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Conceptual Design of a Roller Obstacle Deflector

Tharun Raj, M. Prasad

Abstract*: An Obstacle Deflector is a device mounted in front of the trains to sweep away the obstacle off the track or absorb impact energy to prevent derailment. On considering the same concept which sweeps the obstacle, I have designed a device that sweeps away living obstacles (animals, Humans) from the tracks with life expectancy. Many animals are killed over the tracks in regular train accidents. Based on this issue, here my project discusses with the conceptual design of a roller obstacles deflector that absorbs the impact energy on collision and sideways the obstacle using roller based polyethylene rollers applied in front of the train. The cushioning effect designed for the device helps to reduce the impact force when Train hits the living obstacles (Human, cow and elephant) at speed of 30km/hr. or 8111 mm/s., With a load of 50 Tonne. As per study, human pain can be measured in Del (Dolorimeter) which explains that the maximum limit of pain average human being can withstand is 45 Del. But, breaking of a bone is almost equals to 57 Del. Some studies say Del is equal to 1403.508 N forces. By this data and using the reaction forces resulted at the time of clash in Ansys software simulation, we can state the amt. of pain (in terms of DEL) to some living organisms and can conclude the functionality of the device to save the life. This design works for the limited animal category based upon size and weight of the animal. This design works under the limited speed and with limited load to safeguard the animals and humans on the track. This design does not impact on the existing safety conditions of the railways as it's absorb the impact up to limited extend. The modeling is done using CATIA. The explicit dynamics of impact is done with ANSYS

Keywords: ANSYS, CATIA, Impact, Obstacle Deflector.

I. INTRODUCTION

Following a fatal low speed collision between a train and the animals as well human's studies were carried out over the collisions and concluded that there is a chance of safeguarding the animals & humans under limited speed conditions. Here my project discusses with the conceptual design of a roller obstacles deflector that absorbs the impact energy on collision and sideways the obstacle using rollers under limited speed. The rollers absorb the shock and they are designed in a way to provide cushioning effect on the animal.

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This design works for the limited animal category based upon size and weight of the animal. This design works under the limited speed with limited load that has to be followed in the forest zone area to safeguard the animals. This design does not impact on the existing safety conditions of the train.

An Obstacle deflector is a device mounted in front of the train to sweep away the obstacles as well as to absorb the impact energy using impact absorbers to prevent the train from derailment under collisions. Mostly the obstacles are animals and Metal bars. Earlier they used an equipment called "Cow Catchers" for the cows to prevent going under wheel of the train at the time of collision and derailing it. Later on they came up with the equipment called obstacle deflector which sweeps away the object by absorbing the impact energy.

This device reduces the impact force by the cushioning system provided to it. The angled frame diverts the obstacle sideways and maintains a clear path to the rail. This helps the train to run safe without derailment. These deflectors sweep away the obstacles sideways and maintains a clear path and avoids derailment.

II. METHODOLOGY

3D Design of Obstacle Deflector is done in CATIA software with appropriate dimensions & material composition. The dimensions are considered based upon the Indian railway body features. The material used for rollers are Plastic and for frame is of structural steel. The dynamic impact and reaction forces are solved in ANSYS. The methodology for carrying out the research work involves several steps which is illustrated clearly in the below flowchart. Objective is to design a roller obstacle deflector that sweeps away the living obstacles such as Animals or humans on the tracks with chance of life expectancy.

To analyze and to compare the reaction forces in pain and conclude the functionality of the device.

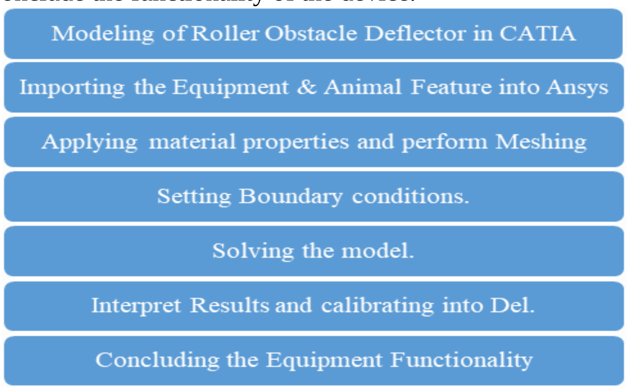

Fig 01. Methodology

A. Dolorimeter

A Dolorimeter is an instrument used to measure pain threshold and pain tolerance. Dolorimetry has been defined as "the measurement of pain sensitivity or pain intensity". Dolorimeters apply steady pressure, heat, or electrical stimulation to some area, or move a joint or other body part and determine what level of heat or pressure or electric current or amount of movement produces a sensation of pain. Sometimes the pressure is applied using a blunt object, or by locally increasing the air pressure on some area of the body, and sometimes by pressing a sharp instrument against the body. The pain can be measured in units called "Del". According to them 45 del is the limit of pain a human can endure and yet, they go on to say that child birth is associated with 57 del of pain (apparently it is equivalent to 20 bones getting fractured at a time) and getting kicked in the nuts is 9000 del of pain.

From the above paragraph, at the birth of the child 57del is equal to 20 bones of fraction or break.

Approximate considerations are taken to calculate the pain.

