HYPERLOOP INDIA

CONTROL SYSTEM

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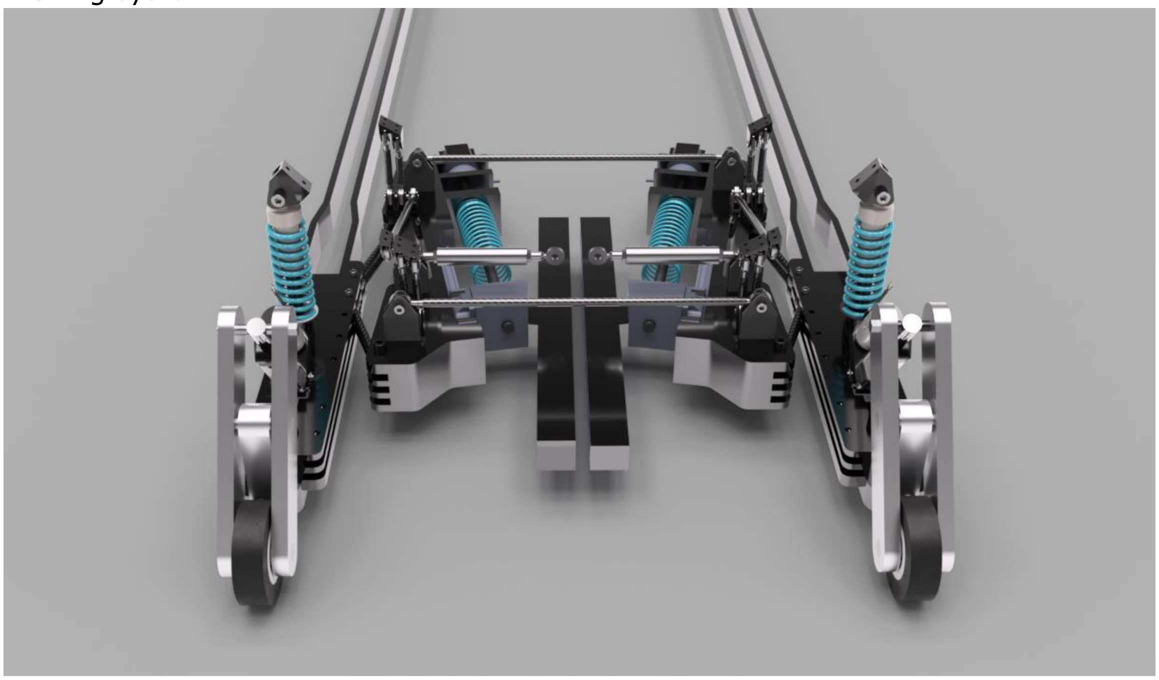
Braking system

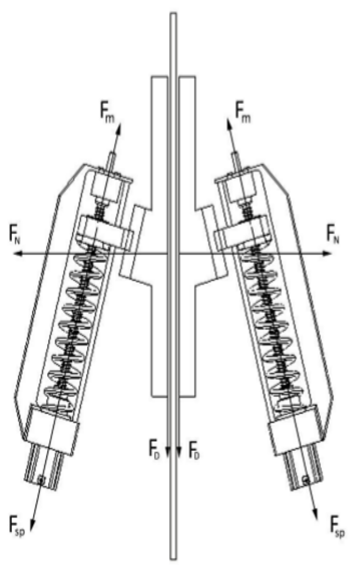


For the complete images of pod, see Appendix

INTRODUCTION

Working of Eddy Brakes

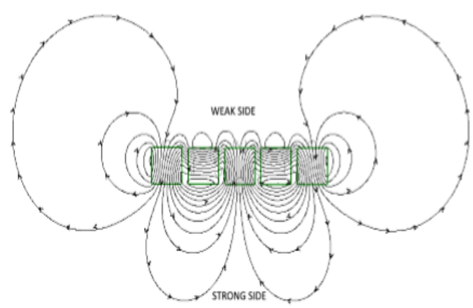
The primary brakes work on the principle of contact-less eddy current braking in order to reduce wear off the central rail. The brakes uses a pair of Halbach array configurations to utilise eddy current repulsion during relative motion, as a retarding force. During engagement of brakes, it experiences a normal and a drag force. The drag force is the primary agent to slow down the pod. During the braking cycle, the eddy brakes are pushed by the motor-driven ball screw mechanism, against the spring force.



