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PROPER SELECTION OF FOOT WEARING SOCKS TEXTILES BASED ON FRICTION COEFFICIENT DISPLAYED BY SLIDING AGAINST INDOOR FLOORS

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ABSTRACT
Proper selection of socks textiles sliding against indoor floor materials can avoid slip accidents. The present work discusses the measurements of friction coefficient displayed by foot wearing socks slid against different types of floors under dry sliding condition. The floor materials are parquet, cement, marble and ceramic, while the socks textiles are wool, polyacrylonitrile, cotton, polyester, spandex, silk and polyamide.

The experiments showed that careful selection of textiles used in fabrics of foot wearing socks should be considered. This selection depends mainly on the indoor floor materials. The results revealed that, socks sliding against cement floor experienced relatively higher friction coefficient than that observed for parquet. The highest friction values were displayed by polyacrylonitrile, spandex, wool, cotton and polyamide. Polyacrylonitrile displayed the highest values of friction coefficient when slid against parquet floor, while natural wool gave the lowest friction values. Polyamide showed the same trend observed for wool, while silk and spandex gave relatively higher friction. Sliding against marble floor showed relatively lower friction values than observed for parquet and cement floors. Polyacrylonitrile, wool and polyamide showed higher friction than that recorded for cotton, polyester spandex and silk. Ceramic floor showed relatively higher friction values than that observed for marble and lower than given by cement and parquet. The difference in the friction values increases the necessity to carefully select the materials of the socks textiles for use in indoor walking to avoid slip accidents.

KEYWORDS
Friction coefficient, electrostatic charge, ceramic, marble, parquet ceramic, porcelain, flagstone tiles.

INTRODUCTION
Prevention of slip accidents indoor can be achieved by the proper selection of socks textiles and floor materials. The effect of the cotton content of socks on the frictional behaviour of foot during walking was investigated, [1 – 3]. It was found that friction coefficient increased with increasing the cotton content in socks, where polyamide socks displayed the lowest friction and cotton socks displayed the highest one.

The friction coefficient and electric static charge generated from sliding of foot wearing socks against indoor flooring tiles. The static friction coefficient displayed by foot wearing socks of different textile materials under dry sliding was investigated. Floor tiles of ceramics, flagstone, parquet, parquet ceramics, marble, porcelain and rubber were tested as floor materials, [4]. Rubber floor displayed the highest friction values, while marble showed the lowest ones. It can be recommended that further experiments should be carried out to determine the position of the floor materials in the triboelectric series in order to properly select the material of the socks to avoid generation of excessive electric static charge.

The effect of flooring materials on friction coefficient was discussed, [5]. The friction coefficient of smooth rubber footwear sliding against different types of flooring materials was investigated under dry sliding condition. The tested flooring materials were ceramic, marble, parquet ceramic, porcelain and flagstone. Footwear sliding against marble flooring experienced relatively lower friction coefficient than that observed on ceramic one. Sliding against parquet ceramic flooring showed relatively higher friction values than that observed for ceramic and marble. Porcelain flooring showed relatively lower friction values than that observed for ceramic and parquet ceramic, while higher than that shown for marble. Flagstone flooring displayed significant increase in friction coefficient.

Friction coefficient is the major scale to quantify floor slipperiness. The friction coefficient of rubber sliding against polymeric indoor flooring materials of different surface roughness was investigated, [6]. It was found that, at dry sliding, the friction coefficient decreased with increasing surface roughness and applied load. At water lubricated sliding, the friction coefficient increased up to maximum then decreased with increasing surface roughness. At water–detergent lubricated sliding, the friction coefficient drastically decreased with increasing the surface roughness. At oil lubricated sliding, the maximum friction values were noticed at 4.0 µm R_a surface roughness. At water and oil lubricated sliding, smooth flooring surface displayed very low values of friction coefficient (0.08) close to the ones observed for mixed lubrication where the two sliding surfaces are partially separated by a fluid film. At dry sliding, friction coefficient of bare foot and polymeric socks, friction coefficient decreased down to minimum then increased with increasing the surface roughness, [7]. In water lubricated sliding, cotton socks showed the highest friction coefficient. Friction coefficient drastically decreased with increasing surface roughness at water and detergent lubricated sliding. For the tested flooring materials lubricated by oil, bare foot displayed drastic reduction in friction coefficient, while cotton socks showed the highest values.

