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Effect of Track Maintenance on Mechanical Properties of a Dirt Racetrack

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Summary

When Thoroughbreds racehorses experience catastrophic injuries, the track surface is often discussed as a factor. This work shows that significant changes in a track occur during routine maintenance. Questions regarding the relative importance of track variability and hardness require further investigation.

Introduction

Racing and training Thoroughbreds often die or are euthanized because of catastrophic injuries. This wastage was first recognized in the literature 25 years ago (Jeffcott *et al.* 1982; Rossdale *et al.* 1985). Severe physical demands are placed on the musculoskeletal system of Thoroughbred race horses during the high speeds reached during racing and training (Evans *et al.* 1992). Because of the importance of musculoskeletal injuries in the race horse there has been considerable interest in studying factors that predispose to such injuries (Estberg *et al.* 1996; Peloso *et al.* 1994; Mohammed *et al.* 1991). While anecdotal associations have been made between race track characteristics and the incidence of musculoskeletal injury, few scientific studies have been performed. One study in Minnesota made an association between vertical impact characteristics of the dirt racetrack and injury (Clanton *et al.* 1991; Robinson *et al.* 1988).

Proper investigation of tracks requires quantitative information describing the surface. Previous tracks measurements have used some type of lightweight drop test apparatus (Clanton *et. al.*, 1991; Oikawa *et. al.*, 2000; Ratzlaff *et. al.*, 1997; Pratt, 1985). Track design was investigated using a heavier system developed by Cheney *et. al.* (1973). The vertical component considered in these studies is the primary force transferred through the forelimb during a gallop (Clayton 2004). The second essential element of loading during motion of a legged animal is horizontal which depends on the shear strength of the track surface (Biewener 2003; Wong 2001). Clanton *et al.* (1991) measured the horizontal shear strength of the track using a drag apparatus. These tests did not account the rate dependent response of the soil (Day 1999). An appropriate test would reproduce the loads and speeds of a horse’s hoof at a gallop and measure the response on a small surface area.

A specialized system was designed with a hoof-shaped impactor (Peterson *et. al.* 2004). The device reproduces the hoof velocity in vertical and horizontal directions and the effective mass at the moment of impact at a gallop. Sensors on the device record the loads and decelerations on impact with the ground. The system measures the effect of the deeper track layers on the impact loads on the hoof.

The purpose of this preliminary study was to evaluate the effect of track maintenance procedures that are commonly used in the western and southern United States on the mechanical properties of the track that are relevant to hoof impact. The purpose-designed drop hammer system was used to provide objective measurements of the mechanical interaction of hoof and track before and after harrowing. The dynamic data are combined with data from soil samples including clay mineralogy. Complete data from a single track is presented, but the composition of the track and the maintenance is common in the region studied.

Materials and Methods

This study compared the properties of the track before and after periodic track maintenance. Typically, the track is harrowed between races and after training using a light weight harrow. At the study track the surface is periodically tilled and recompacted to create a partially compacted intermediate layer of soil between the top lightly harrowed cushion and the firm flat base.

The testing system developed for this study uses two axes of motion to reproduce the loads and speeds of the forelimb of a horse at a gallop (Peterson *et. al.* 2004). The slide with a synthetic hoof (cast rubber, Shore A 95 hardness) attached moves down a pair of steel rails a distance of 1.6m and impacts with an energy of 540 Joules (Figure 1). A second set of linear rails are attached to the slide and held in position by a gas spring. When the hoof impacts the ground the second axis with the spring is compressed. Due to a difference in angle between the two set of rails, the hoof impacts the surface and must slide forward. The impact velocity of the test machine is based on the vertical velocity of a hoof for a horse trotting at 10m/s (Johnston *et al.* 1991; Hjerten and Drevemo 1994). No comparable data for the vertical hoof velocity at a gallop exists, so the system impacts the ground at a speed slightly higher than for a horse at a trot (Reiser *et. al.* 2000). The system replicates the impact and deceleration of the hoof. The complete force profile as described by Gustås et al, (2004) is incomplete because only two degrees of freedom are considered. Load and acceleration data is digitized at 2.5 kHz. The arctangent of the ratio of peak acceleration in the vertical direction to the horizontal direction was used as a measure of the sliding of the hoof on the ground or the shear strength of the surface. The peak value of the load was used as a measure of the vertical impact.

