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FINITE ELEMENT SIMULATION OF CFRP ELEVATOR CAR FRAME BUFFER CRASH USING ANSYS

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ABSTRACT

The purpose of the project is to study the behavior of impact loading for an elevator car frame using static structural analysis and explicit dynamic analysis under different various of boundary conditions. The stresses of the static and dynamic analysis were very similar, which indicates that both the static and dynamic methods are consistent in calculating stresses of the car frame under buffer impact. However, the dynamic analysis allows for a more in depth study of the behavior of the system over the duration of impact, whereas the static method only provides a single snapshot of the system's behavior. Using a representative CFRP elevator car frame, a static analysis of buffer impact was performed using ANSYS Workbench 15.0, where the maximum stresses and deflection were calculated. With the same car frame, two dynamic analyses were performed using ANSYS, where the stresses and deflections over the duration of the impact were calculated.

Key Words:

Deflector, Maximum stress, Elevator Car Frame, ANSYS

1.0 INTRODUCTION

Static Structural Analysis

The ASME A17.1 Elevator Safety Code requires a static structural analysis of the car frame under buffer loading. To account for impact, the normal static loads are doubled, The analysis is the equivalent to a having a car with twice its normal weight resting on the buffer, which is fixed to the ground. This simplification allows the use of hand calculations to solve the problem.

Explicit Dynamic Analysis (without acceleration)

The explicit dynamic approach is not required by the Elevator Safety Code. In this approach, an initial velocity is applied to the mass of the fully loaded car. the car moves downwards at a constant speed until it strikes the buffer that is fixed to the ground. Effects of gravity are ignored for this analysis. This approach assumes that the machine is capable of controlling the system to a certain degree during the impact, such that the car does not accelerate due to gravity.

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Explicit Dynamic Analysis (with acceleration)

In this final method, the mass of a fully loaded car moves downwards at an initial velocity, and is also accelerating due to gravity. This approach assumes that as the car frame comes in contact with the buffer, the hoisting ropes become completely slack. Without any rope tension to counteract gravity loads, the car frame is subject to gravity acceleration

System Properties

The car frame is designed for a net moving mass of 3175kg, of which 1588kg (3500lb) is the duty load, 579kg is the car frame mass, and 1008kg is the cab. The operating speed of the car is 1m/s. summarizes the system properties used for all the analysis. The car frame is made entirely of steel, and lists the material properties that are used.

Where used	**Designation**	**Area A**	**Depth d**	**Web**	**Flange**	
		(in^2)	(in)	Thickness	Width	Thickness
				tw (in)	bf (in)	tf (in)
Crosshead,	C8x11.5	3.38	8.00	0.22	2.26	0.39
Upright	C6x8.2	2.40	6.00	0.20	1.92	0.34
Stringers	C3x4.1	1.21	3.00	0.17	1.41	0.27

Table 1.1 Structural C-Shapes Shape Used for Car Frame Analysis

Three challenging use cases The developments in EMILI are motivated and driven by three use cases described in which have been elaborated by industry partners in collaboration with safety experts and are inspired by actual incidents as the ones described above. The use cases can be roughly classified into public CIs and technical CIs: Public CIs include metro stations and airports and involve a great number of persons that are directly threatened by critical and emergency situations and therefore the corresponding use cases focus on the detection of emergencies and support of the early self-rescue phase of passengers. In contrast, technical CIs include power grids and focus on the fast detection of incidents and the automatic determination of their actual cause giving the chance of accurate and right reactions.

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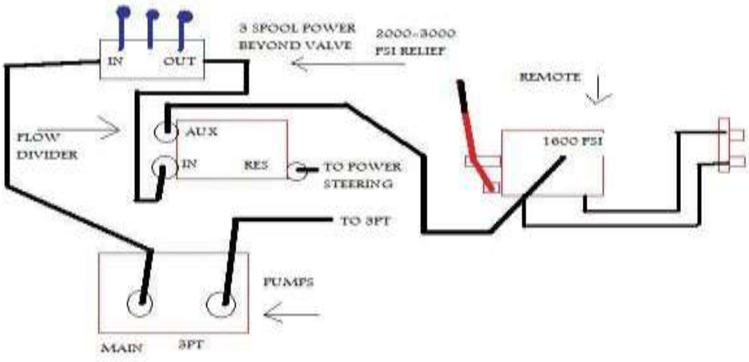

Figure 1.1 EEE Lift Hydraulic circuit

The following descriptions summarize the main scenarios of the use cases from which envision how intelligent control systems can support and improve conventional EM. These scenarios have substantially influenced and inspired the design of Dura. airport The main scenario of the airport use case considers a fire that affects the terminal of a mid-size airport, A fire breaks out in a baggage sorting room located in the basement of the airport terminal. . However, despite these efforts the fire eventually spreads through the ceiling to the ground floor where the passport control filled with passengers and personnel is located. It is inferred from the available sensor data that one predetermined evacuation route leading from the ground floor through the basement is already blocked by smoke and thus cannot be used for evacuation. Moreover, the data obtained by the smoke simulation reveals that the second evacuation route is likely to be blocked by smoke within the next minute.

