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Crashworthiness of a railway vehicle to reduce overriding effect by using Abaqus Software

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ABSTRAC: *While trains are convenient for travel and for transporting goods, they have become a greater danger over the years as their speed has been increased. Override of one vehicle over the another vehicles has long been recognized as one of the most dangerous potential consequences of a collision. There have been several accidents in which majorly affect the crew and passengers fatalities.*

In order to prevent this effect, protection in the form of an anti-climbing structure is provided in most cases, with plates provided With a tooth structure typically being mounted on to each vehicle. In the event of a collision plates in the crash module interlock and prevent the override.

An attempt is made in this paper is Designing of crash module with tooth act as a Anti-climber to evaluate the resistance of the crash module when two objects strikes each other at high relative speeds through crash analysis. The material of the module made up of Aluminum Aw5754.

Then the analysis is carried-out using by using abaqus software. The results are drawn contours of equivalent plastic strain of the crash module when it is moving with 40, 60 ,80 ,100 & 102km/hr by taking to two cases. I) When one of train is fixed at one end. II) when two trains are moving with same speed.

It has proved that Anti-climb teeth prevented either train unit from moving over the other up to the speeds of 100km/hr, the module body underwent controlled deformation to absorb avg of 1.16 mega joules, Aluminum buckling decelerated the train unit is below 7.5g so it can resist overriding effect with the offset distance of up to 40 mm. By comparing the contours of PEEQ at various speeds we can say that up to 102km/hr the deceleration limit is below 7.5g whereas after that it is exceeding the range value we can clearly say that The crash module can reduce overriding effect by absorbing energy up to the speed of 100km/hr so that crash zone will not get damage it act as a anti-climber during collisions.

KEYWORDS— *anti-climb, overriding, contact pair method, kinetic energy, impact test, deceleration.*

I. INTRODUCTION

Crash Zones are frequently incorporated in rail vehicles in order to improve their deformation behavior in collisions. The aim of these improvement is to absorb the impact energy in such a way that crush zones that are deformable in a defined manner convert this energy into deformation energy and in the process the loads to which the persons in the vehicle are exposed are minimized, as well as to ensure that the survival spaces in the vehicle are not too severely deformed in order to reduce the likelihood of injury to the vehicle occupants.

Collisions between rail vehicles take place essentially in the direction of the vehicle longitudinal axis, while a difference in level, due for example to different loading states of the vehicles involved in the collision, may under certain conditions lead to What is termed “override”. In order to prevent this effect, protection in the form of an anti-override structure is provided in most cases, with plates provided with a tooth structure typically being mounted onto each vehicle. In the event of a collision said plates interlock and prevent the override.

Crashworthiness:

When crashworthiness has to be achieved for a railway vehicle, the dominant design goals are to reduce the risk of overriding, to absorb the energy in a controlled manner and to maintain the survival space and the structural integrity of the occupied areas.

The following collision scenarios are to be considered in this paper.

1.By keeping one module is rigid and another module is moving with different velocities i.e. 40,60,80,100,102 km/hr with vertical offset of 40mm

2. A front end impact between two identical train units moving with same speed i.e 40km/hr, 60km/hr,80km/hr,84km/hr,

The following measures shall be employed to provide protection of occupants in the event of a collision:

- Reduce the risk of overriding;
- Absorb collision energy in a controlled manner;
- Maintain survival space and structural integrity of the occupied areas;
- Limit the deceleration;
- Reduce the risk of derailment and limit the consequences of hitting a track obstruction

II. COLLISION REQUIREMENTS

Safe transportation of passengers is the key business objective of any transportation system. Railways are recognized as the safest mode of mass transportation and Safety has been recognized as the key issue for the railways and one of its special attributes. All business strategies emanate from this theme and strive to achieve Accident Free System. Safety is, therefore, the key performance index which the top managements need to monitor and take preventive steps based on trends of accidents which are the manifestations of some of the unsafe practices on the system.