The track considered was a 1 mile dirt oval used by Thoroughbred race horses. The test procedures were determined by the schedule of a track during racing. Given training and racing requirements, two opportunities were available when the track was prepared for use but the horses were no longer on the track: after training in the morning and after racing in the afternoon. Because of scheduling constraints results in this study are from a 40 minute period after training and represents a slightly longer time than normal without adding water.

Measurements were made for three sample impacts at each furlong pole; therefore 24 measurements were made on the 1 mile track. This data was taken after training without harrowing the track so that hoof prints from prior traffic were still visible on the surface. The tests were performed at three random but distinct points at each furlong in locations where no hoof prints were visible on the surface (Peterson et. al., 2005). Samples of the soil were taken at each of the ¼ mile poles from under one of the impact points of the test machine. For each soil sample, moisture and organic content were analyzed (ASTM 2005). Standard sieve analysis was also performed on a composite sample of track materials (ASTM 2007). X-ray diffraction on the clay component of the track material was also performed on material which had passed a 74 micron sieve (Moore and Reynolds 1997).

The track measurements were taken after morning training on two days when a normal afternoon racing card was scheduled. The study commenced after one week of racing during which maintenance had been restricted to the use of a harrow with six rows of evenly spaced tines and a center rolling section. This harrow was used between races and during training breaks in the morning. The roller harrow was set with the teeth at a depth of 2 5/8” below the plane of the wheels of the harrow rollers. A deeper cutting harrow was also used once a day which cuts 2 3/8” below a reference plane which is based on the surface of a compacted top layer of the track, thereby cutting substantially deeper into the track. The result was a layered compaction profile of the track which results in a partially compacted layer underneath the upper loose layer of material. The data for the second day was taken after a pavement ripper on a grader was used to make a 6 inch deep cut below the compacted surface of the track. A rototiller was then used to break up the material and then the loose material was rolled. The track surface was then harrowed as on other days.

Results

Biomechanical hoof data taken on the track described the performance of the surface. The 24 data points taken prior to the heavy maintenance had an average peak load of 13,800 N with a standard deviation of 578 N (horizontal axis on left of Figure 2). After maintenance was performed the average peak load was 9110 N with a standard deviation of 1,320 N (horizontal axis on right of Figure 2). By performing maintenance to loosen and recompact the track the average peak load on the track was reduced by 34 % on the second day. This result is statistically significant (Student t-test at $P<0.05$). However, also notable is that the standard deviation of the peak load increased from 578 N to 1320 N between the two days. At two standard deviations the peak load on the hoof could vary as much as 58% in a single circuit around the track. Prior to maintenance the acceleration ratio had an average value of 0.021 radians (standard deviation 0.007 radians) while after maintenance the value was 0.016 radians (standard deviation 0.009 radians) (shown on the vertical axes of Figure 2).

During track testing four samples were measured with an average moisture content of 9% with a range from 7% to 10%. The track material contained 2.4 % organic material by weight. Sieve analysis of the composite sample showed 13.3 % silt and clay, 65.1% medium and fine sand and 20.3 % coarse sand for the track composition. The results show cohesive components of this fine material to contain 3% Illite & Mica, 1% Kaolinite and 1% Chlorite. Thus the actual percentage of clay that was effective in binding the material for shear strength was actually 5% of the total material passing the 74 micron sieve.

Discussion

The load values reported are somewhat higher than results from Witte et. al (2004). However the previous study was performed at a trot on a surface covered by commercial belting. The high bulk modulus and damping of the belting would reduce the peak load. The accelerations measured were within the range expected from previous work (Ryan et. al., 2006). The reduction in the average peak load on the hoof as a result of this maintenance was shown to be significant. In fact the difference on a single track is of the same order as the difference seen between different tracks (Peterson et. al., 2005). However, in addition to reducing the peak load on the hoof, the standard deviation of the peak load showed an increase. This increase in variability may be a risk to the horse since it may be possible for a horse to adapt to a surface, but it is unlikely to adapt each stride to an inconsistent surface. Because of this, track hardness and variability could both be risk factors for injury.