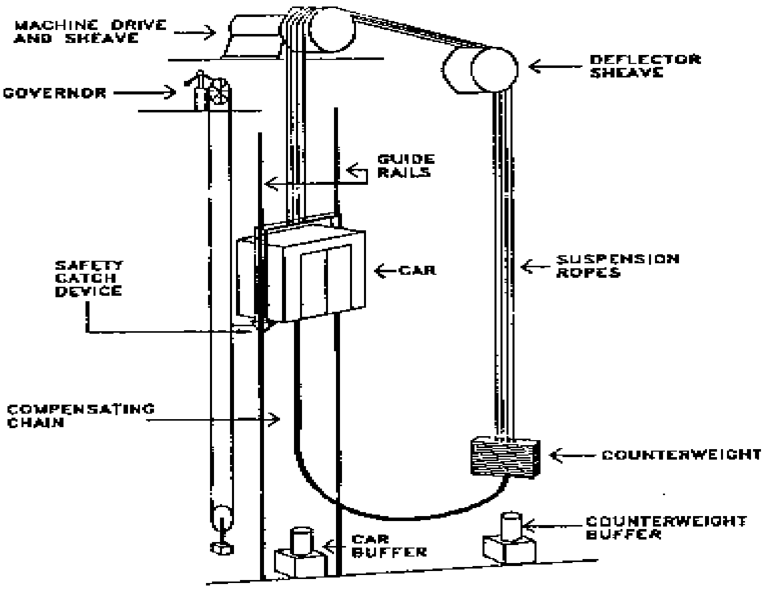

Figure 1.2 Lifting Counter Weight Buffer

The detection of the fire by means of the correlation of several fire detector sensor signals causes the automatic execution of immediate reactions intended to suppress the fire and prevent its spread. However, despite these efforts the fire eventually spreads through the ceiling to the ground floor where the passport control filled with passengers and personnel is located. It is inferred from the available sensor data that one predetermined evacuation route leading from the ground floor through the basement is already blocked by smoke and thus cannot be used for evacuation. Moreover, the data obtained by the smoke simulation reveals that the second evacuation route is likely to be blocked by smoke within the next minute.

2.0 LITERATURE REVIEW

Djamel F.H. Sadok et al.; 2015 This paper describes an innovative distributed framework for monitoring and control of large-scale systems by integrating heterogeneous smart objects, the world of physical devices, sensors and actuators, legacy devices and sub-systems, cooperating to support holistic management [1]. Its featured Service Oriented Architecture (SOA) exposes objects' capabilities by means of web services, thus supporting syntactic and semantic interoperability among different technologies, including SCADA systems [23]. Wireless Sensor and Actuator Network (WSAN) devices and legacy subsystems cooperate while orchestrated by a manager in charge of enforcing a distributed logic. Particularly crafted for industrial networks are new middleware services such as dynamic spectrum management, distributed control logic, object virtualization, WSANs gateways, a SCADA gateway service, and data fusion transport capability. In addition, new application oriented objects such as shop floor, manufacturing line, welding station, robots, and cells have been introduced in the middleware. [5] Juliane Muehlhaus et al.; 2023 Cognitive neuroscience research on semantics recognizes a distinction between categorical and associated relations. However, associations can be divided further, such as into part-whole and functional relations. We investigated the neural basis of both relations using a picture–word interference task in an fMRI study. While the left supramarginal gyrus and the right inferior temporal sulcus were activated by part-whole over functional relations, the same applies to the right parahippocampal complex contrasting the functional over part-whole relations. The small effect sizes of our analyses have to be interpreted with caution. Magnus Haake et al.; 2021 Educational software in which the student takes the role of teacher and instructs a digital tutee – a so-called teachable agent – has repeatedly proven to have positive effects for school children's learning. In a study with 39 preschoolers aged 3:9 to 6:3, we explored the conditions under which children this young would benefit as well from this kind of educational software. We specifically investigated to what extent children of this age group would be able to reason about and reflect upon the actions of their digital tutee, and to what extent they would enjoy an educational game centered around instructing and helping a digital tutee. Results revealed that preschoolers were quite capable of reasoning and reflecting upon their digital tutee. H. ElMaraghy et,. al.; 2019 A great challenge facing industry today is managing variety throughout the entire products life cycle. Drivers of products variety, its benefits, pre-requisites and associated complexity and cost are presented. Enhancing consumers' value through variety and approaches for achieving it efficiently including modularity, commonality and differentiation are discussed. Variant-oriented manufacturing systems paradigms, as enablers of product variety, and the effective co-development of variants and their manufacturing systems to ensure economic sustainability are reviewed. Industrial applications and guidelines to achieve economy of scope with advantages of economy of scale are discussed. Perspectives and insights on future research in this field are offered.

