film separating rubber and ceramic. Treads of 45° displayed the highest friction coefficient. Besides, friction coefficient significantly increased up to maximum then slightly decreased with increasing the treads height. Perpendicular treads displayed the highest friction followed by 45° and parallel treads. At water, detergent and oil lubricated sliding conditions, friction coefficient decreased as the tread width increased due to the increased area of the fluid film. Perpendicular treads caused lower friction coefficient because parallel and 45° treads could scavenge oil away from the contact area more effectively than perpendicular treads. In addition to that, it was found that at dry sliding, friction coefficient significantly increased with increasing treads diameter. As for lubricated sliding surfaces, friction coefficient decreased with increasing treads diameter. Parallel treads showed the highest friction coefficient, while perpendicular treads displayed the lowest friction values.

In the present work, the effect of rubber tread width and motion direction on friction coefficient displayed by the sliding against ceramic flooring was tested at different sliding conditions.

EXPERIMENTAL

Measurement of friction coefficient was carried out at 100 N load. Rubber specimens of 50 × 50 × 5 mm^3 were adhered on wooden block. Flooring materials in form of ceramic tiles of 400 × 400 mm^2.The rubber and tiles surfaces were cleaned with detergent to eliminate any dirt and dust and carefully dried before the test. The rubber test specimens were loaded against dry, water, sand, water + 10% sand and oil lubricated ceramic flooring materials. The test rig used in the present work, was designed and manufactured to measure the friction force displayed by the sliding of the tested rubber specimens against ceramic tiles through measuring the friction force and applied normal force. The ceramic tile was placed in a base supported by two load cells to measure the horizontal force (friction force) and the vertical force (applied load). A digital screen was attached to the load cells to detect the friction and vertical forces. Friction coefficient was determined by the ratio between the friction force and the normal load.

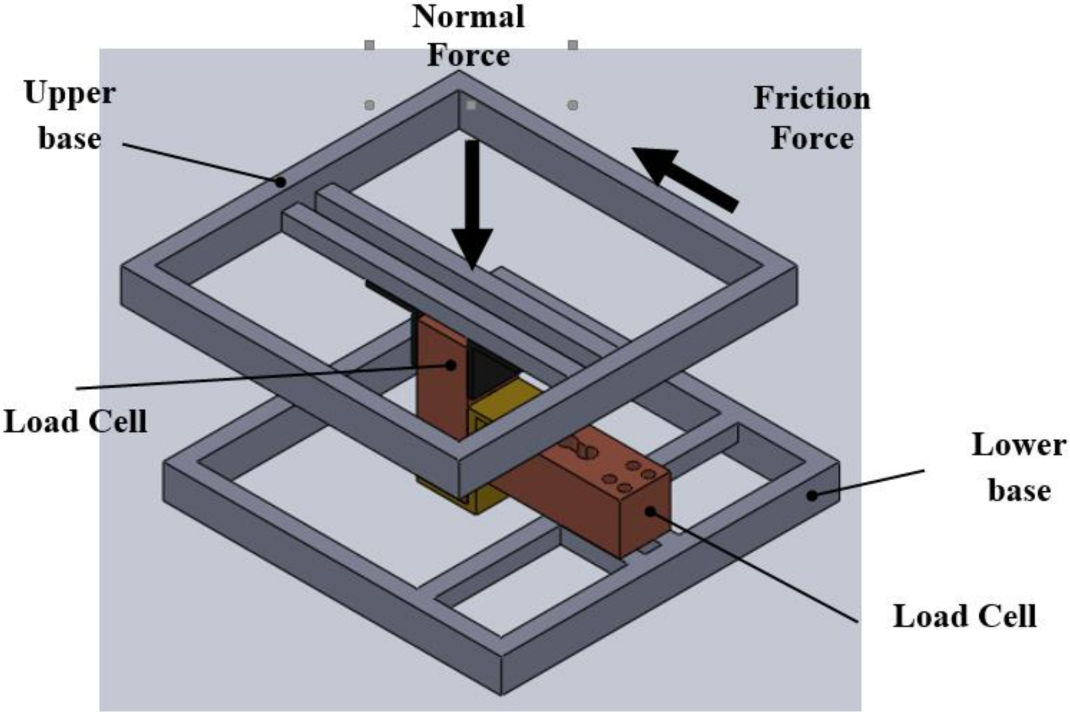

Fig.1 Arrangement of test rig.