57del= 20*(force applied to breaking of bone)

57del= 20x – (Equation 1)

B. Force to Break a Bone:

One cubic inch of bone can withstand the weight of five standard pickup trucks, give or take a few pounds. If you're looking for the specifics to snap a piece of your skeleton, it takes about 4,000 Newton's of force to break the typical human femur.

Means,

1 bone cracking = 4000 Newton's - (Equation 2)

X = 4000N

From above equation 1 and equation 2

57 Del = 20 x

X = 4000N

57 Del = 20 * 4000

1 Del = 20 * 4000 / 57 N

1 Del = 1,403.508771929825N (Approx..)

C. Design of Roller Obstacle Deflector

The Roller Obstacle Deflector is an assembly of major components listed below:

1. Rollers

Rollers are the Plastic components made up of polyethylene, sizing Ø200 X 1000mm.The center roller vary in diameter Ø260 as based upon its heavy function.

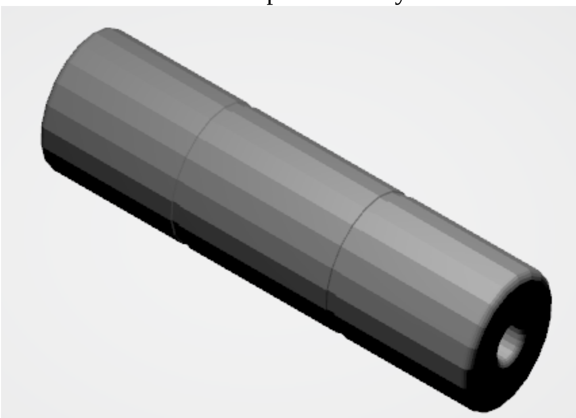

Fig 02. Roller

2. Right wing frame

The Wings are the frames where the rollers assembled using the shaft. The Rollers are placed over the shaft and the shafts are welded to the wings. These wings are assembled to the main frame. Their main function is to absorb the impact by pushing back when hits by an obstacle. The transfer of energy from the Wing is absorbed by the Impact Absorbers. The Left and Right wings are symmetrical to each other.

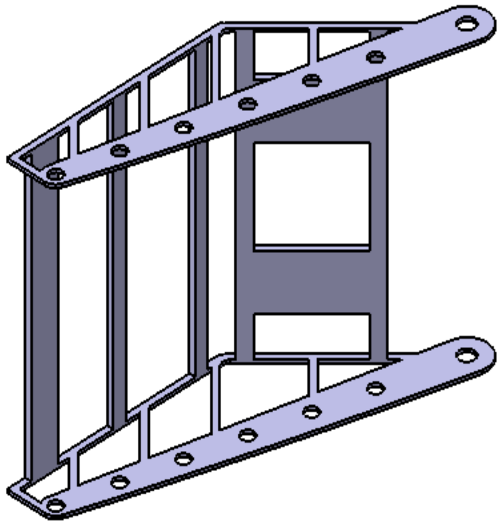

Fig 03. Right Wing frame (Isometric View)

3. Main Frame

The Main Frame is the Structural plate (1134 X 2860 X 20 thk) attached to the body of the train. The frame holds both the wings that support rollers.

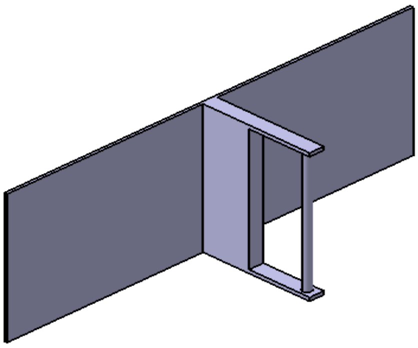

Fig 04. Main Frame

4. Impact Absorbers

Observer the impact from the wing, when the obstacles hit the device the Impact Absorbers (springs) absorb the impact. The Stiffness behavior of the springs is 2800 N/mm.

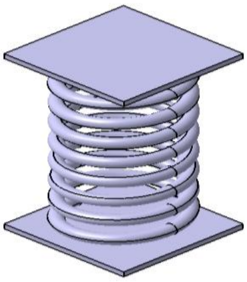

Fig 05. Impact Absorber

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A.Assembly of Roller Obstacle Deflector:

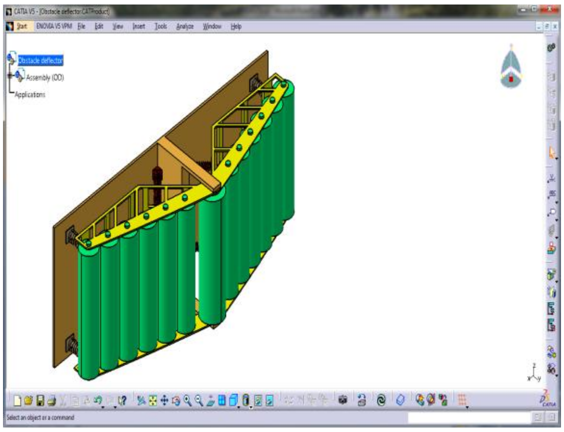


Fig.06. Assembly (3D Isometric View)

