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Effecting Compliance For Crash Through Design And Analysis Of Front Bumper For Light Vehicle

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ABSTRACT

The development possess of automobiles with regard to crashworthiness behaviour depends strongly on virtual testing and simulation. Thus, development work based on cost intensive prototype construction and testing has been extensively reduce for the body in white as well as for exterior and interior trim. The dramatic shortening of the total development time during the last year need much more front loaded development process. The series development in finished by prototype testing which should confirm the virtual development in an ideal case. Optimization work should close the development before the car's launch. During this phase the focus of numerical simulation changes from a more global view to a very local detail local analysis.

Keywords— **crash, optimization, prototype, simulation**

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I. INTRODUCTION

With the rapid urbanization of society, vehicle miles traveled are also increasing at a rapid pace. As a result, the problem of vehicle crashes has reached alarming proportions. Passenger cars are designed with a structure and features meant to reduce impact and resultant injury to passengers in case of a collision which brings us to the question

A good design of car bumper must provide safety for passengers and should have low weight. Different countries have different performance standards for bumpers. Under the International safety regulations originally developed as European standards and now adopted by most countries outside North America, a car's safety systems must still function normally after a straight-on pendulum or moving-barrier impact of 4 km/h (2.5 mph) to the front and the rear, and to the front and rear corners of 2.5 km/h (1.6 mph) at 45.5 cm (18 in) above the ground with the vehicle loaded or unloaded. In North America (FMSS: Federal Motor Vehicle Safety Standards) and Canada (CMVSS: Canadian Motor Vehicle Safety Standards), it should be meet 4KMPH pendulum and barrier impacts.

The study will focus on modifying few of above stated parameters to suggest improvements in existing bumper of passenger car/ SUV present in Indian markets. First, study will focus on studying existing design and based on observations, design improvements will be suggested. Modified front bumper design will be tested using FEM software for deflection, impact force and stress distribution. Results of modified bumper will be compared against existing design.

The aim of this work is to study front bumper of one of the existing passenger car/ SUV in Indian market. Design modifications can be suggested or tried out on following basis:

1. Performance related parameters of bumper
2. Deflection/ Plastic strain induced to be within the limits specified
3. Thickness or geometry to be manipulated for effecting compliance

FEM is backbone of today's automotive industry. In recent times FE analysis is widely used to validate the complex designs like bumper. Use of FEA not only reduces product development time but also saves lot of cost. Hence, this work proposes FE analysis of bumper to validate the design modifications in from bumper of car.

AIMS:

1. To study and develop front bumper for multinational company like Mahindra and Mahindra, Jon dear, TATA motors in S.U.V./CARS/TRUCKS segment for Indian market.
2. Experimentation for Modal analysis and any other tests would be carried out at secured Test Labs.
3. The development process of automobiles with regard to crashworthiness behavior depends strongly on virtual testing and simulation.

To improve Design features would be published at the end of this exercise

II. OBJECTIVES

1. a To study and develop existing bumper
2. To suggest improvement in design
3. To carry out impact analysis using explicit solver and develop bumper design
4. To recommend implementation of enhancement maid in design
5. To carry out model analysis for finding out natural frequency to avoid resonance

III.LITERATURE SURVEY

a **Jovan Obradovic, SimonettaBoria, Giovanni Belingardi"Lightweight design and crash analysis of composite frontal impact energy absorbing structures."** This paper is presenting the steps to follow in order to design specific lightweight impact attenuators. Only after having characterised the composite material to use, it is possible to model and realise simple CFRP tubular structures through mathematical formulation and explicit FE code LS-DYNA. Also, experimental dynamic tests are performed by use of a drop weight test machine. Achieving a good agreement of the results in previously mentioned analyses, follows to the design of impact attenuator with a more complex geometry, as a composite nose cone of the Formula SAE racing car. In particular, the quasi-static test is performed and reported together with numerical simulation of dynamic stroke.