In contrast to hardness, the shear strength measurement was not significantly impacted by maintenance. Shear strength may be less sensitive to maintenance since composition, especially clay content, is a primary source of cohesive properties (Al-Shayea 2001). Currently the maintenance of racetracks is not standardized which makes it difficult to establish standard maintenance protocols which may make a track more consistent. However, these results demonstrate that certain objective parameters in a track can be changed through maintenance.

The track composition and moisture content were typical of tracks in the western United States. The wide particle size distribution makes it more susceptible to compaction (Larson *et al.* 1980; Imhoff *et al.* 2004). The distribution can be narrowed by adding appropriate sand but this may also reduce the shear strength. A tendency toward compaction is also reduced by organic material (Shainberg 2000). The silt and clay measure from the sieve analysis is complemented by the clay mineralogy which indicates that much of the fine material is silt with limited cohesive properties (Mitchell 1993; Al-Shayea 2001).

Conclusions

Significant objective changes in parameters have been demonstrated in this paper as a result of maintenance. To understand the importance of these changes to the health of the horse we need corresponding epidemiological data. It is clearly evident that epidemiological studies for a particular track should include methods of maintenance in the data set because of the large changes observed in the track. The authors plan on doing such correlative studies in the future. In the meantime, the aim of this study was to demonstrate the ability to objectively measure racetrack properties and to evaluate the effect of maintenance on these properties. These aims were achieved.