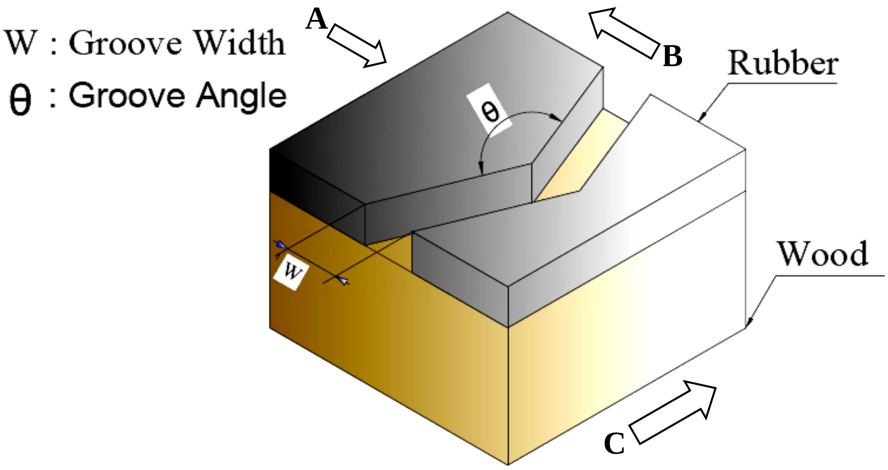

Fig. 2 Test specimens and direction of sliding.

Test specimens were loaded against ceramic tile at dry, water wetted, detergent and oil lubricated sliding conditions, Fig. 2. Rubber test specimens are of 60 shore A hardness.

RESULTS AND DISCUSSION

Friction coefficient displayed by the tested rubber sliding against dry ceramics is shown in Fig. 2. It is clearly shown that friction coefficient significantly increased up to maximum then decreased with increasing groove width. The friction increase was due to the increase of the rubber deflection, while the decrease was due to the decrease of the contact area. As the angle of the groove increased friction coefficient decreased.

In the presence of water, friction coefficient decreased down to minimum at 8 mm groove width then increased with increasing groove width, Fig. 4. As the groove width increased the quantity of water stored in the groove increased. When the rubber was compressed, the stored water formed a film on the sliding surface and consequently decreased friction coefficient. The minimum friction value was 0.18 at groove 8 mm width. When the sliding surfaces were contaminated by sand particles, Fig. 5, friction coefficient showed the same trend observed for water. The values of friction coefficient were much higher than that shown for water sliding. It seems that the groove supplied sand particles into the contact area. The minimum value of friction coefficient was 0.18 at groove 8 mm width. In this sliding condition, it is recommended to use 10 mm groove width to get values of friction coefficient that guarantee safe walking.

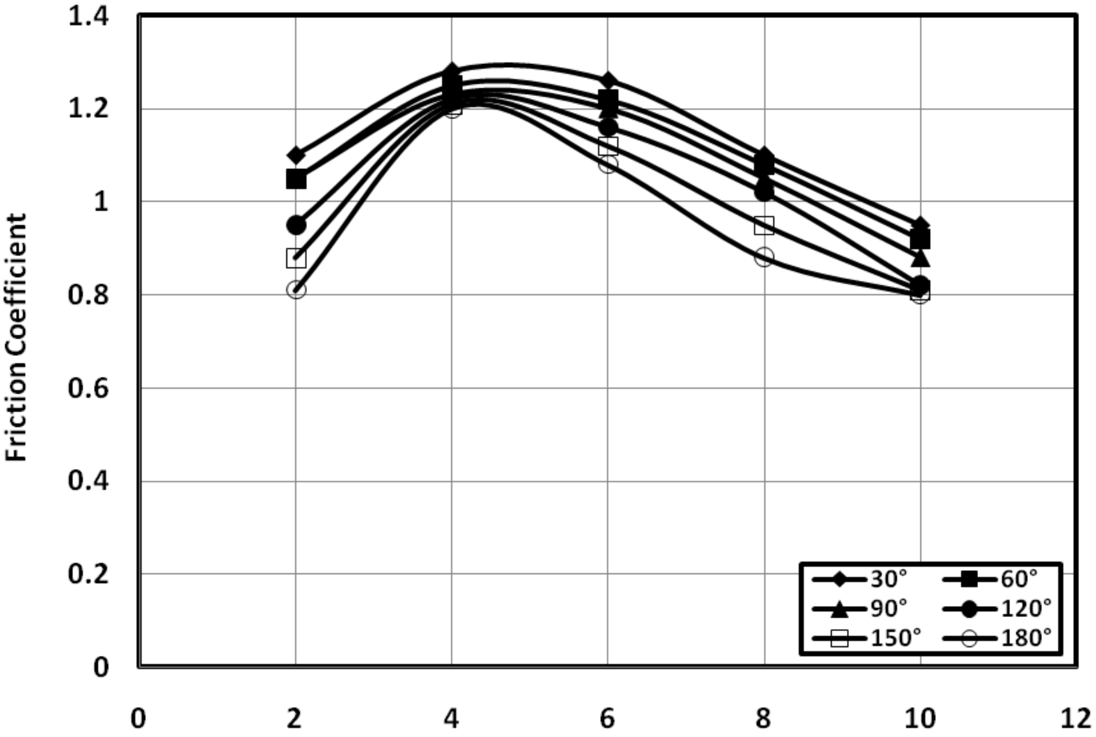

Fig. 3 Friction coefficient displayed by the tested rubber sliding against dry ceramics.

