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Improving the performance of soccer boots on artificial and natural soccer surfaces

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Abstract

An improved understanding of studded shoe-surface interactions is needed to optimise athletic performance in soccer. Soccer studs are required to penetrate the playing surface and provide traction to a soccer player. The translational traction at the shoe-surface interface is important for soccer players performing dynamic accelerating movements. A study has been carried out to evaluate the performance of studded footwear on a natural surface and a third generation artificial surface. A mechanical traction test device was used to quantify the performance characteristics of soccer studs in terms of penetration and traction for both surfaces. Results found from testing an existing soccer stud were used as benchmark values in order to evaluate the performance of five other soccer studs. The effects of the surface properties and stud geometry on stud penetration and traction are discussed.

Keywords: Soccer; Footwear; Surface; Studs; Performance;

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1. Introduction

To perform dynamic athletic movements soccer players require sufficiently high translational traction at the shoe-surface interface. When reviewing the design factors of sport shoes, Reinschmidt and Nigg [1] state traction as a key factor in performance. The aim of this study was to evaluate and compare the effects of surface characteristics and stud geometry on the translational traction performance of studded. For soccer studs to perform appropriately they must penetrate the playing surface and provide the player with the appropriate traction for the desired movement. Improved understanding of the tribological interactions between footwear and playing surfaces help players choose the optimum footwear for performance.

This study uses mechanical test methods to evaluate the performance of the soccer studs. Frederick [2] highlighted the need to develop repeatable test methods to quantify the range of traction that will allow high performance. Many mechanical test devices have been developed to investigate traction at the shoe-surface interface. Unlike player testing, which can be intrusive and suffer from poor repeatability between players,

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mechanical test devices have the advantage of creating objective loading conditions that provide a repeatable measure of shoe-surface traction.

Recent studies have used mechanical devices to investigate and compare the translational tractional performance of stud-surface interactions on natural surfaces and third generation (3G) artificial surfaces. Shorten *et al.* [3] used mechanical testing to compare the traction of 24 shoe-surface combinations. The two 3G artificial surfaces tested provided higher mean translational traction coefficients than the natural turf. However, the condition of the natural surface was not specified. If the surface had been dry and firm the studs may have failed to penetrate the surface, reducing the traction. Alternatively had the surface been wet and soft, although the studs may have penetrated the surface, the soil moisture content would have reduced the friction forces between soil particle bonds within the surface, reducing the traction. Vachon [4] compared three typical stud types (dimple studs, moulded studs, and bladed studs) on three surfaces (a natural surface, a five year old 3G artificial turf with infill and a 3G artificial turf without infill). On the natural surface it was found that the translational traction, measured as a mean coefficient of traction, was independent of sole type and no differences in translational traction were found between stud type for the infilled 3G artificial turf and the natural turf. Interestingly the longer stud designs (moulds and blades) saw a significant increase in translational traction on the 3G artificial turf with an infill. However, the pimple design gave the highest traction on the surface without an infill. The higher traction force experienced may be a result of the higher penetration depth of the moulded and bladed studs into the infill material. These studies highlight the need to quantify surface characteristics and to measure stud penetration in order to understand their effect on traction.

Traditionally translational traction test devices sample the force required to drag a loaded shoe or studded plate through a surface at a pre-determined constant velocity. Kirk *et al.* [5] developed a force-controlled mechanical traction testing device, arguing that such velocity driven test devices do not classify the traction during the initial movement of a player, when, it is argued, they are most risk of loosing performance. High speed video was used to observe shoe-surface interaction as 11 youth team players from a professional soccer club performed a push-off to sprint, a movement which requires high translational traction. The players carried out the movement on a natural surface without any potential restrictions from equipment in order to record their natural movements. The video recordings were used to establish the boundary conditions required to be accurately replicated by mechanical test devices. Observations of the push-off manoeuvre revealed a soccer shoe moves approximately 10 mm in the horizontal direction, until the shoe lifts off the surface. This highlighted the inappropriate movement of many velocity driven translational traction testing devices which drag studs along a surface over a significant distance, after which either the average dynamic or peak coefficient of traction is calculated for comparison. A force controlled pneumatic test device was developed which applies an increasing horizontal force until significant movement occurs on a vertically loaded stud plate.

In this study, the custom built mechanical testing device developed by Kirk *et al* [5] has been used to test the performance of six soccer studs based on vertical penetration into the surface and horizontal traction force, on two separate surfaces. The studs were chosen to offer a variety of penetration and traction characteristics. It was hypothesised the stud geometry would affect stud penetrability which would in turn affect the traction performance.