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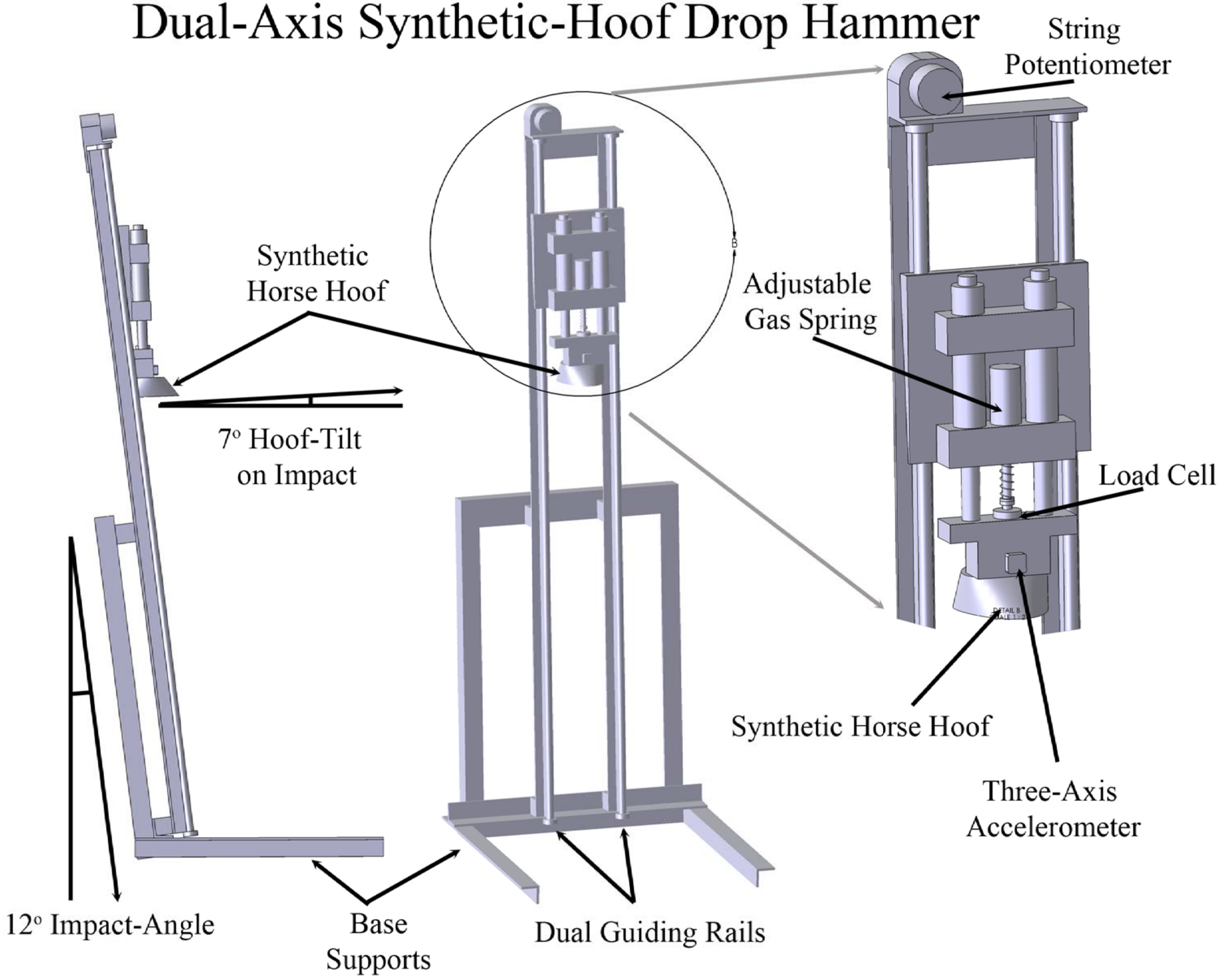
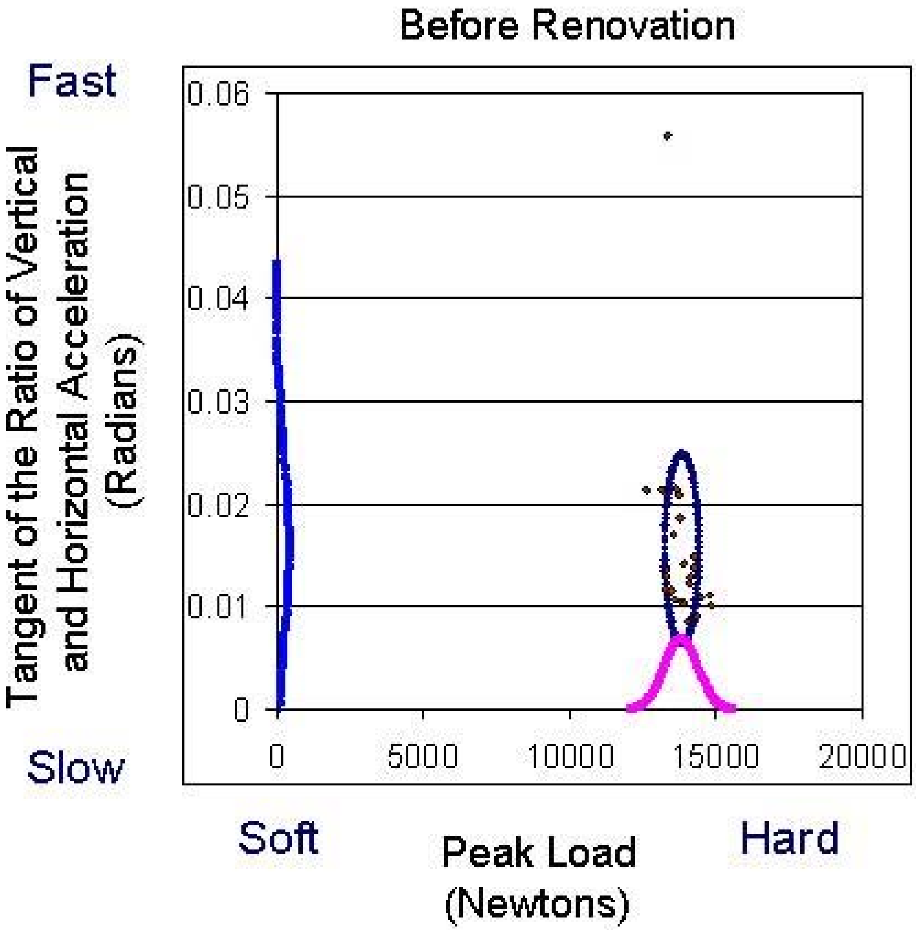
Captions

