#### **STRAIGHT KICKER**

Straight kicker consists of solenoid and plunger. Plunger is the one that hits the ball.

#### **Solenoid:**

The frame of solenoid is made of 6061-Aluminium alloy and is cylindrical in shape with an inner diameter of 11.4mm and an outer diameter of 12.5mm. Its length is 44mm and thickness is 0.55mm. The wires wound around it are 24 AWG wires and the number of turns is approximately 400. We assume that a constant current of 40 A flows in it throughout its application time.

## **Plunger:**

Straight kicker consists of a custom made plunger with magnetic material (pure iron) in the middle and aluminium upon the remaining length. The length of the iron part is 45mm. The diameter of plunger is 11mm.

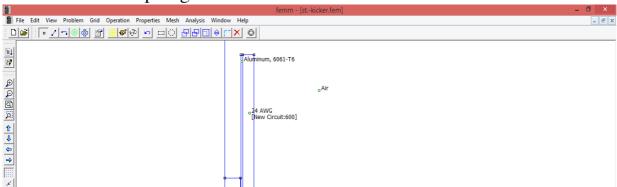
The Dynamic Analysis of a solenoid which when fed by constant current was done using MATLAB 2013a, FEMM 4.2 and ADAMS software's.

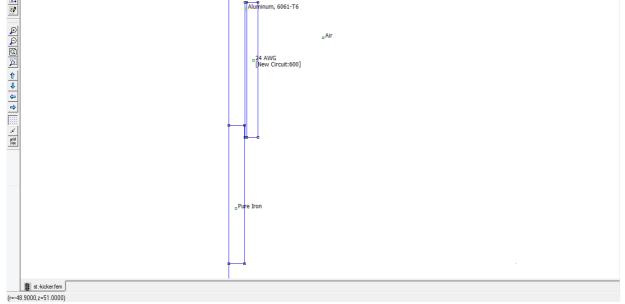
# Approach:

Using FEMM 4.2 software we created the image initial position of plunger in the solenoid across the two cross sections. Then using a code in MATLAB the plunger was made to move a little distance (about 1 mm) into the solenoid in each iteration. In each iteration the force was calculated in the plunger and stored in an array f while its distance from its initial position was stored in x. The iterations were carried on till the plunger reached its final position (here after 40 iterations). The force was calculated in each iteration. Finally the plot of force vs distance was generated. The area of the enclosed in the graph gave us the energy supplied by the solenoid to the plunger.

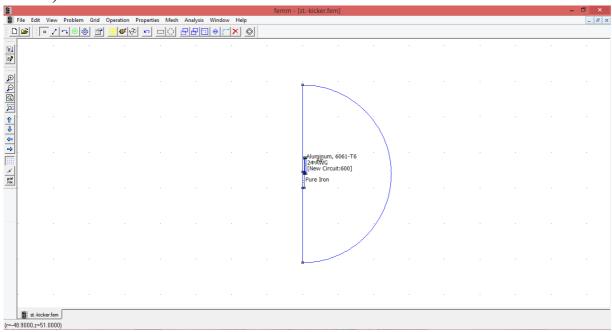
# **Analysis:**

The solenoid and plunger were modelled in Femm 4.2.





The boundary in FEMM simulation is kept sufficiently large in comparison with the solenoid dimensions (here a semi-circle of 210 mm radius).



The following Matlab code was used to generate the graph force vs. displacement of the plunger.

```
opendocument('st.-kicker.fem');
mi_saveas('temp.fem');
n=40;
y=zeros(n,1);
f=zeros(n,1);

for k=1:n
    disp(sprintf('iteration %i of %i',k,n));
    mi_analyze;
    mi_loadsolution;
    mo groupselectblock(1);
```

disp(sprintf(' force = %f',f(k)));

f(k) = mo blockintegral(19);

openfemm

y(k) = (k-1);

```
mi loadsolution;
   mo groupselectblock(1);
   y(k) = (k-1);
   f(k) = mo blockintegral(19);
   disp(sprintf(' force = %f', f(k)));
   mi modifycircprop('New Circuit', 1, 40);
   mi selectgroup(1);
   mi movetranslate(0,1);
   mi clearselected;
end
plot(y, f)
xlabel('Displacement, mm');
ylabel('Force, N');
title('Plunger Force vs. Displacement');
a = trapz(y, f);
disp(sprintf('Area = %f',a));
closefemm
```

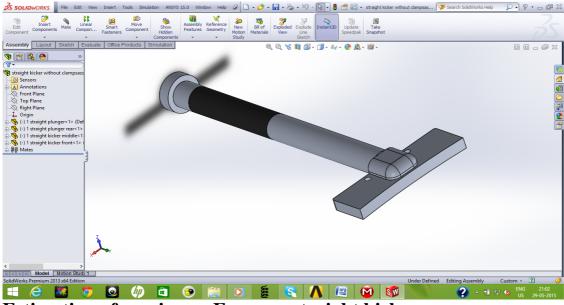
mi analyze;

The following graph is generated. The area is calculated by trapz () function which uses trapezoidal method to find the area under the curve. The graph gives us relation between force and displacement of plunger.

