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## Insights to skin-turf friction as investigated using the Securisport

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### Abstract

The objective of this study was to investigate the effect of the infill and fibers of an artificial turf surface to the overall frictional behavior of the surface. The assessment was conducted using the Securisport test device in accordance to the FIFA Test Method so as to evaluate the effectiveness of the standard test in describing the frictional property of an artificial turf surface. Experiments showed that surfaces of varying infill depths and infill types produced characteristic features in their friction profiles that were a result of the fiber-infill interactions. The surface without infill exhibited the highest frictional values, with distinct peak and trough features. Surfaces completely filled with sand or rubber displayed similar profiles with relatively low frictional values. Test results showed that turf fibers influenced the frictional behaviour of partially-filled systems to a great extent. The results from the Securisport were useful in providing insights to how various turf components affect the skin-turf interaction and may be beneficial in the development of more skin-friendly turf products.

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### 1. Introduction

Skin abrasion injuries are often considered minor and excluded from epidemiological studies due to the minimal influence they have on player performance or game quality. However, when players are asked for their perceptions

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of artificial turfs, many have highlighted skin abrasions as a major disadvantage from higher incidence [1–3]. Studies have shown higher rates of skin injuries suffered on artificial turfs as compared to natural grass fields [4–6].

The first generation (1G) of artificial turfs (developed in the 1960s) were especially unforgiving on the skin, comprising of fibers made from polyamide yarns that are hard and abrasive [7,8]. Despite the ongoing perceived risk of skin abrasion and discomfort when playing on artificial turfs, there has been little progress in product development to address issues of skin injuries since the adoption of polyolefins in the 1970s [9]. Currently, artificial turf products are accredited by sports governing bodies – in particular, the Fédération Internationale de Football Association (FIFA), and World Rugby (formerly IRB) have included requirements for skin friction and abrasion measurements within their artificial turf accreditation processes. They use a mechanical device known as the ‘Securisport’ which consists of a test foot that rotates over the tested surface [10]. The test foot has attached to it a skin equivalent material made of silicone rubber, and a normal load of 100N is applied while the foot rotates at a speed of 40rpm. The Securisport measures the resistant frictional force while the foot traverses the surface, and records the change in the coefficient of friction (COF) over the course of five revolutions. The tested surface is deemed acceptable when the average COF values fall within the range of 0.35 – 0.75. There is no clear justification on how the performance requirements have been determined or the test efficacy.

Research groups from the Institute of Biomechanics of Valencia (IBV) and Ghent University have designed innovative friction devices in an effort to better represent player sliding movement on turf surfaces and included additional measurements of static coefficient [11] and temperature [12] respectively. The IBV study found that artificial turf surfaces that resulted in larger silicone skin damage were classified as more abrasive by live subjects who rubbed their forearms across the surfaces. The Ghent University trials used their bespoke sliding tester apparatus on various artificial turf surfaces for hockey and concluded that watering of the surfaces effectively reduced the temperature rise during sliding, corresponding to the subjective preference of hockey players towards watered pitches. This was based on the assumption that a larger temperature rise implied a higher risk of skin abrasion injury. These studies, though preliminary, are thought-provoking and provided insights to how sliding on artificial turf surfaces might translate to the abrasion of skin.

This paper presents the initial results from a study using the Securisport to investigate how the various components of an artificial turf system affect its overall ‘skin’ frictional behaviour.

## **2. Materials and Methods**

### *2.1. Test Surfaces*

A 40mm monofilament carpet was used for the experiments, together with styrene-butadiene crumb rubber (size range 0.5-1.5mm) (SBR) and 2EW silica sand infills (size range 0.2-0.7mm). Five 1m x 1m carpet samples with varying infill depths and infill types were prepared: carpet-only, 20mm-sand filled, 20mm-SBR filled, 40mm-sand filled and 40mm-SBR filled. The surfaces were prepared by first raking the carpet to lift the fibers which tend to lie inclined to their intrinsic orientation, a result of the manufacturing process. For surfaces that required infill, the infill was applied to the surface in three or six additions for the 20mm- and 40mm-filled surfaces respectively. Conditioning of the surface with a standard hand-pulled studded-roller was carried out after each application of the infill [10]. The infill depths and free-pile heights of each surface were measured and recorded for the test surface before and after each trial. After each test trial, the surfaces were then reconditioned by raking and/or redistribution of infill to ensure consistency of the initial test surfaces. A summary of the specifications of the prepared surfaces is presented in Table 1. The presented values of infilled depth and free-pile height are averaged from five readings equally spaced across the prepared surface.