2. Methods

Two contrasting surfaces were investigated for this study; a natural turf surface and a 3G artificial surface. Testing of the 3G artificial surface took place in laboratory conditions. The surface had a pile length of 50 mm with a 20 mm deep sand and rubber crumb infill. Testing of the natural surface took place in-situ at soccer pitches at the University of Sheffield, UK. These pitches are well maintained and used as a training facility for a local professional soccer club. For the day of testing the gravimetric moisture content of the soil was taken. Ten cylindrical soil cores with 15 mm diameter and 50 mm length were taken from the testing area. The mass of the cores were immediately recorded. The cores were then oven dried at 110° C for 24 hours and the gravimetric moisture content was determined as the mean percentage weight loss of each core.

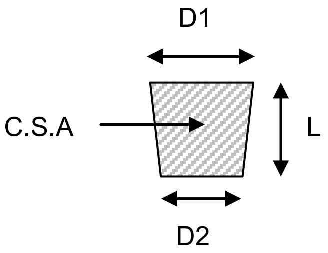
In order to understand the characteristics of each surface, they were tested with the SERG impact hammer, developed by Carré *et al.* [6]. The SERG impact hammer, shown in Figure 1, has an accelerometer contained within a hemispherical hammer profile. As the hammer hits the ground, the voltage signal from the accelerometer is sampled via a data acquisition device (National Instruments model number NI USB6008), in real time at 10,000 Hz and displayed in LabView (version 7.1 National Instruments). The output from the accelerometer was used to calculate force displacement curves throughout the loading phase of each impact.

As discussed, the custom built traction rig, developed by Kirk *et al.* [5], was used to measure the translational traction performance for each stud-surface combination. The rig, shown in Figure 1, simulates a player pushing off into a full sprint, a movement which requires high traction to prevent slipping. The traction rig samples horizontal and vertical forces and displacements throughout a force-controlled horizontal movement. A high pressure pneumatic ram provides a dynamic force in the horizontal direction. The horizontal load is controlled by a solenoid valve which opens the pneumatic cylinder. A hydraulic ram provides a controlled vertical load to a 10 mm deep plate, designed to simulate the forefoot segment of a studded outsole. Load cells in the horizontal and vertical direction provide force data. A development of the previous design of Kirk *et al.* [5] was to include the addition of vertical linear variable differential transducers (LVDT) to measure displacement of the stud plate in both the horizontal and vertical planes. Voltage signals from the load cells the LVDTs are sampled simultaneously, via a data acquisition device (National Instruments model number NI USB6008), in real time at 200 Hz and displayed in LabView (version 7.1 National Instruments). The signals are sampled and transformed into force and displacement measurements.

Fig. 1. Left: SERG impact hammer used in field testing. Right: Custom built rig used for translational traction testing.

The dimensions and geometry of the six studs tested in this study are presented in Table 1. Two of the six studs are existing popular studs. Stud WC is found in adidas World Cup soccer boots, designed for soft surfaces, and stud CM is found in adidas Copa Mundial soccer boots, designed for firm surfaces. The studs were configured in a five stud formation considered to be typical of the studs in contact with the surface during a push-off movement, this is shown in Figure 2. A vertical force of 350 N was applied to the studs. This was found by Kirk et al. [5] to be representative of the vertical force at a time when a player is at most at risk of slipping during a push-off. Traction trials were repeated 3 times for each stud-surface combination. In order to compare traction, data from each trial was processed to find the horizontal force after 10 mm of displacement. As previously discussed high speed video analysis by Kirk et al. [5] showed that a surface ‘gives’ by approximately 10 mm during a movement when the player does not slip. It can be argued that a horizontal displacement greater than 10 mm would result in the perception of slipping.

Table 1. Approximate dimensions of studs used in testing.



