Assignment : 1

Study of a Door Closer via Modelling and Simulation

Submitted to

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For the partial requirement of the course of

System modelling and Simulation

By

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Study of a Common Door Closer

Purpose of the Study:

The purpose of this study is to obtain a mathematical model for the door closer such that its observations of its behaviour and analysis holds true for the real door closer.

Developing mathematical model and solving them is more convenient rather than testing actual systems, we model the system using mathematical equations and then analyse its behaviour. Door closers are used on doors to pull the door and shut slowly enough to avoid slamming, which could cause damage to the door itself. The main elements of door closer are a spring and a damper. A mathematical model of the door closer will be derived and its behaviour will be analysed.

Observation:

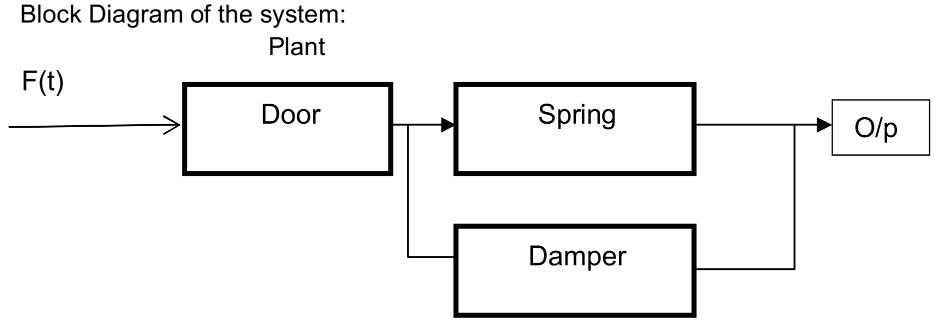
1. The door is initially at rest. It is at an angle of 0 degree.
2. The door rotates around the hinge when someone pushes the door. When the door is left at an angle less than 90 degrees, the door returns to rest position.
3. The movement is limited to 90 degrees from rest. At this position the door is completely open
4. If the door is pulled to an angle and then released, it will try to reach its rest position at an angle of 0 degree without slamming.
5. The door initially moves with higher speeds but as it comes near the rest position, its speed decreases.
6. The door eventually closes without slamming.

Based on the above observation, it can be said that

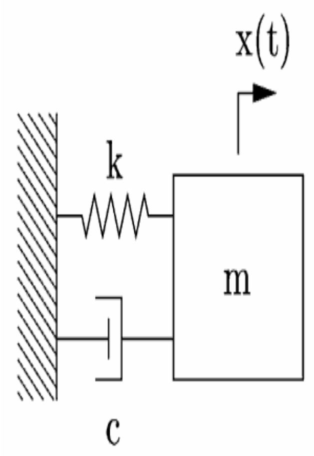
The door closer has to be made of spring and damper. The spring acted in compression so as to push the plunger back to its original position from a deflected position, caused by opening the door. The damper then opposed the motion of the spring, slowing the motion enough to avoid slamming the door

1. When the door is pulled, kinetic energy is converted to potential energy and stored in the spring.
2. When the door is released, potential energy is converted to kinetic energy means spring pushes plunger back to its original position.
3. While moving back to original position damper opposes the motion to prevent slamming.

Block Diagram of the system:



The spring provides the force to close the door, and the damper will slow the closing down enough to avoid slamming it.



Mathematical Model:

$m\, d^2x/dt^2 + c\, dx/dt + kx = 0$

F = m*a=m d^2x/dt^2 where x is the displacement.

c is the damping coefficient and k is the spring constant.

At t=0 x = x (0) open condition

And dx/dt = 0 as we are gently leaving.

We can take x = e^{mt}

dx/dt = m e^{mt} and $d^2x/dt^2 =$ m² e^{mt}

$$m1\,, m2 = \frac{-c \pm \sqrt{c^2 - 4mk}}{2m}$$

And we can get

X = A e^{m1t} + B e^{m2t}

Equation $m\, d^2x/dt^2 + c\, dx/dt + kx = 0$ can be used to make a state space model and it can be simulated through Matlab.

Case 1: m=2 kg, C=500 Ns/m, K=1000 kg/s^2

d^2x/dt^2 = -250dx/dt-500x

at time t = 0, displacement is x0=-20

Velocity is xdot = 0

State Space Model:

```
t=0:.1:10;

u =zeros(1,length(t));

a=[0 1;-500 -250]
```

```
a =     0     1

  -500  -250

 b=[0; 0];

 c=[1 0];

 d=[0]


sys_a=ss(a,b,c,d);
```

For velocity:

```
 c=[0 1];

 sys_b= ss(a,b,c,d);

lsim(sys_a,sys_b,u,t,[-20  0]);
```