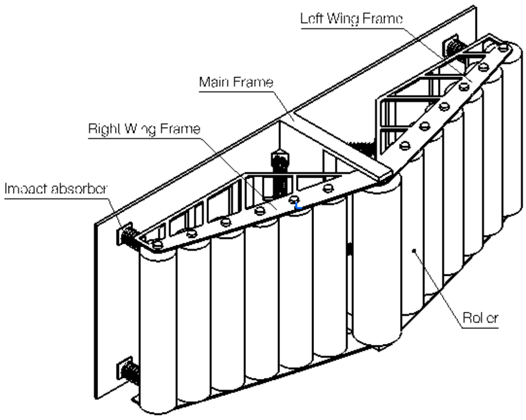


Fig.07. Assembly (2D Isometric View)

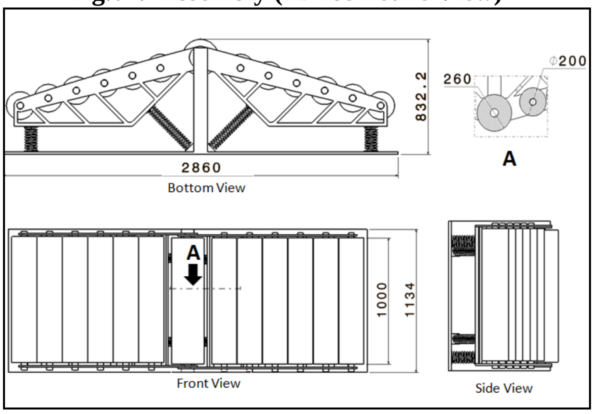


Fig.08. Drawing (Units in mm)

III. MESHING

After the model is created in the Design Modeler window, you need to generate the mesh for the model. Select Mesh in the Tree Outline to display the Details of the "Mesh" window.

Choose the Generate Mesh tool from the Mesh drop-down in the Mesh contextual toolbar; the mesh will be generated.

After the mesh is generated, you need to set the boundary and loading conditions under which the analysis will be performed.

After the boundary and loading conditions are specified for the analysis, you need to evaluate the results that are of importance in the case of a particular analysis.

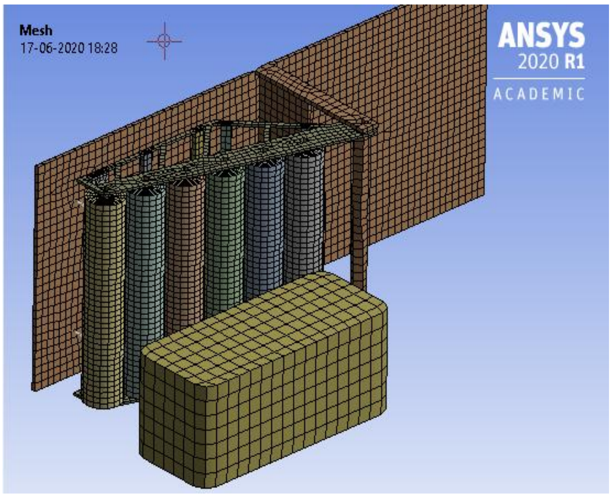


Fig 09. Mesh Generated with Default Mesh Controls

IV. EXPERIMENTAL INVESTIGATIONS

A. Materials

A. Young's modulus

Young's modulus is named after the 19th-century British scientist Thomas Young; but the concept was developed in 1727 by Leonhard Euler, and the first experiments that used the concept of Young's modulus in its current form were performed

Tissue	Young's modulus E kPa	Reference
Human skin	20-100	10
	420-850	11
	200-300	12
Polyurethane (skin simulant)	182 (yield strength: 2.583 MPa)	6
Breast (fibroglandular)	1.8	13
Muscle	$0.675 \cdot 10^6$	14
Soap	$21.45 \cdot 10^3$ (yield strength: 1.63 MPa)	15
Gelatine 20%	96 (0.001 s^{-1} strain rate) 124 (0.01-1 s^{-1} strain rate)	16

Fig 4.1 Young's Modulus Chart

Note: Consider the young modulus of skin = 2.583 MPA

B. B. Stainless Steel (SS):

SS is one of the materials in an iron-based alloy that contains a mini. Of 11% of Chromium. A composite that prevents rusting and provides heat resistance. There are different types of stainless strains that have a percentage of the carbon (0.03 to 1.00 %), nitrogen, silicon, Sulphur, titanium, nickel, copper, and molybdenum.

Density	7750 kg m^-3
Compressive Yield Strength MPa	207
Tensile Yield Strength MPa	207
Tensile Ultimate Strength MPa	586
Young's Modulus MPa	1.93e+005
Poisson's ratio	0.31

Table 01. Material Stainless Steel (SS)

C. Weight of Cow in India:

On average, a dairy cow weighs anywhere from 1,000 (453 kg) to 1,800 pounds (816 kg). It depends on the breed, age, feeding and a few other factors. Jersey cows come in at the lightest weight, while Brown Swiss cows can tip the scale at over 1,800 pounds. The average Dairy Cow has an overall height of 62.0"-69.0" (1.6-1.8 m), withers height of 54.0"-60.0" (0.37-0.85 m), and body length of 92.0"-103.0" (2.3-2.6 m). A typical Dairy Cow weighs between 1,400-2,000 lb. (635-907 kg) and has a lifespan of roughly 4-5 years (farm); 20 (natural).