Stud Reference	L (mm)	D1 (mm)	D2 (mm)	Cross Sectional Area of stud profile (mm^2)
A	12	12	12	144
B	16	12	12	192
C	15	13	7.5	154
D	12.5	13	7.5	121
WC	13	19	9	170
CM	11.2	18	10	157

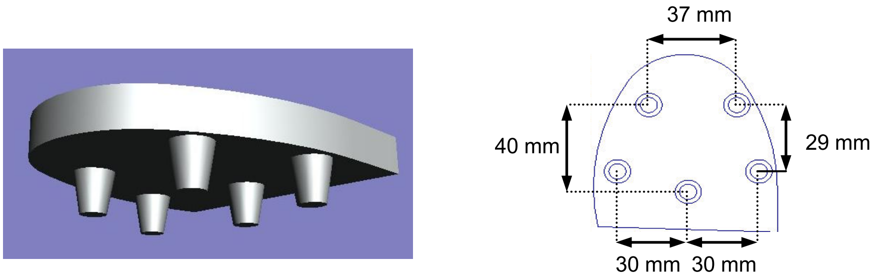


Fig. 2. Illustration and schematic showing the stud plate and the forefoot stud configuration used throughout testing.

3. Results

Representative force-displacement curves from the impact hammer for each surface are shown in Figure 3. The 3G artificial surface experienced higher peak impact forces and lower peak deformations revealing the artificial surface to be a stiffer, harder surface. In terms of soccer the 3G artificial surface can be considered to be a firm ground surface and the natural surface can be considered a soft ground surface. The natural surface testing took place within the month of March, although on the day of testing the weather was dry, following conversation with the ground staff, recent rain had left the pitch in a typically soft condition. The gravimetric moisture content was found to be 30.7 % ± 1.8 %. When evaluating standards for natural soccer pitch surfaces Canaway and Baker [7] commented hardness fell below a preferred limit when the moisture content was within a range of 34-39 %. Therefore a surface with a gravimetric moisture content greater than 34 % would be considered too soft. This suggests the surface tested in this study was within the preferred limits of hardness but in a relatively soft condition. Figure 4 shows the vertical displacement of each stud. The results showed evidence of the stud plate moving vertically into the surface, this is particularly evident for the soft natural surface.

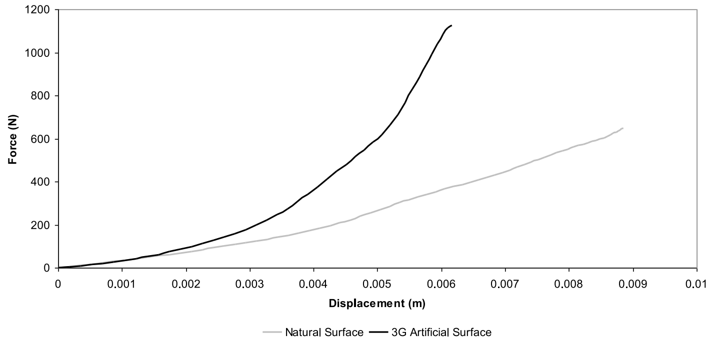


Fig. 3. Representative Force-Displacement plots from each soccer surface during the impact phase of loading using the SERG hemispherical impact hammer.

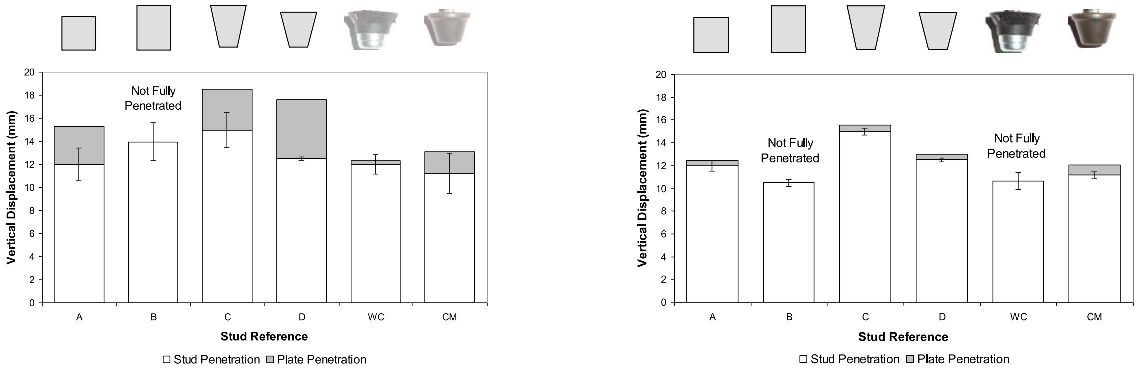


Fig. 4. Mean vertical displacement (± 1 standard error) of studs and stud plate at time of initial movement. Left: Natural Surface. Right: Third Generation Artificial Surface.

