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Analysis on Safety Bumper Placed at the End of Race-Track using MATLAB

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ABSTRACT

A bumper (American English) or shield (British English) is a structure attached to or integrated with the front and rear ends of a motor vehicle, to absorb impact in a minor collision, ideally minimizing repair costs. In racing the bumpers are also used at the end of the race track to stop the out of control vehicles at that instant of time and position with minimum injury. The present work is the analysis on typical safety bumper placed at the end of race-track to stop out of control vehicles. The vehicle of mass 1800kg hits the bumper at a velocity of 90 km/h. Analysis is carried out using MATLAB software. The result shows the curve variation between velocity of car and displacement of bumper. It was found that the velocity of car decreases with increase in displacement of bumper. This analysis helps in preliminary stages of designing the bumpers.

Keywords : bumper, race-track, MATLAB, displacement, velocity

I. INTRODUCTION

Automotive design with economy and safety has been a great challenge. Automotive frontal bumper beam plays an important role in absorbing impact force. Bumper absorbs 15% of total energy in New Car Assessment Programme (NCAP) crash test.

Bumper is a part of an automotive designed that had at a vehicle. Bumper comprised an elongated support which can be attached to the front and rear of the vehicle body and which spans the width of the vehicle body, a shock absorber extending along the support part and extending towards the front and rear of the vehicle body in a substantially convex manner, and an elastic exterior shell which can be connected to the support part and which encompasses the front and rear of the vehicle in an approximate U shape, covering the side of the support part opposite the side facing the front and rear of the vehicle body where in the support part has a middle section that can be firmly supported on the vehicle body.

Bumper is divided in two types, they are front bumper and rear bumper. Main function both of them are for absorbing impact by reducing damage and to the potential for bodily injury during an accident.

For this paper, it is focused on the bumper system which is placed at the end of racing track to stop the vehicles which are out of control. MATLAB is used in analyzing the velocity of vehicle and displacement of bumper after vehicle hits the bumper.

MATLAB is powerful computing software which is presently utilized in a number of educational institutions around the country to solve mathematics and engineering-related problems. The name of the software MATLAB stands for “Matrix Laboratory”

since the built-in capabilities of this package are specifically designed for efficient handling of matrix and array operations. The effective and easy to-use computing environment of MATLAB along with availability of a large number of helpful MATLAB built-in functions has rendered it the popular tool of choice for many educators in various engineering fields. Using the MATLAB interactive environment, programs placed in script files can easily be created and edited to perform the desired computations and to generate the needed output. The capabilities of MATLAB can further be enhanced by additional "toolbox" modules that can separately be purchased through The Math Works, Inc., the company that produces the MATLAB software. These modules are designed to perform a variety of specialized tasks. The solutions presented in this paper are obtained using the basic features of MATLAB without utilizing any specialized MATLAB toolboxes.

II. PROBLEM STATEMENT

A safety bumper placed at the end of a race-track to stop out of control vehicles is as shown in Fig. 1.

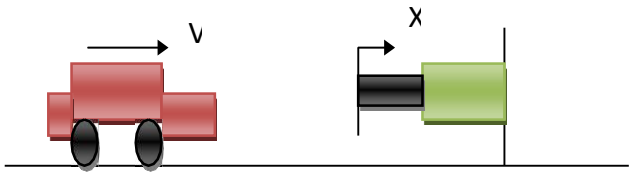

Fig. 1 Safety bumper with displacement' x' and vehicle with velocity 'v'

Let the force that the bumper applies to the vehicle is given by the mathematical relation.

$F = Kv^3(x + 1)^3$

Where, K = 32 kg-s/m5 (a constant)

x = displacement of the front edge of the bumper

v = velocity of the front edge of the bumper

A vehicle of mass 1800 kg hits the bumper at a speed of 90 km/h. writing a MATLAB program to determine and plot the velocity of the vehicle as a function of x for $0 \leqslant x \leqslant 4$m.

III. ANALYTICAL FORMULATION

The formulation for the problem statement as mentioned previously is as below.