Consider:

Weight (mass) of cow = 816 kg
Length = 2.6 m
Width = 0.85 m
Height = 1.8 m
Density of cow (approx.) = mass/volume
= 816 /3.978 kg/m^3
= 205. 12 kg/m^3

Density	205. 12 kg m^-3
Compressive Yield Strength MPa	50
Tensile Yield Strength MPa	50
Tensile Ultimate Strength MPa	100
Young's Modulus MPa	2.583
Poisson's ratio	0.42

Table 02. Cow Material

D. Weight of Elephant in India:

On average, the African bush elephant tips the scales at around 14,000 pounds (6,350 kg), which is 7 tons. That's almost the weight of 3 large SUVs! Asian elephants are slightly smaller than their African counterparts. But they still weigh between 5,000 to 11,000 pounds (2,267 to 4,989 kg), in most cases. Asian Elephants are not as large as their African cousins but can weigh around 5,400 kg and stand over 3.4 m or 11 ft. tall Indian elephant – 10,000 pounds (4,535 kg)

Consider:

Weight (mass) of elephant = 4535 kg
Length = 3.4 m
Width = 4 ft. = 1.2192 m
Height = 11 ft. = 3.3528 m
Density of Elephant (approx.) = mass/volume
= 4535 / 13.898294784 kg/m^3
= 326.2990 kg/m^3

Density	326.2990kgm^-3
Compressive Yield Strength MPa	50
Tensile Yield Strength MPa	50
Tensile Ultimate Strength MPa	100
Young's Modulus MPa	2.583
Poisson's ratio	0.3

Table 03. Elephant Material

E.E. Weight of Human in India:

Consider:

Weight (mass) of Human = 80 kg
Length = 1.5 ft = 0.4572 m
Width = 1 ft = 1.2192 m
Height = 6 ft = 1.8288 m
Density of Human (approx.) = mass/volume
= 80 / 1.019406477312 kg/m^3
= 78.47703 kg/m^3

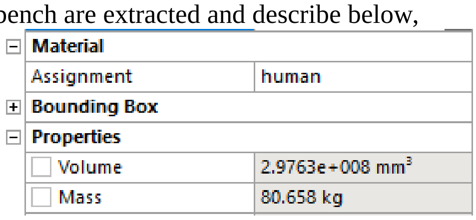
Density	78.47703kgm^-3
Compressive Yield Strength MPa	50
Tensile Yield Strength MPa	50
Tensile Ultimate Strength MPa	100
Young's Modulus MPa	2.583
Poisson's ratio	0.3

Table 04. Human Material

V. ANALYSIS

A. For Human:

After the simulation is complete all the data from ansys workbench are extracted and describe below,



Material	
Assignment	human
Bounding Box	
Properties	
Volume	2.9763e+008 mm³
Mass	80.658 kg

Fig. 5.1. Weight of the human being

The above image describes the weight of the human body in ansys workbench. The simulation of impact of train to human is done and examine. The initial condition of the train is 30 km/hr. or 8111 mm/s as a velocity and where human is standing position. After the simulation stress, strain and deformation are carried out. But due to the impact over human being, reaction force is extracted to see the how much the pain is developing over body of human being.

1. Total Deformation Unit in Mm:

The colors indicated deformation of the modal, the deformation value arranges in a change of color from red to blue. The red indicates maximum deformation and blue indicate a minimum deformation magnitude value as shown below.

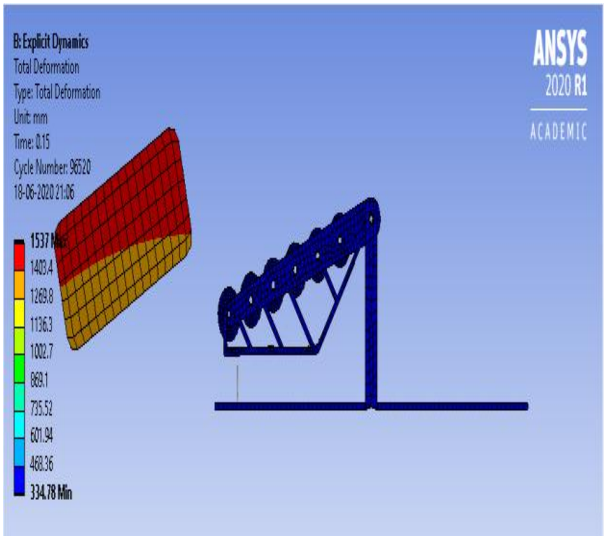


Fig. 5.2 Total deformation of the human being (Top view)

From the above figure, the human is pushed sideward after the impact from train due to the due to the angular design of the Frame. The human is pushed at distance of 1537 mm (1.573m) in 0.15 sec from analysis setting or time interval.