The vertical displacement measurements were used to measure the stud penetration and to find the effective cross sectional area. The effective cross sectional area is the total cross sectional area of the penetrated part of the studs resisting movement in the horizontal direction. As discussed, for a stud to give high performance it must demonstrate high penetrability into a surface and provide an acceptable level of traction. The effective cross sectional area and traction force have been plotted on the same two-axis graph in order to visualise which performed best for each surface, Figure 5. Errors in the effective cross sectional area are only found if the stud did not consistently fully penetrate the surface. The results from stud WC on the soft natural surface was used as a benchmark for traction performance. An acceptable zone of stud traction can be defined to be within the error bars of the benchmark stud.

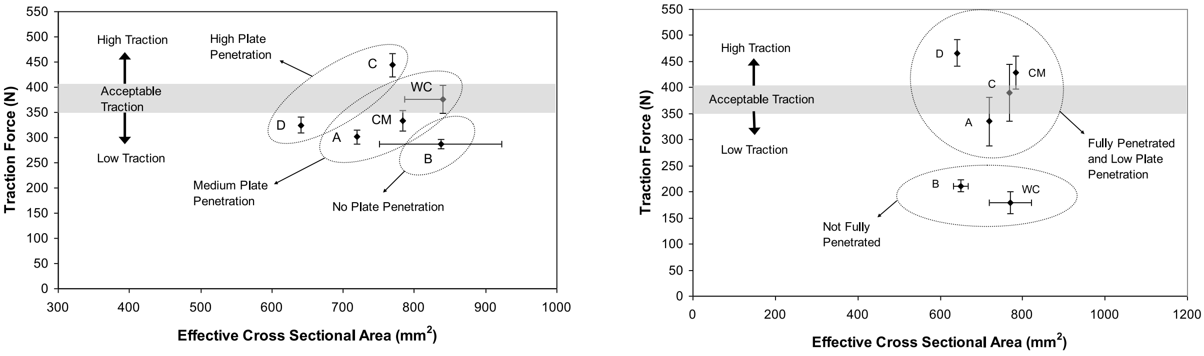


Fig. 5. Traction force and effective cross sectional area of the studs (± 1 standard error). Left: Natural Surface. Right: Third Generation Artificial Surface.

4. Discussion

Figure 4 shows each stud fully penetrated the natural surface except for stud B which was 16 mm long. This may explain its poor traction performance. For the other studs the stud plate has moved vertically into the surface, due to its soft condition. Studs C and D demonstrated particularly good penetration characteristics, this may be due to their conical profile compared to studs A and B, and their smooth material compared to studs WC and CM . Stud C was the only stud to provide significantly higher traction than the benchmark, suggesting it would provide high traction in soft natural surface conditions, if it replaced the WC stud in the same boot. Studs A and B are both cylindrical, the longer stud B provides greater effective cross sectional area than A, even though it did not fully penetrate. However, stud A has slightly more traction, this demonstrates the effect the stud plate has on the overall traction. Figure 5 shows the results can be grouped according to the extent of stud plate penetration. Within these groups, as the mean cross sectional area increases the mean traction increases.

On the artificial surface studs B and WC provide the least traction. Figure 5 shows that these are the only two studs which didn't penetrate fully so the stud plate did not move vertically into the surface. Hence the friction between the plate and the surface is not contributing to the overall traction. Also, as the plate contacts the surface, the surface will be compressed, increasing the bulk density of infill resisting the horizontal movement of the stud system. Stud D and stud C are similar conical studs. However, despite being shorter and providing lower effective cross sectional area, stud D provided the higher traction. It is possible that when stud C moved horizontally into the surface, more infill was displaced away from the stud, reducing the region of compressed infill surrounding it. This leads to greater penetration than D but less traction. Considering the acceptable zone of traction, stud C appears to offer the most appropriate traction on the third generation artificial surface, whereas due to poor penetrability the WC stud is not within the acceptable zone. The CM stud also appears to be a reasonable replacement for the WC stud, in the same boot.

5. Conclusions

- On natural turf traction is dependent on the penetration of the stud plate and a stud's effective cross sectional area. As the penetration of the stud plate increases the traction increases and as the effective cross sectional area of the studs increases the also traction increases.
- On the third generation artificial turf the studs which did not fully penetrate the surface provided low traction. This is because the effects of friction between the plate and the surface, and of the stud plate compressing the surface were not present.

- On the third generation artificial turf the effective cross sectional is not proportional to traction. Stud geometry affects the movement of the infill surrounding the stud during penetration, which in turn may affect the traction.

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