ABSTRACT

The aim of this project is to introduce the principles and concept of an aircraft's elevator operation with the use of simulation models. Considerable simplifications and assumptions are made, and simulations are implemented on the bases of these simplifications. This project would depict the A380 elevator's model structure, geometry, dynamics, actuator and PID controller. The computations and model analysis of our simulations are made In the MATLAB & SIMULINK software.

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1. INTRODUCTION

The A380 Elevator is a flight control system located at the rear of the aircraft with a hinged connection on the aircraft's horizontal stabilizer. This onboard electro-mechanical system serves as the pitch control system deployed to regulate the angle of attack and the wing lift of the aircraft.

To provide pitch control and stability, this mechanical system is controlled by onboard certified pilots through the transfer of signals and with help of its permissible structure and layout, these transmitted signals successfully provide a regulated motion of the elevators.

This mechanical operation, we shall be analyzing with scrutiny in this project using the MATLAB & SIMULINK software.

2. MODEL DESCRIPTION

The basic structure of models involves

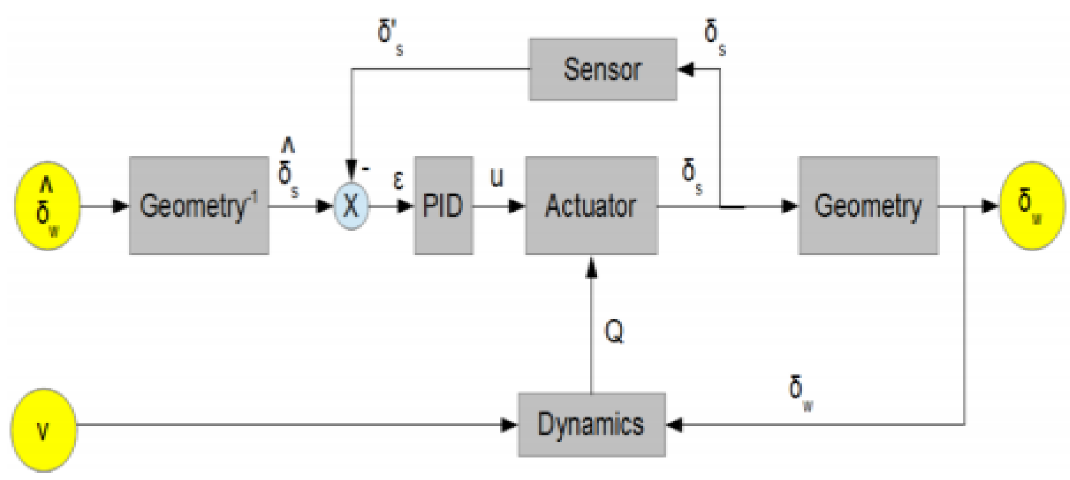


Figure 1 Model structure

In Figure 1 is a block diagram depicting a modular based approach which would be used in the construction of our simulation model.

The model comprises the following four main modules:

3. GEOMETRY

A simple elevator deflection scheme is adopted in this project.

Traveling along the y axis with one motion, our elevator geometry is designed with an axially movable actuator rod intended provide angular deflection of the elevator.

