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

Bob Kirk and Matt Carré

SPORTSURF Sport Surfaces Research Forum

SERG Sports Engineering Research Group

Traction at Shoe-Surface Interface

- Optimise traction
  - performance (grip)

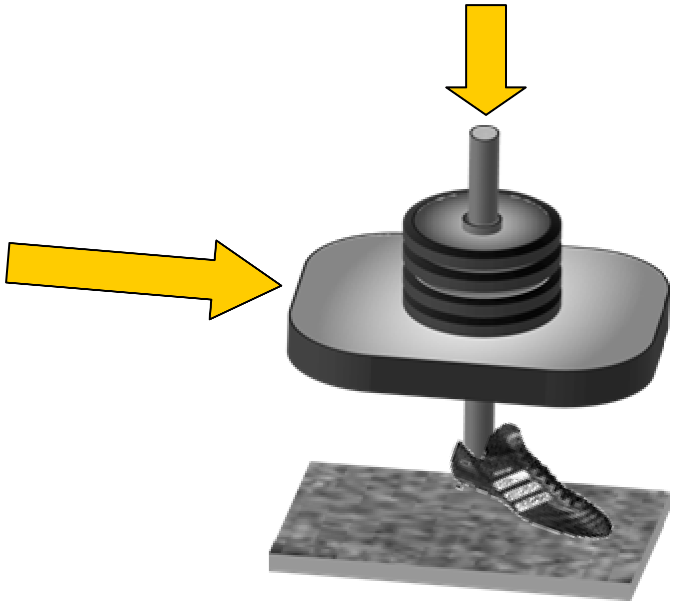
Beckham penalty miss due to slipping of planting foot

  - injury risk (excessive forces and moments)

Owen ACL injury

- **Aim:** ***understand role of shoe and surface parameters in important movements***

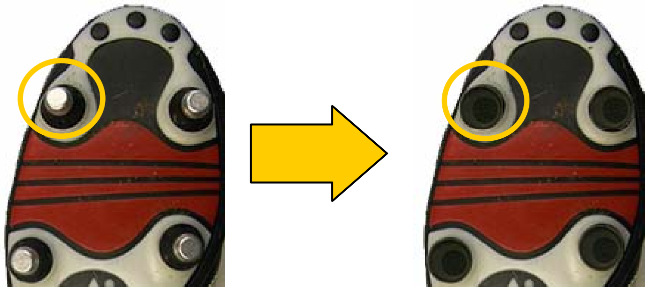
Boundary Conditions in Mechanical Tests



Subjects v Mechanical Tests

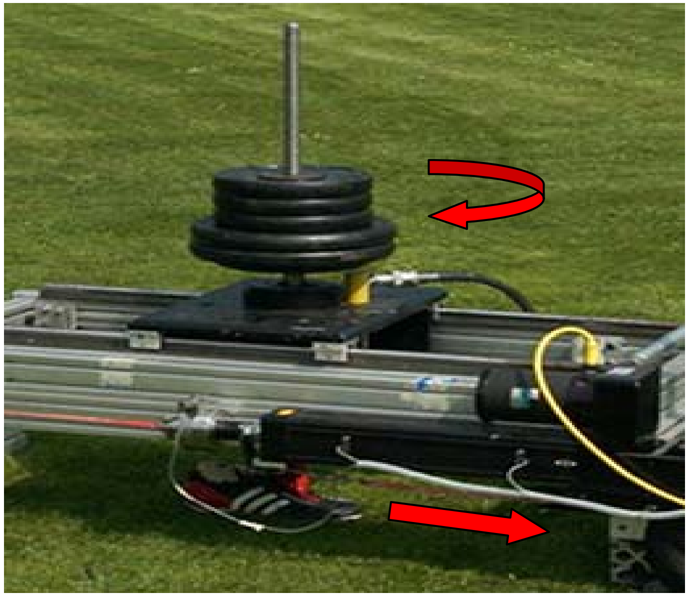
- Subject tests
  - *more realistic loading* of important movements
- However, *difficult to control*
  - intrusion of sensors and lab environment
  - recreating laboratory playing surface
  - *poor repeatability*

→ clouds influences of shoe variations on traction



Product Testing

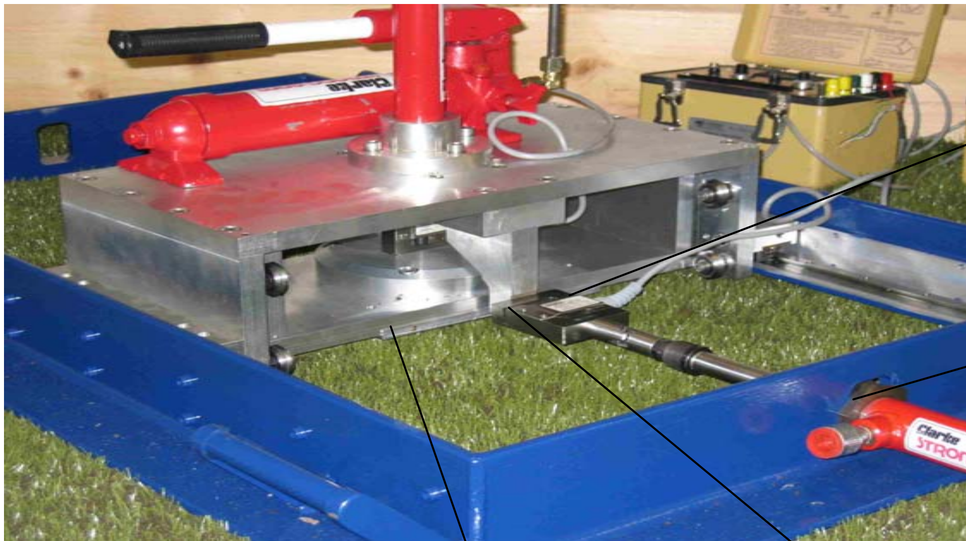
- Full shoe tests



- *Benchmark* shoes

- *Which parameters* causes the *difference* in traction?
- Our methodology – simplified but *controllable* “shoe”

Test Equipment - Traction

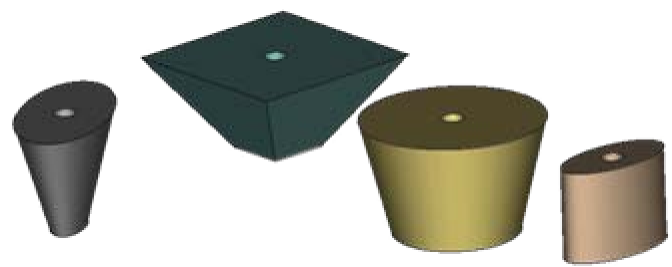


Horizontal and vertical load cells

Translational movement

Flat plate mimics shoe sole

– *control* of stud type and configuration



Bespoke stud geometries (80 shapes)