The changes in the surface properties and frictional characteristics of flooring materials are expected in practical use due to mechanical wear, ageing, soiling and maintenance, [8]. In the sport halls the flooring surfaces are probably changed mainly through mechanical wear, periodic cleaning processes and material transfer from shoe soles (elastomer abrasions and contaminating particles). Coefficients of friction were measured periodically over a period of 30 months on the surfaces of five types of floor coverings in a new sport complex, [9]. Surface changes through mechanical wear range from smoothing to roughening, [10, 11], depending on flooring material and surface characteristics. Surface roughness is known to be a key factor in determining the slip resistance of floors. The effect of surface roughness of ceramic slid against rubber and leather on friction coefficient, was investigated, [12]. Glazed floor tiles of different

roughness ranging from 0.05 and 6.0 μm were tested. The test results showed that, friction coefficient decreased down to minimum then increased with increasing the surface roughness of the ceramic surface.

Slip resistance of flooring materials is one of the major environmental factors affecting walking and materials handling behaviors. Floor slipperiness may be quantified using the static and dynamic friction coefficient, [13]. Certain values of friction coefficient were recommended as the slip-resistant standard for unloaded, normal walking conditions, [14, 15]. Relatively higher static and dynamic friction coefficient values may be required for safe walking when handling loads. Researches revealed significant correlations between surface roughness of shoes and friction coefficient for a given floor surface, [16 - 19]. Abrasion of rubber soling in steps with increasingly coarse grit gradually raised the roughness in parallel with a rise in the friction coefficient on water wet surfaces. Dense rubbers never developed the same order of roughness, and they became smooth and polished when worn on ordinary floors or with mechanical polishing.

In the present work, friction coefficient of foot wearing socks sliding against different types of flooring materials were investigated under dry sliding condition.

EXPERIMENTAL

Experiments were carried out to measure the friction coefficient displayed by the sliding of foot wearing socks against different types of flooring materials, under dry sliding condition through measuring the friction force and applied normal load. The tested materials are placed in a base supported by two load cells, the first measures the horizontal force (friction force) and the second measures the vertical force (applied load), Fig. 1. Friction coefficient was determined by the ratio between the friction force and the normal load.

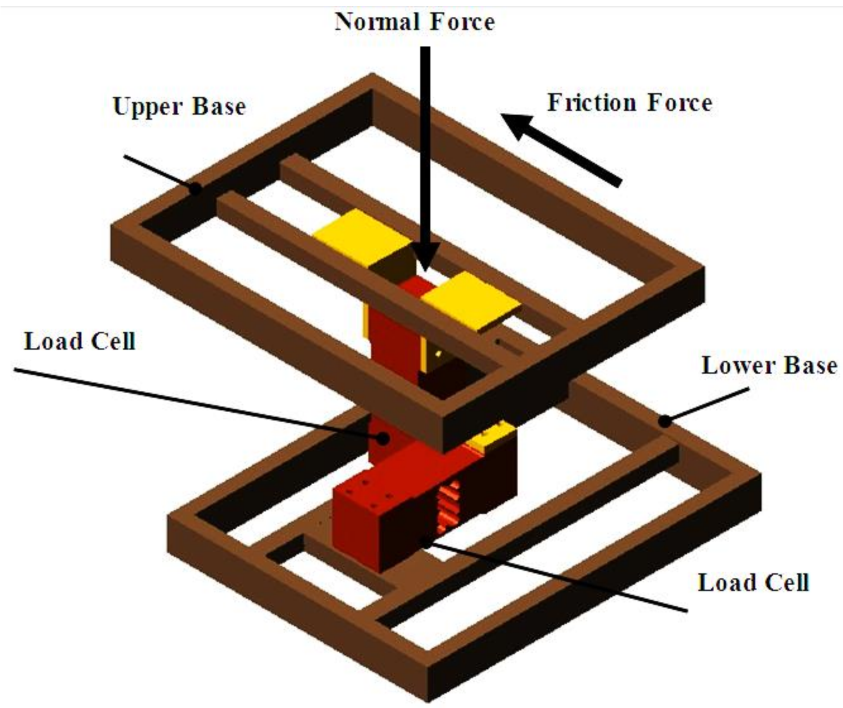

Fig. 1 Arrangement of test rig.