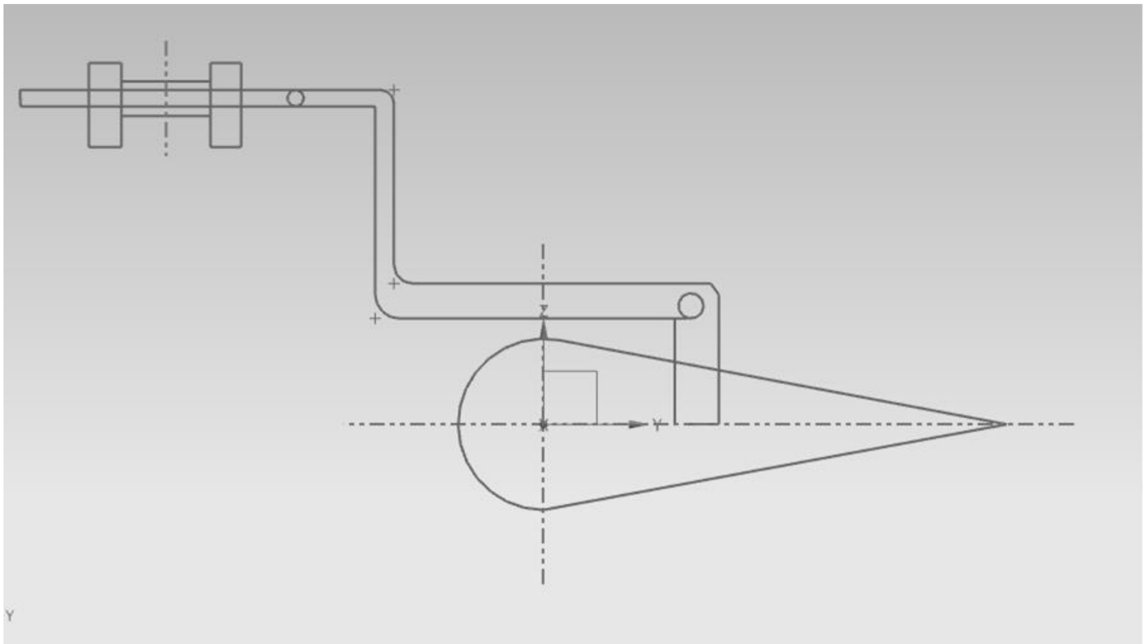
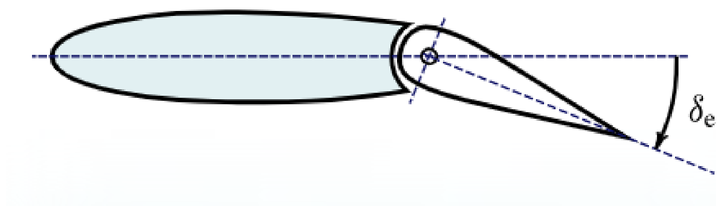


Figure 2 2D Geometry

Figure 2 depicts the 2-dimensional mechanism of our elevator deflection system. In this module segment, the following assumptions are made

- One angle of rotation
- $\delta Emax\_up$ = 15 degrees, $\delta Emax\_down$ = 15degrees.