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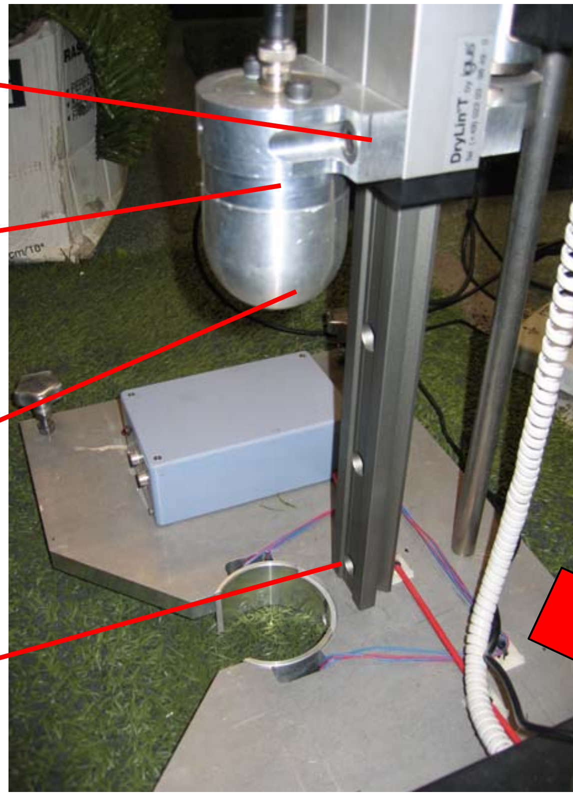
Test Equipment - Penetration

Controllable drop height and mass

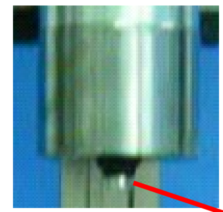
Accelerometer

Inter-changeable hammer geometry

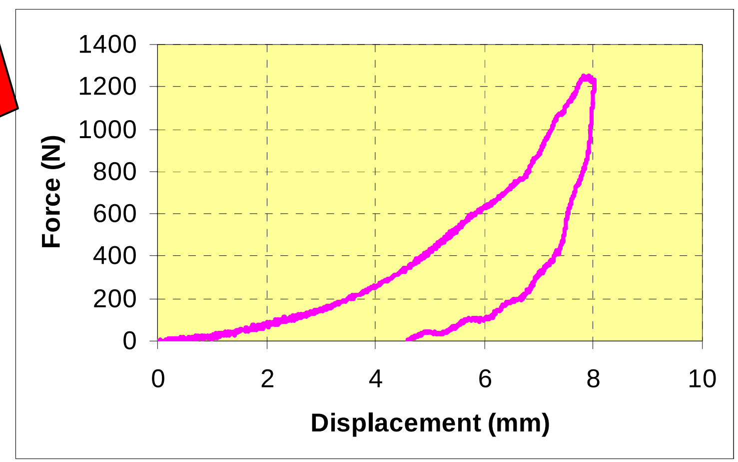
Low friction rail



Stud Dropper

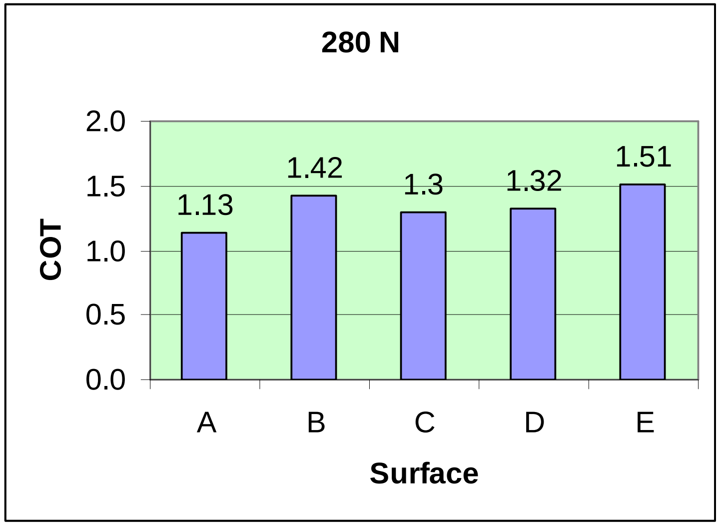


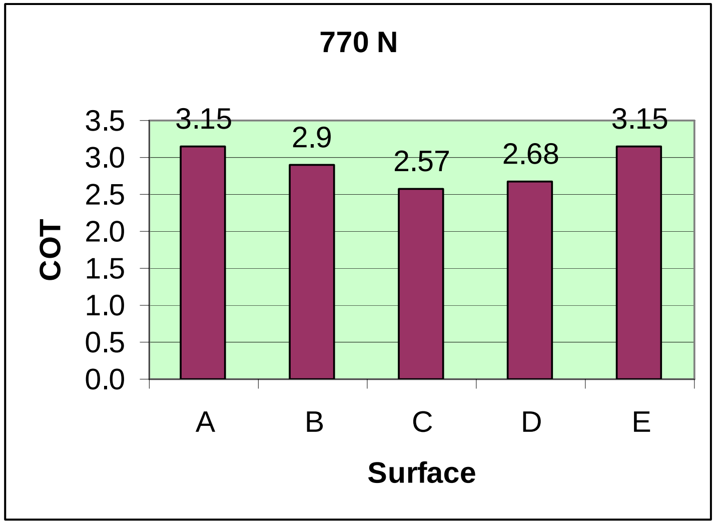
Attach commercial and bespoke studs



Dangers of Mechanical Testing

- Loading must be representative
  - Trends can be reversed!