Ping Zhu , Yu Zhang , Guanlong Chen,"Metamodeling development for reliability-based design optimization of automotive body structure". Metamodels are commonly used in reliability-based design optimization (RBDO) due to the enormously expensive computation cost of numerical simulations. However, for large-scale design optimization of automotive body structure, with the increasing number of design variable and enhanced nonlinearity degree of structural performance, polynomial response surface which is commonly used for vehicle design optimization often suffers exponentially increased computation burden and serious loss of approximation accuracy. In this paper, support vector regression, along with other four complex met modeling techniques including moving least square, artificial neural network, radial basis function and Kriging, is investigated for approximating frontal crashworthiness performance which is one of the most highly nonlinear performances. It aims at testing support vector regression and providing advanced metamodeling technique for RBDO of automotive body structure.

XinYang ,YongXia, QingZhou, Pei-ChungWang, KathyWang,"Modeling of high strength steel joints bonded with toughened adhesive for vehicle crash simulations". Improvement of the structural adhesive increases the difficulties in crash simulations of adhesive-bonded vehicle structures. In this paper, a simplified finite A method that can correct the variation of adhesive thickness is developed. The input failure parameters of the material model are identified with simulations of adhesive-bonded coach-peel and lap-shear coupon tests.

RecepGmruk, Sami Karadeniz,"The influences of the residual forming data on the quasi-static axial crash response of a top-hat section". In this paper the influences of residual effects of a deep drawing forming process on the axial quasi- static crash behaviour of straight thin-walled top-hat section were numerically investigated. The residual forming data on the plastic strains, residual stresses and thickness variations were transferred to crash models, which include both deformed and nominal meshes. The influence of spring-back or spring-in on crash performance of the member was also considered. Numerical simulations were carried out by using the nonlinear finite element code LS-DYNA. As a result of these analyses it appears that the residual forming data and the effects of spring-back significantly influence the crash response and they should be considered in computational impact simulations.

O.G. Lademo,T. Berstad, M. Eriksson, T. Trylandb, T. Furu, O.S. Hopperstad, M.Langseth, "A model for process-based crash simulation". Manufacturing of a bumper system from aluminium extrusions often involves series of forming operations performed in the soft Wtemper condition, and then artificially age-hardening of the components to the material's peak hardness T6 condition. It is probable that proper finite element (FE) modelling of the crash performance of the resulting systems must rely upon a geometry obtained from an FE model following the process route, i.e., including simulation of all major forming operations. The forming operations also result in an inhomogeneous evolution of some internal variables (among others the effective plastic strain) within the shaped components. Results from tensile tests reveal that plastic straining in W-temper leads to a significant change of the T6 work-hardening curves.

F.İncea, H.S. Türkmena, Z. Mecitoğlua, N. Uludağb, İ Durgunb, E. Altınokb, H.Örenelb, "A numerical and experimental study on the impact behavior of box structures"The safety factor of a vehicle mostly depends on the behavior of frontal automotive structures during crash. These structures, which are usually prismatic thin walled structures and are defined as crash boxes, are the main energy absorbers of the crash. Crashworthiness of these structures depends on their dimensions and materials. In this study, the impact behavior of the crash boxes made of steel and aluminum materials are investigated experimentally and numerically. The crash tests are performed by using a drop test unit. The crash test is also modeled using the ANSYS element software.

Tso-Liang Tenga, Fwu-An Chang, Yung-Sheng Liu, Cheng-Ping Peng, "Analysis of dynamic response of vehicle occupant in frontal crashusingmultibody dynamics method". Multibody analyses have been applied extensively in biodynamic modeling and in investigations of the dynamic behavior of biosystems. This study employs the multibody dynamics method to explore frontal collision phenomena. Specifically, this study examines the dynamic response of the human body in a crash event and assesses the injuries sustained to the occupant's head, chest and pelvic regions. Kane's method is used to obtain the governing equations describing the response of the occupant. These equations are then coded into a computer program and solved using fourth-order Runge–Kutta methods.

Bryan C. Baker, Joseph M. Nolan, Brian O'Neill, Alexander P. Genetos "Crash compatibility between cars and light trucks: Benefits of lowering front-end energy-absorbing structure in SUVs and pickups". Passenger vehicles are designed to absorb crash energy in frontal crashes through deformation or crush of energy-absorbing structures forward of the occupant compartment. In collisions between cars and light trucks (i.e., pickups and SUVs), however, the capacity of energy-absorption structures may not be fully utilized because mismatches often exist between the heights of these structures in the colliding vehicles.