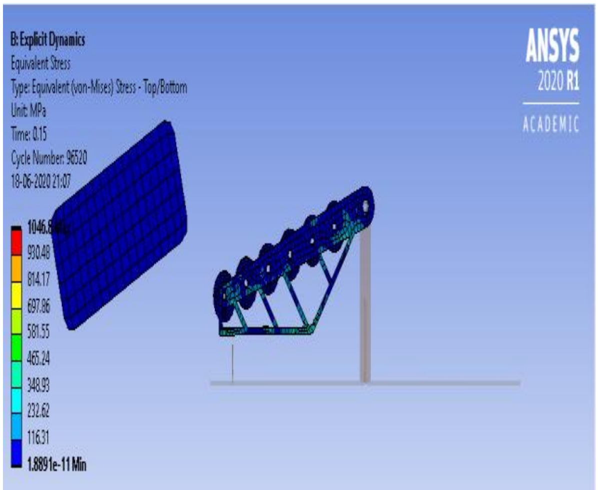


Fig 12. Stress of the Human (Top view)

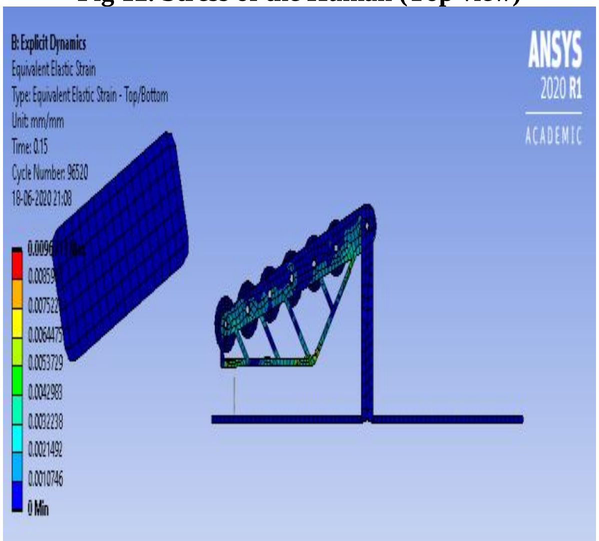
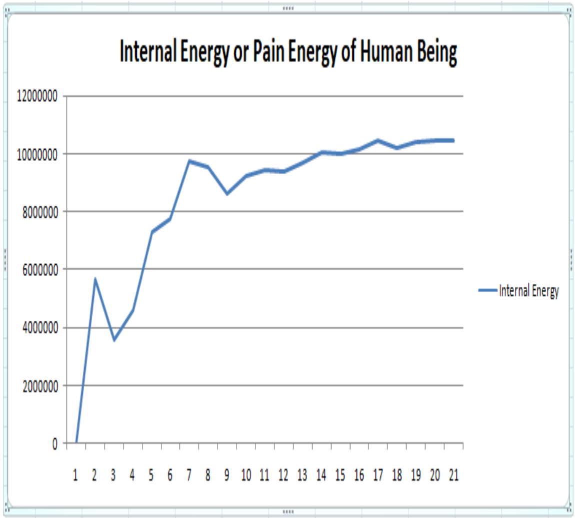


Fig 13. Strain on the Human (Top View)

Table 5.1. Table of stress strain deformation and reaction forces over the human.

		Mm	Mpa	Mm/Mm	Mj	N
		Deformation	Stress	Strain	Internal Energy	Impact Force
1	1.18E-38	0	0	0	0	0
2	7.50E-03	70.865	1046	2.62E-02	5.67E+06	34286
3	1.50E-02	98.572	642.5	1.75E-02	3.60E+06	55043
4	2.25E-02	178.92	828.9	1.57E-02	4.61E+06	10518
5	3.00E-02	196.25	1327	2.28E-02	7.29E+06	47698
6	3.75E-02	202.8	1114	3.24E-02	7.76E+06	68136
7	4.50E-02	262.4	1231	2.11E-02	9.75E+06	31854
8	5.25E-02	308.99	959.1	2.18E-02	9.55E+06	54364
9	6.00E-02	386.24	949.8	1.69E-02	8.64E+06	36170
10	6.75E-02	480.17	1189	1.42E-02	9.24E+06	23906
11	7.50E-02	573.92	809.2	1.78E-02	9.44E+06	13893
12	8.25E-02	668.53	819.9	1.44E-02	9.40E+06	21382
13	9.00E-02	764.23	800.3	2.22E-02	9.71E+06	8923
14	9.75E-02	860.31	990	1.34E-02	1.01E+07	53228
15	0.105	956.51	855.3	1.10E-02	1.00E+07	2258.2
16	0.1125	1053	752.7	1.33E-02	1.02E+07	1082.3
17	0.12	1149.6	889.6	9.83E-03	1.05E+07	3509.5
18	0.1275	1246.4	706.6	1.53E-02	1.02E+07	274.95
19	0.135	1343.2	759.3	1.14E-02	1.04E+07	7558.1
20	0.1425	1440.1	1045	1.05E-02	1.05E+07	749.29
21	0.15	1537	1047	9.67E-03	1.04E+07	67986



Graph 5.1 Internal Energy

Form the above table the impact force can be calculated in terms of reaction force of the

1 del = 1403.508 N

At the time of impact, the human had an experience of 68136 to 274.95 impact force.