Results from Nigg (1990)[1]

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

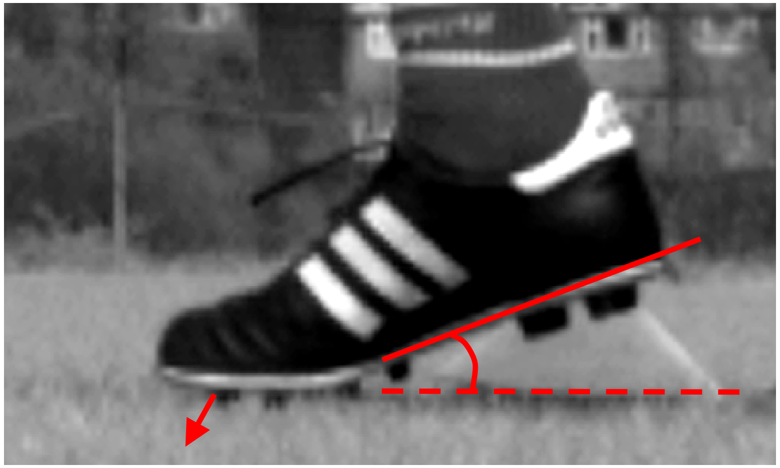
Kinematics of Movements

Forefoot push-off

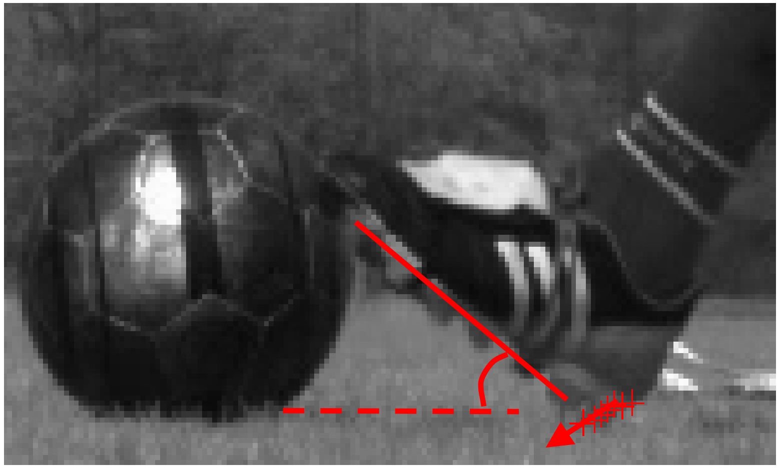
Heel plant
during kicking

Initial Conditions

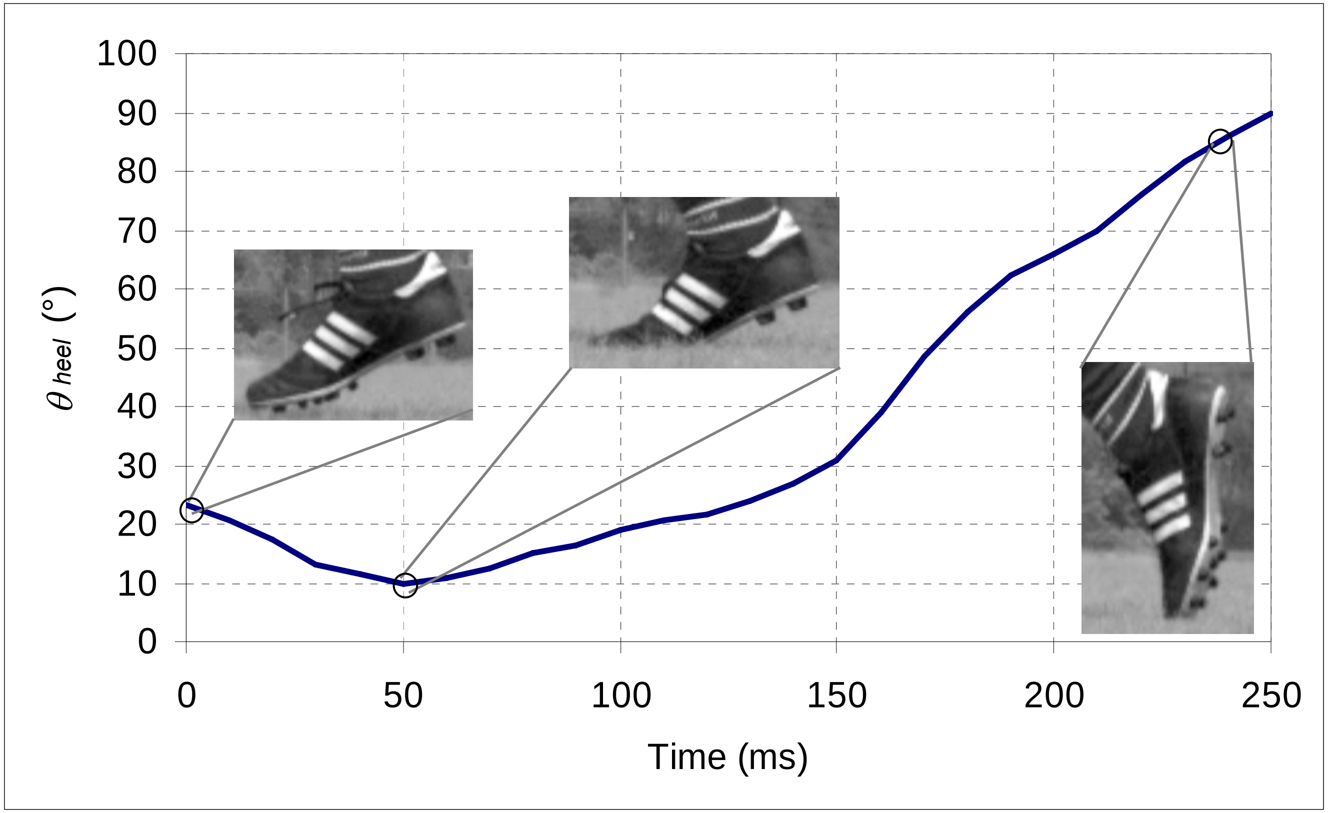
- Forefoot sprint
  - $V_{initial} = 2.6\ ms^{-1}$ @ 55°
  - $\theta_{shoe\text{-}surface} = 25°$



- Heel impact
  - $V_{initial} = 3.0\ ms^{-1}$ @ 32°
  - $\theta_{shoe\text{-}surface} = 25°$