Nader Abedrabbo, Robert Mayer, Alan Thompson,Christopher Salisbury,Michael Worswick, Isadora van Riemsdijk, "Crash response of advanced high-strength steel tubes: Experiment and model". The performance of non-hydroformed and hydroformed structural steel tubes in component-level crash testing was investigated

using both experimental and analytical techniques. In particular, the focus was on high-strength steels that may have potential to enhance crashworthiness of automobiles. Monolithic tubes made from multiple materials and wall thicknesses were considered in this study. The following materials were used: conventional drawing quality (DDQ) steels; high-strength low alloy (HSLA-350) steels; and advanced high-strength steel (AHSS) materials comprising the dual phase alloys DP600 and DP780.

Liquan Mei, C.A. Thole, "Data analysis for parallel car-crash simulation results and model optimization". The paper discusses automotive crash simulation in a stochastic context, whereby the uncertainties in numerical simulation results generated by parallel computing. Since crash is a non-repeatable phenomenon, qualification for crashworthiness based on a single test is not meaningful, and should be replaced by stochastic simulation. But the stochastic simulations may generate different results on parallel machines, if the same application is executed more than once. For a benchmark car model, differences between the position of a node in two simulation runs of PAMCRASH or LS-DYNA of up to 10 cm were observed,

JavadMarzbanrad, Masoud Alijanpour, MahdiSaeidKiasat, "Design and analysis of an automotive bumper beam in low-speed frontal crashes"In this paper, the most important parameters including material, thickness, shape and impact condition are studied for design and analysis of an automotive front bumper beam to improve the crashworthiness design in low-velocity impact. The simulation of original bumper under condition impact is according to the low-speed standard of automotives stated in E.C.E. United Nations Agreement, Regulation no. 42, 1994. The bumper beam analysis is accomplished for composite and aluminum material to compare the weight and impact behavior. The strength in elastic mode is investigated with energy absorption and impact force in maximum deflection situation.

IV. METHODOLOGY

This study will use commercial FEA tools such as ANSYS, Abacus, LSDYNA, etc for carrying out FE analysis limited to the Bumper as a single component (though, the boundary conditions would take into consideration its fitment with the mating parts in the assembly).

FINITE ELEMENT ANALYSIS:

Finite element method is used to analyze structures by computer simulations and therefore it helps to reduce the

time required for prototyping and to avoid numerous test series. The modeling and analysis will be done using Finite element Analysis software.

STEPS FOR FINITE ELEMENT ANALYSIS:

FEA is mainly divided into three following stages:

Preprocessing:

1. Creating the model.
2. Defining the element type
3. Defining material properties
4. Meshing
5. Applying loads
6. Applying boundary conditions

Solution: Solving the pre-processed geometry using a suitable Solver

Post processing: Review of results such as deformation plot, stress plot, etc

For alternative method of computation validation, the component would be tested over a physical setup by the Sponsoring Company. The results so obtained would be shared by the Company via a Test Certificate issued upon request.

V. EXPERIMENTAL SETUP

1 FULL-WRAP FRONTAL COLLISION TEST:-

Dummies are placed in both the driver's and passenger's seats and the vehicle is made to collide with a concrete barrier at a rate of 55 km/h. Actual collisions of this type tend to occur at speeds lower than that of this test.

The dummies are then checked for injuries to the head, neck, chest and legs, the vehicle is checked for damage and deformation, and the results are used to evaluate the degree of passenger protection in 5 levels.

Fig 10st.1 Car Crashed Front View

10.2 OFFSET FRONTAL COLLISION TEST:-

The dummies are placed in the driver's and front passenger's seats and the test vehicle is made to collide head-on with an aluminum honeycomb, on the driver's side (at an offset of 40%). The dummies are checked for injuries to the head, neck, chest and legs, the vehicle is checked for damage and deformation, and the results are used to evaluate the degree of passenger protection in 5 levels.