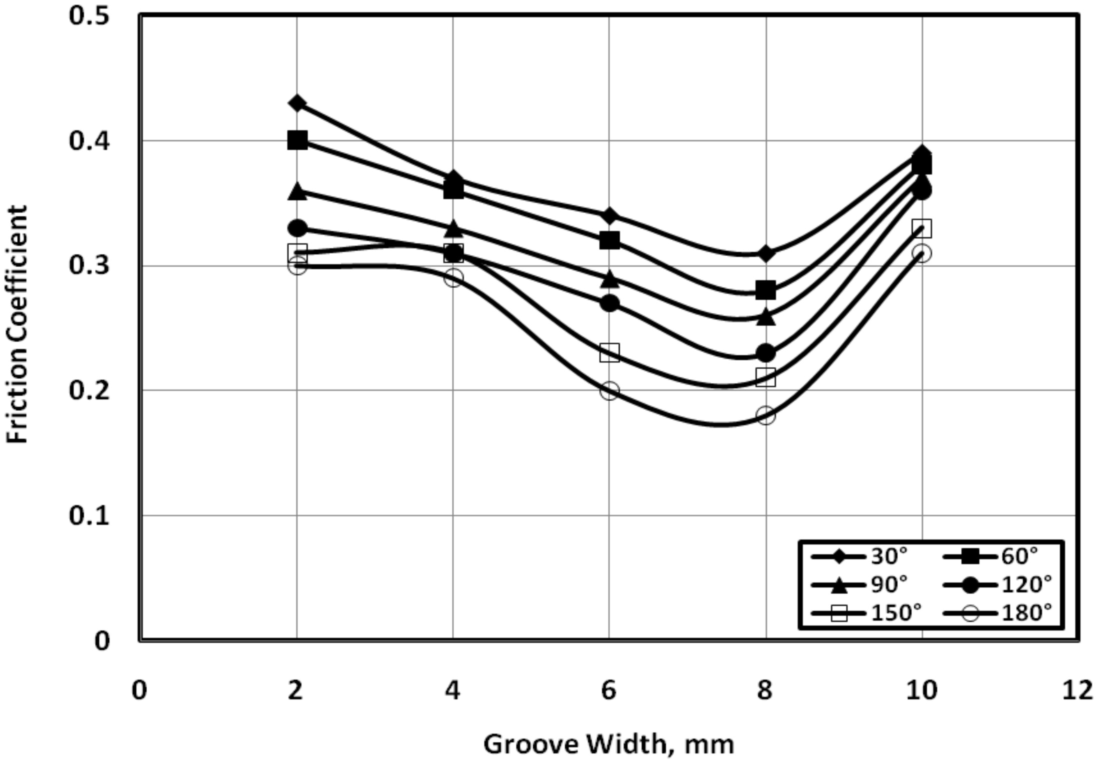

Fig. 4 Friction coefficient displayed by the tested rubber sliding against water wetted ceramics.