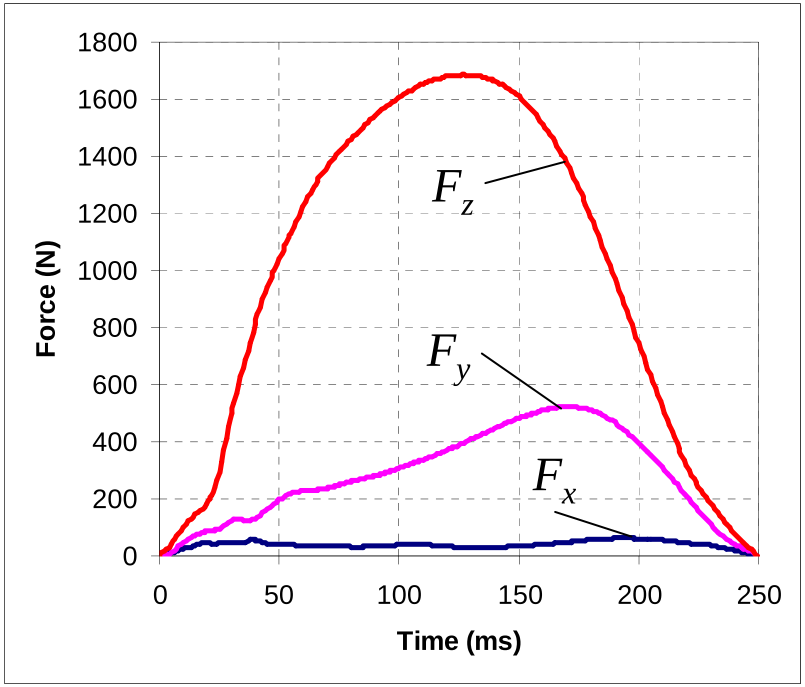


Variation of Orientation

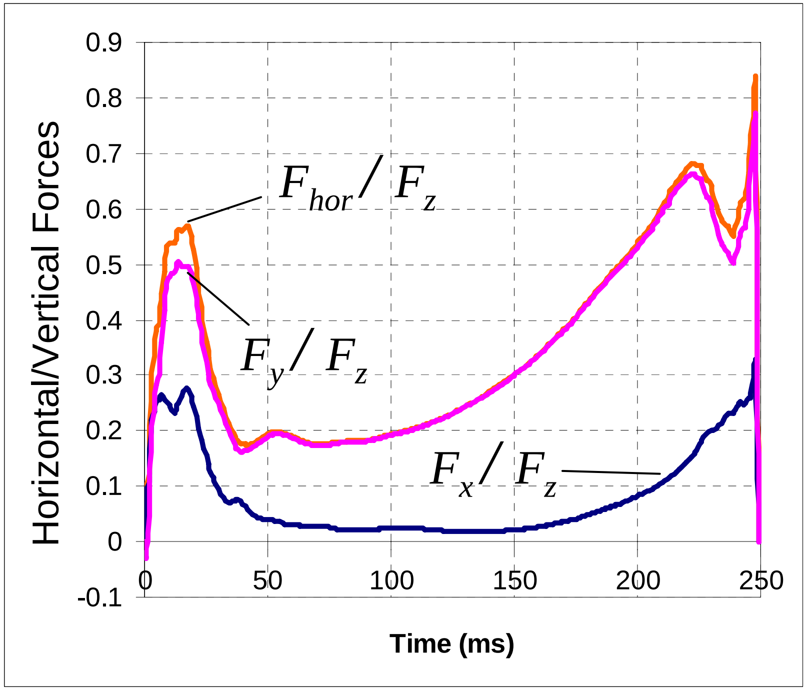


- *Horizontal velocity of shoe ~ 0 relative to surface during movement*

Ground Reaction Forces



Forefoot push-off GRF

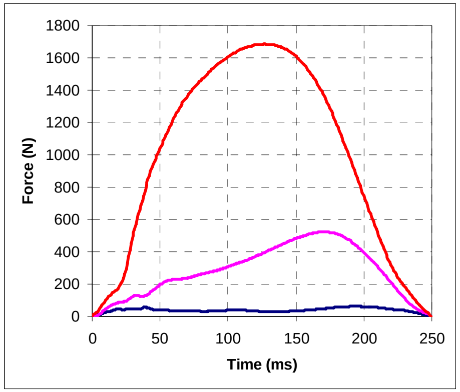


Horizontal/Vertical Forces

- *When* is player most at risk of slipping?

Summary of Loading Scenario

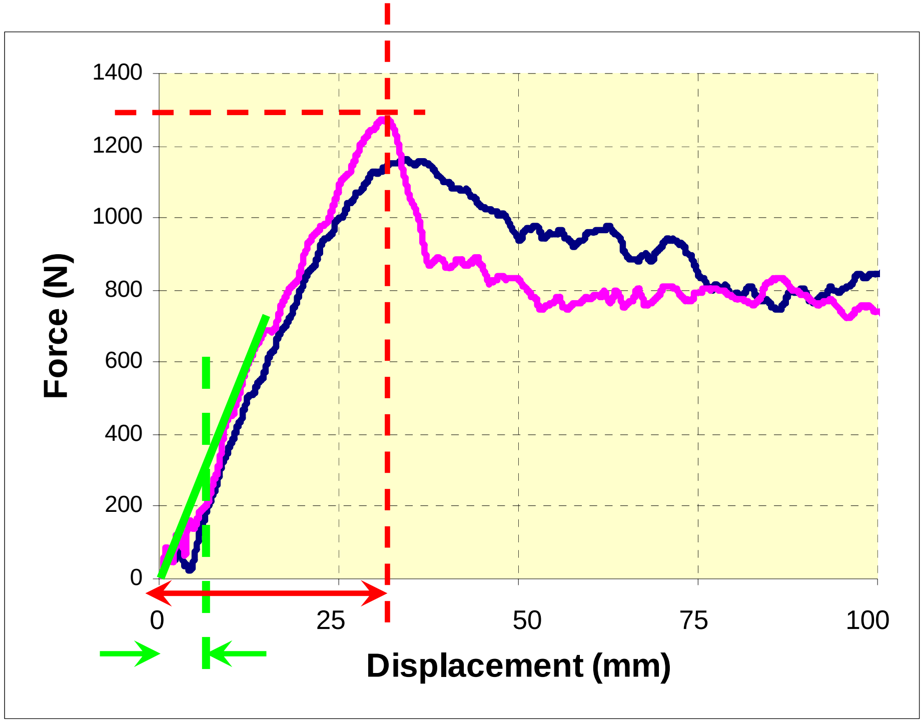
- Forefoot sprint (performance)
  - *oblique penetration* impact (55°)
  - *small movement* between shoe and surface after initial contact
  - *orientation* of shoe varies during impact
    - 40° at time of max a-p force
    - *20°* at time of max $F_{a\text{-}p}/F_{ver}$
  - *normal force* varies through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