Milda Cerniauskaite et. al.; 2017 aimed to prove that the COURAGE in Europe Built Environment (CBE) instrument selected items are relevant to health and disability assessment and evaluation. The two lists of the CBE preliminary items – outdoor checklist and self-reported questionnaire – were linked to the World Health Organization's International Classification of Functioning, Disability and Health for Children and Youth (ICF-CY) through established linking rules. The pool of the CBE 162 preliminary items was linked to a total of 184 categories of ICF-CY, and belonged mainly to two out of the four of the ICF-CY components. Fifteen of the items were not linked to any category of the ICF-CY classification at all. The linking process showed that more than 90% of CBE preliminary items were linked to ICF-CY categories and more than 4/5 of them were linked to the ICF-CY component of environmental factors. The fact that most of the linked CBE preliminary items referred to few ICF categories, on one hand showed that the ICF framework encompasses a lot of different aspects related to functioning and disability; on the other hand, ICF categories are not very detailed for a comprehensive description of the built environment features. P. Schönsleben et. al.; 2022 A great challenge facing industry today is managing variety throughout the entire products life cycle. Drivers of products variety, its benefits, pre-requisites and associated complexity and cost are presented. Enhancing consumers' value through variety and approaches for achieving it efficiently including modularity, commonality and differentiation are discussed. Variant-oriented manufacturing systems paradigms, as enablers of product variety, and the effective co-development of variants and their manufacturing systems to ensure economic sustainability are reviewed. Industrial applications and guidelines to achieve economy of scope with advantages of economy of scale are discussed. Perspectives and insights on future research in this field are offered

3.0 EXPERIMENTAL DETAIL

Geometry

Using Pro/Engineer, a simplified car frame model is created. The car frame used has a size that is typical of a 3500lb duty system and is made of imperial structural steel shapes a general view of the car frame. The uprights are made of structural C-Shape C6x8.2. The crosshead and plank are made of C8x11.5. The platform stringers are C3x4.1. The first number of the designation is the depth d of the and the second number is the weight of the shape, in pounds per ft. For example, a C6x8.2 has a cross section 6 inches deep and weights 8.2 lbs/ft. The platform is 6mm thick steel and the strike plate is 25mm thick steel simplified as a cylinder with 200mm diameter and 300mm height. The models use for this project required 0.028 m/s time increments. The simulation wasset to run for 400ms. Stresses and deflections were recorded every 0.5ms to an output file. We use more familiar tools to create models. However, models imported from cad systems may require extensive repair if they are not of suitable quality for meshing. While building the Model in the CAD systems we to observe Ansys solid modelling procedures with regard to planning, symmetry and the amount of detail needed for a finite element analysis. For example, for axis symmetric models, the Ansys program requires that the global Y axis be the axis of rotation. Avoid creating closed curves (that is, a line that starts and ends at the same point) and closed surfaces (such s a surface that starts and ends at the same edge). Ansys can't store closed curves or closed surfaces (it requires at least two key points).

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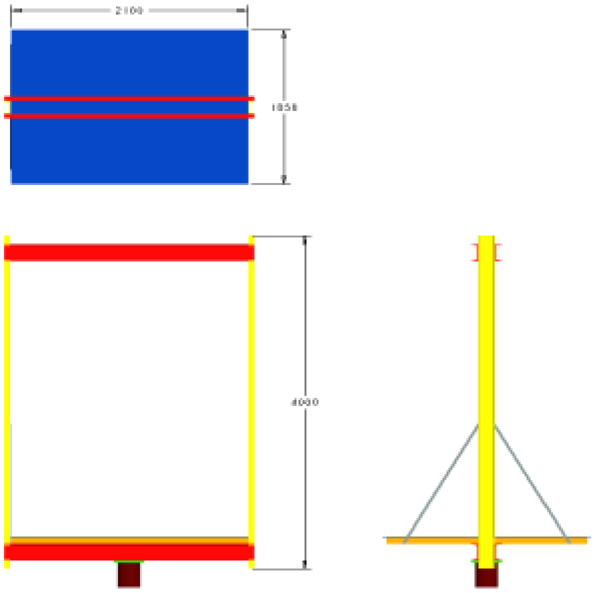

Figure 3.1 Geometry Part

Figure 3.2 Geomentry Part

The dynamic method without gravity yielded similar displacement as the static analysis, but the maximum stress was half of the static method. The lack of gravity forces in the system most likely under predicted stresses in the system. Compared to the dynamic method with gravity, this method without gravity does not seem to accurately predict car frame stresses and deflection under buffer impact. threatened It is inferred from the available sensor data that one predetermined evacuation route leading from the ground floor through the basement is already blocked by smoke and thus cannot be used for evacuation. Moreover, the data obtained by the smoke simulation reveals that the second evacuation route is likely to be blocked by smoke within the next minute These scenarios have substantially influenced and inspired the design of Dura. airport The main scenario of the airport use case considers a fire that affects the terminal of a mid-size airport, A fire breaks out in a baggage sorting room located in the basement of the airport terminal.

