Mechanical Test Devices used to Investigate Influences of Parameters on Traction in Football

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Traction at Shoe-Surface Interface

• Optimise traction
  – performance (grip)

  – injury risk
   (excessive forces and moments)

• Aim: understand role of shoe and surface parameters in important movements
Boundary Conditions in Mechanical Tests
Subjects v Mechanical Tests

- **Subject tests**
  - *more realistic loading* of important movements
- **However, difficult to control**
  - intrusion of sensors and lab environment
  - recreating laboratory playing surface
  - *poor repeatability*

clouds influences of shoe variations on traction
Product Testing

- Full shoe tests
  - Benchmark shoes
  - *Which parameters* causes the *difference* in traction?
  - Our methodology – simplified but *controllable* “shoe”
Test Equipment - Traction

- Flat plate mimics shoe sole – control of stud type and configuration
- Horizontal and vertical load cells
- Translational movement
- Bespoke stud geometries (80 shapes)
Test Equipment - Penetration

Controllable drop height and mass

Accelerometer

Inter-changeable hammer geometry

Low friction rail

Stud Dropper

Attach commercial and bespoke studs

Graph: Force (N) vs. Displacement (mm)
Dangers of Mechanical Testing

- Loading must be representative
  - Trends can be reversed!

Results from Nigg (1990)\(^1\)

\[\text{Loading scenario must be representative of movement simulated}\]

\(^1\)Nigg (1990) The validity and relevance of tests used for the assessment of sports surfaces. Medicine and Science in Sports and Exercise, v 22, pp. 131-139
Kinematics of Movements

Forefoot push-off

Heel plant during kicking
Initial Conditions

• Forefoot sprint
  – $V_{initial} = 2.6 \text{ ms}^{-1} @ 55^\circ$
  – $\theta_{\text{shoe-surface}} = 25^\circ$

• Heel impact
  – $V_{initial} = 3.0 \text{ ms}^{-1} @ 32^\circ$
  – $\theta_{\text{shoe-surface}} = 25^\circ$
• Horizontal velocity of shoe ~ 0 relative to surface during movement
Ground Reaction Forces

- When is player most at risk of slipping?
Summary of Loading Scenario

- Forefoot sprint (performance)
  - *oblique penetration* impact (55°)
  - *small movement* between shoe and surface after initial contact
  - *orientation* of shoe varies during impact
    - 40° at time of max a-p force
    - 20° at time of max $F_{a-p}/F_{ver}$
  - *normal force* varies through movement
    - 1400 N at time of max anterior-posterior force
    - 350 N at max $F_{a-p}/F_{ver}$

more representative mechanical testing
Traditional Mechanical Testing

- Shoe dragged along ground
  - velocity / displacement driven movement
  - force of actuator matches movement

- Peak force recorded
  - occurs after significant displacements
  - how relevant to performance traction ???
Appropriate Loading Scenario

- Foot is active control system
  - player runs differently on different surface without conscious thought (Denoth et al. 1985)
  - biological feedback loops

Movements are mixture of force and displacement control
Force-controlled Test

- *Force-control* perhaps more relevant to many football movements

- Ideal movement: $V_{hor} = 0$
  - foot pushes against surface

- Surface failure
  - performance lost (immediately)
Results and Understanding Data
Drop Test - Surfaces

Hemisphere 30 cm

Displacement (mm)

Force (N)
Artificial Athlete Correlations

\[ y = -0.0235x + 81.313 \]

\[ R^2 = 0.7399 \]
Traction – Stud Parameters

- Stud variables
  - length
  - width
  - cross-sectional area
  - face area
  - angle
  - slenderness
  - other shape parameters

- Difficult to only vary *one variable at a time*
Multiple Parameter Dependence

- Multiple parameters vary for each point
  - length
  - width
  - shape …

- Poor understanding from plot 2-D graphs of experimental data
Artificial Neural Networks

- **Non-linear data regression**
  - multi-parameter traction function
  - handles non-linearity
  - fits data well
    - test data 2.6 %
    - unseen data 10.1 %
    - linear model 35.6 %

- **Uses**
  - prototype shape traction predictor
  - influence of variables
1) Enter values of stud parameters

Cross-sectional Area (mm²)  200
Length (mm)  15
S1  0.6
S2  0.7

2) Click Evaluate

Dynamic Traction (N)  332.7

Shape Parameters

\[ S_f = \frac{\text{cross-sectional area}}{\text{face area}} \]

\[ S_2 = \frac{\text{min width}}{\text{max width}} \]

Benchmark Values

- adidas World Cup FF  159.3 N
- adidas World Cup Heel  282.4 N
- adidas Copa Mundial FF  136.4 N
- adidas Copa Mundial Heel  167.2 N
1) Choose parameter to vary

2) Enter values

Constant values

- Cross-sectional Area (mm²): 300
- Length (mm): Min. 0, Max. 18
- S1: 0.5
- S2: 0.707

Dynamic Traction (N)

Length (mm)

Traction equation:

\[ Traction = 0 + 0.034x^2 + 1.105x^3 + 24.955x^2 + 114.955x \]

Plot

Hold plot? Yes

Display equation? Yes
Conclusions

• Mechanical tests devices should recreate closely actual loading conditions

• Kinematic and kinetic data essential
  – loading
  – shoe orientation
  – velocity
  – insight into movement

• Non-linear influences of stud parameters
  – artificial neural networks show promise in modelling data
  – prototype prediction
Questions

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