COLLISIONS:

Collisions are the most dreaded accidents. It is very difficult to stop such collisions because of speed of moving trains, which need a lead distance to stop. Collisions happen due to human errors and/or faulty equipment.

1.3.1 Head-On & Rear-End-Collisions

A head-on collision is one where the front ends of two ships, trains, planes or vehicles hit each other, as opposed to a side-collision or rear-end collision. With rail, a head-on collision often implies a collision on a single line railway.

When accident takes place generally two impacts will effect on rail vehicles i.e.. Primary impact – occurs when the train impacts a large stationary (train or object lying on the tracks) or moving object (another train moving towards or away), which will produce an initial longitudinal deceleration. Secondary impact – occurs when a train derails causing it to rollover and/or impact trackside features or other coaches, which produces a complex combination of vertical, lateral and longitudinal decelerations. Due to the complexity of the decelerations and resulting motions produced in Secondary Impacts, only Primary Impacts have been considered in this paper.

1.3 Overriding in rail vehicles

The most important requirement of the anti climbing system is that it must improve a vehicle's resistance to override in train-to-train collisions for both colliding and coupled vehicles. An improvement in resistance is best measured by the increase in collision speed at which override can occur for particular colliding train configurations. However, improvement is also achieved by increasing the reliability with which the system is effective against override at a particular speed.

1.4 Deceleration limit

The mean longitudinal deceleration in the survival spaces should be limited as far as it is practicable to 5g, and shall not be more than 7.5g.

The method of determining the mean deceleration for each considered vehicle in the train unit shall correspond to the time from when the net contact force on the vehicle exceeds zero to the time when it next falls again to zero.

Crashworthiness design of railway vehicle:

In order to fulfill the overriding criteria imposed a new design concept for an anti-climb unit has been developed for railway vehicle, equipped with two anti-climb units that incorporate an interlocking feature (see figure 1). This feature ensures that the contact faces cannot slide over each other vertically. Thus, the anti-climb units are fully engaged over the whole collision process.

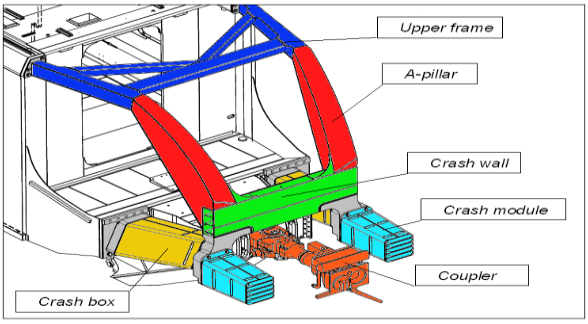


Fig 1.crash module

Both lateral anti-climb units (crash modules) are designed to absorb energy at a comparatively low force level and to deform before the yield level of the subsequent structural components is reached. Therefore, the crash modules are not foreseen to act as traditional buffers. They have not been designed to withstand the static loads according without yielding.

The crash module design is based on sheets of aluminum alloy EN AW-5754. The major properties of this material are the low yield strength and the good plastic forming characteristics, which enable large deformations without fracture. The material parameters have been controlled to tighter limits than usual in railway structures.

The crash module is a tapered tube with a square cross section. The tube is divided into chambers by partition sheets. The division of the crash module into several chambers provides a better stability against eccentric forces acting on the structure.

III. OBJECTIVE OF THIS PAPER:

This paper contains designing of two crash modules with tooth structure which act as a anti-climb feature, the model is done by Catia V5 and analyze its behavior by abacus software. Crash analysis is done to the crash modules by considering two cases with vertical offset of 40mm to find out the capability of the crash module by comparing the energy absorption and deceleration limit at different speeds.