Model Generation:

In ANSYS terminology, model generation usually takes on the narrower meaning of generating the nodes and elements that represent the spatial volume and connectivity of the actual system. Thus, model generation in this discussion means the process of defining the geometric configurations of the model's nodes and elements. The ANSYS program offers the following approaches of model generation. Creating a solid model within ANSYS using direct generation of the component within the software itself or importing model created in any other computer aided design software which is compatible with Ansys software. Direct generation of solid in Ansys software is somewhat tedious because the person who knows completely about Ansys software can create few parts in software. Some parts with complicated structure and dimensions cannot be created by this software. In these cases, it is better to model the problem in any other computer aided design software and import the component for analysis into this Ansys software, because created a complete component in Ansys software is somewhat time consuming processes.

Importing the Model:

As an alternative to creating the solid models within ANSYS, we can create them in favorite CAD system and then import them into ANSYS for analysis, by saving them in the IGES file format or in a file format supported by an ANSYS connection product. Creating a model using a cad package has the following advantages: We avoid a duplication of effort by using existing cad models to generate solid models for analysis. We use more familiar tools to create models. However, models imported from cad systems may require extensive repair if they are not of suitable quality for meshing. While building the Model in the CAD systems we to observe Ansys solid modelling procedures with regard to planning, symmetry and the amount of detail needed for a finite element analysis. For example, for axis symmetric models, the Ansys program requires that the global Y axis be the axis of rotation. Avoid creating closed curves (that is, a line that starts and ends at the same point) and closed surfaces (such s a surface that starts and ends at the same edge). Ansys can't store closed curves or closed surfaces (it requires at least two key points). If a closed curve, closed surface, or "trimmed" closed surface defined by IGES entities, Ansys will attempt to split it into two or more entities as much as possible, write to the iges file by data that the Ansys program supports.

1. Static Analysis Used to determine displacements, stresses, etc. under static loading conditions both linear and nonlinear static analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.
2. Modal Analysis Used to calculate the natural frequencies and mode shapes of a structure. Different mode extraction methods are available.
3. Harmonic Analysis Used to determine the response of a structure to harmonically time-varying loads.
4. Transient Dynamic Analysis Used to determine the response of a structure to arbitrarily time varying loads. All nonlinearities mentioned under Static Analysis above are allowed.
5. Spectrum Analysis An extension of the modal analysis, used to calculate stresses and strains due to a response spectrum or a PSD input (random vibrations).
6. Buckling Analysis Used to calculate the buckling loads and determine the buckling mode shape. Both linear (eigen value) buckling and nonlinear buckling analyses are possible.
7. Explicit Dynamic Analysis This type of structural analysis is only available in the ANSYS program. ANSYS provides an interface to the explicit finite element program. Explicit dynamic analysis is used to calculate fast solutions for large deformation dynamics and complex contact problems. In addition to the above analysis types, several special-purpose features are available.

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Boundary Condition :

The detection of the fire by means of the correlation of several fire detector sensor signals causes the automatic execution of immediate reactions intended to suppress the fire and prevent its spread. However, despite these efforts the fire eventually spreads through the ceiling to the ground floor where the passport control filled with passengers and personnel is located. It is inferred from the available sensor data that one predetermined evacuation route leading from the ground floor through the basement is already blocked by smoke and thus cannot be used for evacuation. Moreover, the data obtained by the smoke simulation reveals that the second evacuation route is likely to be blocked by smoke within the next minute.

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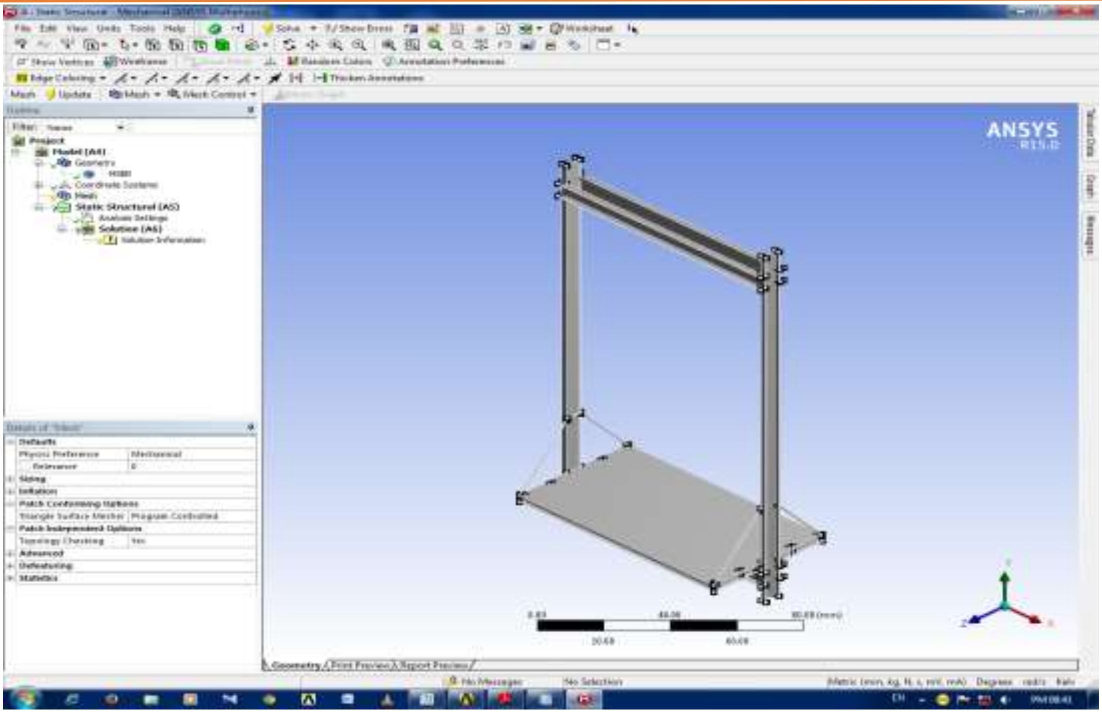