→ more representative mechanical testing

Traditional Mechanical Testing

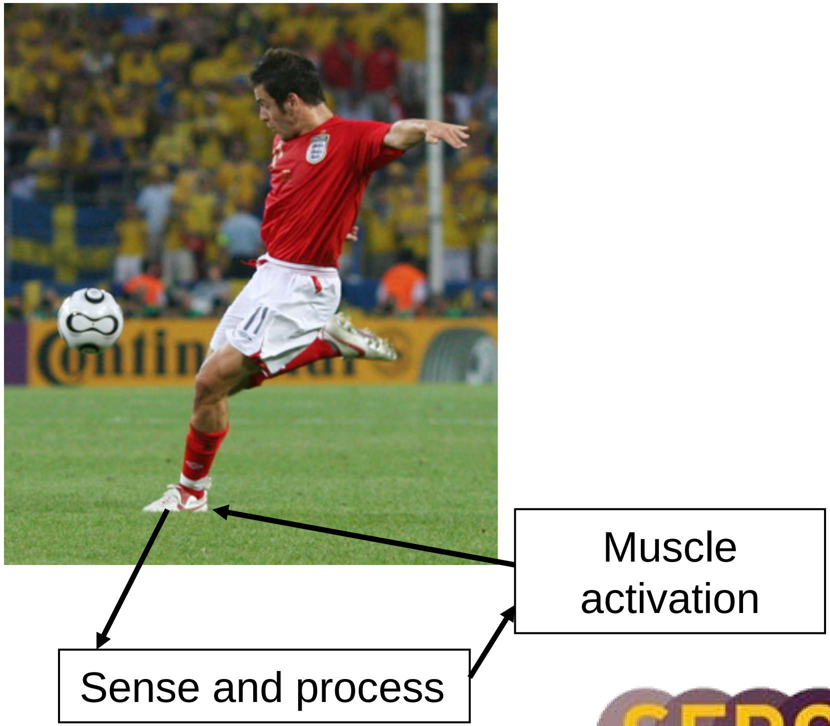
- Shoe dragged along ground
  - *velocity* / displacement *driven* movement
  - force of actuator matches movement
- *Peak* force recorded
  - occurs after *significant displacements*
  - *how relevant to performance traction* ???



Appropriate Loading Scenario

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

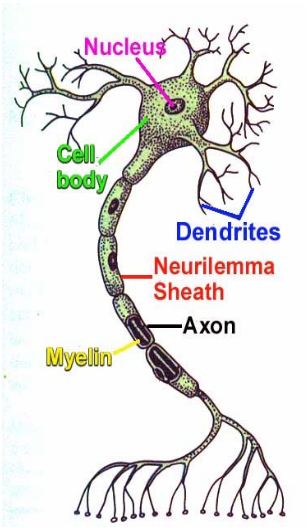
Movements are mixture of force and displacement control

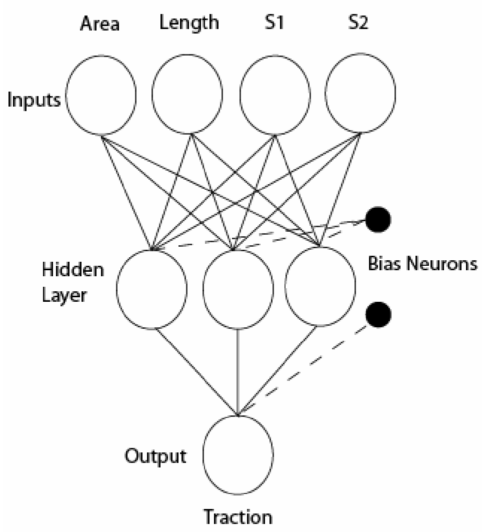


Force-controlled Test

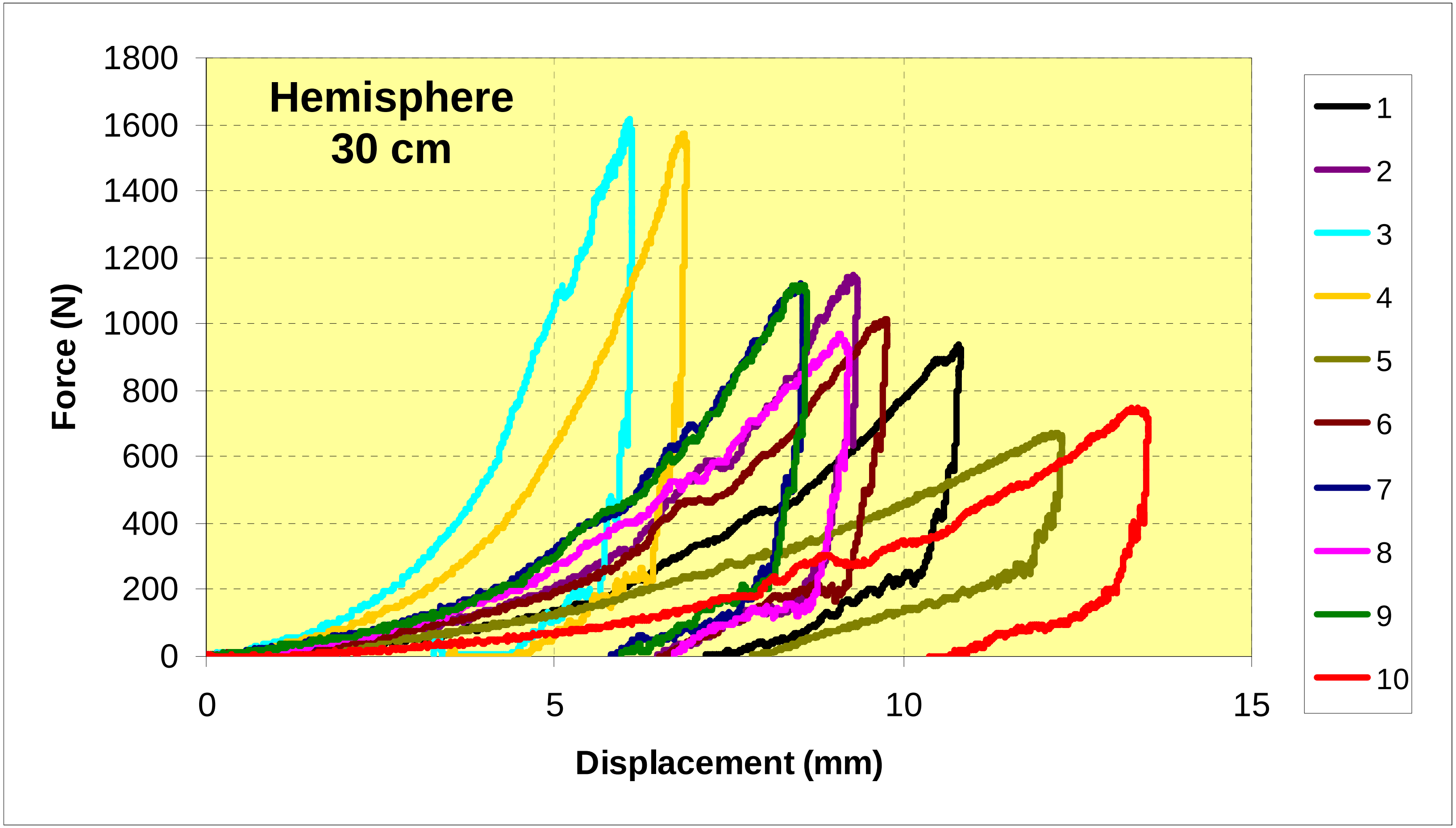
- *Force-control* perhaps more relevant to many football movements
- Ideal movement: $V_{hor} = 0$
  - foot pushes against surface
- Surface failure
  - performance lost (immediately)