X del = 68136 N

By cross equation, X = 68136/1403.508

= 48.54 dels

This concludes, the human experiences less impact force or del (average max del capacity of human being is 57 del (breaking of 20 bones)

B. For Elephant:

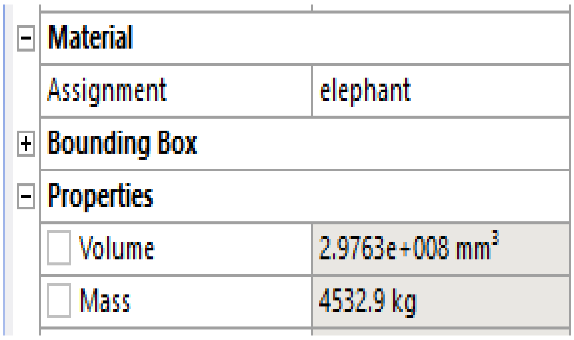


Fig 5.10. Weight of the Elephant

The above image describes the weight of the elephant body in ansys workbench. The simulation of impact of train to elephant is done and examine. The initial condition of the train is 30 km/hr or 8111 mm/s as a velocity and where elephant is standing position. After the simulation stress, strain and deformation are carried out. But due to the impact over elephant being, reaction force is extracted to see the how much the pain is developing over body of elephant.

1. Total Deformation Unit in Mm

The colors indicated deformation of the modal, the deformation value arranges in a change of color from red to blue. The red indicates maximum deformation and blue indicate a minimum deformation magnitude value as shown below.

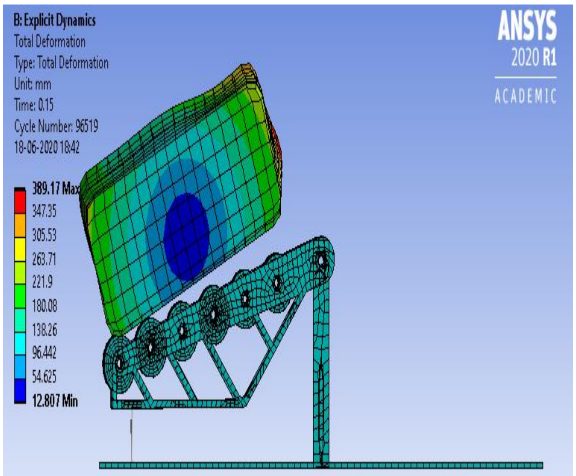


Fig 5.11. Total deformation of the Elephant (Top view)

From the above figure, the elephant is pushed sideward after the impact from train due to the angular design of the Frame. The elephant is pushed at distance of 389.17 mm (0.3 m away) in 0.15 sec from analysis setting or time interval.

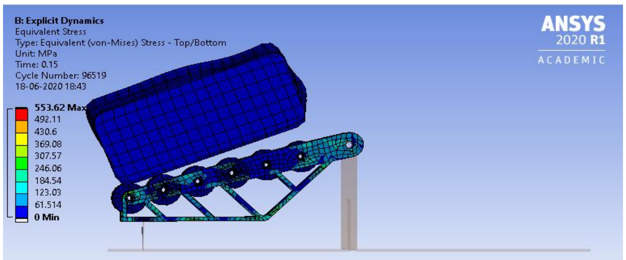


Fig 15. Stress on Elephant (Top view)

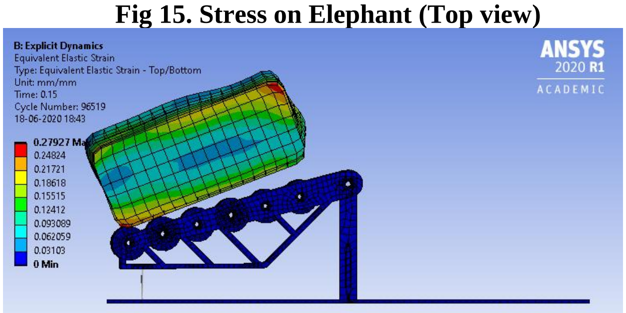
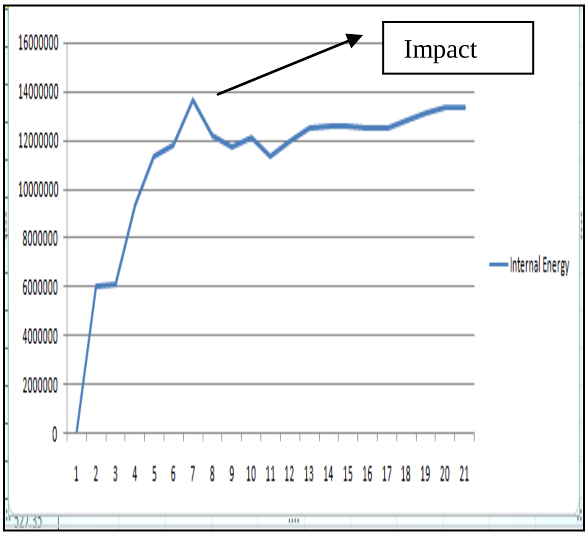


Fig 16. Strain of the Elephant (Top view)