Actual collisions of this type tend to occur at speeds lower than that of this test. It may be noted that the results of this test do not apply to collisions at extremely high speeds, and/or other types of collisions such as when passengers are not wearing seatbelts, and/or collisions in which one of the vehicles is a large truck.

Fig 10.2 Car crashed Top View

10.3 SIDE COLLISION TEST:-

Among the passenger injuries which occur in automobile collisions, side collisions cause the most damage next to frontal collisions. In this test, a truck with a weight of 950 kg is made to collide at a speed of 55 km/h with the side of a stationary test vehicle with a dummy in the driver's seat. The dummy is checked for injuries to the head, chest, abdomen, and waist, and the results are used to evaluate the degree of passenger protection in 5 levels.

The front of the truck, which has been made to look like a normal passenger car, has also been fitted with a shock absorbent aluminum honeycomb which provides a similar degree of hardness as such a vehicle.

Actual collisions of this type tend to occur at speeds lower than that of this test. It may be noted that the results of this test do not apply to collisions at extremely high speeds, and/or other types of collisions such as when passengers are not wearing seatbelts, and/or collisions in which one of the vehicles is a large truck.

Fig 10.3 Car crashed by side

10.4 DUMMIES USED IN COLLISION TESTS:-

The dummy's job is to simulate a human being during a crash, while collecting data that would not be possible to collect from a human occupant. All crash tests are conducted using the same type of dummy. This guarantees consistent results. A dummy is built from materials that mimic the physiology of the human body. For example, it has a spine made from alternating layers of metal discs and rubber pads. The dummies come in different sizes and they are referred to by percentile and gender. For example, the fiftieth-percentile male dummy represents the median sized male -- it is bigger than half the male population and smaller than the other half.This dummy was developed in the United States and represents the average adult male. It is 188 cm in height and weighs 85 kg. In the side collision tests, the Euro SID-1 dummy is used. This dummy was developed in Europe and is 188 cm in height and weighs 85 kg.

In the full-wrap and offset frontal collision tests, the Hybrid III dummy (pictured below) is used to represent a human body.

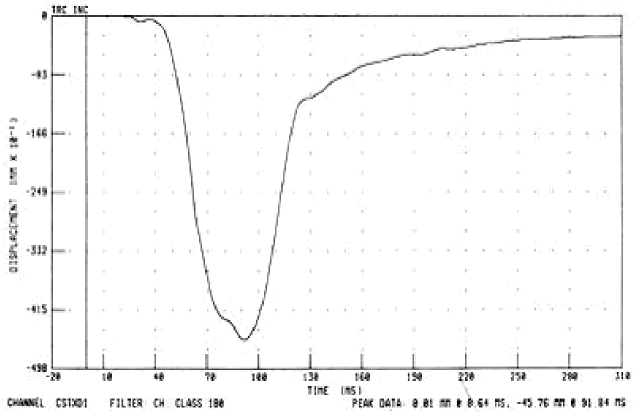
Fig 10.5 Dummy

The dummies contain three types of instrumentation:-

10.4.1 Accelerometers
10.4.2 Load sensors
10.4.3 Motion sensors

These are described below:-

10.4.1



ACCELEROMETERS:-

These devices measure the acceleration in a particular direction. This data can be used to determine the probability of injury. Acceleration is the rate at which speed changes. For example, if you bang your head into a brick wall, the speed of your head changes very quickly (which can hurt!). But, if you bang your head into a pillow, the speed of your head changes more slowly as the pillow crushes (and it doesn't hurt!).The crash-test dummy has accelerometers all over it. Inside the dummy's head, there is an accelerometer that measures the acceleration in all three directions (fore-aft, up-down, left-right). There are also accelerometers in the chest, pelvis, legs, feet and other parts of the body.