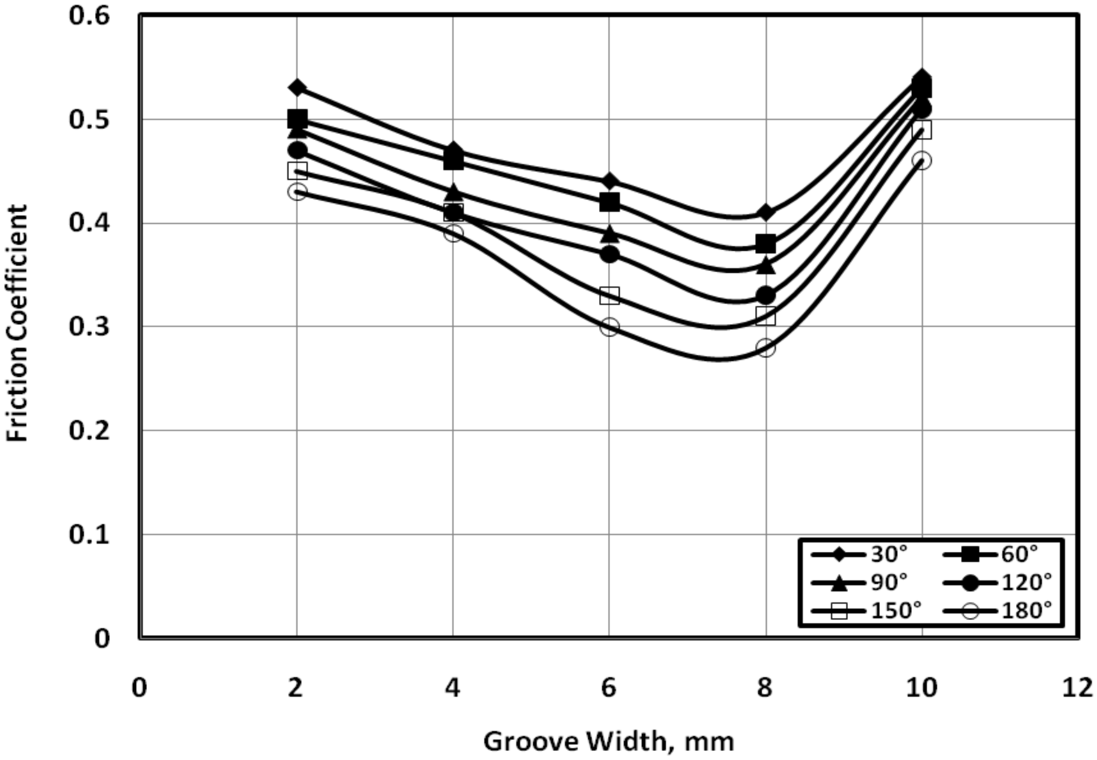

Fig. 5 Friction coefficient displayed by the tested rubber sliding against sand contaminated ceramics.

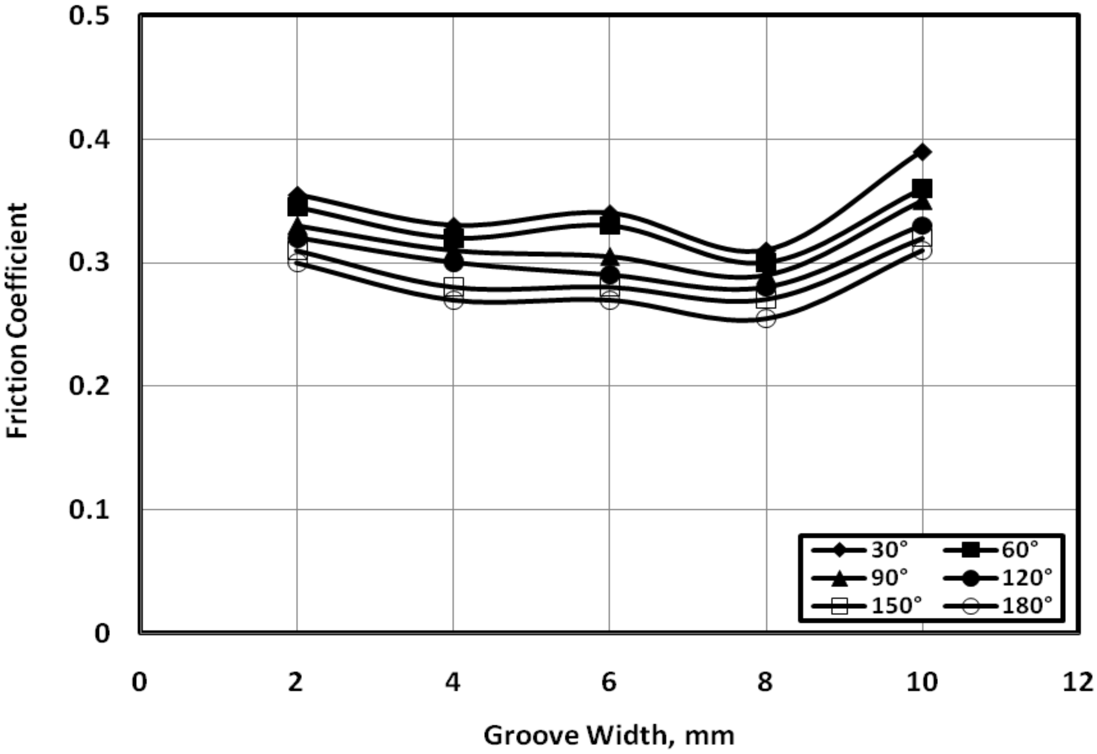

Fig. 6 Friction coefficient displayed by the tested rubber sliding against water and sand contaminated ceramics.