		Mm	Mpa	Mm/Mm	mJ	N
		Deformation	Stress	Strain	Internal Energy	Impact Force
1	1.18E-38	0	0	0	0	0
2	7.50E-03	70.685	1047	0.29586	5.98E+06	29685
3	1.50E-02	85.885	762.1	0.51287	6.12E+06	34695.00
4	2.25E-02	125.77	852.5	0.78287	9.32E+06	26661.00
5	3.00E-02	142.52	671	0.86458	1.13E+07	18144
6	3.75E-02	148.6	824.3	0.92791	1.18E+07	6414.4
7	4.50E-02	176.24	801.3	0.85457	1.37E+07	64829
8	5.25E-02	171.28	774.7	0.73516	1.22E+07	91039
9	6.00E-02	175.18	710.8	0.59904	1.17E+07	66119
10	6.75E-02	180.32	745.5	0.52791	1.21E+07	31757
11	7.50E-02	169.13	450.7	0.43912	1.13E+07	52409
12	8.25E-02	191.71	661.2	0.35542	1.20E+07	71342
13	9.00E-02	212.19	657.4	0.28867	1.25E+07	84754
14	9.75E-02	235.36	718.6	0.20738	1.26E+07	13870
15	0.105	262.49	666.5	0.20295	1.26E+07	16835
16	0.1125	285.19	671.5	0.19066	1.25E+07	38570
17	0.12	298.05	645.1	0.20313	1.25E+07	1227.7
18	0.1275	312.96	526.7	0.22274	1.28E+07	527.35
19	0.135	344.8	483.4	0.2418	1.31E+07	3383.4
20	0.1425	372.64	608.3	0.26274	1.34E+07	296.68
21	0.15	389.17	553.6	0.27927	1.33E+07	11300

Table 5.2 Table of stress, strain, deformation and reaction forces over the Elephant



Graph 5.2 Internal Energy of Elephant

Form the above table the impact force can be calculated in terms of reaction force

1 del = 1403.508 N

At the time of impact, the elephant had an experience of 34695 to 26661 impact force.

X del = 34695 N

By cross equation = 34695/1403.508

= 24.7 dels

This concludes, the elephant experiences less impact force or del (average max del capacity of human being is 57 del (breaking of 20 bones).

C. For Cows:

⊟	Material	
	Assignment	cow
⊞	Bounding Box	
⊟	Properties	
	Volume	2.9763e+008 mm^3
	Mass	815.5 kg

Fig 5.20. Weight of the cow

The above image describes the weight of the cow body in ansys workbench. The simulation of impact of train to human is done and examine.

The initial condition of the train is 30 km/hr. or 8111 mm/s as a velocity and where cow is standing position. After the simulation stress, strain and deformation are carried out.

But due to the impact over cow reaction force is extracted to see the how much the pain is developing over body of cow.

1. Total deformation unit in mm:

The colors indicated deformation of the modal, the deformation value arranges in a change of color from red to blue.

The red indicates maximum deformation and blue indicate a minimum deformation magnitude value as shown below.

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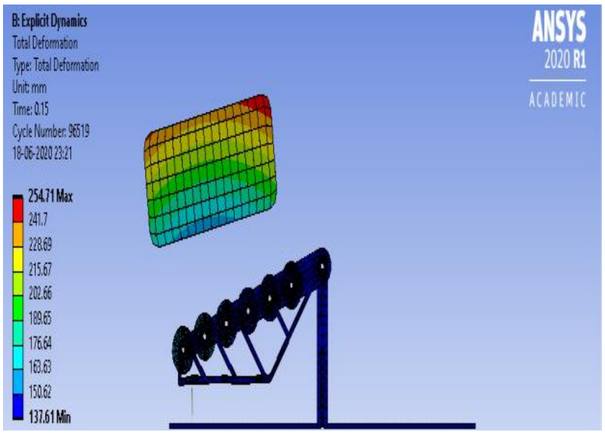


Fig 5.21. Total Deformation of the Cow

From the above figure, the cow is pushed sideward after the impact from train due to the angular design of the Frame. The cow is pushed at distance of 254 mm in 0.15 sec from analysis setting or time interval.

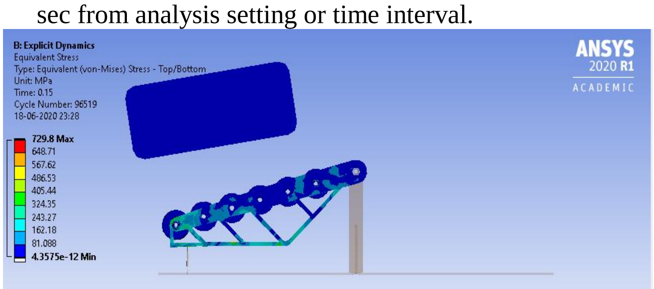


Fig 19. Stress of The Cow

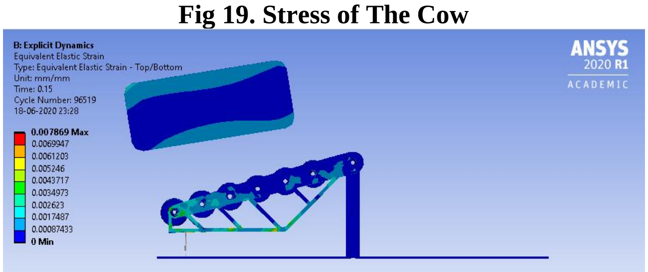
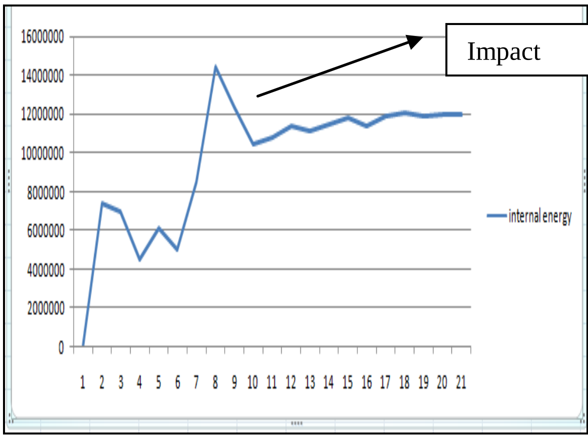