Sock fabrics used in the present experiments are wool, polyacrylonitrile, cotton, polyester, spandex, silk and polyamide. Wool is a natural fiber from the coat of animals. The feel of wool varies from soft to scratchy. Many people have wool sensitivity when their skin becomes irritated from wearing wool. Wool fibers are known as Mohair, Angora wool, and Cashmere. Cotton has soft and smooth feel. It is also breathable and biodegradable. Spandex is made of synthetic fiber that provides elasticity, recovery, and close fit. It is combined with stretch or textured nylon or polyester and used as the principal stretch fiber in socks. Polyacrylonitrile is synthetic fibres of wool-like appearance. Polyamide is elastic and stronger than the other commonly used fibres. Polyester, the most used polymeric fibre, is washable, quick-drying and resistant to stretching and shrinkage. Silk is a natural fibre which can be woven into textiles. It is produced by certain insect larvae to form cocoons. The shimmering appearance of silk is due to the triangular prism-like structure of the silk fibre.

The tested flooring materials were parquet, cement, marble and ceramic tiles in form of a quadratic sheet of 0.4 m × 0.4 m. The sliding surfaces were thoroughly cleaned with soap water to eliminate dirt as well as dust and carefully dried before the tests. The tested socks materials were adhered to wooden block of 50 × 50 × 50 mm^3 and loaded against the tested floor materials. Friction test was carried out at normal load varying from 0 to 200 N at dry sliding condition.

RESULTS AND DISCUSSION

The results of the experimental work are illustrated in Figs. 2 – 9. Safety of walking on indoor floor can be enhanced by increasing friction coefficient displayed by the sliding of foot wearing socks against indoor floor. The values of friction coefficient displayed by sliding against parquet floor are shown in Figs. 2 and 3. Polyacrylonitrile displayed the highest values of friction coefficient with increasing load because its fibres have properties closely like those of wool of exceptional resilience, and crimpiness. Natural wool gave the lowest friction values because wool fiber is made up of millions of coiled springs that stretch during use and coil back to their original positions so that the feel tends from scratchy to soft. Scratch feeling of wool occurs when the diameter of the fibre is above 30 microns. Polyamide showed the same trend observed for wool, while silk and spandex gave relatively higher friction.

Socks sliding against cement floor, Figs. 4 and 5, experienced relatively higher friction coefficient than that observed for parquet. The highest friction values were displayed by polyacrylonitrile, spandex, wool, cotton and polyamide. Based on the American and European standards the friction values are high enough for safe indoor walking at higher loads. The building codes have established that a static friction coefficient less than 0.50 represents the minimum slip resistance threshold for safe floor surfaces. The Americans Act Accessibility Guidelines for Disabled, [21, 22], contain recommendations for static coefficient of friction more than 0.60 for accessible routes (*e.g.* walkways and elevators) and 0.80 for ramps. In Europe, it was proposed that a floor is ‘‘very slip-resistant’’ if friction coefficient is 0.3 or more. A floor with friction coefficient between 0.2 and 0.29 is ‘‘slip resistant’’. A floor is classified as ‘‘unsure’’ if its friction coefficient is between 0.15 and 0.19. A floor is ‘‘slippery’’ and ‘‘very slippery’’ if friction coefficient is lower than 0.15 and 0.05, respectively.