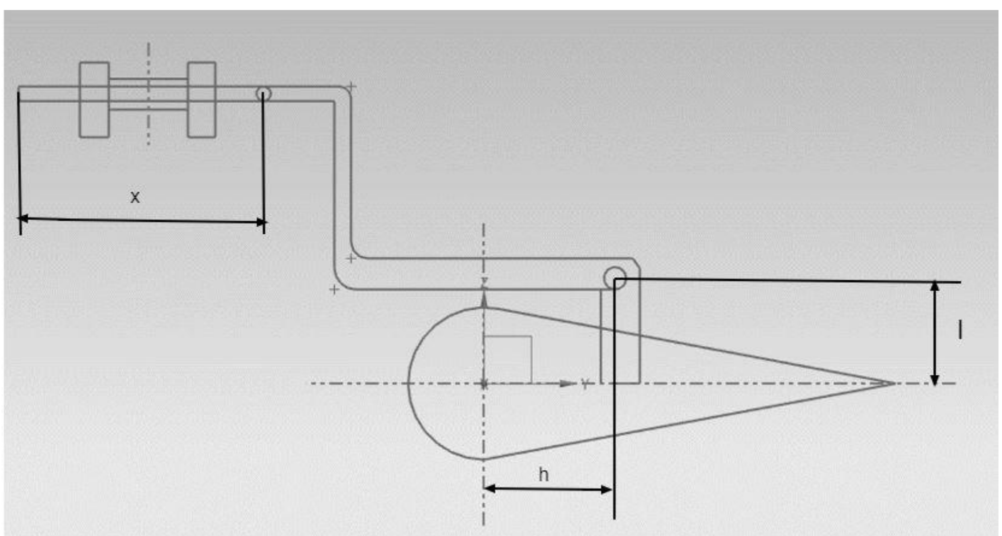


3.1 Parameters:

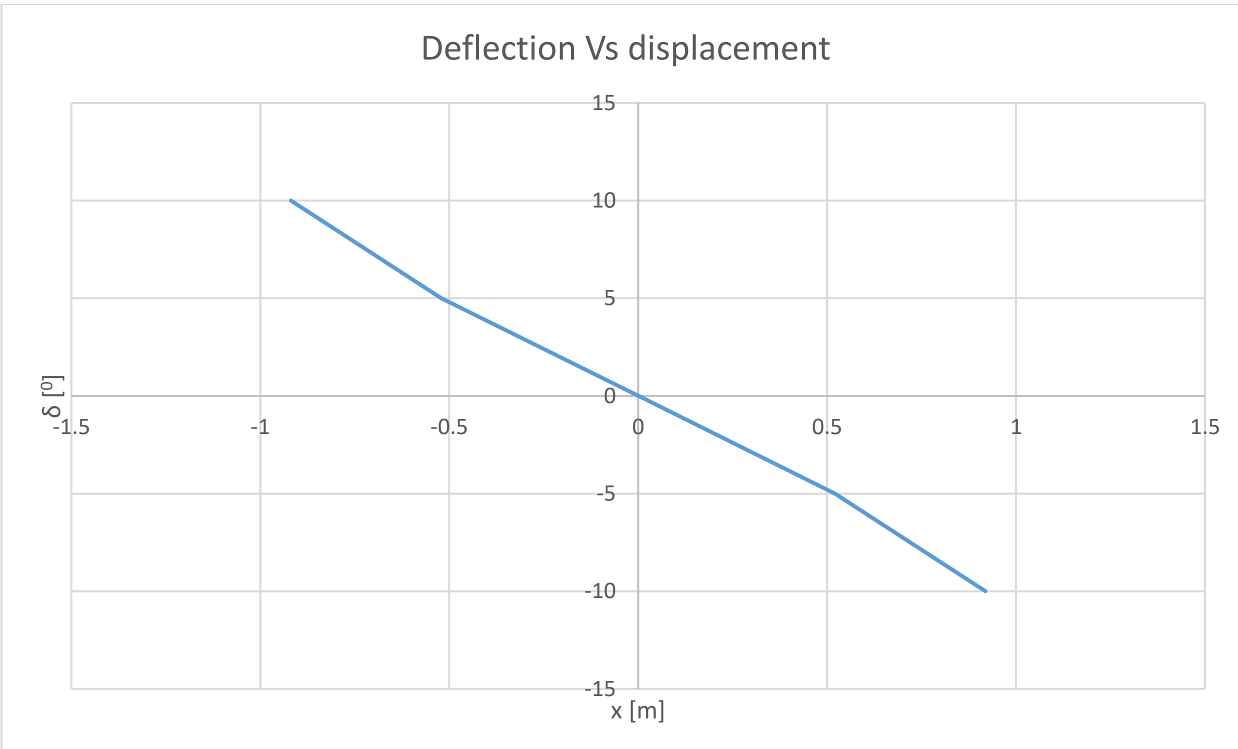
x is the displacement of the actuator rod

l= 0.18 [m]

h= 0.5 [m]