The deceleration of the car once it hits the bumper can be calculated from Newton's second law of motion.

$$ma = -Kv^3(x + 1)^3$$

which can be solved for the acceleration a as a function of v and x:

$$a = \frac{-K v^3(x+1)^3}{m}$$

The velocity as a function of x can be calculated by substituting the acceleration in the equation:

which gives:

$$vdv = adx$$

$$\frac{dv}{dx} = \frac{-K v^3(x+1)^3}{m}$$

The last equation is a first order ODE that needs to be solved for the interval $0 \leqslant x \leqslant 4$ with the initial condition:

v = 90 km/h at x = 0.

IV. MATLAB SOLUTION

Numerical solution of differential equation is shown in the following program written in a script file (m-file), which should be executed by typing the file name in command prompt in MATLAB.

4.1 MATLAB Program:

```
global k m
k=32; m=1800; v0=90;
xspan=[0:0.2:4]; v0mps=v0*1000/3600;
[x v]=ode45(@bumper,xspan,v0mps) plot(x,v)
xlabel('x (m)'); ylabel('velocity (m/s)')
```

The function file with the differential equation named bumper.m to be saved: function dvdx=bumper(x,v)

global k m dvdx=–(k*v^2*(x+1)^3)/m;

4.2 MATLAB Result:

Output obtained from the MATLAB is as shown in Table 1, where x is displacement and v is the velocity at front end of the bumper, also typical variation in the curve x vs. v is as shown in Fig. 2. It can be observed the there is decrease in velocity with increase in displacement. Displacement is varied between 0m to 4m with the increment of 0.2m.

Table 1. Ouput x vs. v

x =	v =
0	25.0000
0.2000	22.3356
0.4000	19.0022
0.6000	15.4599
0.8000	12.1627
1.0000	9.3757
1.2000	7.1575
1.4000	5.4705
1.6000	4.1922
1.8000	3.2462
2.0000	2.5317
2.2000	1.9985
2.4000	1.5913
2.6000	1.2814
2.8000	1.0409
3.0000	0.8537
3.2000	0.7059
3.4000	0.5885
3.6000	0.4942
3.8000	0.4180
4.0000	0.3558

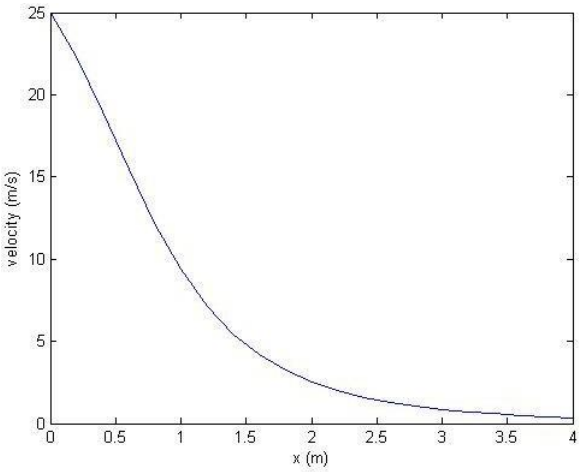

Fig 2. Plot displacement (x) vs. velocity(v)

V. CONCLUSION

The present work is the analysis on typical safety bumper placed at the end of race-track to stop out of control vehicles. The vehicle of mass 1800kg hits the bumper at a velocity of 90 km/h. Analysis is carried out using MATLAB software. The result shows the curve variation between velocity of car and displacement of bumper.

The following conclusions drawn from the analysis are:

1. MATLAB is a simple, powerful and faster computation platform for solving higher order differential equations and plotting 2D and 3D graphics result.
2. Various built-in functions, added features and capabilities in post-processing are available in MATLAB, which makes easy to write program and understand the obtained results.
3. Paper becomes a ready reckoner for engineers in understanding bumper displacements when vehicles hit the bumper.
4. The solution obtained for the analysis which shows MATLAB can give accurate result for higher order complex differential equations and can eliminate theoretical approaches.
5. Result shows that the velocity of vehicle decreases with increase in displacement of bumper.
6. The decisions related to the design of bumpers can be made faster.

The work is no more exhaustive, further analysis with varied displacement and velocity can be brought and highlighted in future scope of paper work.

VI. REFERENCES

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