Fig 20. Strain of the Cow

		Mm	Mpa	Mm/Mm	mJ	N
		Deformation	Stress	Strain	Internal Energy	Impact Force
1	1.18E-38	0	0	0	0	0
2	7.50E-03	70.448	1015	8.24E-02	7.36E+06	43694
3	1.50E-02	81.083	922.5	5.54E-02	6.96E+06	12016
4	2.25E-02	96.505	693.9	2.82E-02	4.51E+06	39022
5	3.00E-02	155.9	1001	1.40E-02	6.11E+06	48652
6	3.75E-02	221.22	651.1	2.46E-02	5.05E+06	2381
7	4.50E-02	283.94	1003	6.19E-02	8.51E+06	12963
8	5.25E-02	322.65	2134	2.21E-02	1.45E+07	27351
9	6.00E-02	333.14	1725	1.99E-02	1.23E+07	33635
10	6.75E-02	326.79	1073	1.45E-02	1.05E+07	14000
11	7.50E-02	318.46	1121	1.15E-02	1.08E+07	5541
12	8.25E-02	310.95	1034	1.04E-02	1.14E+07	18140
13	9.00E-02	301.27	843.6	1.36E-02	1.12E+07	2187
14	9.75E-02	293.43	745	1.93E-02	1.15E+07	13207
15	0.105	286.85	1005	1.00E-02	1.18E+07	14259
16	0.1125	278.84	833	8.96E-03	1.14E+07	12977
17	0.12	272.58	646.3	8.28E-03	1.19E+07	52807
18	0.1275	267.85	877.2	1.99E-02	1.21E+07	24314
19	0.135	261.81	764	7.69E-03	1.19E+07	1256
20	0.1425	257.63	686.3	1.53E-02	1.20E+07	2064
21	0.15	254.71	729.8	7.87E-03	1.20E+07	1327

Table 3.3 Table of stress strain deformation and reaction forces over the Cow



Graph 5.1 Internal Energy of Cow

Form the above table the impact force can be calculated in terms of reaction force of the cow:

1 del = 1403.508 N

At the time of impact, the cow had an experience of 39022 to 48652 impact force.

X del = 48652 N

By cross equation, X = 48652 /1403.508

= 34.66 dels

This concludes, the cow experiences less impact force or del (average max del capacity of human being is 57 del (breaking of 20 bones).

VI. SUMMARY& RESULTS

Now days, Safety plays a major role in any Industry. The safety is the most worth feature in the phase of transportation. Majority of the Vehicle manufacturers considers customer safety. No one cares about the pedestrian and the other living features. Hence my idea gives a growth on the topic of animal safety as well as pedestrians. The design of Roller Obstacle Deflector changes the Phase of safety devices. The results confirm that the design works in delivering its functions in saving the life of the living obstacles.

The equations that describe the Pain in Newton's are considered by the studies on the respective subjects. The compared pain values between animal and human given a natural Phenomenon of absorbing pain in their respective body size and shape. Hence we can conclude by the Phenomenon that the functionality of the equipment meets the required results.

VII.CONCLUSION

In every year, the Railways witnessed 31 animal deaths per day. Last year, the number of animal deaths stood at 12,625. The number has been continuously increasing ever year. So far, train accidents killed 3,479 cows in 2019.

In order to prevent such incident and accident, I here create a logical solution that can minimize the cause of the death and lost. In this thesis, I create a roller based device installed in front of the train as shown in figure. This equipment helps to absorb the impact when railways hit human, cow and elephant at speed of 30km/hr. or 8111 mm/s.

From the chapter above, as per study of human being pain can be measures in DEL (dolorimeter) which explain that the maximum limit of pain of average human being can withstand is 45 Del. But at position of breaking a bone is almost 57 del. By using related data, we conclude 1 Del is equal to 1403.508 N force approximately and by using the reaction force results obtained by simulation in ansys software, we can compare the amount of pain (in terms of DEL) to some living organism. and able to conclude the life expectance when they met an accident.

In first scenario, the train with equipment collides to human being leads to a forces of 68136 N (at time of impact) is equal to 48.54 Del. At that force or Del the impact of train causes a minor fracture of bone (48.54 < 57 Del).

In second scenario, the train with equipment collides to elephant being leads to a force of 34695 N (at time of impact) is equal to 24.7 Del. At that force or Del the impact of train causes a minor fracture of bone (24.7 < 57 Del) due to higher strength and weight when it compared to human

In third scenario, the train with equipment collides to cow being leads to a forces of 48652 N (at time of impact) is equal to 34.66 Del. At that force or Del the impact of train causes a minor fracture of bone (34.66 < 57 Del) due to higher strength and weight when it compared to human.

For above scenario, my analytical and logical experiment can be useful to reduce the accidental deaths on railway tracks, and this can be improvised by further studies.

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