Figure 3.3 Boundary Condition

MESHING

In ANSYS terminology, model generation usually takes on the narrower meaning of generating the nodes and elements that represent the spatial volume and connectivity of the actual system. Thus, model generation in this discussion means the process of defining the geometric configurations of the model's nodes and elements. The ANSYS program offers the following approaches of model generation. Creating a solid model within ANSYS using direct generation of the component within the software itself or importing model created in any other computer aided design software which is compatible with Ansys software. Direct generation of solid in Ansys software is somewhat tedious because the person who knows completely about Ansys software can create few parts in software. Some parts with complicated structure and dimensions cannot be created by this software.

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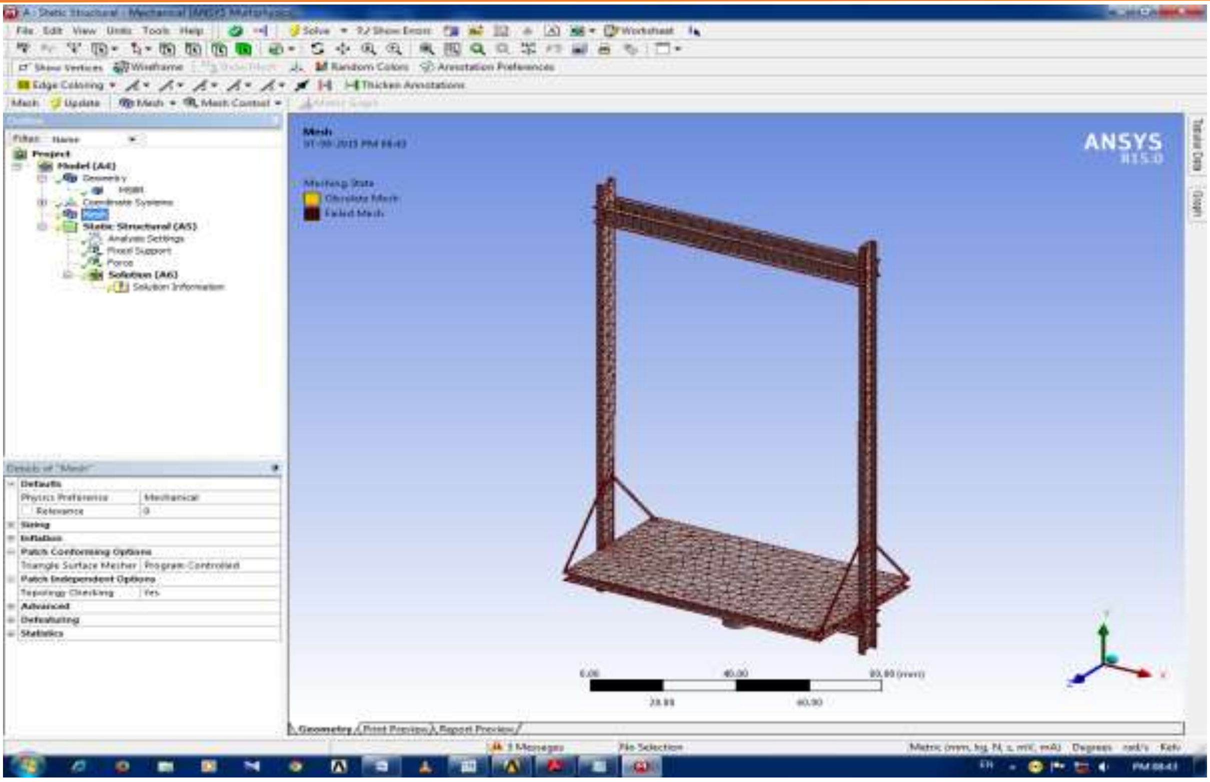

Figure 3.4 Meshing

Deformation Load:

The static structural analysis shows that the high stress areas are near the strike plate. Peak stresses are concentrated at the platform stringers in the region between the two planks., stress shown in this area is approximately 105-163MPa. Stresses decrease to about 37-75MPa as we move away from this region. The uprights and crosshead has very little stress at less than 12Mpa. The A17.1 allowable stress for ASTM A36 steel is 190MPa. The results indicate that the requirement is met. the displacement of the car frame. The maximum buffer compression is 52mm, which consistent with the value predicted. The deformation of the car frame is very low relative to the compression of the buffer.