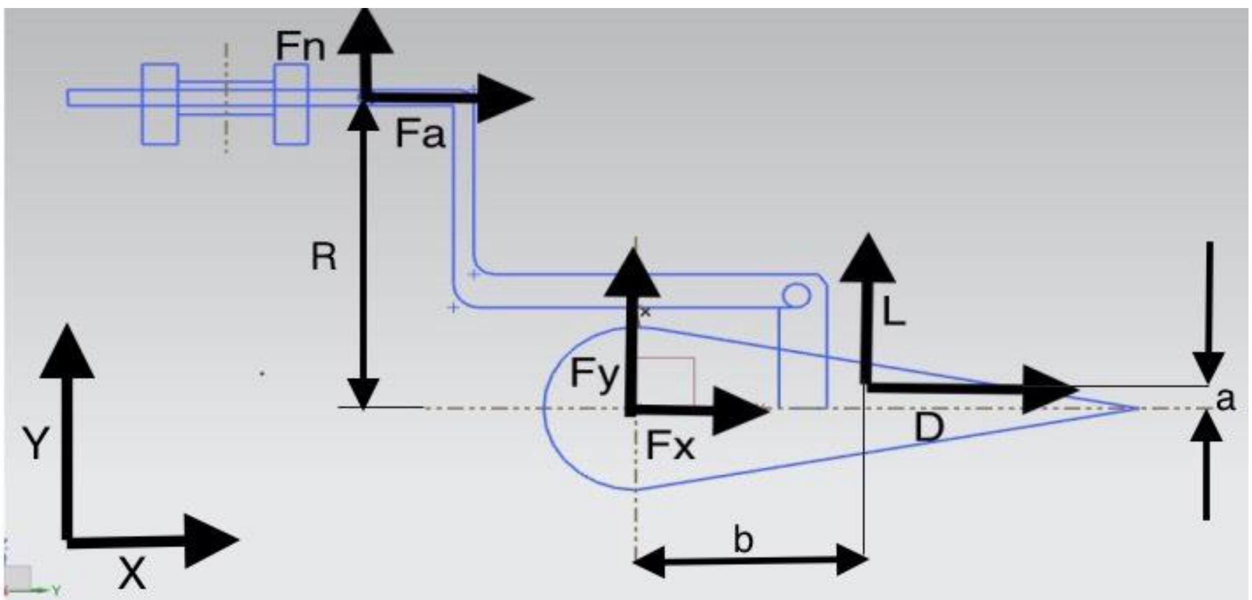


With these Known parameters, we can denote the relation between the deflection and actuator displacement graphically as



4. Dynamics

This segment is an approach to understanding the behavior of our system through studying the performance and stability of our system after the input of a velocity V and deflection δ. It is concerned with how forces acting on the elevator influences its speed and deflection. These forces include aerodynamic forces and pressure induced by the actuator.



The following assumptions were made in this segment:

- The Upward hinge force from the actuator is negligible (Fn=0)
- The deflection is equivalent to the angle of attack of the horizontal stabilizer
- The value of the velocity is equivalent to that of the aircraft
- The values of the parameters are:

a= 0.214 [m]

b= 0.411[m]

R=0.9 [m]

4.1 Equilibrium Equations

- $\sum x : F_A + D - F_x = 0$
- $\sum Y : L + F_y = 0$
- $\sum M_o : F_A * R + D * \mathrm{a} - \mathrm{L} * \mathrm{b} = 0$
- $F_A = \frac{L \cdot b - D \cdot a}{R}$
- $F_x = F_A$+D
- $F_y = -\mathrm{L}$

4.2 Aerodynamic Forces

$$L = \frac{1}{2}\rho v^2 s C_L$$

$$D = \frac{1}{2}\rho v^2 s C_D$$

$$C_L = C_L(\alpha); \quad C_D = C_D(\alpha);$$

Where:

Air density ρ : *1.225 kg/m^3*

s : 62.35 *m^2*

$c_{L\alpha}$: 5.5

e: 0.7

AR: 7.5

lift coefficient (when α=0) c_{Lo}: 0.29

c_{Do}~ 0

Proceeding we get,

$$c_L = c_{L\alpha} * \alpha + c_{Lo}$$
$$c_L = 5.5 * \alpha + 0.29$$
$$c_D = c_{Do} + \frac{{c_L}^2}{\pi\, AR * e}$$
$$c_D = c_{Do} + \frac{(5.5*\alpha+0.29)^2}{\pi\, AR * e}$$

The induced actuator force which is dependent on the velocity and deflection can be expressed with the following relation.

$$F_A = \frac{\frac{1}{2}\rho v^2}{R}((5.5*\alpha+0.29) *b-(c_{Do} + \frac{(5.5*\alpha+0.29)^2}{\pi\, AR*e}*a))$$

The dynamic load plot can be graphically represented as:

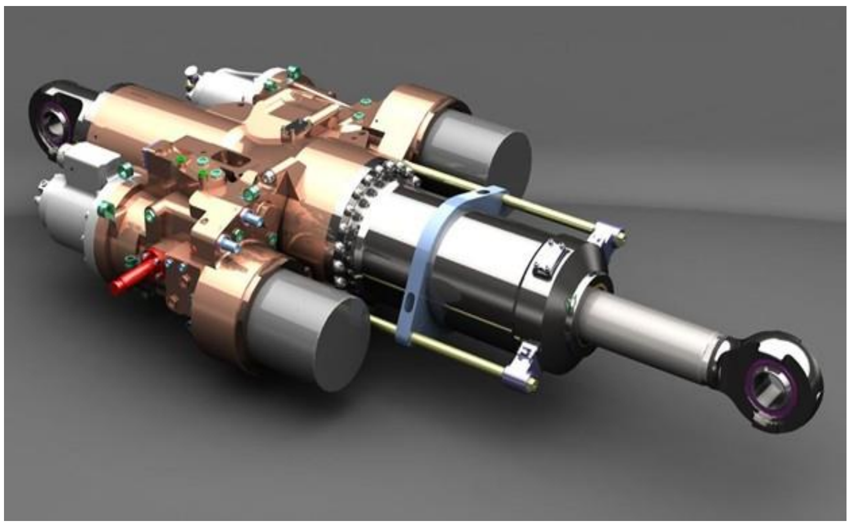
5. Actuator

The A380 being our reference aircraft, we would be Using an Electro-Hydrostatic Actuator (EHA). This actuator which is intended to enable controlled transmission of motion of our elevator is hydraulically autonomous in flight. Electro hydrostatic Actuators, often referred to as “power by wire,” are fully self-contained actuation systems that combine design elements from electric and electrohydraulic actuation.

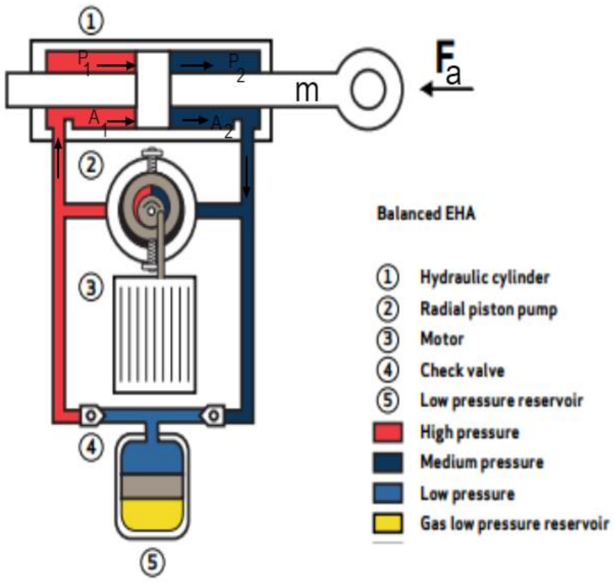
They receive power from an electric source and transform an input command signal (usually electrical) into motion. They typically include a servomotor, hydraulic pump, accumulator and servo actuator.

5.1 Choice of model:

A Dual Motor-Pump Module from the manufacturer MOOG, with Flow Summed EHA 70,000 lb Stall Load / 42 Horsepower



5.2 Mathematical model



- $m\ddot{x} = A_1P_1 - A_2P_2 - F_a$

For simplification purposes, we assumed that our pressure behind the piston being dependent on the input pressure which will be identified as the constant P_0 by a margin of pressure difference ΔP *we get*

- $m\ddot{x} = A_1P_0 - A_2(P_0 + \Delta P) - F_a$

This pressure difference would also be assumed to be our PID input alongside our dynamic load F_a.

Where:

- m= 12.3 kg
- A1= 0.00292m^2
- A2= 0.000633m^2
- P_0 = 2.0684e+7 pa (3000psi)
- ΔP PID input

Having the following parameters and relation, we can express our final relation as:

12.3 $\ddot{x} = (0.00292 * 2.0684e{+}7) - (0.000633 * (2.0684e{+}7 + \Delta P)) - (\frac{\frac{1}{2}\rho v^2}{R}((5.5*\alpha+0.29)*b-(c_{Do}+\frac{(5.5*\alpha+0.29)^2}{\pi\, AR*e}*a)))$

6. PID CONTROLLER

A proportional–integral–derivative controller (PID controller. or three-term controller) is a control loop feedback mechanism widely used in industrial control system and a variety of other applications requiring continuously modulated control. A PID controller continuously calculates an *error value* as the difference between a desired setpoint (SP) and a measured process variable (PV) and applies a correction based on propagational, integrational and derivative terms (denoted *P*, *I*, and *D* respectively). (Wiki, n.d.)