Results and Understanding Data

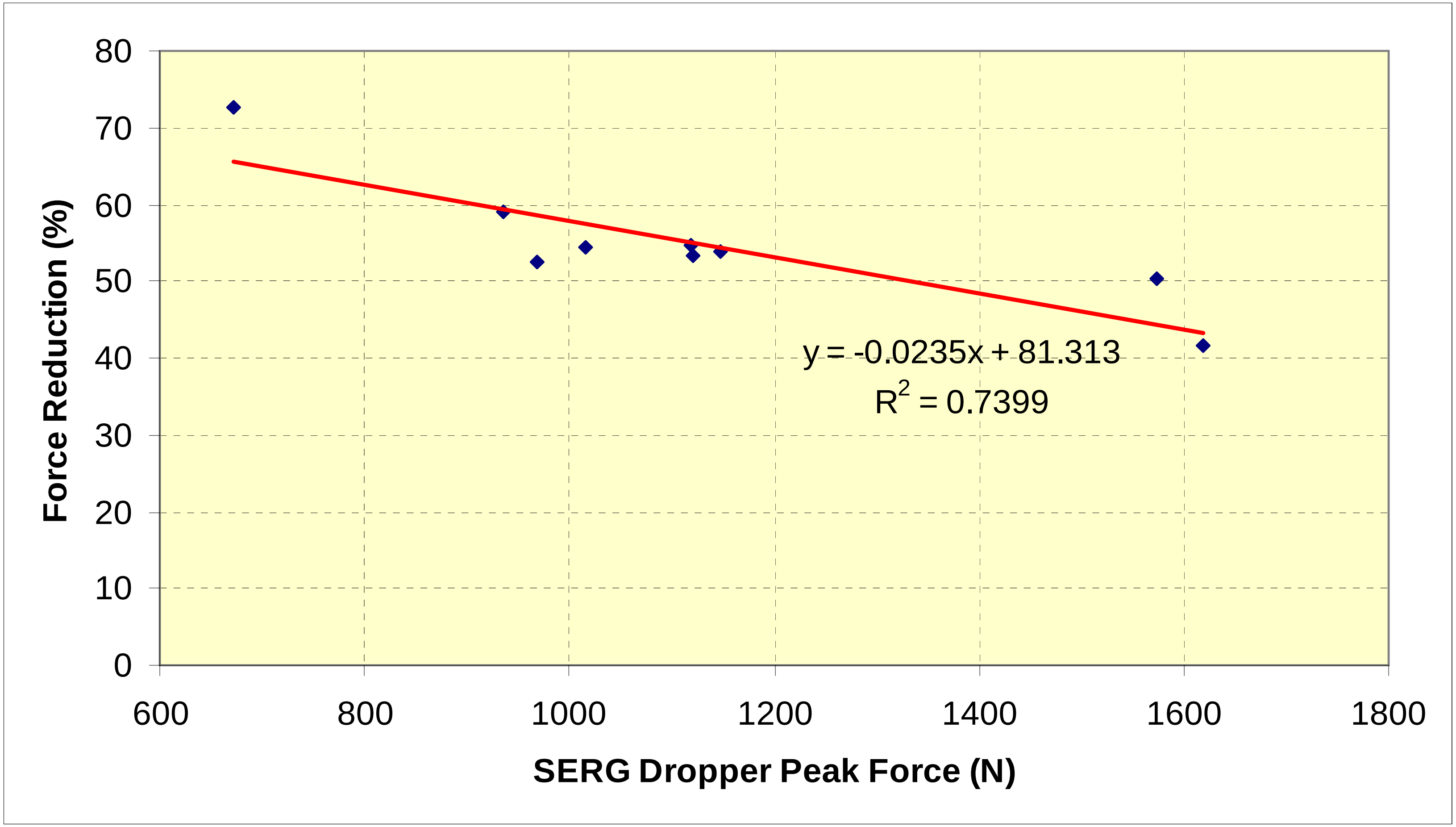




Drop Test - Surfaces

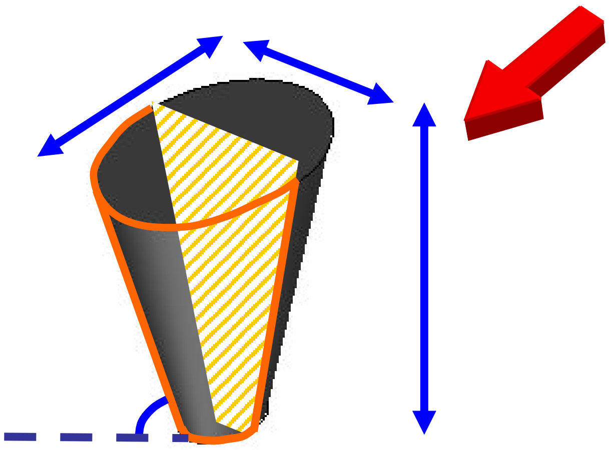


Artificial Athlete Correlations



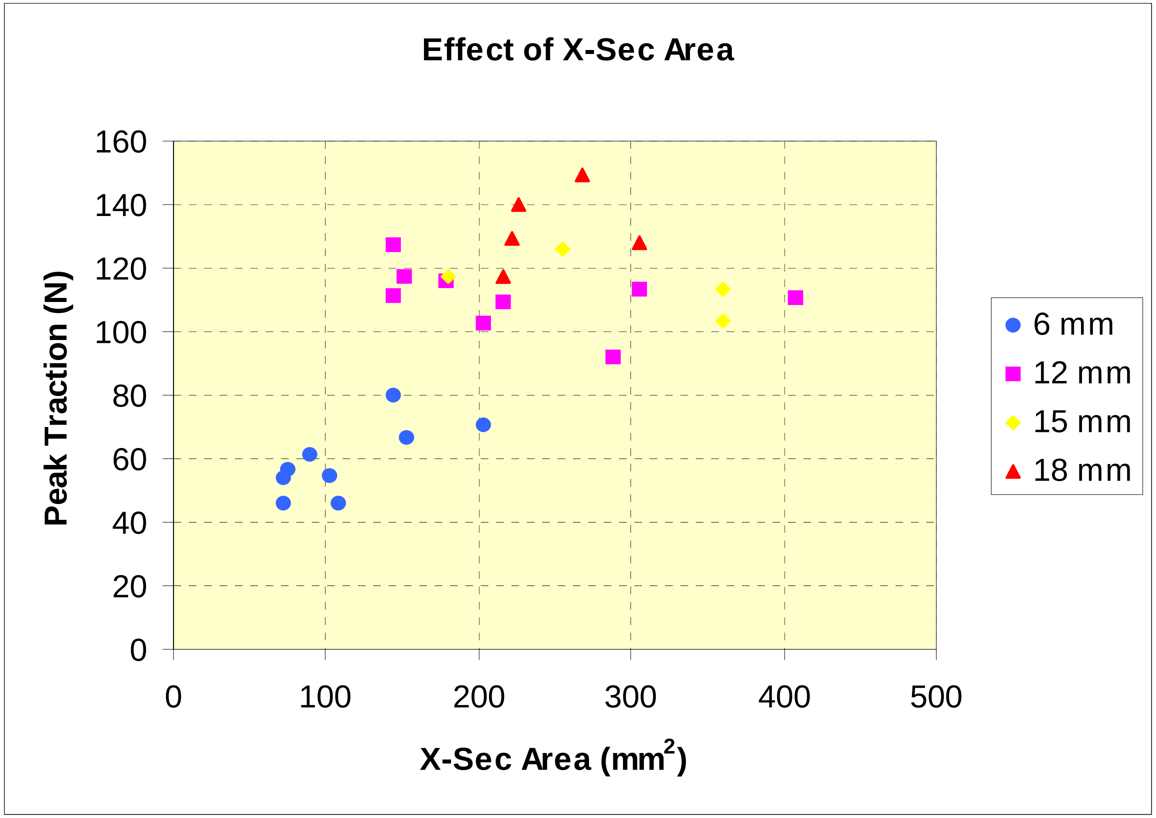
Traction – Stud Parameters

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