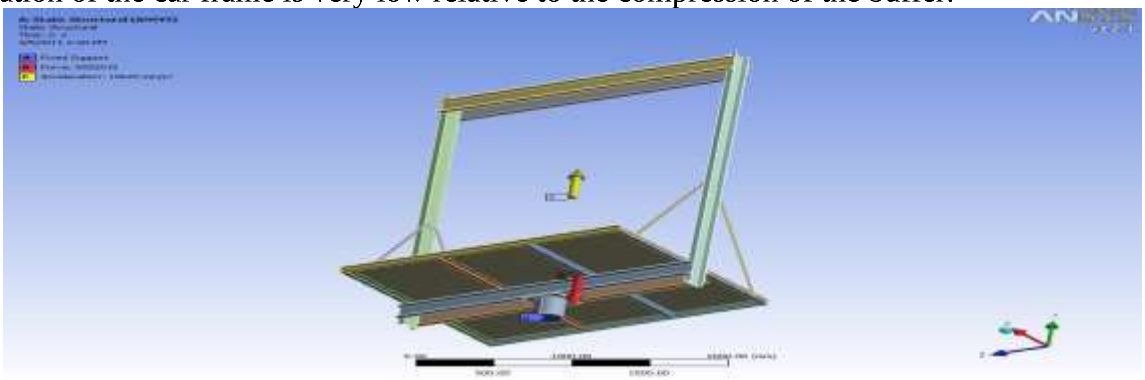

Figure 3.5 Deformation Load

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Equivalent Load

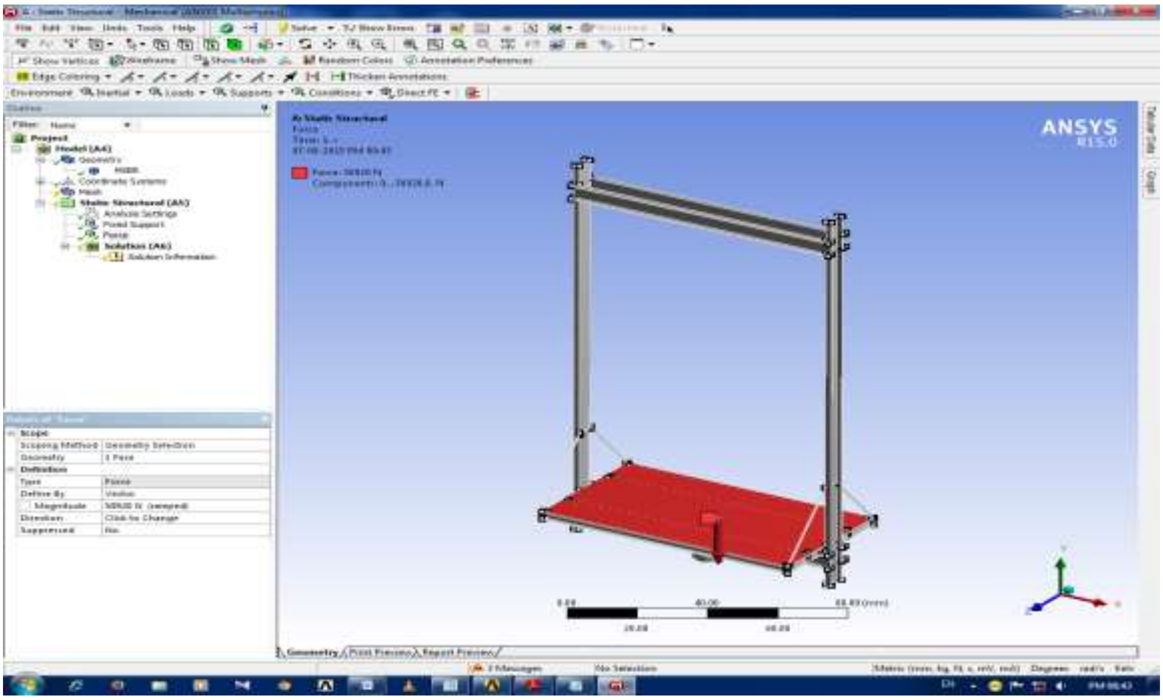

Figure 3.6 Equivalent Load

We use more familiar tools to create models. However, models imported from cad systems may require extensive repair if they are not of suitable quality for meshing. While building the Model in the CAD systems we to observe Ansys solid modelling procedures with regard to planning, symmetry and the amount of detail needed for a finite element analysis. For example, for axis symmetric models, the Ansys program requires that the global Y axis be the axis of rotation. Avoid creating closed curves (that is, a line that starts and ends at the same point) and closed surfaces (such s a surface that starts and ends at the same edge).