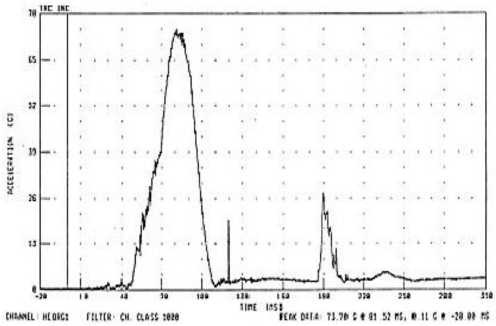


Fig 10.6 Graph for Acceleration Vs time

The graph above shows the acceleration of the driver's head during a 35 mph (56.3 kph) frontal crash. Notice that it is not a steady value, but fluctuates up and down during the crash. This reflects the way the head slows down during a crash, with the highest values coming when the head strikes hard objects or the airbag

10.4.2 LOAD SENSORS

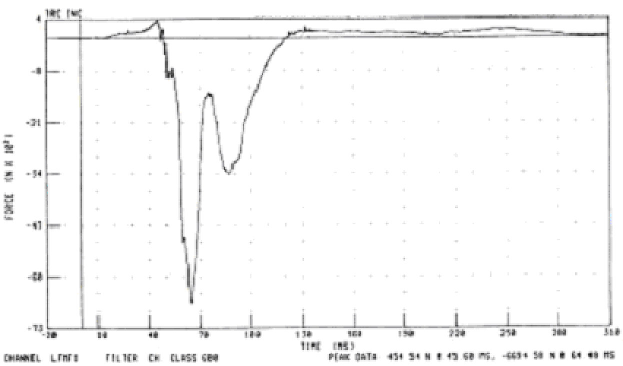


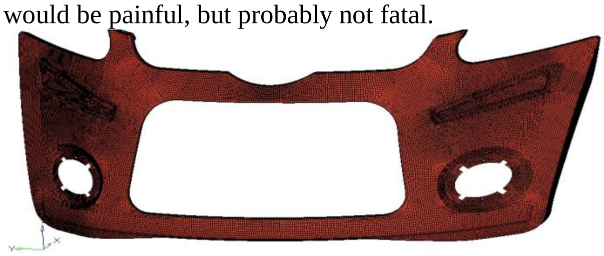
Fig10.7Graph of the force in the driver's femur during a crash

Inside the dummy are load sensors that measure the amount of force on different body parts during a crash. The graph above shows the force in Newton in the driver's femur (the thigh bone), during a 35-mph frontal crash. The maximum load in the bone can be used to determine the probability of it breaking.

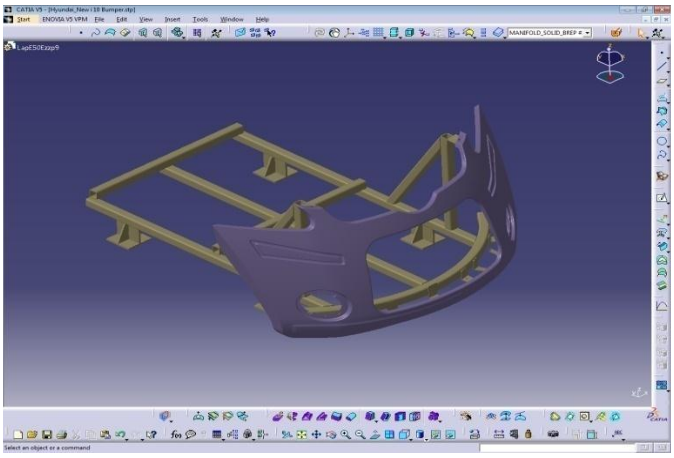
Property	**units**	**Base PP Homop olymer**	**0% glass**	**0% glass s**	**0% glass filled PP**
Density	g/cc	0.90	1.06-1.08	1.15-1.17	.19-1.21
Tensile strength at yield	MPa	35	35.5	36.0	37.0
Tensile strength at break	MPa	23	32.5	35.0	36.0
Elongation at break	%	60	30	20	30
Flexural strength	MPa	330	440	450	450
HDT 66 psi	deg. C.	75	90	97	112