### *2.2. Test Method*

The frictional measurements were carried out in accordance to FIFA-08 from the FIFA Handbook of Test Methods [10] using the Securisport Friction Tester manufactured by Wassing Messtechnik GmbH. The silicone skins (Maag Technik AG, Switzerland) were prepared by washing with deionized water and dried at ambience conditions for 24 hours. The device was carefully levelled, the silicone skins were then secured onto the test foot,

which was subsequently attached to the Securisport and a normal load of 100N was applied via pneumatic application. The test foot was then moved across the surface at a rotational speed of 40rpm for five revolutions. Instead of reading off the average value as displayed on the Securisport software, the raw data file that records the changes in normal load, torque and COF against time was analyzed in detail. The trials were repeated three times for every surface, each with a new silicone skin sample.

Table 1. Measured specifications of the prepared surfaces prior to testing

Surface	Carpet	Infill	Infill depth (mm)	Free-pile height (mm)
A	40mm monofilament	None	N/A	N/A
B	40mm monofilament	Sand	21 ± 0.1	18 ± 0.1
C	40mm monofilament	SBR	22 ± 0.2	17 ± 0.2
D	40mm monofilament	Sand	36 ± 0.2	3 ± 0.2
E	40mm monofilament	SBR	35 ± 0.4	4 ± 0.2

### 3. Results

The surfaces were prepared with high repeatability as seen from the controlled values in Table 1. COF against time graphs are shown in Fig. 1, for the five tested surfaces – vertical lines at 1.5s intervals indicate the completion of a rotation of the test foot. It is observed that the general trend of COF tapers off to a steady value after the third rotation (time = 4.5s) with each surface displaying characteristic COF behaviour at the initial phase of the rotations. For surface B which was partially filled with sand, the COF values rose gradually after overcoming the first peak for static friction to achieve a steady state value of 0.803. On the other hand, surface C which was partially filled with rubber infill showed a large broad peak in COF values spanning the first and second rotations, achieving a maximum value of 1.052. These behaviors were thought to be caused by the different infills being used. However, when the system was filled completely with either sand (surface D) or rubber (surface E), the COF profiles behaved similarly – with an initial peak representative of the static friction and subsequently oscillating about a steady value of 0.594 and 0.579 respectively. Surface A which comprises of solely the 40mm monofilament carpet showed the highest COF values measured. Beyond the initial static friction, the COF of the surface increased in a behaviour similar to that of surface C to reach a peak value of 1.098 and subsequently oscillating about an average value of 0.979. It is notable that the steady-state COF values of surfaces B and C lie between that of the unfilled and fully-filled surfaces.

Fig. 1 (f) also shows the decrease in infill depth as measured on each surface after testing. Surface B showed the least change in the level of sand after five rotations of a loaded foot over the surface. The depth of rubber infill decreased significantly for the partially rubber-filled surface C, with an infill depth 4.0mm lower than that of the surface prior to testing. The fully-filled surfaces showed comparably large changes in infill depth. Sand-filled surface D had a slightly lower reduction of infill depth (average 3.8mm) when compared to the rubber-filled surface E (average 4.5mm). The significant changes in infill depth measured on the fully-filled surfaces are evident from the images shown in Fig. 2.

