TEST Engineering & Management

July-August 2020
ISSN: 0193-4120 Page No. 4430- 4435

Comparison of Carbon Steel and Stainless Steel As Tube Material On Bus Super Structure Strength Against Rollover

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Article Info
Volume 83
Page Number: 574 - 585
Publication Issue:
July-August 2020

Article History
Article Received: *25 April 2020*
Revised: *29 May 2020*
Accepted: *20 June 2020*
Publication: *10 August 2020*

Abstract

The rollover is one of the severe conditions of accidents which generally take place in traffic of highway. The worlds important focus is on Safety.. Everyday different vehicles meet with variety of accidents which are noticeable in number and can not be neglected. Rollover is one of the very frequent cause of accidents. Most rollover crashes occur when a vehicle runs off the road or rotates sideways on the road by ditch, curb and soft soil or by some other objects. In most of the rollover accidents of buses, its superstructure faces strong impact with the surface of road. This impact leads to collapse of bus roof resulting severe injury to the occupants and extreme damage to the frame of bus. National Highway Traffic Safety Administration (NHTSA, 2002 b) USA reported that only about 3% of all crashes are rollovers that caused 33% of total crash related deaths. The researcher discusses and compares the effect of Carbon steel Vs Stainless steel as the tube material on bus super structure strength against rollover.

Keywords: *Bus super structure, Carbon steel, Stainless steel;*

I. INTRODUCTION

Depending on the reasons that commence, there may be different types of roll overs. The may be trip-over type, fall-over type, flip-over type, bounce-over type, turn-over type, or another vehicle collision, climbover type, end-over-end etc. Kecman, D. and Tidbury, G. H. [1] presented a pioneer researchwhich was accepted as a base of United Nations Economic Commission for Europe (UN-ECE) Regulation 66 on the process of calculating different parameters for the certification of rollover related issues. White, D. M. [2] worked on the Rollover Accident Simulation Program (RASP) developed to study the design factors which affect rollover stability. The height of CG was the most critical factor affecting the damages in rollover accidents. Kumagai et al., [3] simulated a full scale bus using FEA program meeting the requirements of ECE 66. The results were compared with that of full scale dynamic rollover test of a bus. Dias and et al in [4] present a new method for predicting the rollover limit of buses, based on a theoretical model and dynamics.

Kecman, D. and Randell, N. [5] studied on the methods of structural design by ECE Regulation 66. Both Quasi-static and full dynamic analysis of the rollover test can be used for the development of the structure. Analysis of eleven rollover accidents from a sample of seventy eight bus collisions occurred in France by Botto et al. [6]. The 41% of all accidents was found as rollovers.

Rasenack et al. [7] presented a survey of bus collision between 1985 and 1993 in Germany. Very few of the collisions resulted to rollovers accounting 50.2 % of all severe injuries and 90% of all fatalities. Characteristics of on-road rollovers regarding steering wheel angle amplitude, steering wheel rate, lateral acceleration, yaw rate, body roll angle and roll rate were presented by Marine et al [8]. Roper, L. David studied the effect of lateral speed, height of the center of gravity and different types of road surfaces numerically in his detailed work to investigate the

Published by: The Mattingley Publishing Co., Inc.

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ISSN: 0193-4120 Page No. 4430 - 3680

reasons of rollover that helps to initiate rollover. Ferrer, I. and Miguel, J. L. [10] presented a report on the reasons of fatalities during rollover accidents of high speed buses. A-pillar, roof rail and header intersection was assessed by Bish, Jack et al. [11]. Their work suggested improve the strength of roof sufficiently to prevent roof crash during rollover that might decrease the degree of fatalities. Eger and Kiencke [12] study shows the investigations of the influence of various parameters and their variations on rollover accidents for that even simple models could deliver noticeable properties of vehicle rollover.

From the study ,it is observed that , no research has been carried out on the Strength of Bus Superstructure to Prevent Rollover Crash of bus frame. Most of the works were related to the survey of the number of injuries based on fatalities. Some of the researches have been conducted to analyze the reasons of rollover. The effect of rollover on the superstructure of bus and the detailed analysis of that is very important to decrease the extremity of damages on both of the occupants and the bus frame. This research presents a numerical study on the effects of total mass of bus and the strength of bus superstructure on the safe residual space in bus during rollover accident.

In this research, two different materials those are **Carbon steel vs Stainless steel**were chosen to see their effect on rollover.