## Static Structural Analysis of straight kicker

We used ADAMS software to estimate the force while the static structural analysis as done using ANSYS software. Initially a solid works model was created of the straight kicker. The material used was aluminum alloy and cast iron. This model was then used in ADAMS and ANSYS.

The solid works model of the straight kicker:



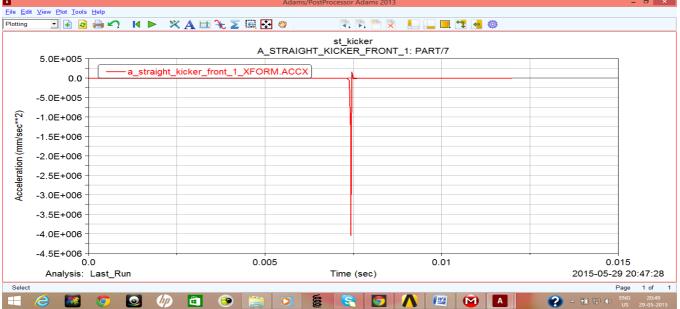
# **Estimation of maximum Force on straight kicker:**

For the estimation of the maximum force on the kicker during the collision with the ball, ADAMS simulation was used. We got the maximum deceleration of the front part of the kicker and multiplying it with the mass of kicker we got the required force.



# **Estimation of maximum Force on straight kicker:**

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Maximum deceleration =  $4.1 \times 10^6 \,\mathrm{ms^{-2}}$  (approx)

Mass of the kicker = 64.35 gm

Maximum force = 263835 N

Analysis using ANSYS: In the analysis we are looking at the worst possible case. So we assumed that the entire force is acting on the front face of the kicker while all the side faces are acting as fixed supports. The results of the analysis are as follows:

#### **Total deformation:**

■ Edge Coloring ▼ ゟ ▼ ゟ ▼ ゟ ▼ ゟ ▼ ゟ ▼ ★ ▼ ★ | | | | -1 Thicken Annotations
Result 2.9e+004 (Auto Scale) ▼ 📦 ▼ 📳 ▼ 🕬 🐻 🚳 Probe | Displ

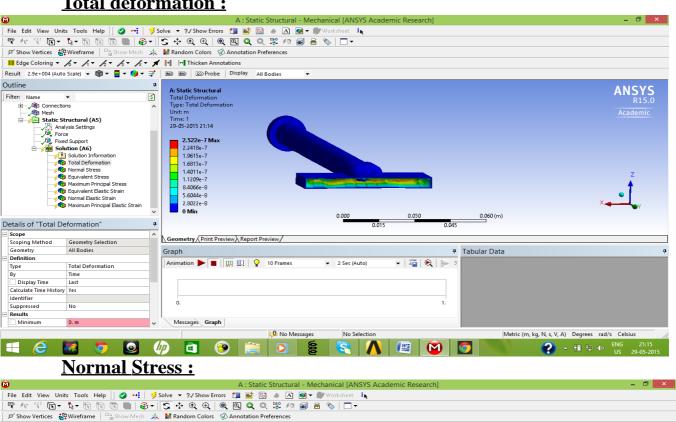
Connections

Mesh

Static Structural (A5)