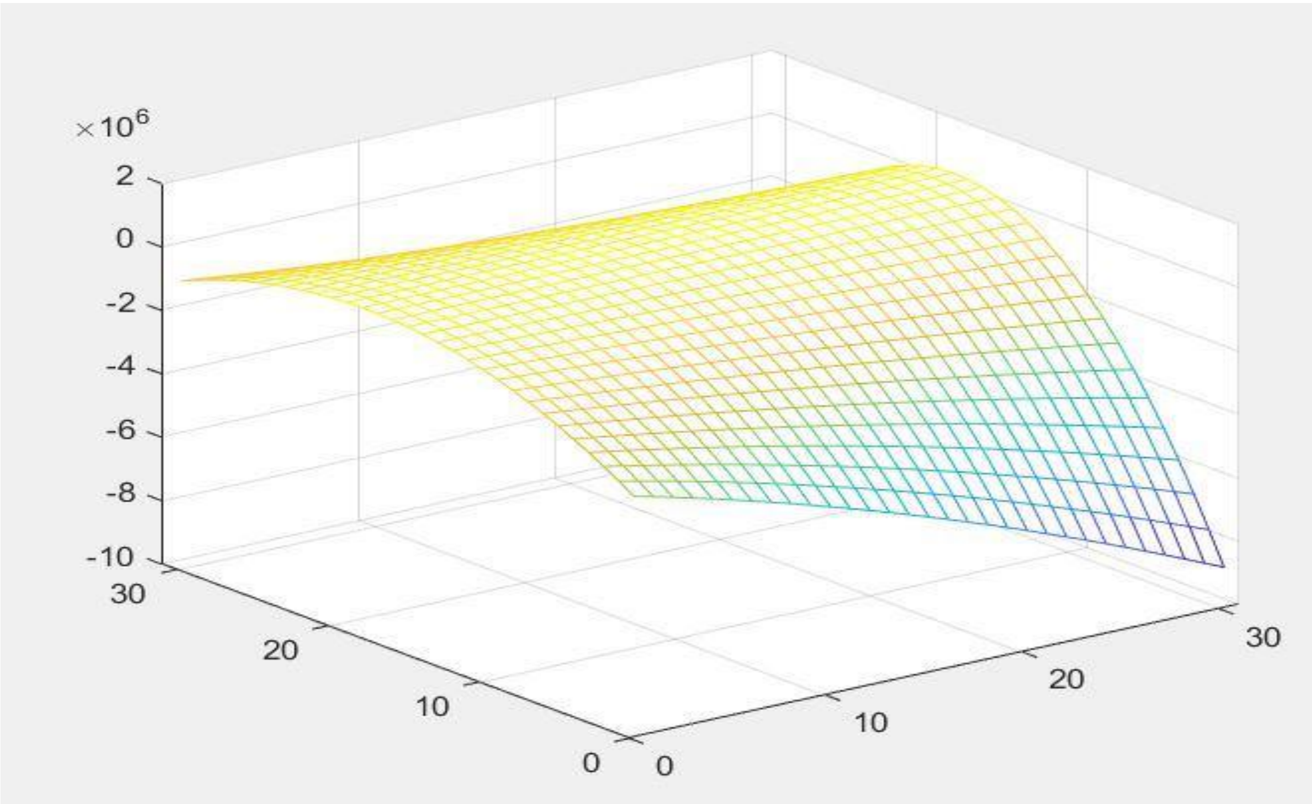
In practical terms it automatically applies accurate and responsive correction to our control function.