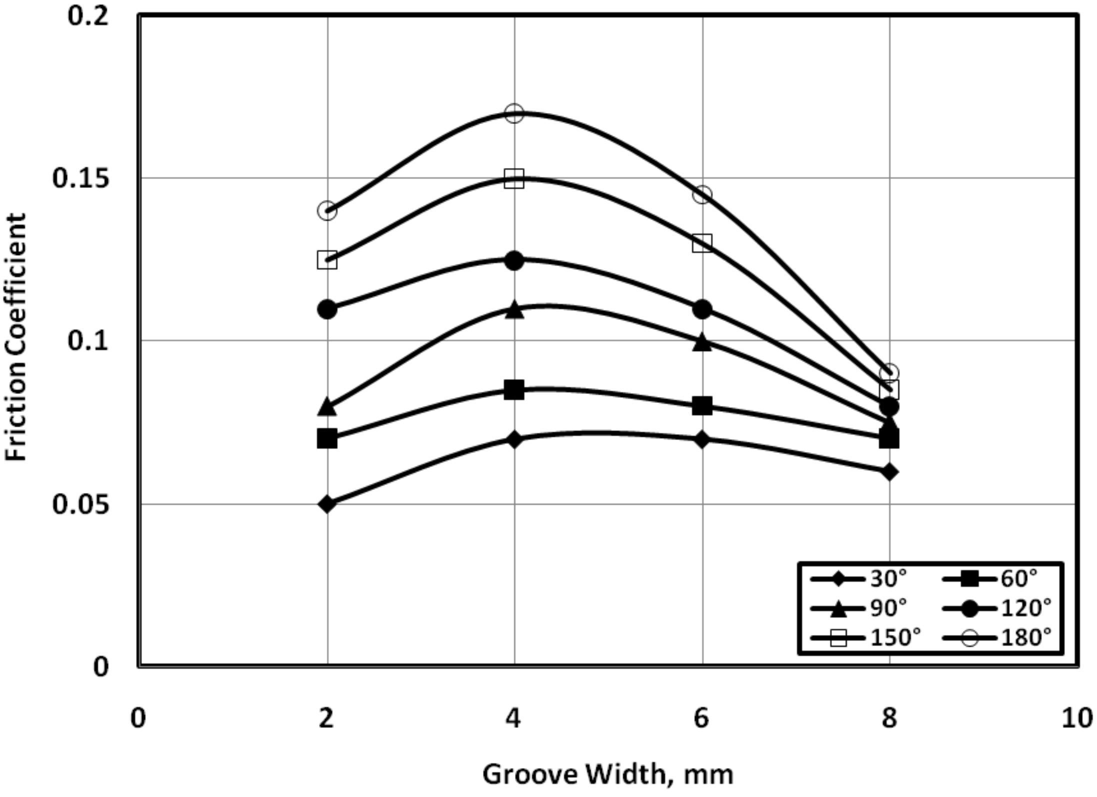

Fig. 7 Friction coefficient displayed by the tested rubber sliding against oil lubricated ceramics.

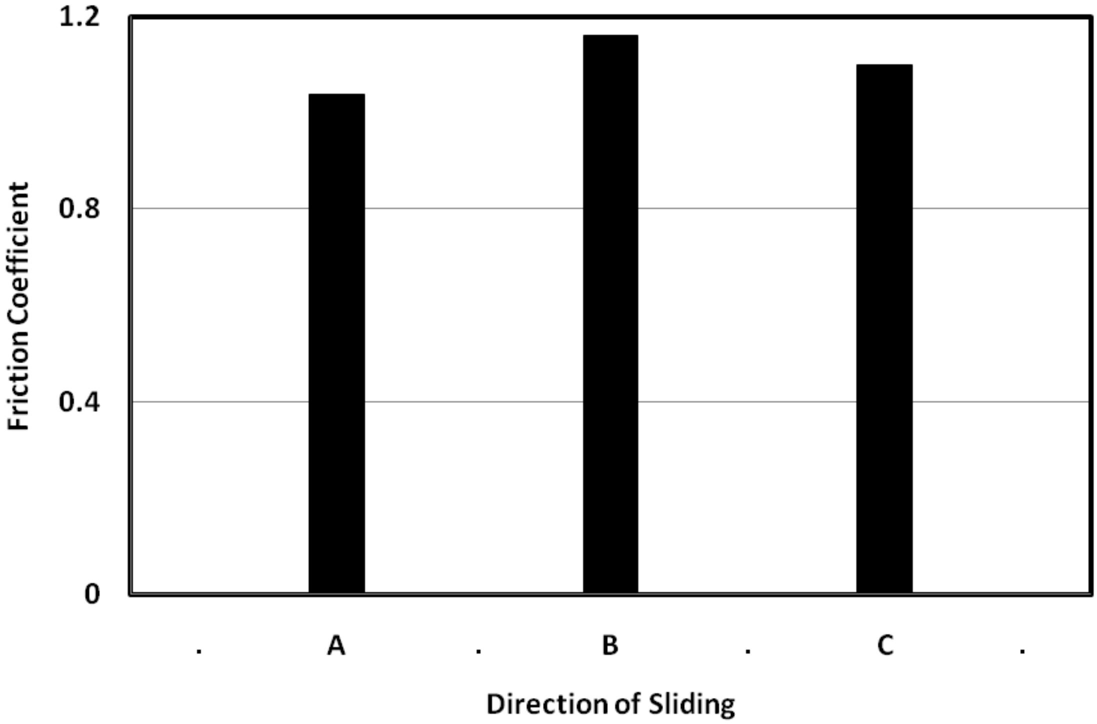

Fig. 8 Effect of sliding direction on friction coefficient displayed by the tested rubber sliding against dry ceramics.