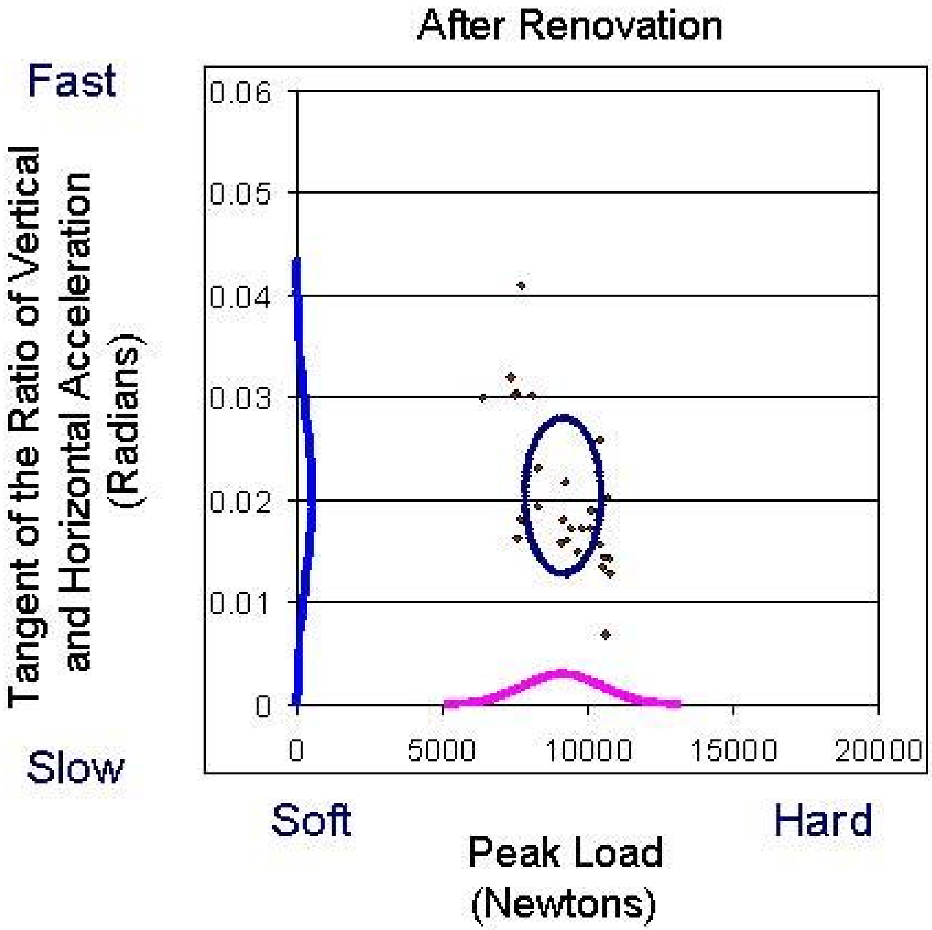
Figure 1: Two axis test machine developed to replicate the load and speed of the forelimb of the horse (Peterson et al. 2004).

Figure 2: Graphical depiction of surface properties before (A) and after (B) track maintenance by harrowing. The horizontal axis shows the peak load on the machine with the vertical axis showing the shear strength. The ellipse drawn on the figure depicts one standard deviation of the data as the length of the minor and major axes.

Dual-Axis Synthetic-Hoof Drop Hammer




Before Renovation
Fast
Tangent of the Ratio of Vertical and Horizontal Acceleration (Radians)
Slow
0.06
0.05
0.04
0.03
0.02
0.01
0
0
5000
10000
15000
20000
Soft
Peak Load (Newtons)
Hard


After Renovation
Fast
Tangent of the Ratio of Vertical and Horizontal Acceleration (Radians)
Slow
0.06
0.05
0.04
0.03
0.02
0.01
0
0
5000
10000
15000
20000
Soft
Peak Load (Newtons)
Hard