### 4. Discussion

From the COF profiles of the tested surfaces, frictional values of artificial turf systems appear to be dependent on the complex interaction between carpet fibers and the infill particles. For surface A, the foot rotates over the fibers with and against their intrinsic orientation. When the foot is traveling in the same direction as the fiber orientation, the fibers smooth out under the foot and lie flat against the carpet backing, resulting in lower frictional values. As the foot completes half a rotation, it starts to move against the orientation and the fibers are forced to bend and fold backwards, creating resistance and building up to the peak COF values as shown in Fig. 1a. This produces the cyclic peaks and troughs in the COF profile. The same effect is evident but to a lesser extent for rubber-filled surface C.

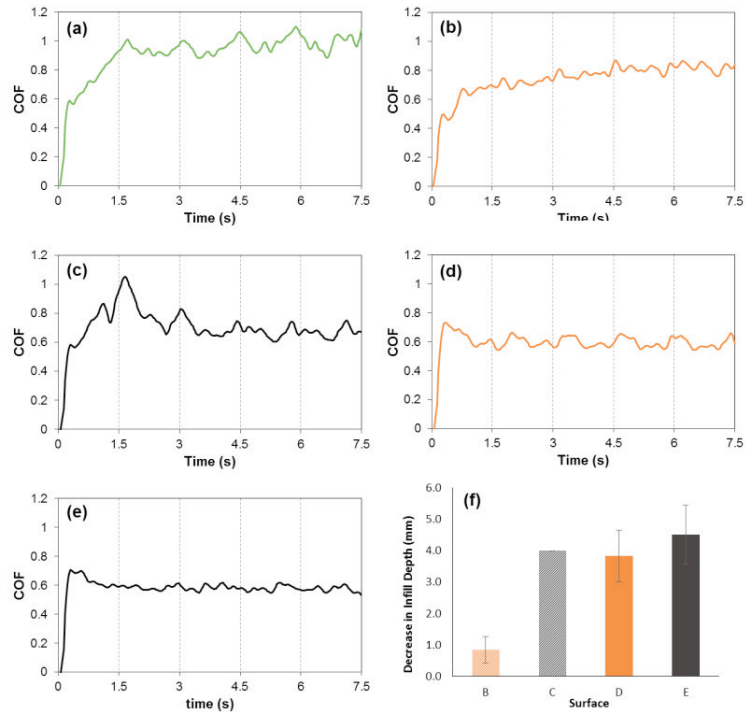


Fig. 1. COF versus time profiles of surface (a) A: no infill, (b) B: 20mm of sand, (c) C: 20mm of SBR, (d) D: 40mm of sand and (e) E: 40mm of SBR. Fig. 2(f) shows the average changes in infill depth after testing for surfaces B – E.



Fig. 2. Surfaces (a) D and (b) E after testing show significant decrease in infill depths along the path of the test foot.

The evident influence of the fibers on the COF profile of surface C may be attributed to the compressibility of the rubber infill, illustrated in Fig. 4. When the normal load is applied to the stationary foot, significant compression of the rubber particles under the foot occurs (Fig. 4a). As the foot starts to rotate around the surface, it compresses the rubber infill in its path as well as moves some particles to the side of the foot. Both compression and displacement of the rubber result in significant decrease in the infill depth (Fig. 2), exposing a larger length of the fibers (Fig. 4c) allowing for greater interaction with the test foot. The condition of the surface hence changes continuously for the initial phase of the trial (first 2 rotations) and thereafter reaches a relatively consistent state. On the other hand, sand particles are tightly packed in surface B and the loaded foot causes minimal movement of the infill (Fig. 4d). This implies that the foot-surface interaction remains relatively constant during the trial, and the friction measured is representative of the surface property. The COF profile of surface B shows a similar gradual increase of friction to a

steady value as that of the carpet-only surface but without the cyclic peaks and troughs. This implies that the sand was capable of stabilizing the fibers, eliminating the effect of intrinsic orientation in the exposed free-pile height.

For the fully-filled surfaces, the effect of turf fibers at the foot-surface interface is insignificant. Hence, when the foot rotates across surfaces D and E, friction is dominated by the mechanism of rolling friction where the test foot moves across a 'ball-bearing' type system with infill particles rolling over each other. The large decrease in infill depths for both surfaces is due to the splaying of the fiber tips at the top surface, reducing their effectiveness in holding the top layer of infill in place. However, the portion of fibers exposed in this instance is not enough to influence the frictional property of the surface.

