MEDICINE AND SCIENCE IN SPORTS
Vol. 7, No. 2, pp. 132-135, 1975

Cleat-surface friction on new and old Astroturf

K. DOUGLAS BOWERS, JR. AND R. BRUCE MARTIN

Division of Orthopedic Surgery,
West Virginia University Medical Center and
West Virginia University Department
of Intercollegiate Athletics
Morgantown, West Virginia

ABSTRACT. The authors have studied the alterations in cleat-surface friction of AstroTurf associated with use and exposure. Three cleat types were studied on five year old turf and on an unused, unexposed turf sample of the same production batch. Tests were carried out with and against surface grain under wet and dry conditions. It was found that with use and exposure the surface friction of AstroTurf does change, affecting both player performance and safety.

ARTIFICIAL TURF, MECHANICAL PROPERTIES, EFFECT OF USE AND EXPOSURE.

Traction, or friction, defined as the resistance to movement when one surface slides on another, is all important in many athletic events: soccer, baseball and football to name a few. On natural surfaces traction results from cleat-surface friction and from cleat penetration. On artificial surfaces, cleat penetration is minimal and traction is primarily a function of cleat surface to playing surface friction.

Traction affects both performance and safety. Players must be able to start rapidly from a stationary position, accelerate and decelerate rapidly, change direction, cut sharply and stop suddenly, and in each instance be assured of sound footing. Too firm foot fixation can in effect produce "footlock," contributing to knee and ankle trauma. Poor foot fixation results in slipping contributing to player-surface contact trauma. Greater traction results in faster running, faster running results in increased hitting velocity, and increased hitting velocity contributes to more severe player to player contact trauma. Increase traction allows for sharper cutting angles which can aid performance but produces greater stress to supporting structures of joints (2).

We have observed that non-contact falls due to slipping have become much more frequent on our AstroTurf field over the past five years. We have felt this to be related to progressive surface layer compression with a rather marked grain effect. We therefore undertook the study of testing different cleat materials on our five year old football field surface of Monsanto's AstroTurf and on unused and unexposed AstroTurf of the same production batch.

Submitted for publication September, 1974.
Accepted for publication January, 1975.

Method

In order to eliminate the complexities of cleat-surface contact when a shoe is resting on the AstroTurf, the device shown in Figure 1A was constructed. Three cleats taken from a shoe are fastened in a triangular array on a platform, and the unit is loaded symmetrically with weights (F_N). It is then pulled across the AstroTurf using the crank tower shown in Figure 1B. A load ring records the pulling or friction force (F_F) on a chart recorder, more weight is added and the test is repeated. This arrangement insures that the cleats contact the surface in a uniform manner and allows one to observe the static and dynamic frictions as well as the amount of "chatter" during the sliding. A typical record is shown in Figure 2. The F_N and F_F data were divided by 3 to obtain forces per cleat: f_N and f_F respectively.

Three types of cleat were tested: the Riddell 78 polyurethane screw-on type cleat in a slightly worn state; a slightly worn cleat from a Riddell 391 red-molded, urethane sole, 20 cleat shoe; and a very worn Riddell 391 cleat. Each cleat type was tested on the 5 year old AstroTurf at Mountaineer Field (installed the summer of 1969) and in the laboratory on "new" AstroTurf: a section of the same AstroTurf and pad as covers the playing field but which has been stored away from sunlight, rain, and

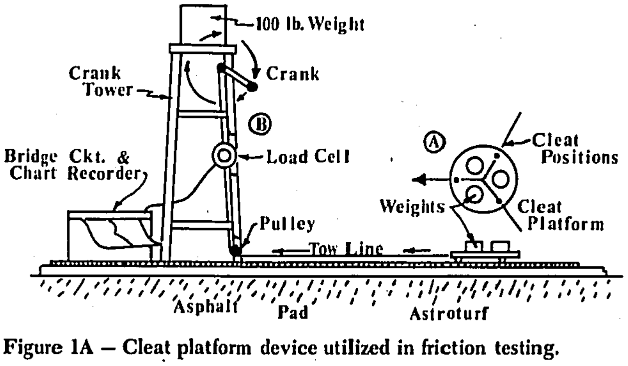

Figure 1A — Cleat platform device utilized in friction testing.
Figure 1B — Crank tower used in pulling the loaded cleat platform across turf.