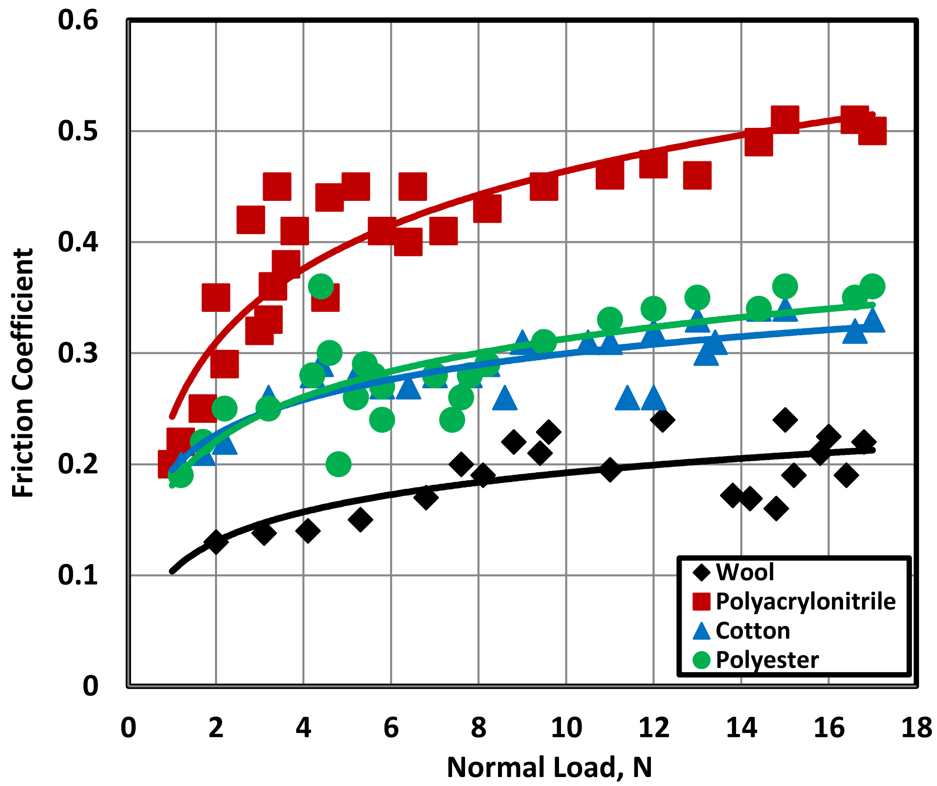

Fig. 2 Friction coefficient displayed by sliding of socks against dry parquet floor.

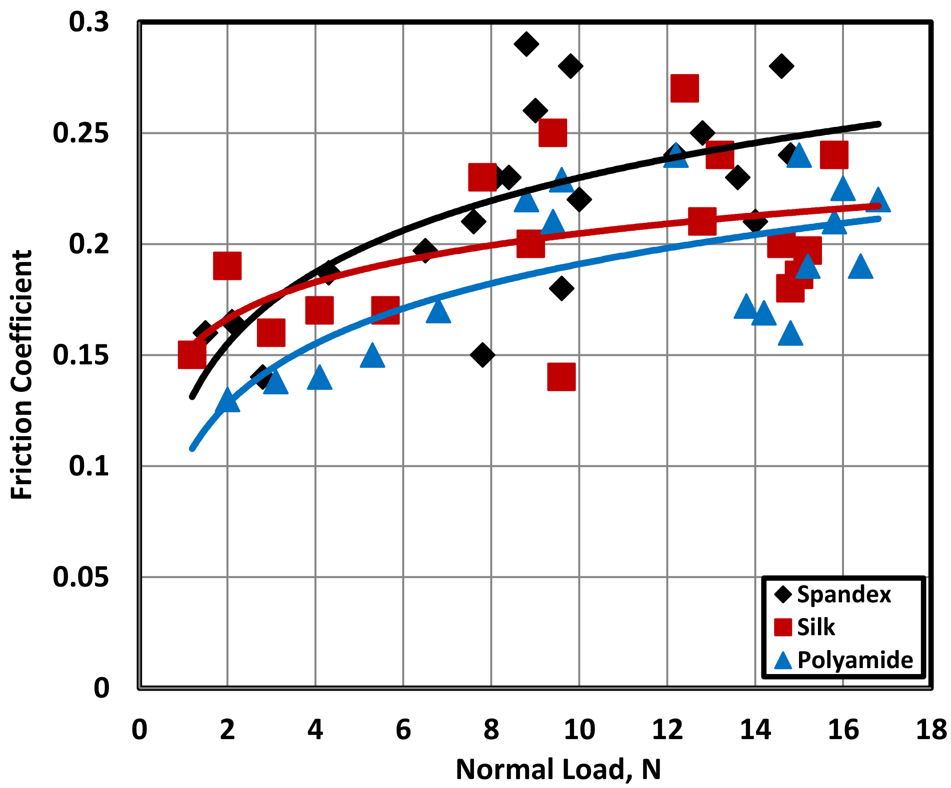

Fig. 3 Friction coefficient displayed by sliding of socks against dry parquet floor.