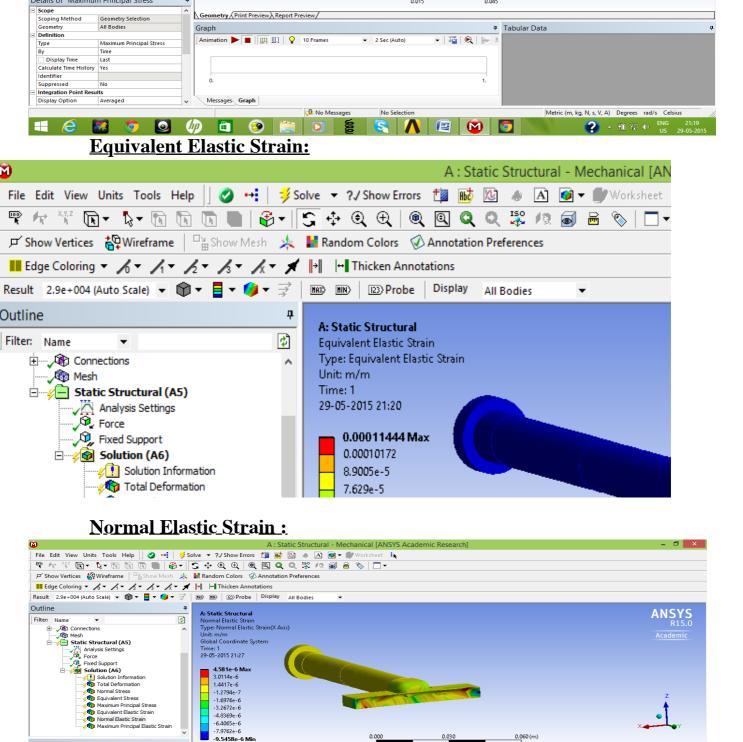
**3** 

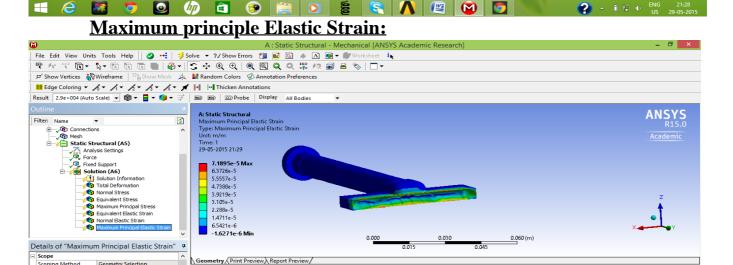
HIX HIX Display All Bodies



ANSYS

#### **Normal Stress:** File Edit View Units Tools Help | 🔗 📲 | 📝 Solve 🕶 ?/ Show Errors 🗂 📓 🚨 🐞 🛕 📦 🖝 | 🖤 worksheet The Art of the ■ Edge Coloring ▼ ゟ ▼ ゟ ▼ ゟ ▼ ゟ ▼ ゟ ▼ ★ ▼ ★ ■ I II Thicken Annotations Result 2.9e+004 (Auto Scale) ▼ 📦 ▼ 📳 ▼ 🎒 ▼ 📆 ■ DProbe Display All Bodies Outline ф ANSYS R15.0 Filter: Name er. Name (B) (Connections) (B) Mesh Static Structural (AS) Analysis Settings (C) Fixed Support (B) Solution (A6) (C) Total Deformation (C) Normal Stress (C) Equivalent Stress (C) Equivalent Elastic Strain (C) Normal Stress (C) Equivalent Elastic Strain (C) Normal Stress (C) Equivalent Elastic Strain (C) Normal Elastic Strain **\$** Normal Stress Type: Normal Stress(Y Axis) Unit: Pa Global Coordinate System Time: 1 29-05-2015 21:16 2.3617e6 Max 1.3335e6 3.0538e5 -7.2276e5 -1.7509e6 -2.779e6 -3.8072e6 Normal Elastic Strain Maximum Principal Elastic Strain -4.8353e6 -5.8634e€ 0.060 (m) 0.030 Details of "Normal Stress" Geometry (Print Preview) Report Preview/ Geometry Selection All Bodies Tabular Data Graph Animation 🕨 🔳 🛄 🖳 💡 10 Frames ▼ 2 Sec (Auto) - I II | 🔍 | 🖟 Normal Stress Туре Orientation Y Axis Last Global Coordinate System Display Time Messages Graph Suppressed 0 No Messages Metric (m, kg, N, s, V, A) Degrees rad/s Celsius No Selection ? - + 10 12 (I) ENG 21:17 US 29-05-20 **Equivalent stress:** A: Static Structural - Mechanical [ANSYS Academic Research Max) MIN) [23) Probe | Display All Bodies Outline ANSYS A: Static Structural Equivalent Stress Type: Equivalent (von-Mises) Stress Unit: Pa Filter: Name **(4)** Connections Mesh Static Structural (A5) Time: 1 29-05-2015 21:18 Analysis Setting Analysis Setting Force Fixed Support Solution (A6) 8.0522e6 Max Solution (A6) Solution Information Total Deformation Normal Stress Equivalent Stress Maximum Principal Stress Normal Elastic Strain Maximum Principal Elastic Strain 6.2628e6 8.9469e5 1.0987e-10 Min Details of "Equivalent Stress" Geometry Print Preview Report Preview 7 Tabular Data Graph Definition Animation 🕨 🔳 🛄 🖳 💡 10 Frames ▼ 2 Sec (Auto) → | I | Q | | Har | 3 Туре Equivalent (von-Mises) Stress By Display Time Calculate Time History Yes Identifier Suppressed No Integration Point Results Display Option Messages Graph Metric (m, kg, N, s, V, A) Degrees rad/s Celsius ② ^ 10 12 (b) ENG 21:18 US 29-05-2015 **Maximum principle stress:** MAX MIN 23 Probe Display All Bodies Outline Filten Name Mesh Statis Structural (A5) Analysis Settings Force Force Solution (A6) Solution fror Total Deform. A: Static Structural Maximum Principal Stress Type: Maximum Principal Stress Unit: Pa Time: 1 29-05-2015 21:19 ANSYS R15.0 **\$** 3.1426e6 Max 2.3778e6 1.613e6 8.4818e5 83359 -6.8146e5 -1.4463e6 Solution (AG) Solution Information Total Deformation Normal Stress Equivalent Stress Maximum Principal Stress Equivalent Elastic Strain Normal Elastic Strain Maximum Principal Elastic Strain -2.2111e6 -2.9759e£ -3.7407e6 Min 0.060 (m) Details of "Maximum Principal Stress" Geometry Print Preview Report Preview Scoping Method Geometry Selection All Bodies Tabular Data Definition mation 🕨 🔳 🛄 📖 💡 10 Frames - | III | 🗨 | 🖟 Calculate Time History Yes Identifier Integration Point Resu Display Option Messages Graph No Messages Metric (m, kg, N, s, V, A) Degrees rad/s Celsius 0 21:19 US 29-05-2015