- Difficult to only vary *one variable at a time*

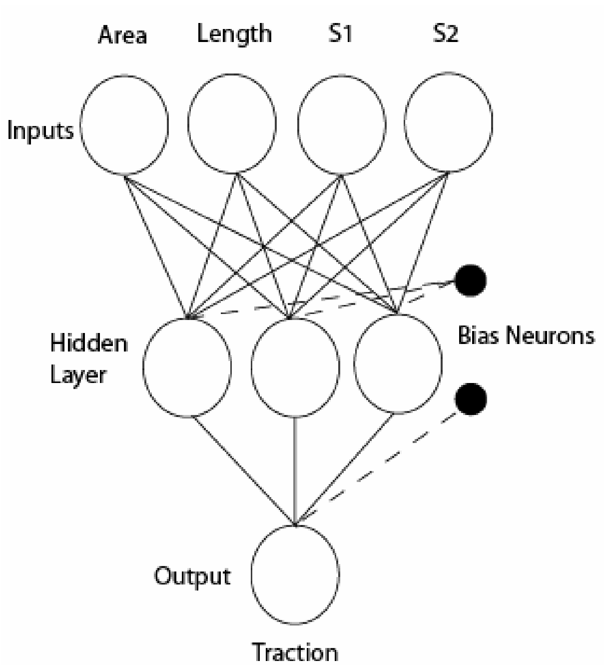
Multiple Parameter Dependence

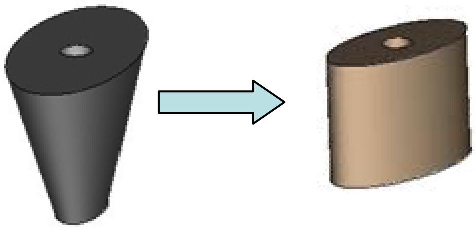


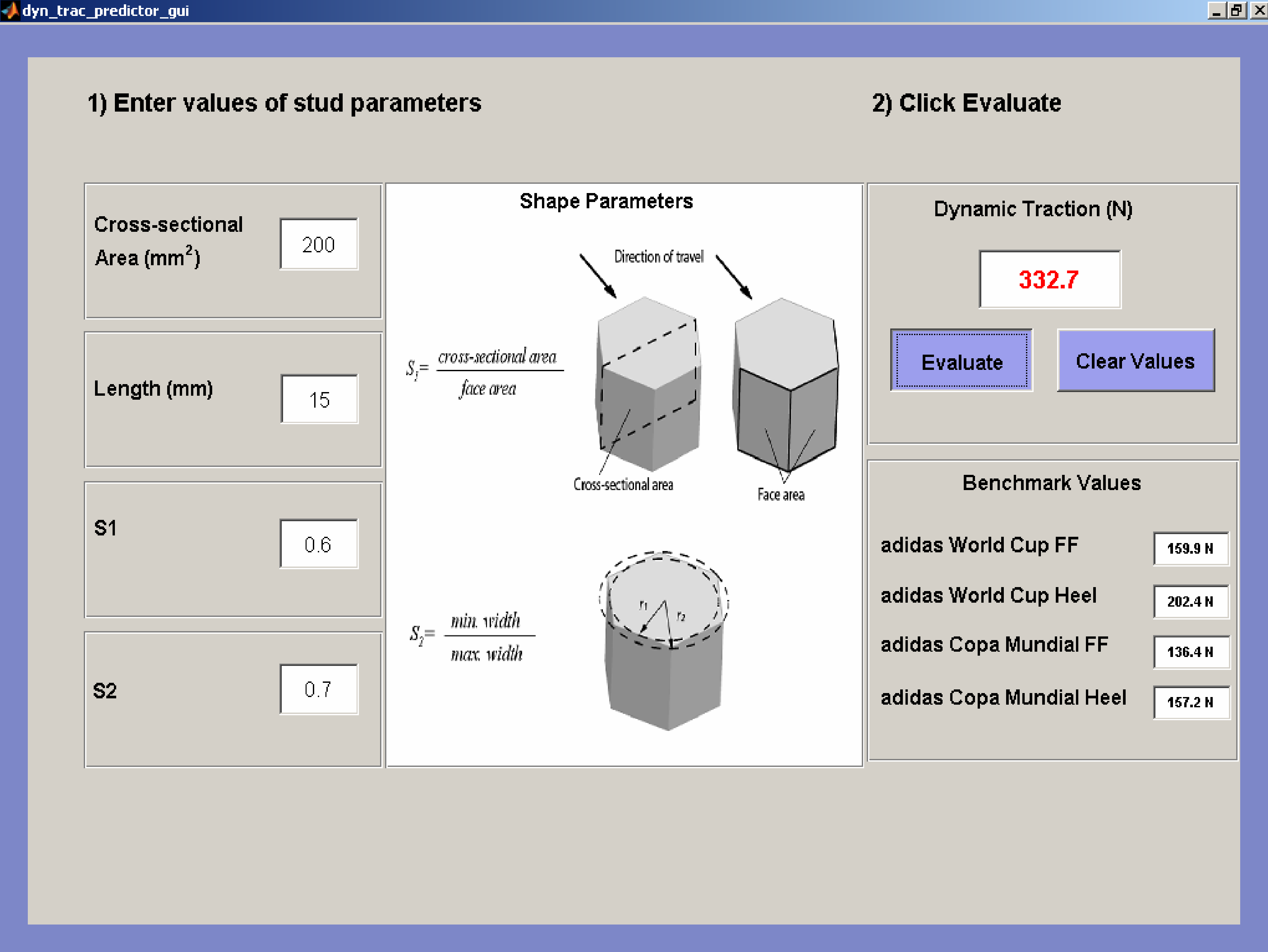
- Multiple parameters vary for each point
  - length
  - width
  - shape …
- Poor understanding from plot 2-D graphs of experimental data