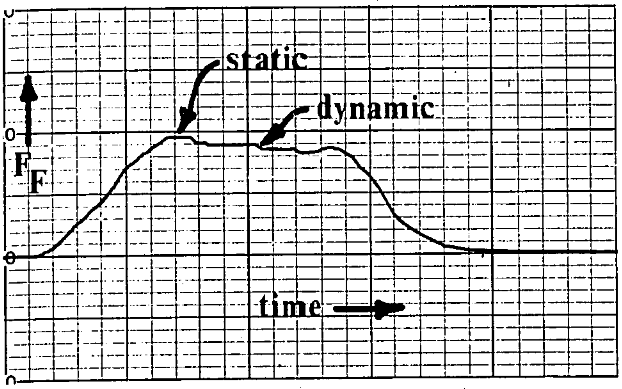

Figure 2 – Typical record as seen on chart recorder showing static and dynamic frictions.

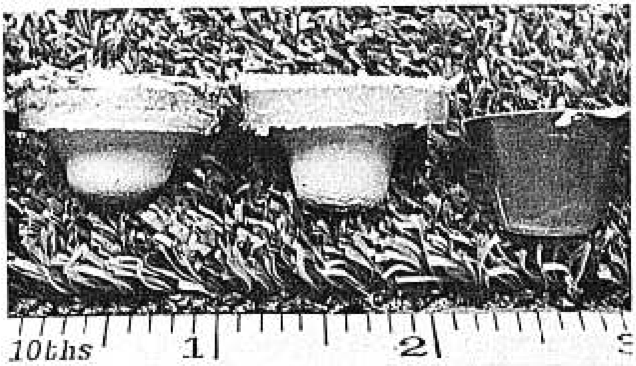

Figure 3 – Cleats used in testing lying on new AstroTurf, from left to right. Riddell 391 very worn, Riddell 391 slightly worn and the Riddell 78 slightly worn. Scale in inches.

TABLE 1. Relative cleat dimensions.

Cleat	Sole-tip Height, mm	Tip diameter mm
Riddell 78	12	11
Riddell 391		
New	10	10
Worn	8	10

temperature extremes. In each case the tests were conducted with and against the AstroTurf's "grain," and under dry and wet conditions. ("Wet" being enough water to splash when the surface is slapped but not enough to cover the fibers.) The temperature range for the tests was about 60° to 85°F.

Figure 3 shows the cleats tested in relation to new AstroTurf. Table 1 gives their relative dimensions.

Results

Figure 4 shows a typical graph of the dynamic f_F versus f_N. The relationship is approximately linear and in this case considerable difference is observed between friction with and against the grain.

In all cases the dynamic f_F was at least 90% of the static value.

Figure 5 summarizes the results. It shows relative values of dynamic f_F in all the situations tested. The values

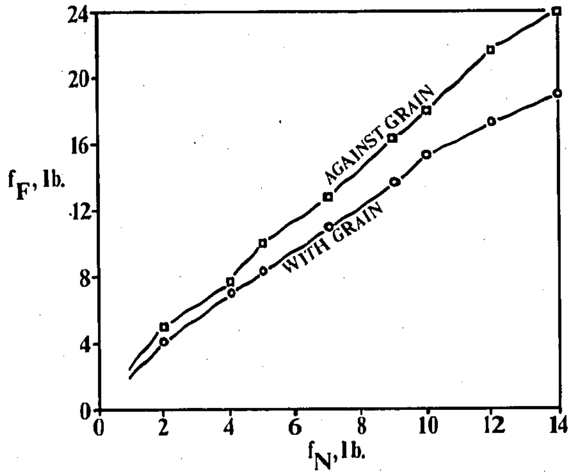

Figure 4 – Typical graph of dynamic f_F versus f_N showing approximate linear relationship.