II. MATERIALS OF BUS SUPERSTRUCTURE: CARBON STEEL VS STAINLESS STEEL

Steel is an alloy made out of iron and carbon. The carbon percentage can vary depending on the grade, and mostly it is between 0.2% and 2.1% by weight. Though carbon is the main alloying material for iron some other elements like Tungsten, chromium, manganese can also be used for the purpose. Different types and amounts of alloying element used determine the hardness, ductility and tensile strength of steel. While in Carbon steel, Carbon as the main alloying element. In carbon steel, the properties are mainly defined by the amount of carbon it has. For this alloy, the amounts of other alloying elements like chromium, manganese, cobalt, tungsten are not defined.

Stainless steel has a high chromium content that forms an invisible layer on the steel to prevent corrosion and staining. Carbon steel has a higher carbon content, which gives the steel a lower melting point, more malleability and durability, and better heat distribution.

I. Distinguishing Parameters Of Carbon Steel And Stainless Steel

Stainless steel is lustrous and comes in various grades that can increase the chromium in the alloy until the steel finish is as reflective as a mirror. To the casual observer, carbon steel and stainless steel are easy to distinguish. Carbon steel is dull, with a matte finish that is comparable to a cast iron pot or wrought iron fencing.

There is an in built chromium oxide layer in stainless steel, which is not present in carbon steel.

Carbon steel can corrode whereas stainless steel is protected from corrosion

Stainless steel is preferred for many consumer products and can be used decoratively in construction, while carbon steel is often preferred in manufacturing, production and in projects where the steel is mostly hidden from view. Stainless steel has lower thermal conductivity than Carbon steel

II. Comparison Of Mechanical Properties [ ] Of Carbon Steel And Stainless Steel

Table I: Mechanical properties of carbon steel

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(*Clauses* 3.1 *and* 11.2)

Grade	Tensile Strength (*Min*) MPa	Yield Stress (*Min*) MPa	Elongation on Gauge Length 5.65 √S₀, *Min* Percent
YSt 210	330	210	20
YSt 240	410	240	17
YSt 310	450	310	14

NOTES

1 1 MPa = 1N/mm² = 0.102 kgf/mm².

2 Elongation percent for tubes up to and including 25 mm nominal bore for all grades shall be 12 minimum.

Table II: Mechanical properties of stainless steel

Tensile Strength ksi	Tensile Strength MPa	Yield Strength (0.2% offset) ksi	Yield Strength (0.2% offset) MPa	Elongation in 2" (50.80mm) %	Hardness (Rockwell)
120.5	831	69	476	58	B98

III. METHODOLOGY

Bus super structure made up of tubes of uniform thickness. Therefore tubes are modeled using shell elements in their middle plane. An average element length of 8mm is maintained. The chassis consists of many parts like suspension systems,axles and tires. Hence accurate capturing of the mass of all subsystems on chassis is required. The chassis controls the dynamics of during the total bus rollover. Appropriate geometrical properties and material properties assigned to the shell elements. Joint modeling method was a consistent method for the tubes and weld joints modelling process.Fig 1 shows Finite Element Model of complete bus structure.

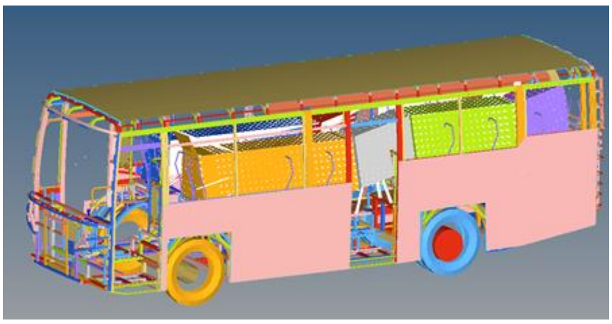

Fig 1: Finite Element Model of complete bus structure

Fig 2 shows an experimental test for Bus rollover proposed by standard AIS031 [1]. The vehicle should be elevated by a platform that rotates it with angular velocity (it should not exceed 5 degrees per second) until it rolls due to effects of gravitation.

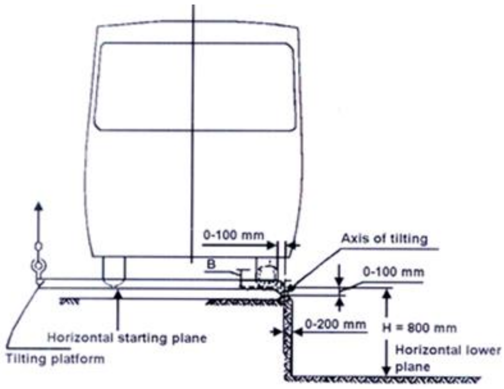

Fig 2. AIS031 Axis of tilting

In AIS031 survival space requirement of passenger as defined standard is modeled in the bus FE model. This template has standard size and position with respect to seats of passenger. Template surfaces with respect to seat and bus structure clearifies about the relative position of survival space which is shown by Figure 3 .

