Chapter 1

CADY TRAFFIC SIMULATOR: A NEW APPARATUS TO SIMULATE ATHLETIC FIELD TRAFFIC

ABSTRACT

Realistic traffic simulation is crucial to the validity of athletic field research. Previously developed athletic field traffic simulators contain studded drums that turn at different speeds creating shear forces at the playing surface. The Cady Traffic Simulator (CTS) (a modified walk behind core cultivation unit) has been recently developed at Michigan State University. The objective of this study was to compare the magnitude and direction of the forces produced by two traffic simulators; the Brinkman Traffic Simulator (BTS), a pull behind unit, and the Cady Traffic Simulator (CTS). Both simulators were operated over an in-ground force plate which measured the forces in three directions; front to back, side to side, and vertical. The CTS produced higher compressive forces and higher net shear forces when operated in either direction. The loading rate of the CTS was higher than the BTS, indicating that the CTS produced dynamic forces similar to that of pushing or running.

INTRODUCTION

The goal in using traffic simulation in athletic field research is to subject turfgrass areas to the conditions experienced by actual playing surfaces. Athletic fields are exposed to forces of varying magnitude and direction. These forces often exceed seven times the body weight of participants because of the actions performed on the playing surface (ie. starting, stopping, running, changing direction, blocking, tackling, etc.) (Canaway 1976) (Gatt et al. 1997). The majority of the wear produced on an athletic field is believed to be caused primarily by these dynamic forces.

Effective athletic field traffic simulators must exert forces necessary to induce soil compaction i.e., vertical and create forces necessary to cause tissue tearing i.e., horizontal. Traffic simulators currently used consist of two cleated or two smooth rollers differentially connected to turn at different speeds to create a shearing action at the playing surface while inducing a rolling type compaction (Canaway 1976, Cockerham and Brinkman 1989, Shearman et al. 2001). The Brinkman Traffic Simulator (BTS) has been described as a very useful research tool because it creates uniform, reproducible wear (Minner 1989). Cockerham and Brinkman 1989 originally estimated that 2 passes with the BTS were necessary to create the same number of cleat marks m^{-2} that one NFL game would produce between the hashmarks at the 40 yard line. However, turfgrass researchers have estimated that up to 15 passes were necessary to simulate the same amount of wear (Kurtz 1987). These rolling types of simulators create both a vertical and horizontal force component, but do not closely simulate the highly variable forces produced at the playing surface during athletic competition. A simulator that produces dynamic forces at the playing surface which are more representative of competing athletes is needed.

A traffic simulator (a modified walk behind core cultivation unit) has been developed with the goal of producing a realistic pattern of wear typically generated between the hashmarks of a football field (Cockerham 1989). The Cady traffic simulator has a "foot" attached to each of the four core heads. The feet alternately strike the ground as the machine moves over the turf surface producing dynamic forces in three directions.

The machine can be operated in two directions; forward and reverse. Operating height can affect the severity of wear, which is adjusted using a metal spacer system on the hydraulic cylinder of the unit. Preliminary tests have indicated an optimal spacer height of 5.1 cm when operating in the forward direction and 8.3 cm when operating in the reverse direction (Henderson et al. 2002).

Both simulators produce a similar number of cleat marks per unit area, but create different levels of wear given the same number of passes. The BTS was designed to create the same number of cleat marks per square meter in two passes (603 cleat marks m^{-2}) that one NFL football game would create between the hashmarks, at the forty yard line (Cockerham and Brinkman 1989). The forward and reverse passes of the CTS combine to create 667 cleat marks m^{-2} and has been shown to create more wear than the BTS (Calhoun et al. 2002).

The objectives of this technical note were 1) to describe the Cady Traffic Simulator, and 2) to quantify the magnitude and direction of forces produced by the Brinkman Traffic Simulator (Figure 1) and the Cady Traffic Simulator (Figure 2).

MATERIALS & METHODS

A greens core cultivation unit (Jacobsen, Charlotte, NC, AERO KING 30, Model 82561) was modified in three ways to create a traffic simulator (Figure 3). *1) Metal spacer system*: the addition of hydraulic cylinder spacers enabled well-graded sand of the operating height (Figure 3A*)*. *2) Crank arm adjustment*: *moving the pin from the lower arm crank arm hole to upper crank arm hole* creates more lateral motion when the feet hit the ground (Figure 3B). *3) Simulated cleated feet*: tine holders were removed and replaced with "feet" constructed from a section of tire. Each looped tire section has seven cleats fastened to the bottom (Figure 3C). *Figure 4 shows a detailed drawing of the foot* construction.