Equivalent Elastic Strain

The static structural analysis shows that the high stress areas are near the strike plate. Peak stresses are concentrated at the platform stringers in the region between the two planks, stress shown in this area is approximately 105-163MPa. Stresses decrease to about 37-75MPa as we move away from this region. The uprights and crosshead has very little stress at less than 12Mpa. The A17.1 allowable stress for ASTM A36 steel is 190MPa (3). The results indicate that the requirement is met. the displacement of the car frame. The maximum buffer compression is 52mm, which consistent with the value predicted. The deformation of the car frame is very low relative to the compression of the buffer.

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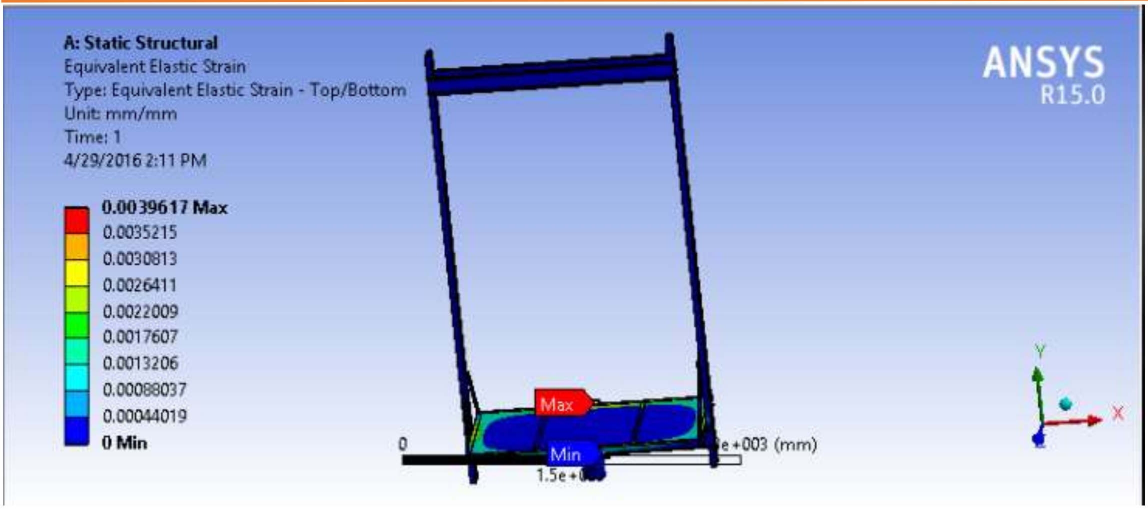

Figure 3.7 Equivalent Elastic Strain – Top/Bottom

Total Deformation

The areas of maximum stress are located on the stringers in the same location found The maximum stress of 80MPa occurs at 75ms, as shown in and the maximum deflection is about 50mm. While calculated deflection is consistent with the static analysis, the maximum stress is about half of the value calculated by static analysis in section 3.1. The results suggest that during a buffer impact, dynamic forces account for about half of the total stresses in the system, while static gravity forces (absent in this analysis) account for the other half of the stresses. The static method, which used 2x static loads, would therefore produce stresses consistent with a dynamic method where gravity is included, as demonstrated.