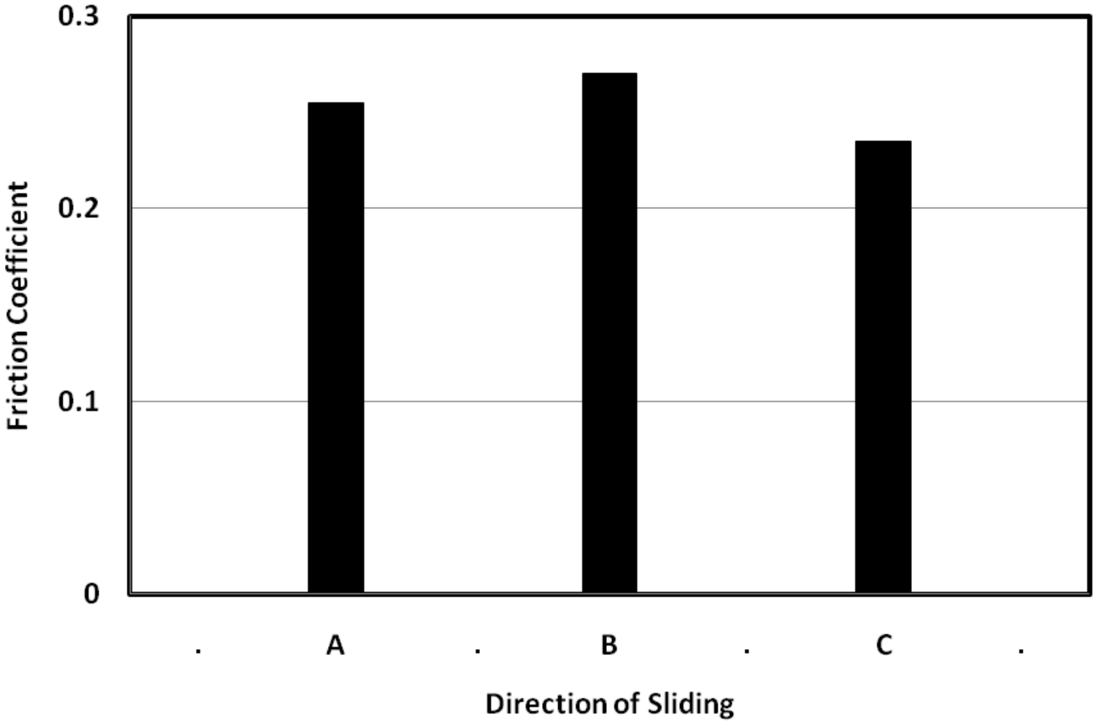

Fig. 9 Effect of sliding direction on friction coefficient displayed by the tested rubber sliding against water wetted ceramics.