The forces exerted on the ground by the BTS and CTS were measured using an in-ground force platform (LG6-4-8000, Advanced Mechanical Technology, Inc., Watertown, MA) located at the McPhail Equine Performance Center, Michigan State University, East Lansing, Michigan. The force plate dimensions were 61 cm by 123 cm. The surface of the plate was protected by a 1.3 cm thick rubber mat which was adhered solidly to the plate. The force plate was capable of measuring applied forces in three dimensions as well as the three corresponding moments of force. The bit resolution of the force was 12 N in the vertical direction and 3 N in both horizontal directions. Images in this dissertation are presented in color.

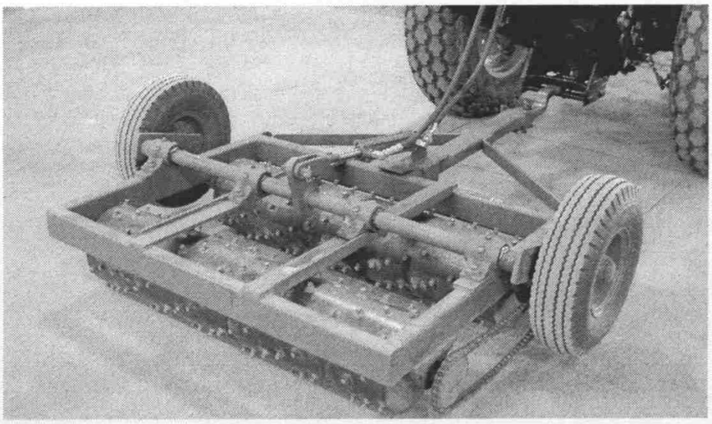

Figure 1. Overall view of the Brinkman traffic simulator.

Figure 2. Overall view of the Cady Traffic Simulator.

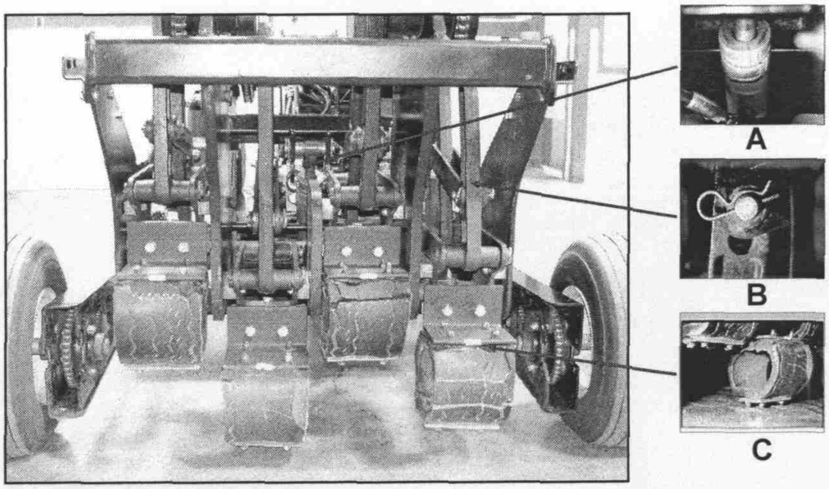

Figure 3. Modifiations made to the self-propelled aerifier A) Metal spacer system. B) Crank arm adjustment. C) Simulated cleated foot.