▼ 2 Sec (Auto)

Animation 🕨 🔳 🛄 🖳 💡 10 Frames

Messages Graph

Tabular Data

Metric (m, kg, N, s, V, A) Degrees rad/s Celsius

- | III | € | Her

Details of "Normal Elastic Strain"

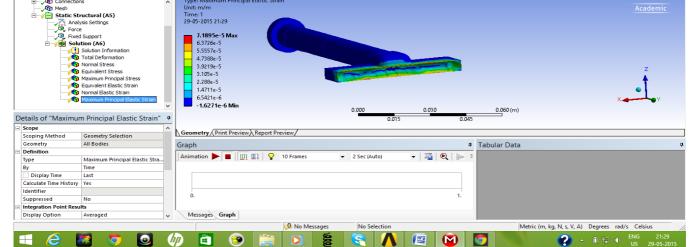
□ Scope
Scoping Method Geometry Selection
Geometry All Bodies

Calculate Time History Yes

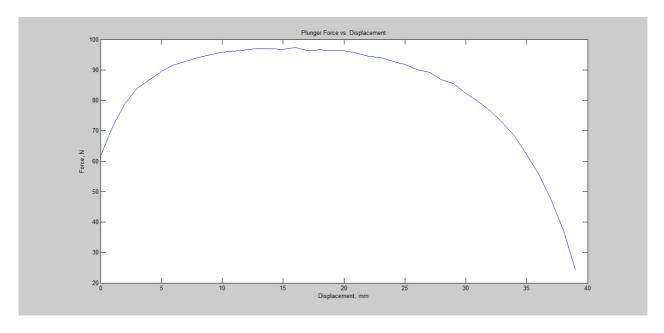
Normal Elastic Strain

Global Coordinate System

Geometry Definition



**Conclusion :** As expected the front portion of the kicker bears the brunt of the collision.



The area enclosed by the graph = 3290.940units

Thus Energy = 3.290 Joules (approx.).

The approx. polynomial of this function is:

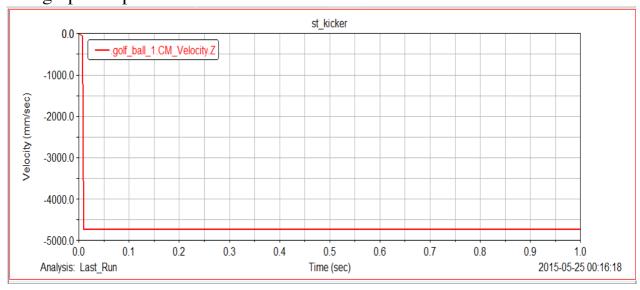
$$y = p1*x^{10} + p2*x^{9} + p3*x^{8} + p4*x^{7} + p5*x^{6} + p6*x^{5} + p7*x^{4} + p8*x^{3} + p9*x^{2} + p10*x + p11$$

### Coefficients:

p5 = -9.6523e-05 p6 = 0.0021383 p7 = -0.031974 p8 = 0.32827 p9 = -2.372 p10 = 12.159 p11 = 61.585

Later, the polynomial function was feeded in Adams-View software and simulation was done by applying force as obtained in matlab on the plunger.

The graph of speed of ball is:-



The simulation gave a speed of ball is about 5m/s.