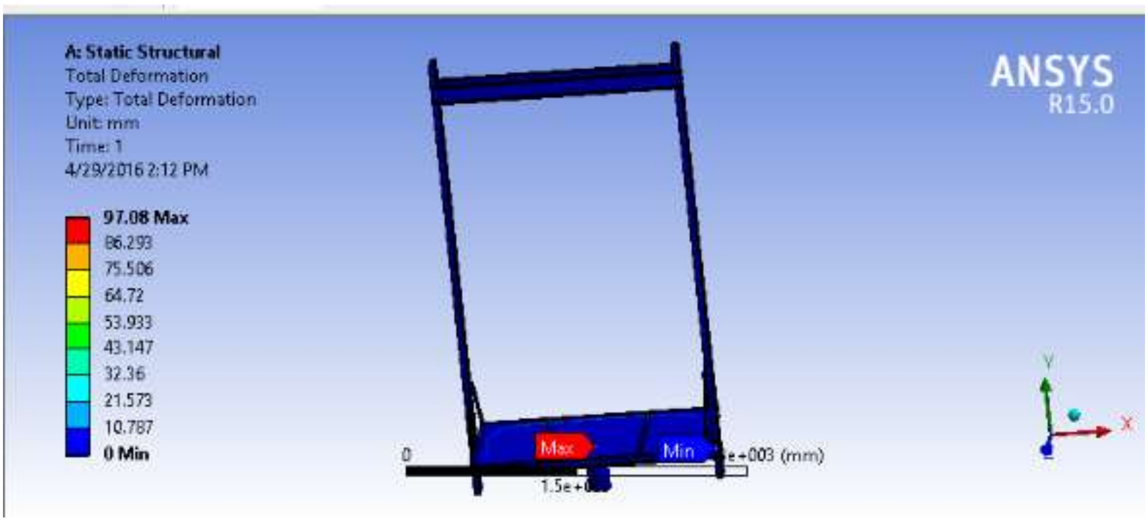

Figure 3.8 Total Deformation

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Equivalent Elastic Strain

Similar to the static structural analysis, this explicit dynamic analysis shows high stresses in the same region of the stringers between the planks, and tracks the stress and displacement of the two representative elements in this region over 400ms. Element E993987 has the highest stresses in the system while its nearby element E1049750 has slightly lower stresses. The results indicate that stresses reach a peak of 155MPa at about 90ms, where displacement is a maximum of approximately 72mm. The displacement is greater than the value calculated by static analysis, but is close to the 80mm predicted by the differential equations in Section 6.3, below. Stresses decrease to about 37-75Max as we move away from this region. The uprights and crosshead has very little Equivalent Elastic strain at less than 12Max. The A17.1 allowable stress for Total Deformation 36 steel is 190Max (3). The results indicate that the requirement is met. the displacement of the car frame. The maximum buffer compression is 52mm, which consistent with the value predicted

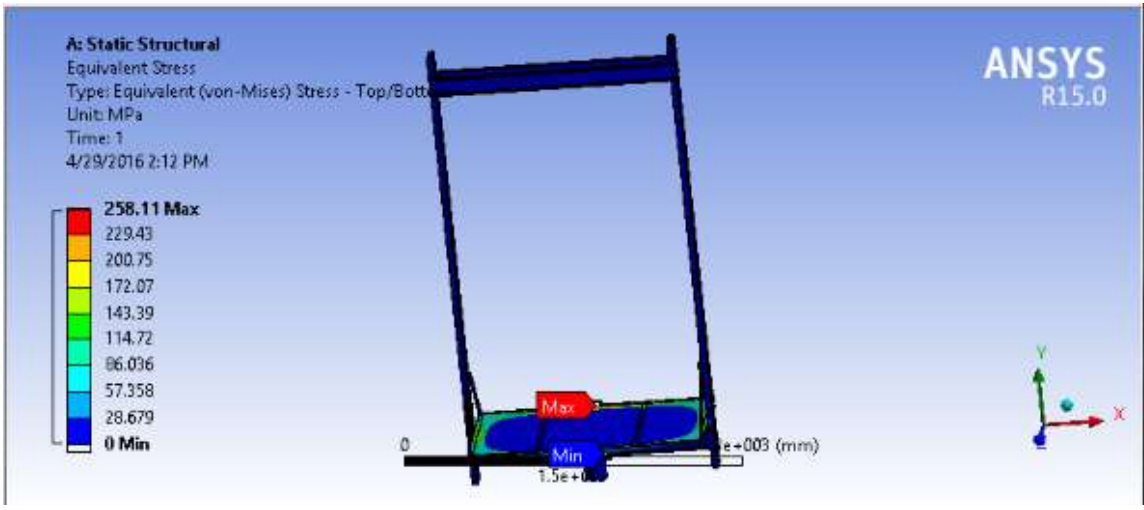

Figure 3.9 Equivalent Elastic Strain -Top/Bottom

S.No.	Name	Result
1	Equivalent (VON-MISS) Stress	250.73 Mpa
2	Equivalent Elastic Strain	0.0013492 mm
3	Total Deformation	32.78 mm

Table 3.1 Resultant Table

4.0 RESULTS AND DISCUSSION

Equivalent (von-miss) Stress, Equivalent Elastic Strain & Total Deformation of Carbon Fiber Rein Forced Polymer Is Increased. When Compared To Mild Steel So it Result Is Better Performance When Used As Car Frame Buffer.

Comparison of results

Table 5.1 Comparison of results

S.No.	Name	Mild steel	Carbon fiber reinforced polymer
1	Equivalent (VON-MISS) Stress	250.73 Mpa	258.11Mpa
2	Equivalent Elastic Strain	0.0013492 mm	0.0039617 mm
3	Total Deformation	32.78mm	97.06mm

5.0 Conclusion

Equivalent (von-miss) Stress, Equivalent Elastic Strain & Total Deformation of Carbon Fiber Rein Forced Polymer Is Increased. When Compared to Mild Steel So it Result Is Better Performance When Used As Car Frame Buffer.

The dynamic method without gravity yielded similar displacement as the static analysis, but the maximum stress was half of the static method. The lack of gravity forces in the system most likely under predicted stresses in the system. Compared to the dynamic method with gravity, this method without gravity does not seem to accurately predict car frame stresses and deflection under buffer impact.

To further validate the analysis presented, an actual test would need to be performed. The car frame and buffer should closely match the properties used for another material that analysis.

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