F_N= Normal Force
F_D= Drag Force
F_{sp}= Spring Force
F_m= Actuator Force

The system uses two arrays of 18 1x1x1 inch N52 separated by 18 1x1x1/8 inch N52 permanent magnets arranged in a Halbach array configuration backed with 1/4" 1018 steel plate positioned on either side of the center rail. The steel backplates serve to increase the performance of the magnetic circuit and decrease the pod's stopping distance.

Halbach array is a special arrangement of permanent magnets that augments the magnetic field on one side of the array while cancelling the field to near zero on the other side. This is achieved by having a spatially rotating pattern of magnetisation.



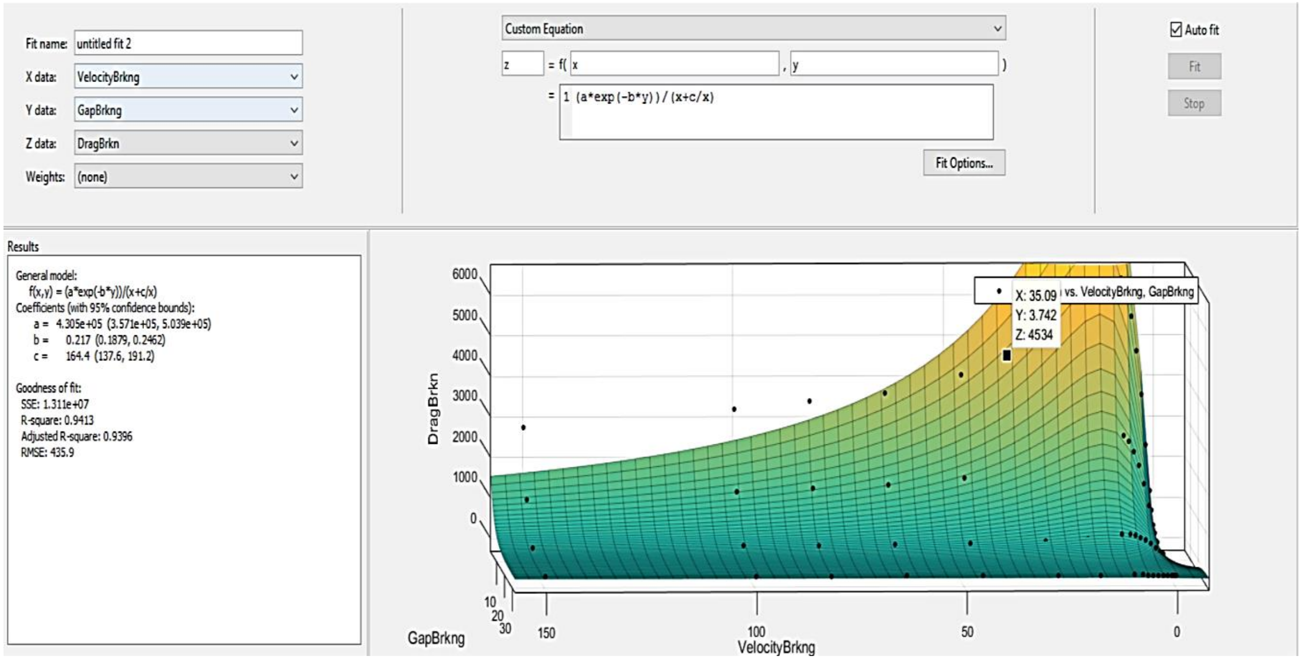


Fig 1 relation between GapBrkng (brake pad distance), VelocityBrkng(velocity of pod) and DragBrkn(drag force due to braking) from simulation data from FEM

THE BRAKING DRAG IS NON-LINEAR FUNCTION

```
%drag model
function drag = braking_drag(x,v)
%Predefined constants
a =  -5.557e+05;
b =       0.2308;
c =        227.8;
%function for drag
drag = a*exp(-b*x)/(v + c/v);
end
```

WHERE v is the present velocity

x is the brake magnet distance from I rail which varies from 32mm to 11 mm w.r.t I rail