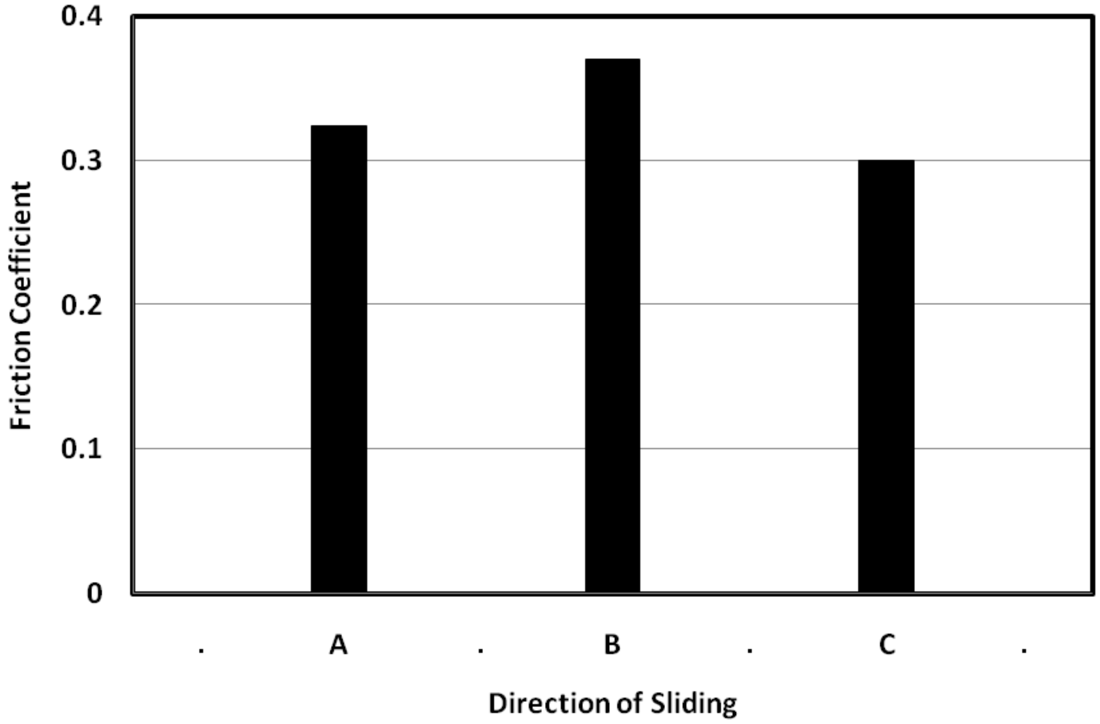

Fig. 10 Effect of sliding direction on friction coefficient displayed by the tested rubber sliding against sand contaminated ceramics.

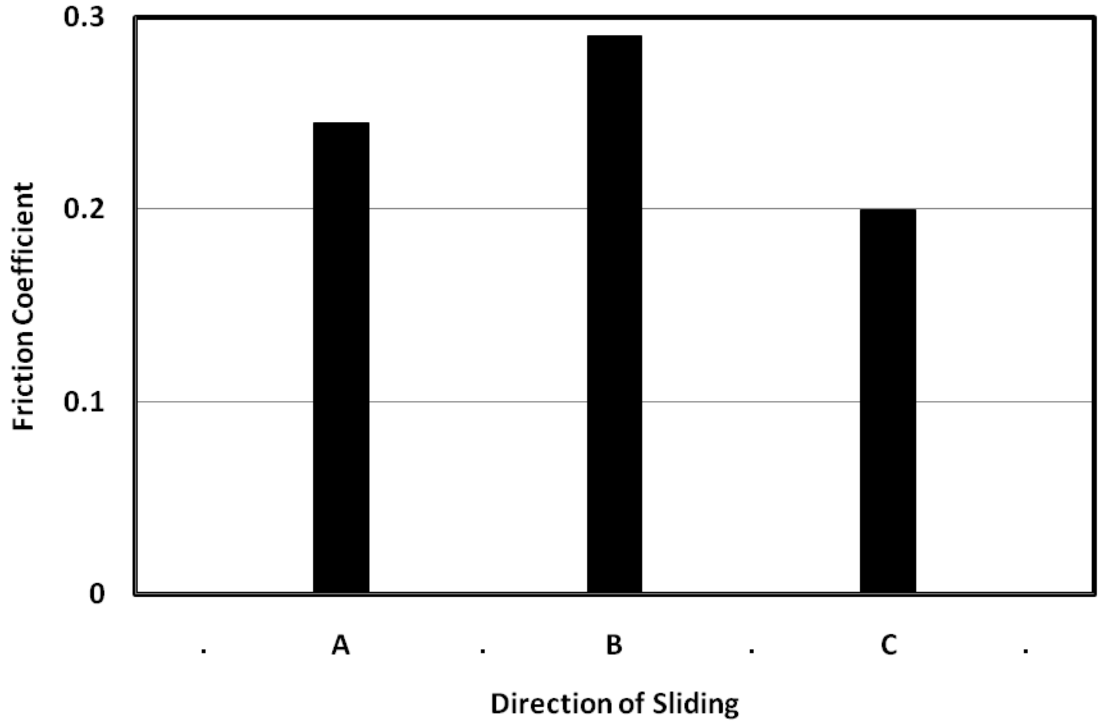

Fig. 11 Effect of sliding direction on friction coefficient displayed by the tested rubber sliding against water and sand contaminated ceramics.