IV. DATA COLLECTION:

Geometrical parameters of crash module, It is a rectangular taper tube consists of:

S.No	Description	Unit	value
1	For Front end height, width	mm	305
2	length	mm	764
3	For rear end height, width	mm	355
4	No of tooth aligned		5
5	Distance between two modules	mm	70
6	Depth of penetration	mm	40

Mechanical properties of Aluminum AW 5754 are:

S. No	property	units	value
1.	Density	kg/m3	2.7 e-9
2.	Young's modulus	Mpa	68200
3.	Poison ratio		0.33

Plasticity values are:

Yield strength	Plastic strain
80	0
115	0.024
139	0.049
150	0.079
158	0.099
167	0.124
171	0.149
173	0.174

V. MODELLING:

Modeling is a pre-processor tool, the modeling of Crash module is created using the CATIAV5 software is a feature-based, parametric solid modeling system with many extended design and manufacturing Applications. As it is sophisticated computerized software which gives friendly experience. As a comprehensive CAD/CAE/CAM system, covering many aspects of Mechanical design, analysis and Manufacturing , CATIA represents the leading edge of CAD/CAE/CAM technology.

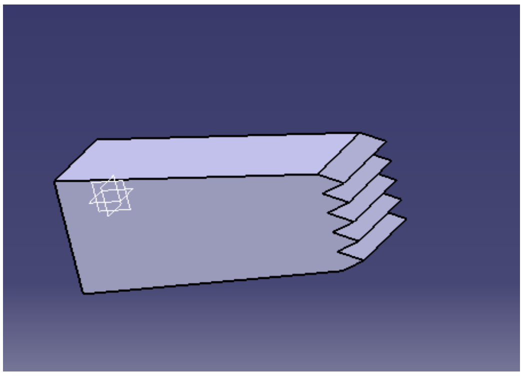


Fig 2 model of two crash module by Catia v5

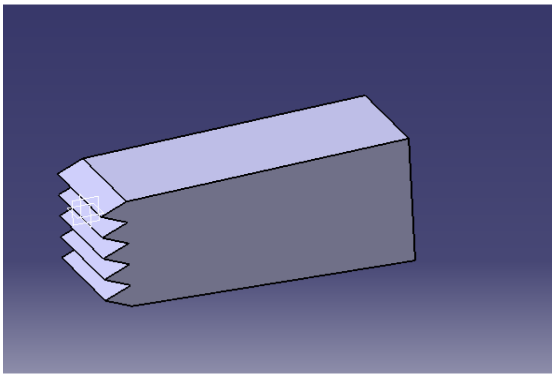


Fig 3.model of two crash module opposite by Catia v5

These two crash modules are imported to abacus after that two rigid plates are created which gives support to the modules during analysis with the dimensions.

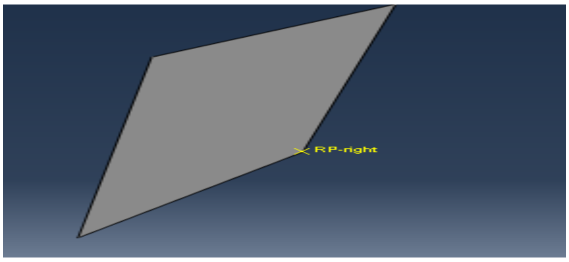


Fig 4 Modeling of two plates by using ABAQUS

ABAQUS/Explicit provides ABAQUS Analysis Technology focused on transient dynamics and quasi-static analyses using an explicit approach appropriate in many applications such as drop test, crushing and many manufacturing processes.

Meshing

This is one of the most important modules since accuracy of the results will depend on the meshing of the assemblies. This module can be used to generate meshes and even verify them.

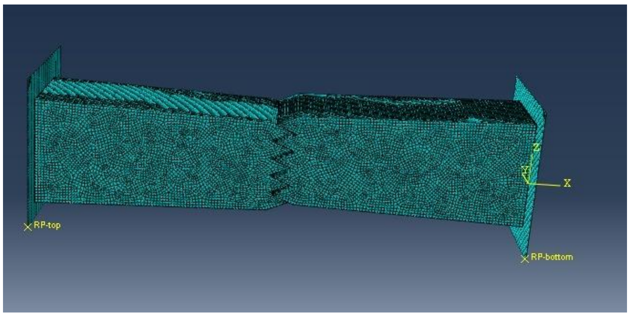


Fig:5 Meshing of the module

There were 203690 elements in the model and 218887 nodes are created, and the dynamic simulations captured a period of 0.5 seconds. To promote a speedy run time, software run with two processors with activated parallel processing.