CONTROL SYSTEM

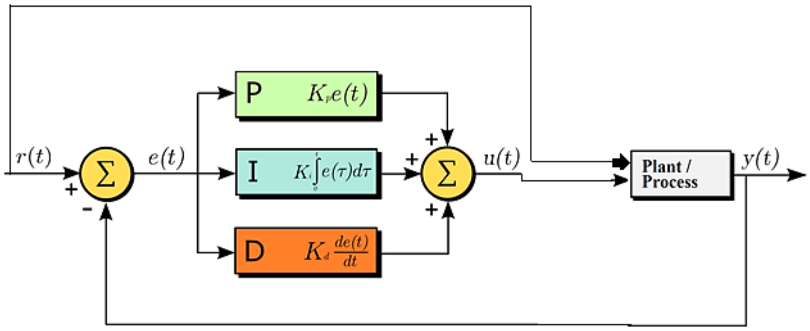


Fig 2

r(t) is desired velocity of pod

y(t) is actual measured velocity of pod

u(t) is the brake magnets distance from I rail

e(t) is the error in present velocity and desired velocity

THE BRAKING DRAG DEPENDS ON TWO INPUTS NONLINEARLY

- Brake magnets distance from I rail
- Present velocity of the pod

The PID control requires the plant model to be linear.

The plant model is linearized at two operating points so that it meets system requirements and suffice simulations on Simulink.

The PID control tries to follow a set point trajectory defined.

For the complete MATLAB CODE, see samarthjainabout.github.io/version 3.rar

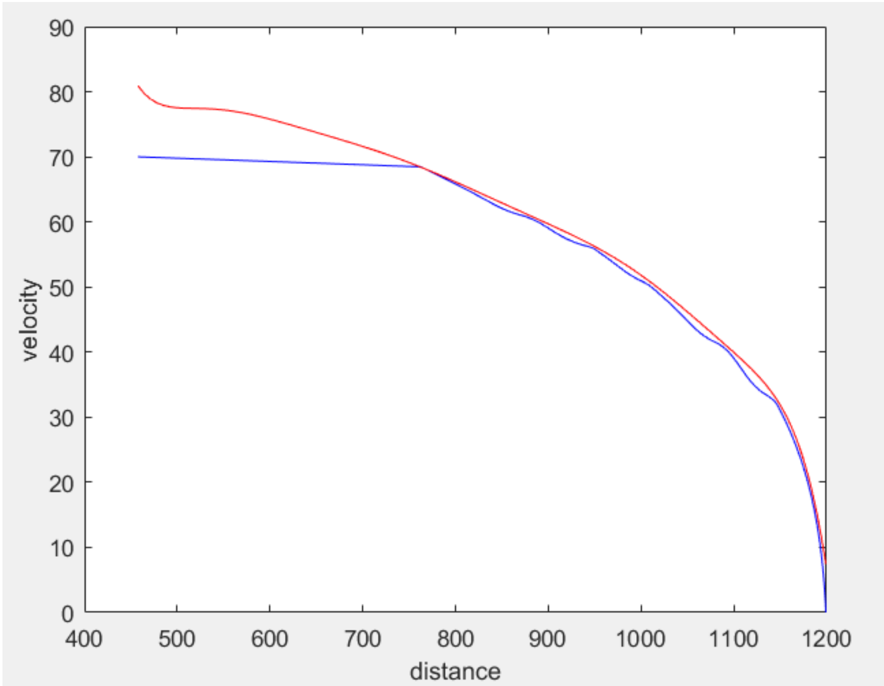


Fig 3 Red is the set point trajectory at 80 m/s initial velocity

Blue is the trajectory followed by pod at initial velocity of 70 m/s with PID control