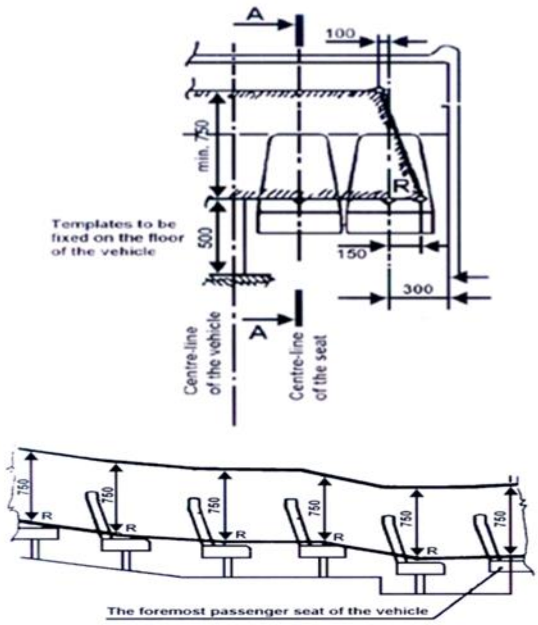

Figure 3. Space template used for survival

Bus Rollover test as per AIS031 conducted physically by rotating complete bus through a rotating platform till it reaches up to the point where

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it rotates and falls by its own. This position is called angle of repose. By applying law of conservation of energy angular velocity can be calculated.

At equilibrium Potential Energy=At impact Kinetic energy

$$Mg\,\Delta h = \frac{1}{2} I\omega^2 \qquad (1)$$

Where,

M = Mass of the bus, kg

g = Gravitational constant, mm/sec2

Δh = Drop of centre of gravity from highest point till impact position

I = Moment of Inertia of bus, kg-mm4

ω = Angular velocity, rad/sec

Figure 4 shows the at the impact kinetic energy is 49 kJ.

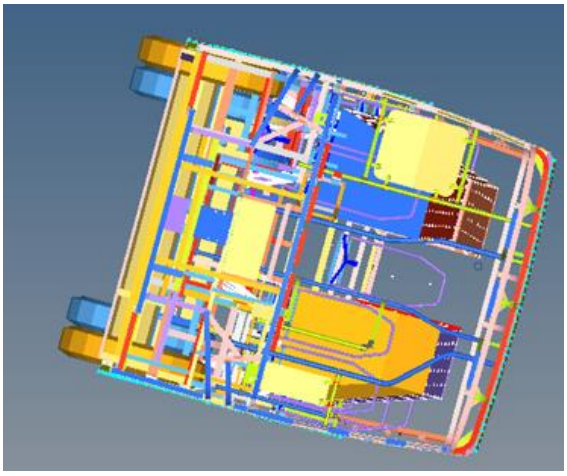

Fig4:Position of the Bus rollover model for Initial impact

A. *Bus Superstructure Thickness And Weight*

In baseline case, all tubes were considered as 3mm with carbon steel material. Total weight of the superstructure was measured as 3.6 tons. With stain less steel material, thickness of tubes were reduced as 1.6mmand total weight for this case was measured as 1.92 tons. For the graphical representation of weight refer Fig 5.

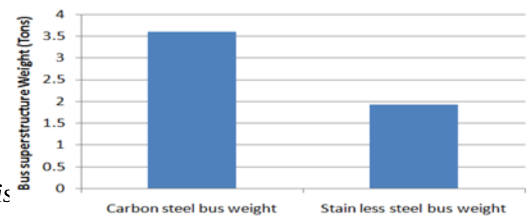

Fig 5: Bus superstructure weight

IV. ANALYSIS

Figure 6. shows deformation of bus structure in case of steel tubes . In case of steel tubes the survival space is intruding significantly. The model is considered to be failed as per AIS031. The deformation of bus in case of stainless steel material is shown in Figure 7. The bus is showing adequate survival space in case of stainless steel material. The energy balance curves are shown clearly in Figure 8.