fig10.8 Chest deflection during a 35mph frontal impact

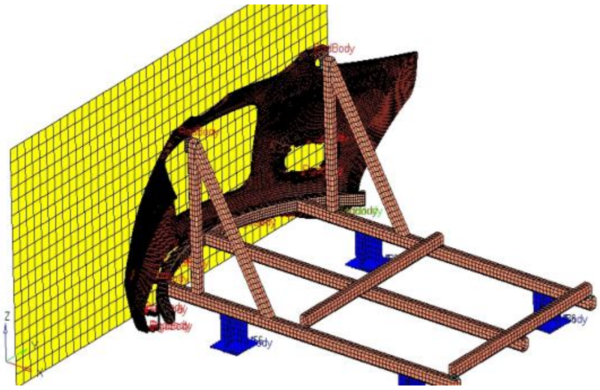
10.4.3 MOMENT SENSOR ;-These sensors are used in the dummy's chest. They measure how much the chest deflects during a crash.The scan above shows the driver's chest deflection during a crash. In this particular crash, the driver's chest is compressed about 2 inches (46 mm). This injury would be painful, but probably not fatal.



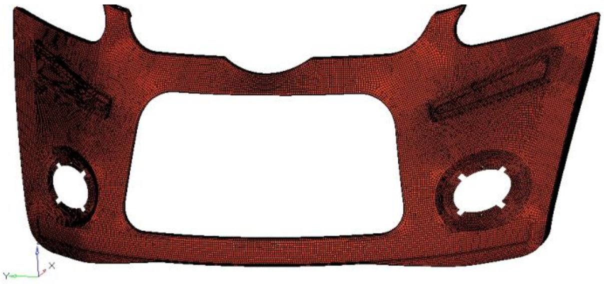
MESHING OF FRONT BUMPER



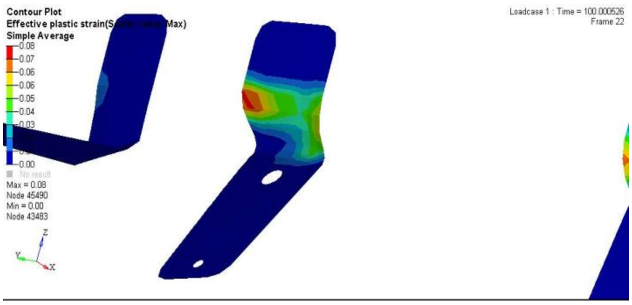
3 D GEOMENTRY



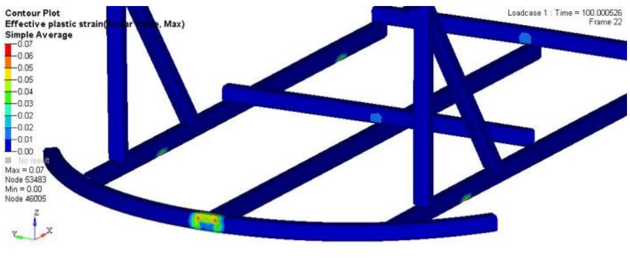
ISOMETRIC VIEW OF FRONT BUMPER



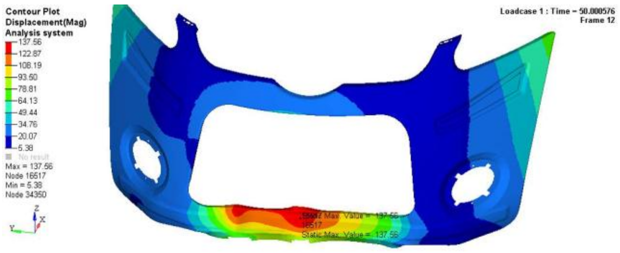
CASE 1: THICKNESS 4MM



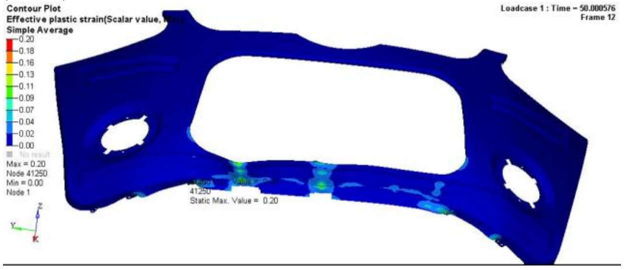
PLASTIC STRAIN ANALYSIS OF BRACKET



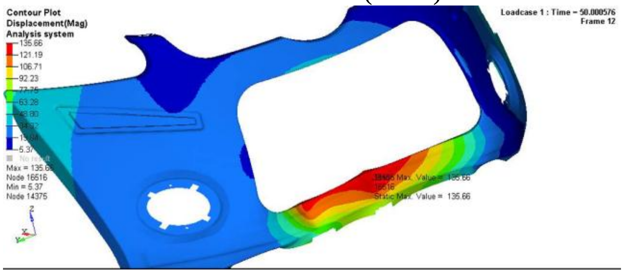
PLASTIC STRAIN ANALYSIS OF SRUCTURE



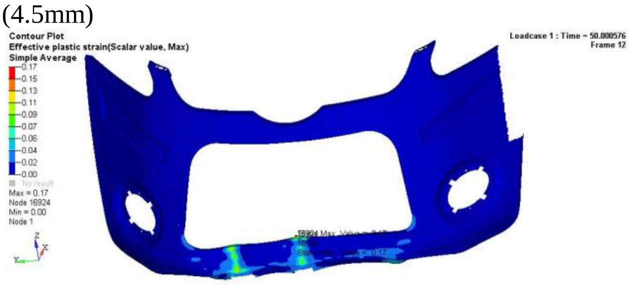
DISPLACEMENT ANALYSIS OF FROMT BUMPER (4mm)