VI. RESULTS:

i)when one of the end is fixed

To meet the crashworthiness of trains the module should absorb max energy which is dissipated during the collision these are the various values about the total energy absorption by the two modules, kinetic energy at various speeds.

From the above table it observe that crash module moving with different speeds by absorbing energy even at high speeds i.e 80km/hr. after that it is not able to absorb energy it is becoming under zero values at a period of 0.5 sec, the tooth is unable to absorb at certain speeds when one object strikes the fixed one.

S.N	**Speed Km/hr**	**Obstacle Mass kg**	**Kinetic energy kJ**	**Total energy to be absorbed KJ At 0.1sec**	**At 0.5sec**
1	*40*	*100,000*	*3.674e8*	*229658*	*1.446e6*
2	*60*	*100,000*	*7.867e8*	*871842*	*4.933e6*
3	*80*	*100,000*	*1.358e9*	*2.220e6*	*1.75e7*
4	*100*	*100,000*	*2.275e9*	*6.057e7*	*1.091e8*
5	*102*	*100,000*	*3.04578*	*0.12957*	*0.647*

Contour plot of equivalent plastic strain values to find deceleration limit:

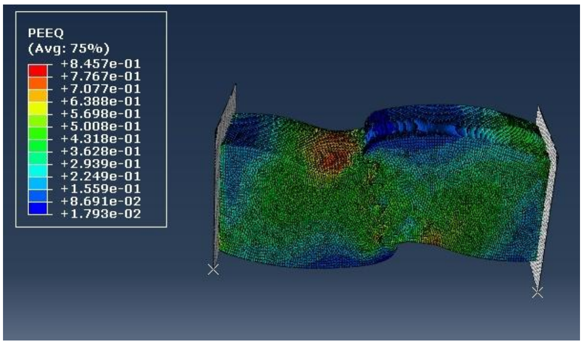


Fig: 6When it is moving at a speed of 60km/hr.

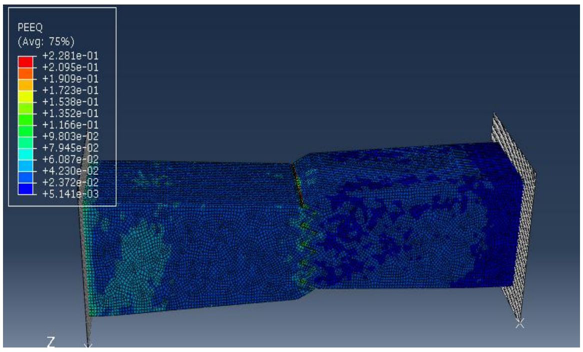


Fig:7 When it is moving at a speed of 80km/hr

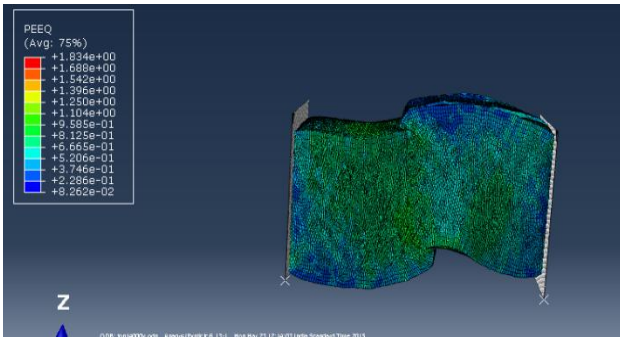


Fig:8 When it is moving at a speed of102km/hr

From the above results we can observe that for speeds of 40, 60, 70, 80km/hr the decelerated value is below 7.5g and absorb maximum energy. whereas in case of speed 102km/hr it is exceeded the value +8.262e-02 which is above the limited value. It proves that anti-climber can be applicable below 100 km/hr when one end is fixed.