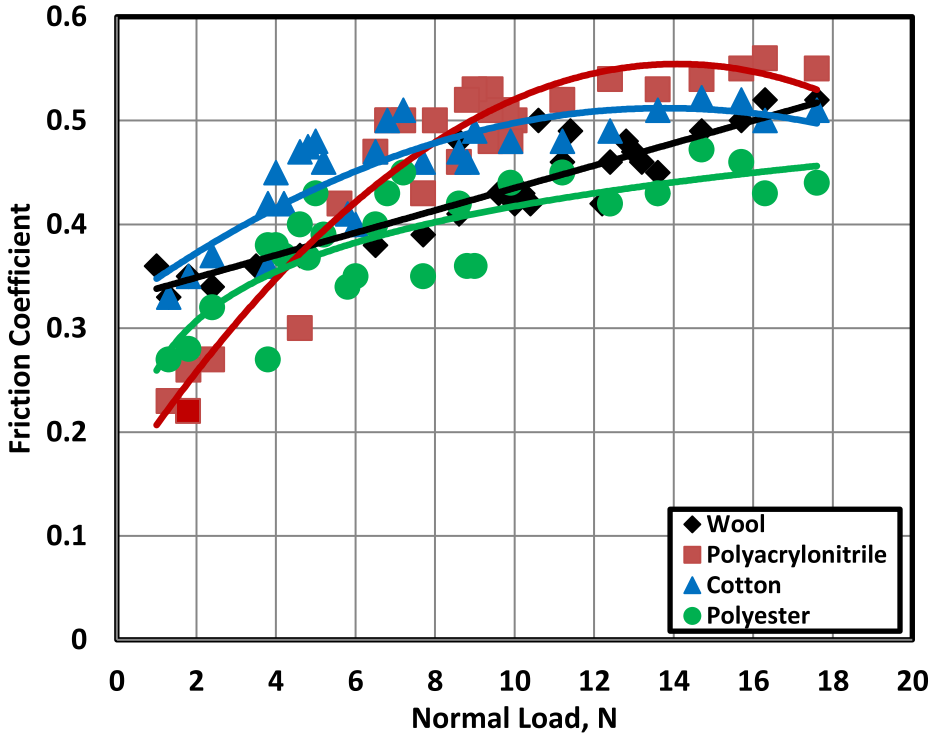

Fig. 4 Friction coefficient displayed by sliding of socks against dry cement floor.