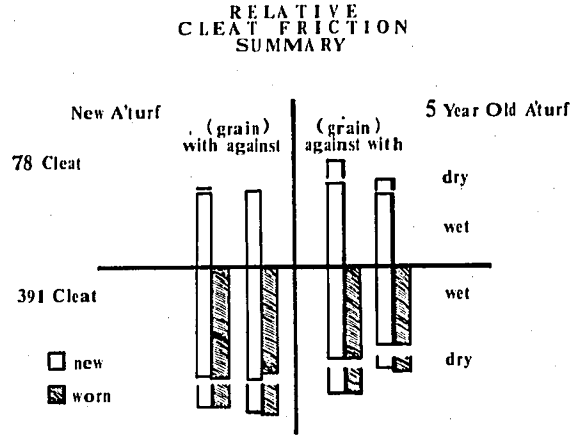

Figure 5 – Summary of results showing relative values of dynamic f_F in all situations tested. W.G. is measured "with the grain"; A.G. is measured "against the grain." The 78 cleat is made of polyurethane rubber, the 391 cleat of urethane.

f_F were calculated using the equation of the least squares linear regression line through the data:

$$f_F = A + B f_N \quad [1]$$

Table 2 gives the slopes (B) and intercepts (A) of these lines; this information can be used to calculate F_F under various conditions for any number of cleats (n_c) in contact with the surface, using the relation:

$$F_F = f_F n_c = (A + B f_N) n_c \quad [2]$$

It should be pointed out that the intercepts are relatively small and the values of B amount to friction coefficients for cleat-AstroTurf sliding.

Examination of Figure 5 reveals that the two styles of cleat tested exhibited opposite frictional changes as the AstroTurf is used and exposed to the elements for 5 years. The 78 cleat produces more friction on an old field than on new AstroTurf while the 391 cleat reverses this behav-

TABLE 2. Values of A and B for calculating f_F using equation 1.

		DRY			WET		
NEW ASTROTURF		With	Average	Against	With	Average	Against
Cleat 78	A.	-.42	.63	2.04	-.02	.13	.28
	B.	1.16	1.10	.93	1.06	1.07	1.08
Cleat 391 new	A.	1.23	2.25	3.26	.77	.85	.92
	B.	1.86	1.83	1.81	1.47	1.48	1.48
Cleat 391 worn	A.	.01	1.36	2.71	.56	1.36	2.16
	B.	1.95	1.90	1.86	1.51	1.40	1.30
OLD ASTROTURF		With	Average	Against	With	Average	Against
Cleat 78	A.	.67	1.60	2.53	-.21	.16	.20
	B.	1.22	1.29	1.36	1.05	1.11	1.19
Cleat 391 new	A.	1.69	1.51	1.34	.26	.65	1.05
	B.	1.28	1.45	1.63	1.05	1.12	1.19
Cleat 391 worn	A.	.80	.96	1.12	.00	-.23	-.47
	B.	1.38	1.51	1.63	1.09	1.20	1.31

ior. In general, however, the 391 cleat has greater friction than the 78 cleat.

The worn 391 cleat does not behave much differently from the new one in any of the areas of comparison. Apparently the cleat-AstroTurf friction coefficient depends more upon the cleat material than upon the shape or state of wear. It should be noted that urethane is a much softer material than polyurethane, and was actually gouged and cut by the AstroTurf fibers at the higher normal loads.

The anisotropy of the friction due to the AstroTurf's grain is minimal on a new field but becomes significant on the 5 year old field. The percent difference is about the same for the two styles of cleat: 16% more friction against the grain on a wet field and 22% on a dry field. Some of the practical implications of this are demonstrated in the next section.

When the 78 cleat is used on a new field, cleat friction will be about the same whether the field is wet or dry (and in either grain direction), but the other cleat-field combinations give substantially reduced friction on a wet field. In the case of the 78 cleat used on an old field, wetness also reduces the effect of grain direction.

Discussion

In an attempt to elucidate the importance of the accentuated "grain" found in old AstroTurf, we have analyzed a simple player maneuver. Consider the situation shown in Figure 6. A player of weight W = 175 lb. is running downfield with velocity V_1 = 20 ft./sec. He wishes to change direction to the left by some angle θ as quickly as possible to avoid another player. To do this he will plant the edge of one foot and accelerate his body an amount