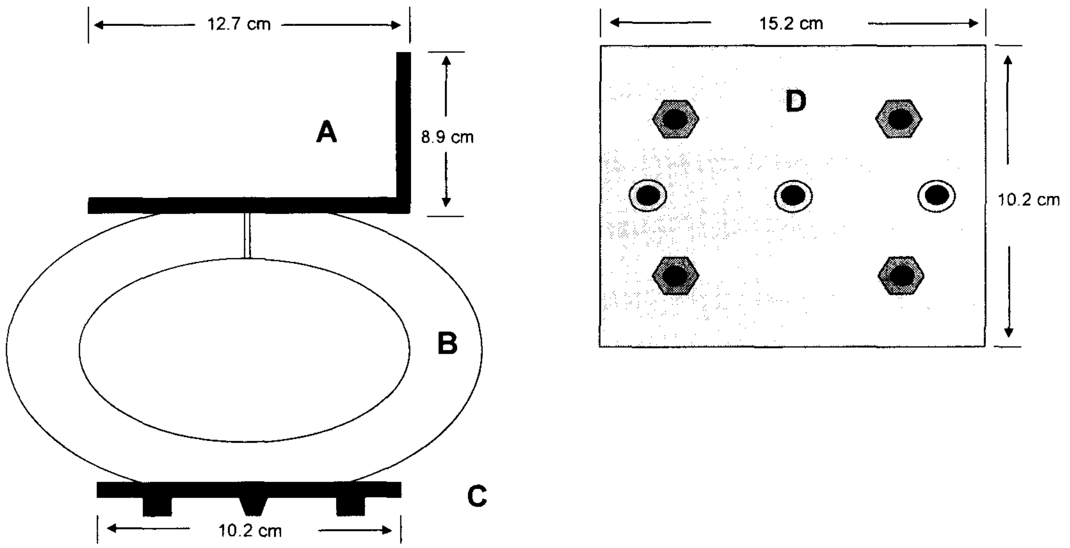

Figure 4. Cady Traffic Simulator “foot” construction. **A**) Angle iron (9.5 mm thick, 15.2 cm wide) fastened to piece of tire using four 8.0 mm carriage bolts and stop nuts **B**) Piece of tire (45.7 cm) looped with tread side out (preferably 8-ply, load range D) **C**) Steel plate fastened to piece of tire using four 8.0 mm carriage bolts and stop nuts. **D**) Bottom view of steel plate, showing four carriage bolts with stop nuts and three screw-in cleats.

To test the CTS (680.0 kg), the machine was passed over the force plate in both operating directions at the optimal spacer heights. For each direction/spacer height combination, five trials were conducted. The machine was oriented such that the direction of travel was parallel to the short axis of the force plate and all four feet struck within the boundaries of the plate while the machine passed over it. To insure that only the feet struck the force plate during the trials, 1.9 cm plywood was placed on both sides of the force plate to support the tires of the machine above the platform.

Before testing the BTS, both drums were completely filled with water to ensure maximum force production. To test the BTS (571.5 kg), the machine was pulled over the force plate using a tractor. The traffic simulator was oriented such that the direction of travel was parallel to the short axis of the force plate so that both rollers struck within the boundaries of the plate. Five trials were collected.

For each trial, each machine was started 30 to 40 cm from the edge of the plate, allowed to cross the entire width of the plate, and stopped 30 to 40 cm past the opposite edge of the plate. Force data were collected through the entire trial. Figure 5 provides a schematic of the direction of travel for each machine tested and the relative direction of forces measured.

RESULTS & DISCUSSION

The ground reaction force analysis showed significant force production by each machine in three directions: 1) vertical, 2) front to back, and 3) side to side. For ease of comparison, the front to back forces and the side to side forces

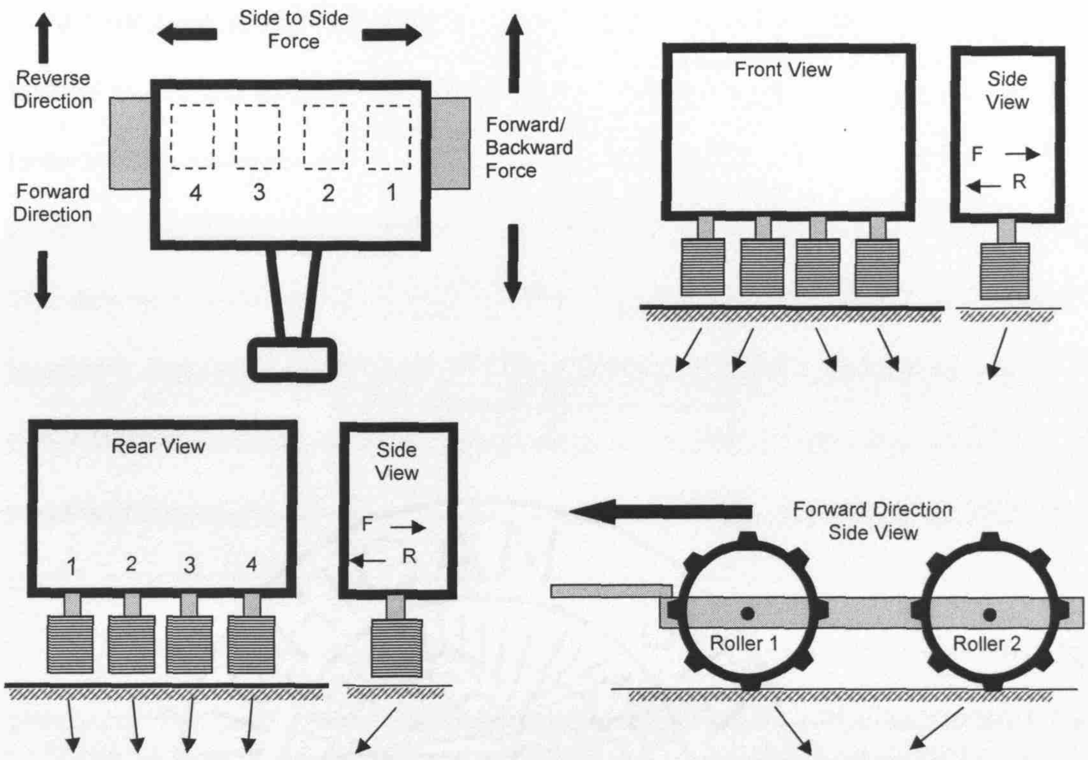

Figure 5. Direction of travel and relative direction of forces measured for the Brinkman Traffic Simulator and the Cady Traffic Simulator. A) Top view of the Cady Traffic simulator. The directions of travel are shown along with the directions of the measured forces. B) Direction of forces for the various feet when operated in the forward direction. C) Direction of the forces of the various feet when operated in the reverse direction. D) Side view of the Brinkman traffic simulator showing the directions of the front/back forces applied by the rollers.