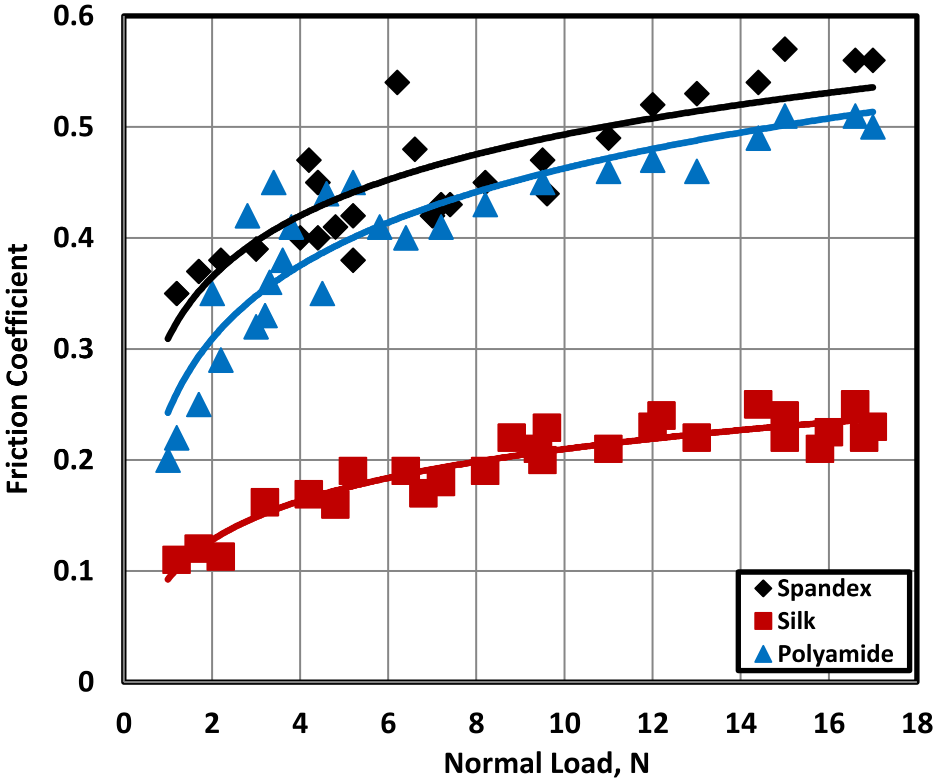

Fig. 5 Friction coefficient displayed by sliding of socks against dry cement floor.

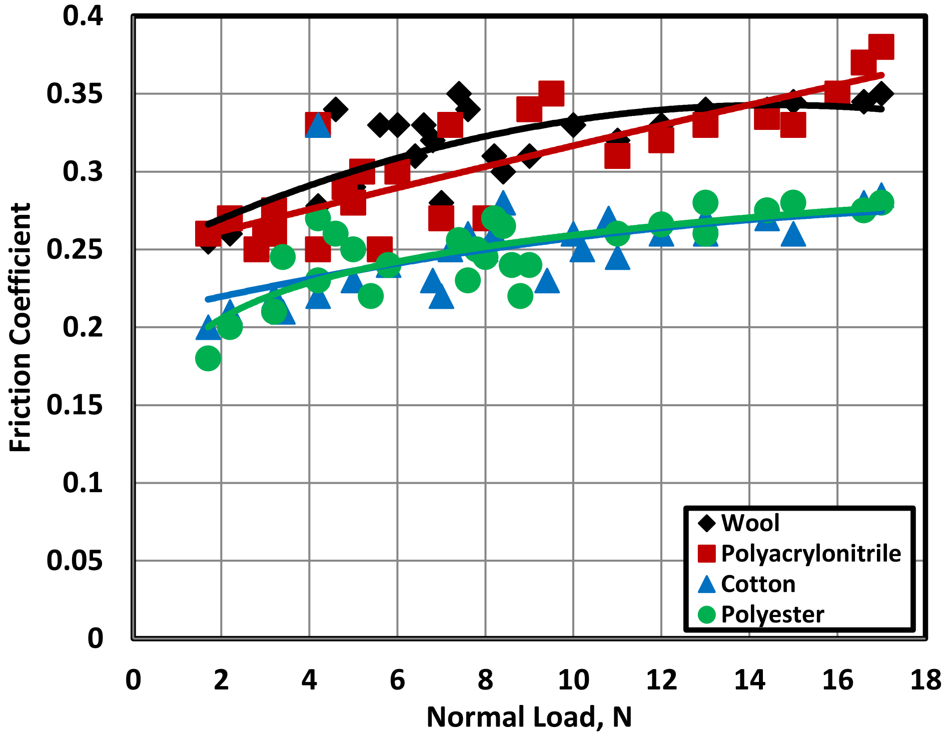

Fig. 6 Friction coefficient displayed by sliding of socks against dry marble floor.