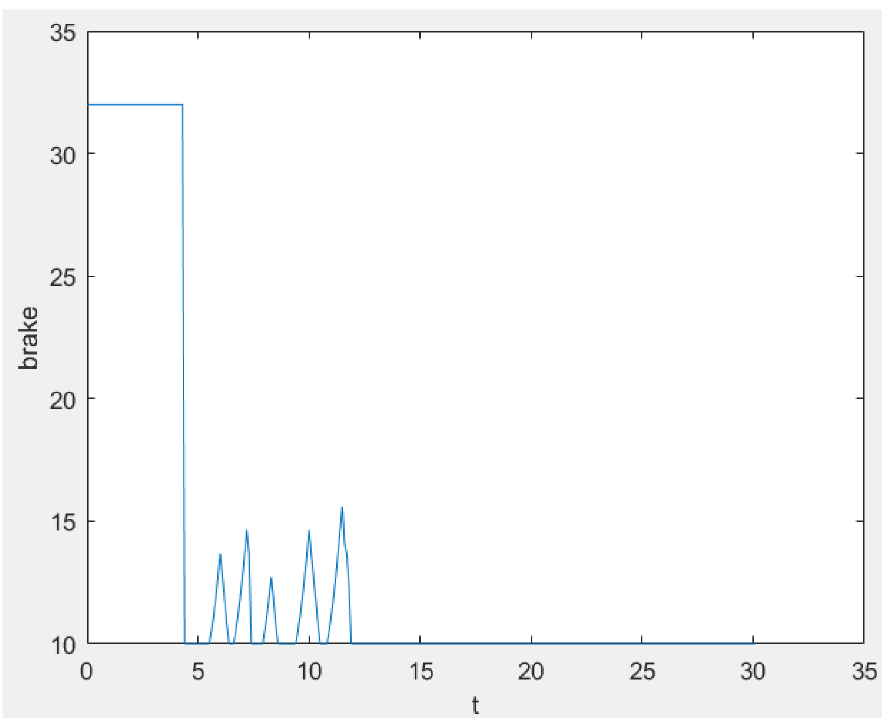


Fig 4 Active control by varying brake pad distance from I rail from 32 mm to 10 mm

Bibliography

1. Basdogan, Cagatay. ”Discrete PID controller.” http://portal.ku.edu.tr/~cbasdogan/Courses/Robotics/projects/Discrete_PID.pdf
2. Y.X. Su et al. “ Mechatronics 15 (2005) 1005–1024.” http://downloads.deusm.com/designnews/1477-Elsevier06.pdf

Appendix

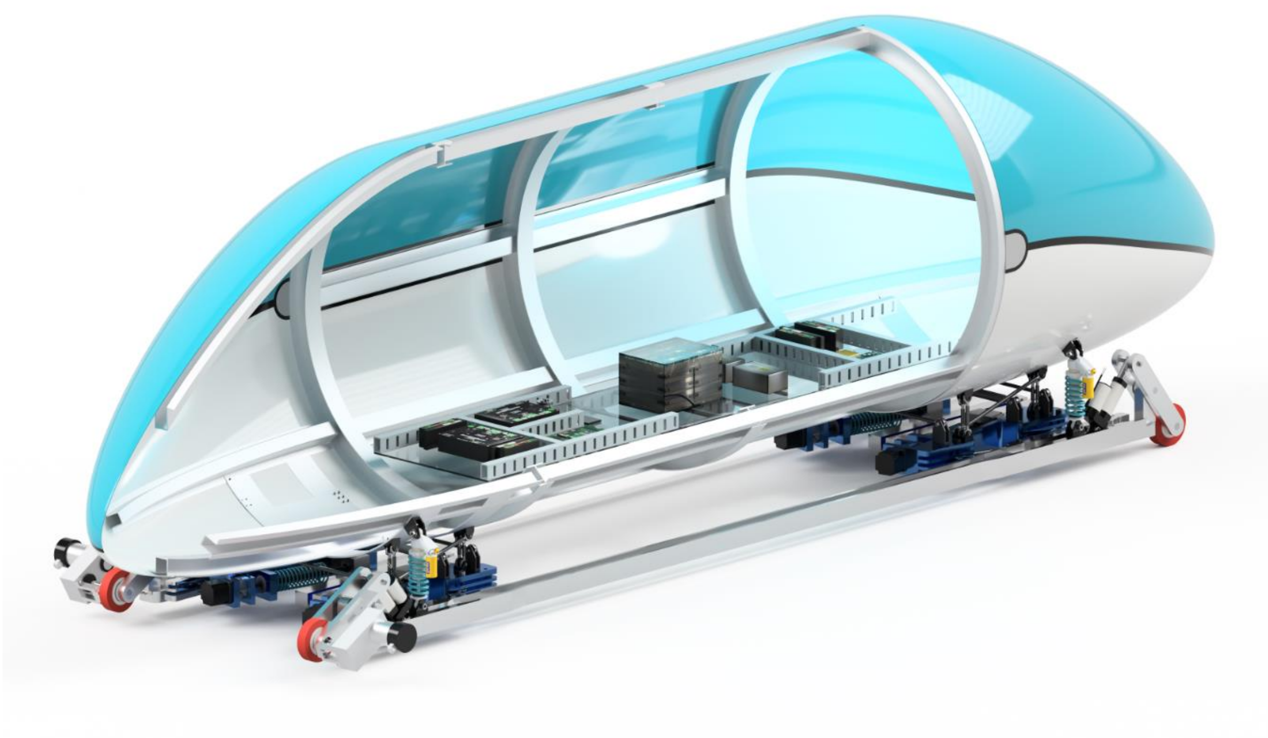


Fig 5 COMPLETE VIEW OF POD