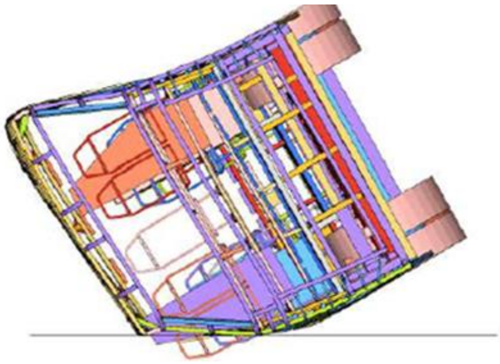

Figure 6: With steel tubes

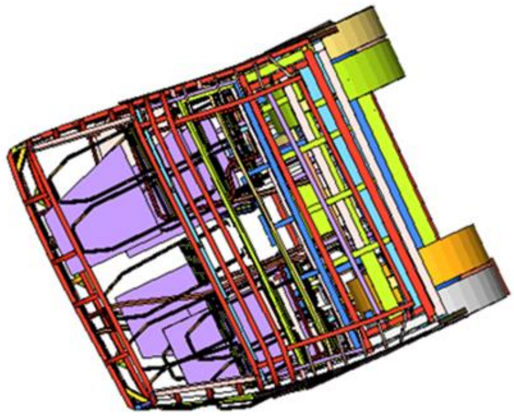

Figure 7: With Stainless steel.

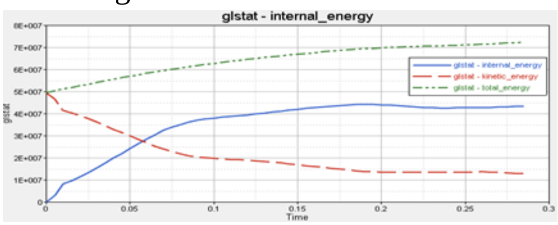

Fig 8: Co-driver side’s rollover Energy balance graph

The positions of templates along with the survival space in case of stainless steel material are shown in Fig 9.

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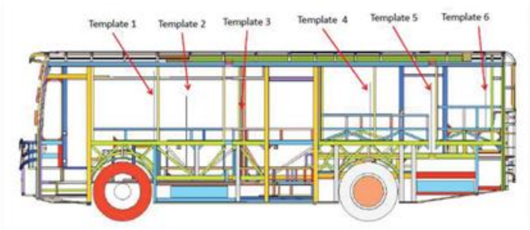

Fig 9: Template locations in bus

Table III : Template positions in bus

Template No	Clearance between superstructure & Residual Space
TEMPLATE 6	30.03
TEMPLATE 5	39.4
TEMPLATE 4	18.3
TEMPLATE 3	45.3
TEMPLATE 2	36.7
TEMPLATE 1	9.7

V. RESULTS &CONCLUSION

Simulation'soverview is clearly observed at each time interval. For every step of progress the analysis results were noted. The bus first comes into contact with the ground when the roof corner touches and hits the ground. By absorbing the kinetic energy by its elastic-plastic behavior the bus structure starts deforming.The bus structure's main vertical tubes starts bending and thereby absorbing the major part of kinetic energy as the deformation progresses. Cant rail also plays a major role in this energy absorption process. When the waist rail touches the ground the deformation stops and the bus starts sliding as the bus completely left the tilting platform.

When the kinetic energy of the model is completely absorbed and converted into internal energy the deformation stops. The template starts bouncing in between the simulation. The behavior of stainless steel structure showed more structural strength as compared to steel..

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Dr Suwarna Torgal has completed BTech in the yr 1995 and MTech in the year 1999 from Karnataka University and accomplished doctorate degree in mechanical Engineering in the year 2010 from IET Devi Ahilya Vishwavidyalaya, Indore
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Her academics is excellant as she was National award winner i by the Karnataka state government. Also she was University topper during her Mtech.
From 2003 she is working with IET,DAVV, as Faculty of mechanical engineering. In the research field she has really done good progress by publishing more than 40 papers in the reputed journals which are scopus indexed Springer Publications and so on. Chaired many sessions in the conferences. she has also presented more than 13 papers in the conferences, she has guided 15 M tech students and seventeen batches of of B Tech students.She is also receiver of funding from MPCST and from UGC 12th plan. In the university she is one of the active members as being the member Board of Studies, member girls welfare mentor for the girl students ,the coordinator of cultural fests, member anti ragging committee, superintendent for exam and evaluation also is a master trainer at the university level for the smart girl training program She is associate member Institution of Engineers Indore local centre, life member of of association of Machines and mechanism,
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