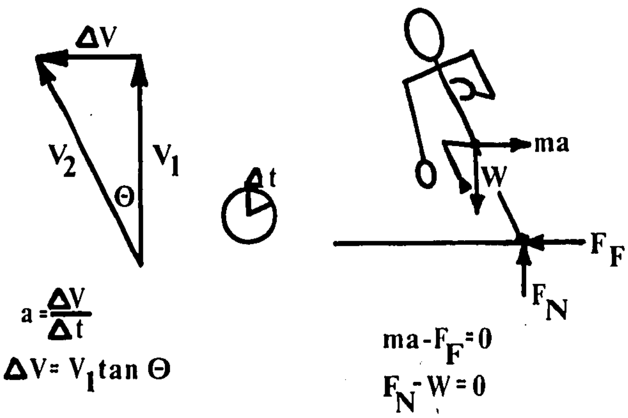

Figure 6 — Diagrammatic analysis of θ slip exercise.

$$a = \frac{\Delta V}{\Delta t} = \frac{V_1 \tan\theta}{\Delta t} \qquad [3]$$

Here Δt is the time interval required to change his velocity direction; we shall assume Δt = .1 sec.

From the free-body diagram of the player one has

$$ma = F_F \qquad [4]$$

$$W = F_N \qquad [5]$$

where m is the player's mass (5.43 slugs). From the friction properties of the cleat — AstroTurf interface, one has

$$F_F = f_F n_c = (A + B f_N) n_c \qquad [2]$$

Combining these equations yields

$$F_F = An_c + BW) = \frac{V_1 m \tan\theta}{\Delta t},$$

or

$$\Theta_{slip} = \tan^{-1}\left[\frac{(An_c + BW)\,\Delta t}{V_1 m}\right] \qquad [6]$$

If $n_c = 3$, one finds that for the new 391 cleat on 5 year old dry AstroTurf, θ slip is 15° against the grain but only 12° with the grain. If the field were wet, θ slip with the grain would be less than 10°. These calculations can only roughly estimate the bounds on such a complex maneuver, but their usefulness in comparing similar situations seems incontrovertible.

We have shown in a previous publication (1) that the impact absorbing characteristics of the 5 year old AstroTurf on Mountaineer Field were greatly deteriorated when compared to the new field, the asphalt underbase, and sod. This is clearly detrimental to player safety. If one accepts the idea that increased cleat friction contributes to both player performance *and* injuries by (a) increasing collision speeds and contact forces and (b) providing better footing and more frequent "footlock," then Figure 5 contains some useful information relative to safety. That is, the Riddell 78 cleat should definitely be used in preference to the Riddell 391 cleat on a new AstroTurf field, but on a five year old field (at least on Mountaineer Field) the 78 cleat is only slightly safer in terms of reduced friction.

This discussion of safety in terms of avoiding increased friction may seem at odds with the analysis presented above relative to a runner's maneuverability. It might be said that increased friction will decrease slipdowns and resulting injuries. We would argue that such injuries are not so important as footlock related trauma, and consequently safety and friction are inversely related (to some reasonable point, of course).

On the other hand, safety also depends on the homogeneity and isotropy of the playing surface; an athlete should not find himself falling down one minute and succeeding the next because the playing surface is not uniform. The previous analysis simply attempts to document the degree to which this might be a problem on an AstroTurf field. If these arguments in favor of some nominal, uniform friction are sound, one must conclude that the 78 cleat on wet or dry new AstroTurf satisfies both criteria much better than any other cleat-surface combination in Figure 5.

Conclusions

1. With use and exposure AstroTurf undergoes certain physical changes resulting in cleat-surface friction changes.
2. Anisotropy of the friction due to AstroTurf's grain is minimal on new turf but becomes significant on the five year old field.
3. Cleat wear of the shoe most commonly used on AstroTurf, the Riddell 391, has little effect on friction.
4. The Riddell 78 type cleat produces more friction on five year old used and exposed AstroTurf than on the unused and unexposed AstroTurf, the Riddell 391 type cleat reverses this behavior.
5. In general, the 391 cleat has greater friction than the 78. The 78 cleat has significantly less friction than the 391 on unused and unexposed AstroTurf but only slightly less friction than the 391 on the used and exposed AstroTurf.
6. The loss of friction quality exhibited by used AstroTurf with the Riddell 391 type cleat seems clearly detrimental to player performance; the effects on player safety are more debatable.

ACKNOWLEDGEMENTS. The authors are grateful to Mrs. Carol Ammons, Mrs. Jane Clayton, Miss Judith Wolf and Mr. Roy Williamson who assisted in the research and preparation of this paper. Thanks are also extended to the WVU Athletic Department who provided the cleats and new AstroTurf specimen.

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