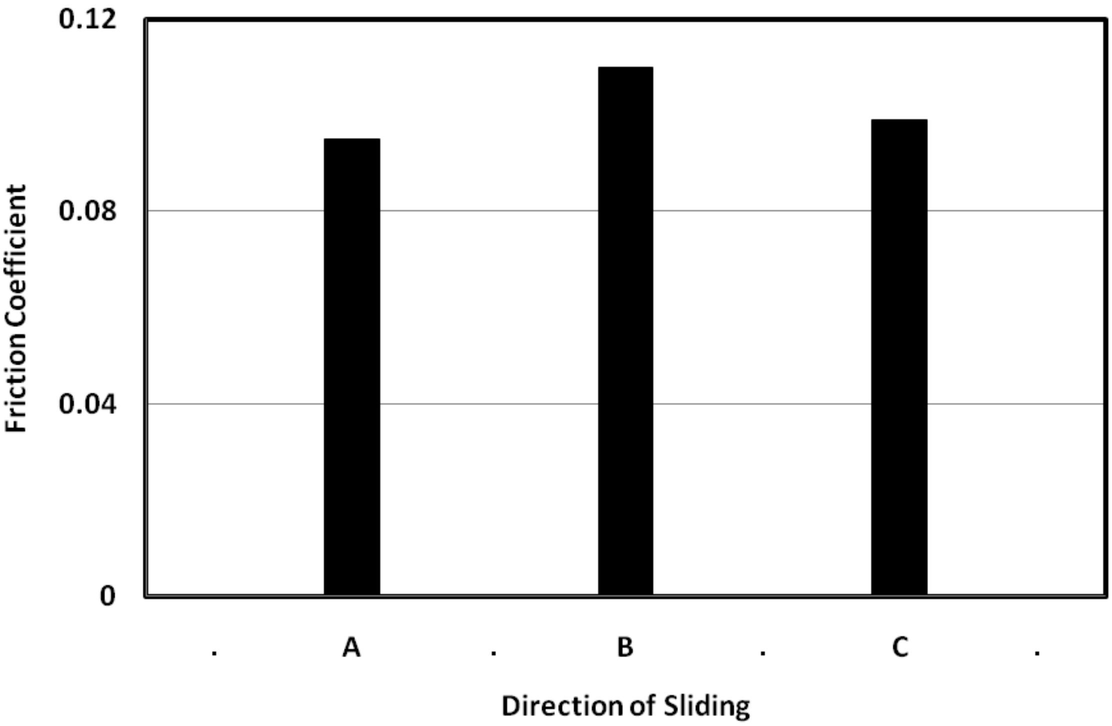

Fig. 12 Effect of sliding direction on friction coefficient displayed by the tested rubber sliding against oil lubricated ceramics.

Friction coefficient, displayed by the tested rubber sliding against water and sand contaminated ceramics, is shown in Fig. 6. Friction coefficient represented relatively lower values than that observed for sand contaminated sliding, Fig. 5. The groove width showed slight influence of friction coefficient due to the easy motion of sand particles facilitated by the water. The friction values indicated that sand particles dominated the contact and consequently influenced the friction coefficient.

When the oil was covering the sliding surfaces, friction coefficient increased up to maximum then decreased with increasing the groove width, Fig. 7. The groove of 4 mm width gave the highest friction values. As the groove width increased, its ability, to store the oil scavenged from the contact area and feed back again into the sliding surfaces, increased.

The effect of sliding direction on friction coefficient displayed by the tested rubber sliding against dry ceramic is shown in Fig. 8. The experiments were carried out on the test specimens of 120° groove angle and 6 mm groove width. Direction (B) showed the highest friction value followed by (C) then (A). This behavior can be interpreted on the amount of rubber deflection which is much influenced by the motion direction.

Friction coefficient displayed by the tested rubber sliding against water wetted ceramics showed higher values for (B) direction followed by (A) and (C), Fig. 9. The difference in the values of friction coefficient was insignificant. In the presence of water film, it seems that the ability of the groove to store the fluid was responsible for the variation of the values of friction coefficient.

When sand was contaminating the ceramic surface the differences in friction coefficient was significant, Fig. 10. The highest value was presented by direction (B), while the

minimum was given by direction (C). The percentage friction difference was 19 %. The nature of contact between the sliding surfaces could control the friction values. Sand particles could strongly affect that contact.

Surfaces contaminated by sand particles and wetted by water showed relatively higher difference between the highest and lowest values (31 %), Fig. 11. It seems that water facilitated the motion of sand particles so that the effect of sand particles was much pronounced.

The effect of sliding direction on friction coefficient displayed by the tested rubber sliding against oil lubricated ceramics is illustrated in Fig. 12. The differences in friction values was significant. It seems that oil could decrease the adhesion between rubber and ceramic and consequently deformation decreased.

CONCLUSIONS

1. Friction coefficient displayed by the tested rubber sliding against dry ceramics significantly increased up to maximum then decreased with increasing groove width.
2. In the presence of water, friction coefficient decreased down to minimum then increased with increasing groove width.
3. Sliding surfaces contaminated by sand particles showed the same trend of friction coefficient observed for water. The values of friction coefficient were much higher than that shown for water sliding.
4. For water and sand contaminated ceramics, friction coefficient represented relatively lower values than that observed for sand contaminated sliding.
5. When the oil was covering the sliding surfaces, friction coefficient increased up to maximum then decreased with increasing the groove width.
6. Friction coefficient displayed by the tested rubber sliding against ceramics was influenced by the sliding direction at all the sliding conditions.
7. As for water wetted sliding, the difference in the values of friction coefficient was insignificant.
8. When sand contaminating the ceramic surface the differences in friction coefficient were significant.
9. Surfaces contaminated by sand particles and wetted by water showed relatively higher difference than that observed for sand contaminated ceramic.
10.For oil lubricated ceramics, the difference in friction values was significant.

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