DelTech Canon Settings for FIFA Testing

John Dunlop
19 December 2005

Soccer ball canon manufactured by DelTech Service, Werkplaats 99, Bovensteweg, Netherlands

The canon comes with no recommendations on setting to obtain the conditions required by FIFA test .*'Determination of Angled Ball Rebound'*

Here I have analysed the theoretical trajectory of a soccer ball ejected by such a canon

BALL TRAJECTORIES

The ballistic trajectories of a ball are affected by three forces – the force of gravity, G, a drag force, due to its air resistance, and the Magnus force, caused by rotation or spin of the ball. This latter force has been neglected in this study.

The trajectory of the ball can be described by the coupled differential equations,

$my'' = -mg - bv^2$ and
$mx'' = -bv^2$

where $v^2 = x'^2 + y'^2$.

x and y represent the two defining coordinates and the primes and double primes the first and second time derivatives.
m is the ball mass and
the drag constant b is given by $b = C_D(\pi d^2/8)\rho$
C_D being the drag coefficient, d the ball diameter and ρ the density of air

Measured values of 220 mm for d, 440 g for m and 1.22 kg/m^3 for ρ may be substituted.
The value chosen for the Drag Coefficient for a soccer ball is problematic here as the speed range envisaged, 50 - 55 kph, gives a Renoylds Number of 200,000 - right in the transition zone between lamellar and turbulent flow in which unstable flights are to be expected. The values obtained in '*Free Flight Aerodynamics for Sports Balls*' (published on this web-site) suggest a range of 0.25 – 0.28
giving a value for b/m of 0.013 -0.015.

The above differential equations may be solved using integration techniques – I have started at the end point, the contact, and worked backwards in time. The FIFA requirement is a bounce on the ground surface at 50 kph and at a grazing angle of 15 degrees.
The typical trajectory of a ball giving this contact is shown in Fig. 1, the ball travelling left to right and the dimensions in metres.

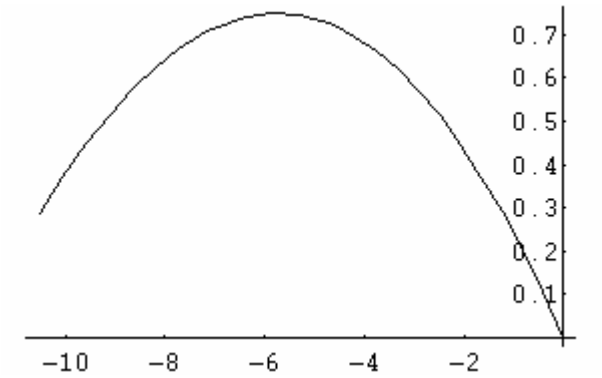

Fig 1. Trajectory of a soccer ball satisfying FIFA bounce requirements

CANON SETTINGS

The DelTech canon comes with a mounting tripod and an angular setting device whereby it can be directed horizontally, or elevated or depressed by fixed angles. The angular spacing is 6 degrees. Thus there is a choice of firing angles viz: 0, +/- 6, +/- 12, +/-18 … degrees when the tripod base is set horizontal.
The intersections of the trajectory with these fixed angular positions gives the following possible settings for the canon.

Angle	**-12**	**-6**	**0**	**+6**	**+12**	**degrees to horizontal**
Muzzle velocity	**50.8**	**52.5**	**54.5**	**56.7**	**59.2**	**kph**
Muzzle height	**265**	**625**	**748**	**610**	**150**	**mm**

These produce contacts distant from the canon and times of flight as:

Distance	1.1	3.4	5.7	8.3	11.2	m
Time	79	237	395	620	740	ms

The setting of –12 degrees might be preferred - the distance travelled is less, which reduces variability due to the unstable ball flight mentioned above.
But for tracking using the Stalker speed gun, consideration must be given to the number of data points obtained. Thus –12 degrees gives 2, -6 gives 7, 0 gives 24 etc. I would therefore recommend the –6 degree setting.

No analysis of uncertainty is presented here as the FIFA testing protocol disregards such considerations.