were combined, using Pythagorean Theorem($c^2 = a^2 + b^2$), for each machine and termed Net Shear Force. The vertical force component of each machine has been termed Compressive Force. The Brinkman Traffic Simulator (BTS) produced significant compressive forces. Each drum exceeded 2000 N (Table 1). The direction of the net shear force in the front drum was rearward while it was forward in the rear drum (Figure 5). The rear roller created a substantial net shear force exceeding 1700 N at an angle close to the optimal angle of 45 degrees for pushing (ie. Blocking), this explains why this apparatus has been a useful research tool for several years.

The CTS forces were measured in both the forward and reverse operating directions. The peak values per foot were averaged over the four feet of the CTS. Operated in the forward direction, the four feet produced an average compressive force over 5 times greater than when operated in the reverse direction (Table 1). The forward direction also produced more variable forces than the reverse direction. Operating in the reverse direction, the magnitude of the forces dropped significantly, but created the greatest angle on impact (Table 1). Given the large compressive force created in the forward direction and the high angle of impact induced operating in the reverse direction, it was determined that operating the CTS once in reverse and once forward over an area would combine to produce the desired wear effects of tearing (reverse) and compaction (forward).

Comparing the total load production of each machine describes the overall capability of each machine, but examining multiple load characteristics of each

Table 1. Average peak ground reaction forces and stresses recorded for the Cady Traffic Simulator and the Brinkman Traffic Simulator.

Machine	Force (N)†		Stress (MPa)‡		Angle from vertical§ (deg)	Speed $m\ s^{-1}$
	Compressive	Net Shear¶	Compressive	Net Shear#		
Cady, Forward Direction††	5899 (1283)§§	1613 (873)	43.53 (9.47)	11.91 (6.44)	22.0 (11.3)	0.30 (0.013)
Cady, Reverse Direction‡‡	1041 (44)	454 (50)	7.68 (0.33)	3.35 (0.37)	52.1 (2.9)	0.31 (0.013)
Brinkman, Front Drum	2831 (29)	1004 (78)	0.81 (0.01)	0.29 (0.02)	19.5 (1.4)	1.32 (0.007)
Brinkman, Rear Drum	2297 (47)	1711 (65)	0.66 (0.01)	0.49 (0.02)	36.7 (0.7)	1.32 (0.007)

† Force was measured in Newtons (N).

‡ Stress values were calculated using an individual cleat surface area of 193.5 mm^2 (7 cleats $foot^{-1}$ on the CTS and 18 cleats $drum^{-1}$ on the BTS) and were converted to Megapascals (MPa).

§ The angle of impact was measured from the vertical axis (normal to the force plate surface) in degrees.

¶ Front to back forces and side to side forces were combined using Pythagorean Theorem($c^2 = a^2 + b^2$), for each machine and termed Net Shear Force.

Front to back stresses and side to side stresses were combined using Pythagorean Theorem($c^2 = a^2 + b^2$), for each machine and termed Net Shear Stress.

†† Cady Traffic Simulator (CTS) was operated in nuetral at idle engine speed with the power take-off engaged enabling the feet to strike the ground creating forward movement.

‡‡ Cady Traffic Simulator (CTS) was operated in the reverse gear at idle engine speed with the power take-off engaged enabling the feet to strike the ground.

§§ *Standard deviation of measurements recorded.*

machine enables a more comprehensive means of comparison. Load characteristics such as total load, surface pressure, presence of shear stress and rate of application can highly influence compaction, a major component of wear production (Soane 1970). Each time a "foot" of the CTS hits the ground the total load is spread over a much smaller surface area compared to the BTS. Each foot of the CTS has a cleat surface area of 1354.9 mm^2 compared to the cleat surface area of each roller of the BTS contacting 3483.9 mm^2. The smaller surface area leads to a much larger force production per unit area for the CTS The CTS produced a higher compressive stress and net shear stress when operated in either direction than the BTS (Table 1). The average of the peak compressive stress produced by the feet of the CTS when operated in the forward direction was approximately 30 times higher than the combined compressive stresses of both drums of the BTS. The average of the peak net shear stress produced by the feet of the CTS when operated in the forward direction was approximately 15 times higher than the combined net shear stresses of both drums of the BTS.

The higher force production per unit area of the CTS explains why it has shown to be more destructive than the BTS. The CTS has been used in 2001 and 2002 at the Hancock Turfgrass Research Center, Michigan State University to simulate football traffic on research studies (Calhoun et al. 2002).