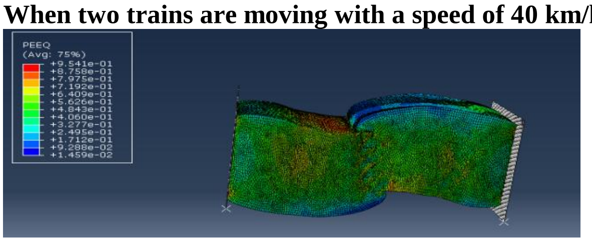
Case (II)

From the above table we can observe that when both trains moving at same speed if we take the time period from o.1 to o.5 sec in case of 40,60,72,km/hr speeds the energy absorption is increased while coming to the speed at 87km/hr the absorption of energy is decreased from 4.044 to 3.301 the tooth is unable to absorb at this speed and PEEQ value also greater than limited value by this we can say that up to 87km/hr crash module can resist overriding by absorbing energy .

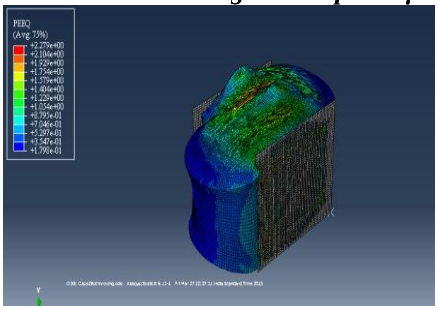
S.N	**speed km/hr**	**Kinetic energy KJ at 0.5sec**	**Total energy absorbed At 0.1sec**	**At 0.5sec**
1	40	4.095e8	465885	1.749e7
2	60	1.224e9	1.4436e7	1.607e8
3	72	1.607e9	1.069e8	2.426e8
4	87	5.348e9	4.0444e8	3.301e9

Contour plot of equivalent plastic strain values to find deceleration limit:

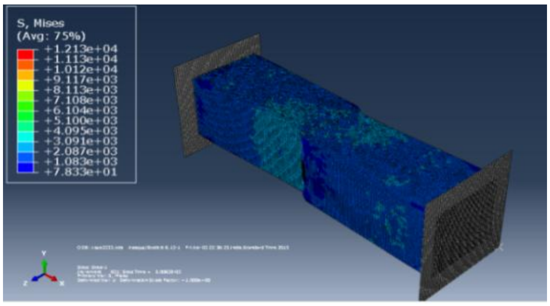
1. **When two trains are moving with a speed of 40 km/hr:**



2.when two trains are moving with a speed of 72km/hr



3.When two trains are moving with a speed of 87 km/hr:



VII. CONCLUSION:

1. The anti-climb teeth prevented either train unit from moving over the other , In case of fixed end the module body underwent deformation to absorb 1.3 mega joules. aluminum buckling decelerated the train unit at an avg of 1.5g upto100km/hr.

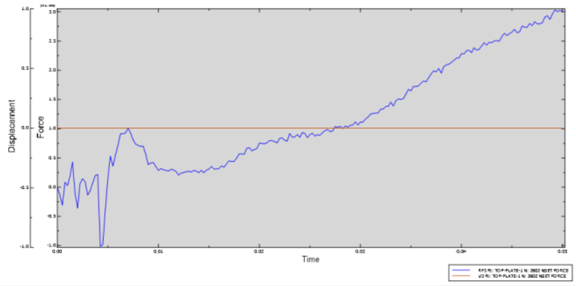
2. In case of same speed the module body underwent deformation to absorb 1.5 mega joules. Aluminum buckling decelerated the train unit at an avg of 2.75g.