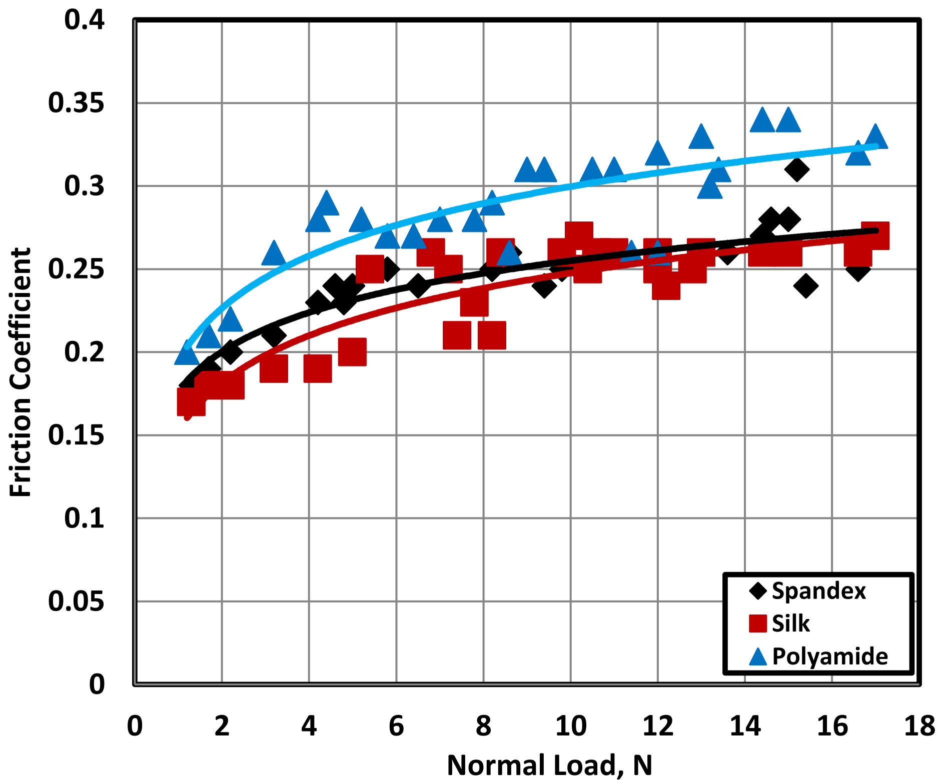

Fig. 7 Friction coefficient displayed by sliding of socks against dry marble floor.

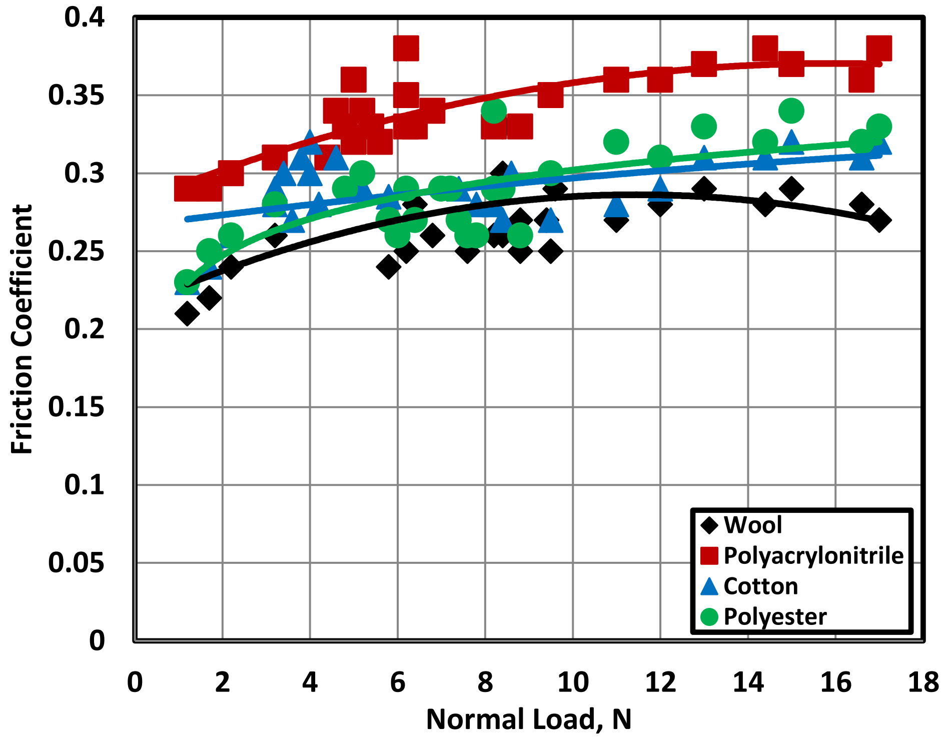

Fig. 8 Friction coefficient displayed by sliding of socks against dry ceramic floor.