7. SENSOR

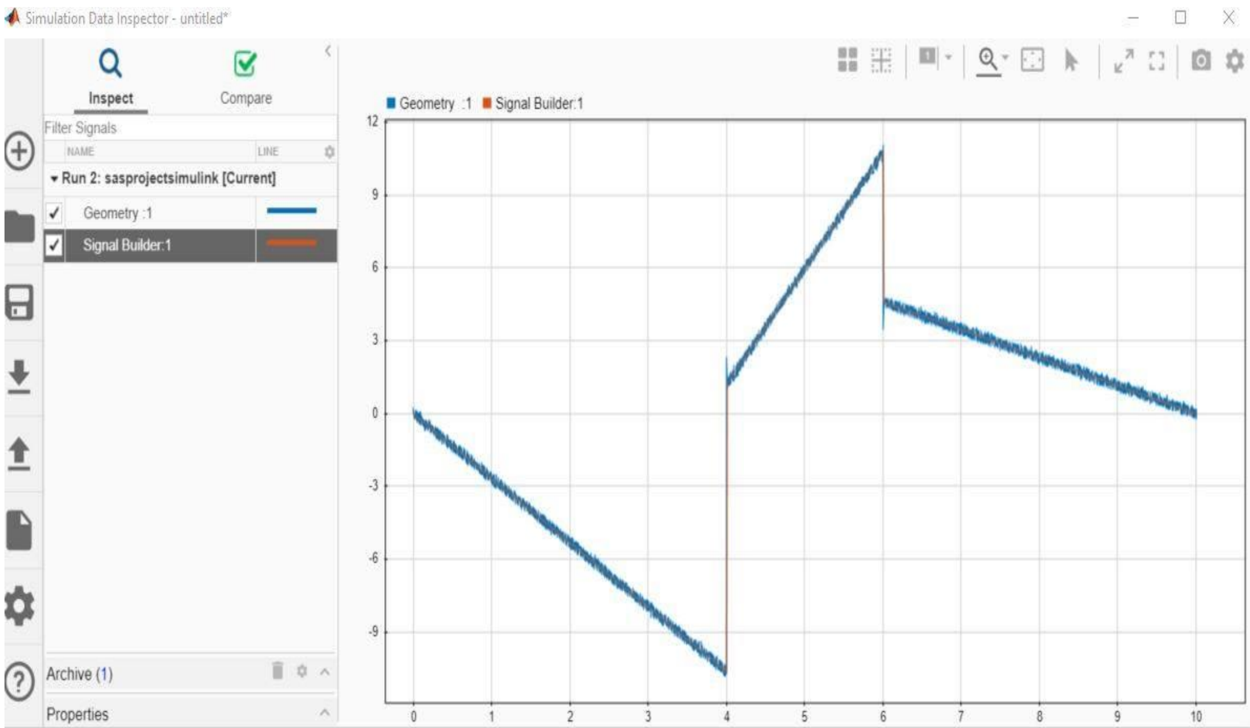
A sensor is a device that detects and responds to some type of input from the physical environment. The specific input being motion yields the output which is generally a signal that is converted to human-readable display at the sensor location or transmitted electronically over a network for reading or further processing.

8. RESULT

8.1 Dynamic load plot



8.1 Sample simulation:



9. SOURCE CODE

```
%%%%%%geometry and geometry paramters%%%%%%

sigma=[-15:1:15]

h=0.5;

x=h*(sind(sigma));%%displacement

plot(sigma,x)

ylabel('x')

xlabel('sigma')

v=[180:5:330]%%range of velocity with an interval of 5

density=1.225;

a=0.214;

R=0.9;

b=0.411;

e=0.7;

AR=7.5;

%%%%Matrix formation of Force in for loop%%%%

m=size(sigma,2);

n=size(v,2);

F=zeros(m,n);

for i= 1:m

  for j= 1:n

    F(i,j)=(((0.5*density*(v(j)*v(j))/R)*((((5.5*sigma(i))+0.29)*b)-
((((30.25*(sigma(i)*sigma(i)))+(3.19*sigma(i))+0.0841)*a)/(pi*AR*e)))));

    end
```

```
end
plot(sigma,F)
ylabel('F')
xlabel('sigma')
%%%%actuator and it's paramters%%%%
mass=12.3;
A1=0.00292;
A2=0.000633;
p0=2.0684*(10^7);
deltaP=1.724*(10^6);
```

10. BIBLIOGRAPHY

1	https://www.meil.pw.edu.pl/daas/DAAS2/Teaching/SAS/Files-for-Students
2	http://airfoiltools.com/airfoil/details?airfoil=sc20714-il
3	https://www.airbus.com/aircraft/passenger-aircraft/a380.html
4	https://en.wikipedia.org/wiki/PID_controller