3.Our goal is to achieve an overall compressive strength for the train unit to 1,500 KN, without undergoing any yield and deformation in the passenger structure.

4. Because of aluminum 5754 material we used It shows that compressive strength to about 3,600kn, with only small amounts of plastic deformation in the passenger zone .

5.The above results gives the clear idea that tooth at the crash module can reduce overriding effect by absorbing energy so that crash zone during collisions in both cases.

Case (i)
Graph obtained at a speed of 60km/hr



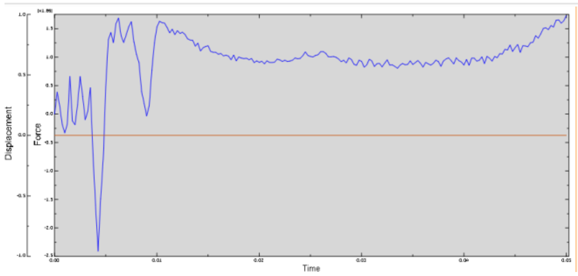


Fig :9 Graph obtained at a speed of 80km/hr

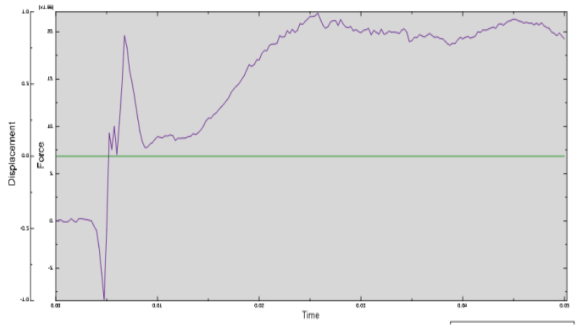
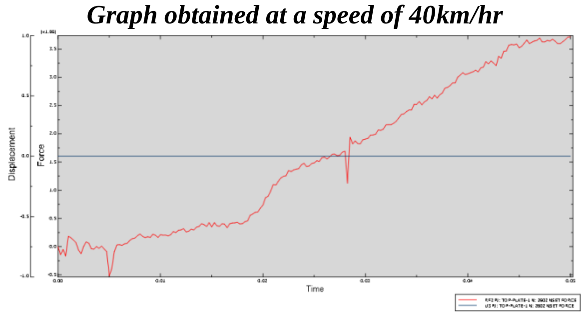


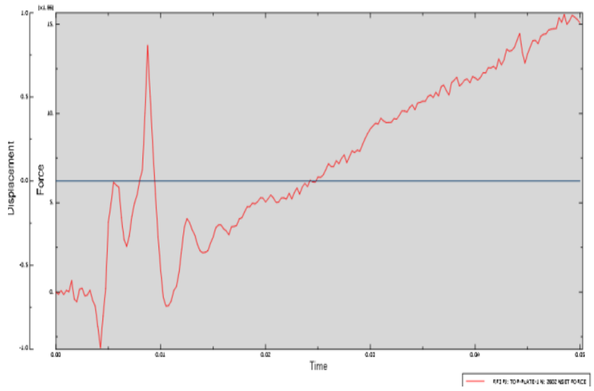
Fig:10 Graph obtained at a speed of 102km/hr

Case (ii):

Graph obtained at a speed of 40km/hr



Moving at a speed of 102km/hr



From the above mentioned graph, it is concluded that the object is behaving in the real physical scenario. Initially when the time is zero, the Energy in the objects are zero and displacement of the object is also zero. When the force applied on the object with respect to the time the object start displacing. When it reaches a certain time interval, the object got displaced to a certain distance.

When object is moving with certain speed time period increases it interacts with components so that stress will undergo high where stress undergo deformation time period increases stress also increases by mating with objects and by absorbing energy. Energy is absorbed by different points absorption coefficient is constant up to safe control after reaching certain point it doesn't control the speed because of elasto-plastic behaviour it is time increases through which velocity increases other impact deformation that takes place displacement too much stress will undergoes failures.

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