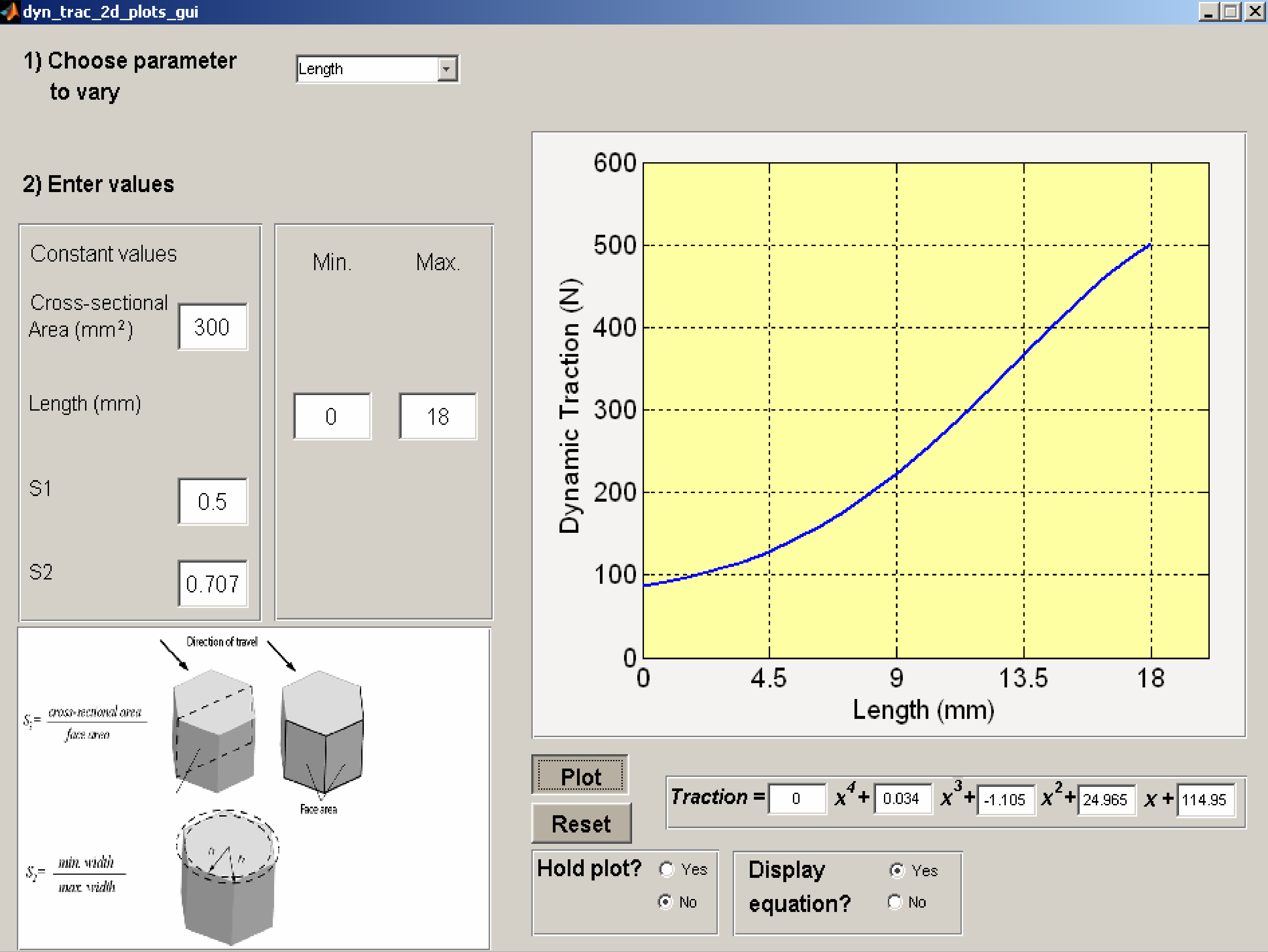
Artificial Neural Networks

- *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






dyn_trac_predictor_gui
1) Enter values of stud parameters
2) Click Evaluate
Cross-sectional Area (mm2)
200
Length (mm)
15
S1
0.6
S2
0.7
Shape Parameters
Direction of travel
S1= cross-sectional area / face area
Cross-sectional area
Face area
S2= min. width / max. width
r1
r2
Dynamic Traction (N)
332.7
Evaluate
Clear Values
Benchmark Values
adidas World Cup FF
159.9 N
adidas World Cup Heel
202.4 N
adidas Copa Mundial FF
136.4 N
adidas Copa Mundial Heel
157.2 N


dyn_trac_2d_plots_gui
1) Choose parameter to vary
Length
2) Enter values
Constant values
Cross-sectional Area (mm²)
300
Length (mm)
S1
0.5
S2
0.707
Min.
Max.
0
18
Direction of travel
S1 = cross-sectional area / face area
Face area
S2 = min. width / max. width
600
500
400
300
200
100
0
0
4.5
9
13.5
18
Dynamic Traction (N)
Length (mm)
Plot
Reset
Traction =
0
x4 +
0.034
x3 +
-1.105
x2 +
24.965
x +
114.95
Hold plot?
Yes
No
Display equation?
Yes
No

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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