Velocity in green displacement in blue

Case 2: m=2 kg, C=400 Ns/m, K=1000 kg/s^2

$d^2x/dt^2 = -200dx/dt-500x$

At time t = 0, displacement is x0=-20

Velocity is xdot = 0

State Space Model:

```
a=[0 1;-500 -200];

 b=[0; 0];
```

```
c=[1 0];
d=[0];
sys_a=ss(a,b,c,d);
c=[0 1];
sys_b= ss(a,b,c,d);
lsim(sys_a,sys_b,u,t,[-20 0]);
subplot(1,1,1);
lsim(sys_a,sys_b,u,t,[-20 0]);
```

case 3: m=2 kg, C=600 Ns/m, K=1000 kg/s^2

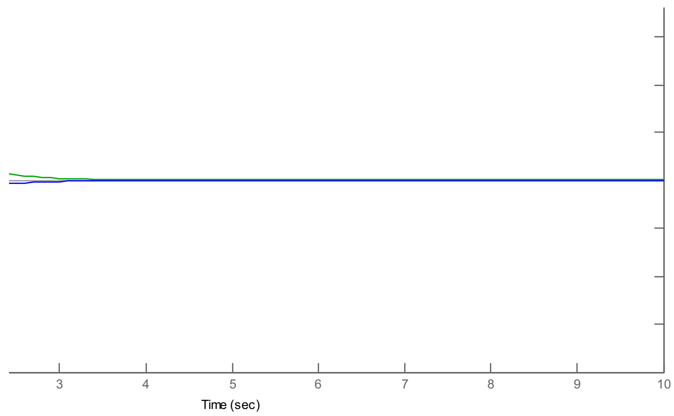
d^2x/dt^2 = -300dx/dt-500x

at time t = 0, displacement is x0=-20

Velocity is xdot = 0

State Space Model:

```
a=[0 1;-500 -300];
b=[0; 0];
c=[1 0];
d=[0];
sys_a=ss(a,b,c,d);
c=[0 1];
sys_b= ss(a,b,c,d);
lsim(sys_a,sys_b,u,t,[-20  0]);
```



Case 4: m=2 kg, C=500 Ns/m, K=1200 kg/s^2

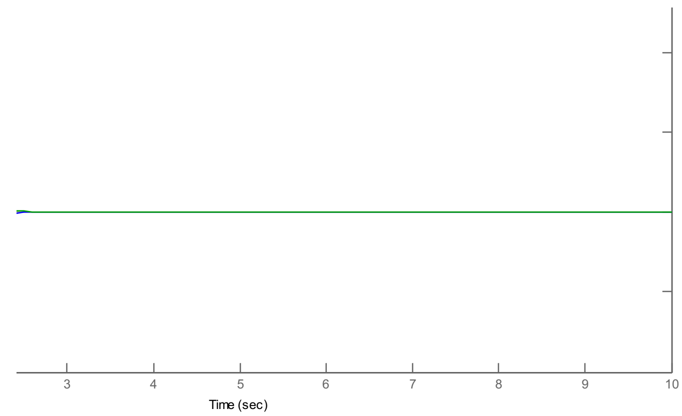
d^2x/dt^2 = -250dx/dt-600x

at time t = 0, displacement is x0=-20

Velocity is xdot = 0

State Space Model:

```
a=[0 1;-600 -250];
 b=[0; 0];
 c=[1 0];
 d=[0];
 sys_a=ss(a,b,c,d);
For Velocity:
 c=[0 1];
 sys_b= ss(a,b,c,d);
 lsim(sys_a,sys_b,u,t,[-20 0]);
```



Case 5: m=2 kg, C=500 Ns/m, K=800 kg/s^2

d^2x/dt^2 = -250dx/dt-400x

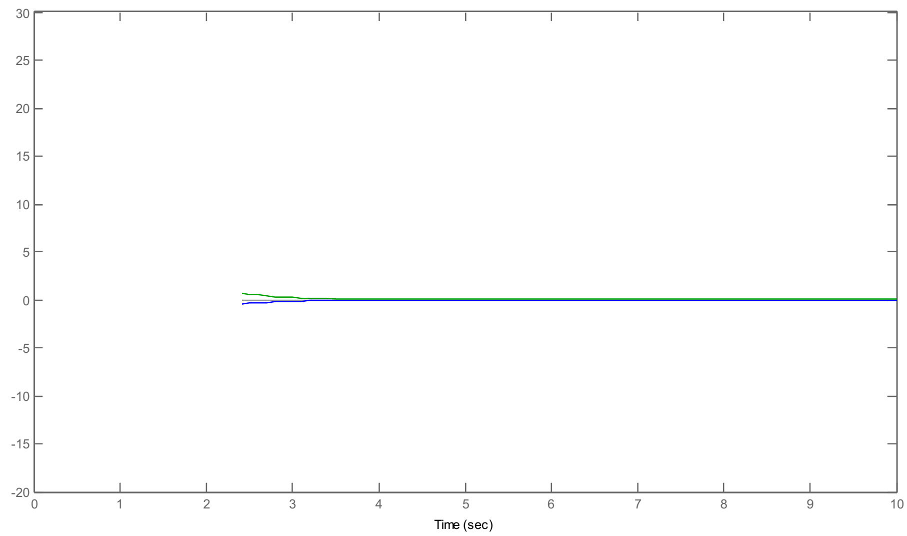
at time t = 0, Displacement is x0=-20

Velocity is xdot = 0

State Space Model:

```
a=[0 1;-400 -250];
 b=[0; 0];
 c=[1 0];
 d=[0];
 sys_a=ss(a,b,c,d);
 c=[0 1];
 sys_b= ss(a,b,c,d);
```

lsim(sys_a,sys_b,u,t,[-20 0]);



Results:

Here graph shows that when we release the door without any force, door comes to rest within certain time period. Initially velocity is zero but then it becomes maximum instantly then gradually it reduces to zero because of damping effect.

Conclusion:

By creating mathematical model of spring mass and damper system of door closer we can conclude that spring coefficient and damping coefficient determine the velocity of door. With different combination of spring and damping coefficient we can create system with over damping, critical damping or under damping.

Example of this type of system is Vehicle suspension like car suspension.