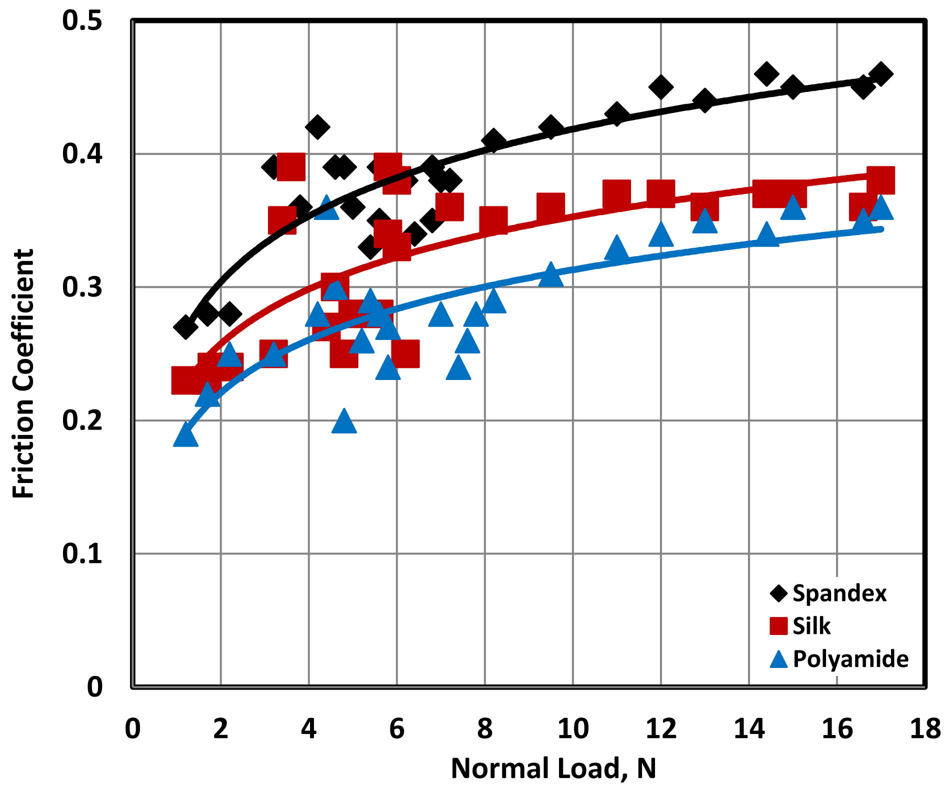

Fig. 9 Friction coefficient displayed by sliding of socks against dry ceramic floor.

Friction coefficient displayed by sliding against marble floor showed relatively lower values than observed for parquet and cement floors, Figs. 6 and 7. The friction values fulfill the European standards, where the static values of friction coefficient of 0.3 - 0.5 had been recommended as the slip-resistant standard for unloaded, normal walking conditions. Higher static coefficient of friction may be required for safe walking when handling loads, which is guaranteed by the American standards. Polyacrylonitrile, wool and polyamide showed higher friction than that recorded for cotton, polyester spandex and silk.

Sliding against ceramic floor showed relatively higher friction values than that observed for marble and lower than given by cement and parquet, Figs. 8 and 9. At higher normal loads, the highest friction value (0.46) was displayed by spandex, while the lowest one (0.47) was displayed by wool. The difference in the friction values increases the necessity to carefully select the materials of the socks textiles for use in indoor walking to avoid slip accidents.

CONCLUSIONS

1. Polyacrylonitrile displayed the highest values of friction coefficient with increasing load when slid against parquet floor. Natural wool gave the lowest friction values. Polyamide showed the same trend observed for wool, while silk and spandex gave relatively higher friction.
2. Socks sliding against cement floor experienced relatively higher friction coefficient than that observed for parquet. The highest friction values were displayed by polyacrylonitrile, spandex, wool, cotton and polyamide.
3. Friction coefficient displayed by sliding against marble floor showed relatively lower values than observed for parquet and cement floors. Polyacrylonitrile, wool and polyamide showed higher friction than that recorded for cotton, polyester spandex and silk.
4. Sliding against ceramic floor showed relatively higher friction values than that observed for marble and lower than given by cement and parquet. The difference in the friction values increases the necessity to carefully select the materials of the socks textiles for use in indoor walking to avoid slip accidents.

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