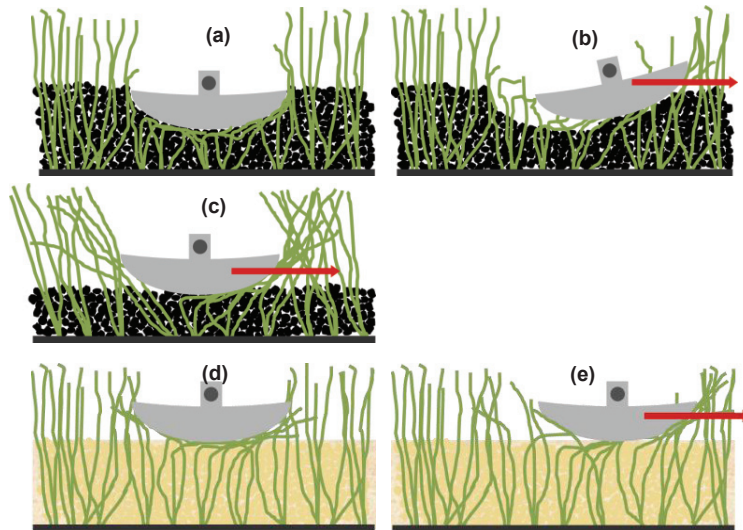


Fig. 3 a-e. Schematics postulating the mechanism of infill and fiber interaction during the test.

In evaluating the effectiveness of the Securispot for measuring the frictional property of an artificial turf surface, the standard test device was deemed to be capable of distinguishing between the prepared surfaces. It was also able to identify key frictional characteristics of each surface, providing insights to how the various components of the artificial turf contribute to the overall friction behaviour. However, how these frictional values correlate to that experienced by a player sliding on the turf surface is still unknown. The normal load applied in the FIFA-08 test method, the rotational motion and speed of the test foot are non-representative of human movement [13] when sliding during game play and the biofidelity [14] of the silicone skin to that of human skin is also questionable.

During the study, it was observed that when applying normal loads above that stated in the test method, excessive compression of the surface and the high static friction prevented the foot of the Securispot from moving across the surface and instead could lift the equipment. Furthermore, fluctuations in the normal load were observed in early trials where the device was not carefully levelled on the surface, a limitation of using the pneumatic load system.

However, the lack of literature describing the biomechanics of a player sliding movements is a limitation to the design of better testing devices. The alternative tests devised by the IBV and Ghent University groups both involved a linear movement of the test foot similar to that of a player sliding, but compromised in portability of the device and maximum achievable test speed. The use of the silicone skin as a skin-equivalent eliminates the variability of skin properties from live sources (e.g. animals or humans) as well as the ethical issues concerning testing with human subjects, however.

## 5. Conclusion

In this study, the effect of artificial turf components on its overall frictional behaviour was investigated, using a standard skin-surface friction tester known as the Securispot. It was observed that the interaction of the turf fibers

with the infill contributes most to the COF profile. The large movement of the compressible rubber infill during testing allowed for a stronger influence of the fibers on the friction as longer pile lengths are exposed. Key features from the carpet-only surface were hence evident in the rubber-filled surface with cyclic peaks and troughs caused by the intrinsic orientation of the turf fibers. The tightly packed sand infill provided a consistent test surface and improved stability of the turf yarns, hence displaying a gradual increase in COF to a steady-state value. Overall, the COF values of the partially-filled surfaces were found to be higher than that of the fully-filled system implying that friction of artificial turf surfaces increases with increasing free-pile height. Although it has limitations, the Securispport was found to effectively distinguish between the prepared surfaces, and provided insights to how the turf components affected frictional behaviour of the overall artificial turf surface. These insights provide relevant considerations for improving the skin-friendliness of turf products, suggesting that improvements in the reduction of friction from the fiber yarns may be more of a priority than adapting the infill.

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