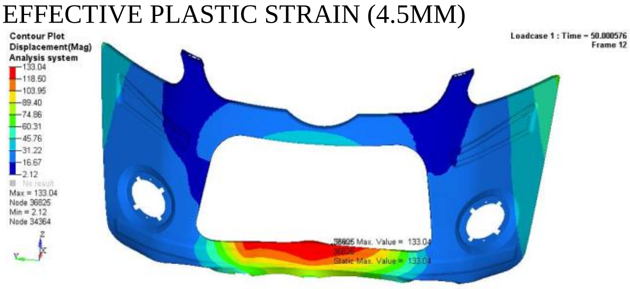
EFFECTIVE PLASTIC STRAIN (4MM)



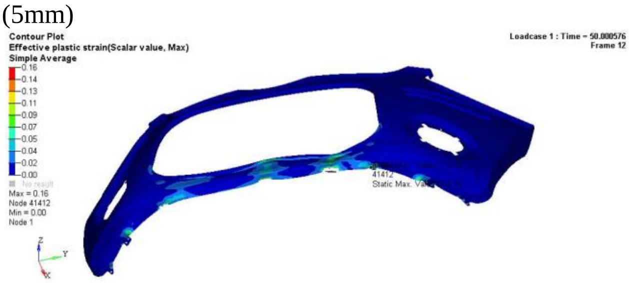
DISPLACEMENT ANALYSIS OF FROMT BUMPER (4.5mm)



EFFECTIVE PLASTIC STRAIN (4.5MM)



DISPLACEMENT ANALYSIS OF FROMT BUMPER (5mm)



EFFECTIVE PLASTIC STRAIN (5MM)

CALCULATION FOR V= 4 Km/ hr

3. POINT BEND TEST CALCULATIONS

Input data :

Mass of bumper = 2.6 Kg

Mass of rigid frame = 10 Kg

Total mass of assembly = 12.6 Kg

Deacceleration time = 0.005 sec

Initial velocity of bumper = 4 Km/hr

= 4*1000/3600

V= 1.111 m/sec

Final velocity of bumper = 0 Km/hr

Deacceleration of bumper = a = V_2-V_1/.005

= 0-1.111/.005

a = 222.2 m/sec^2

Force on front bumper : F= m*a

=12.6*222.2

= 2.8*10^3 N

F = 2.8 KN

Force on front bumper : F= m*a

=12.6*555.4

= 6.999*10^3 N

F = 7 KN

Analysis of bumper for force: F = 2.8 KN

M_{max} = w*l/4

= 2.8*10^3*70/4

M_{max} = 49*10^3 N-mm

σ_c/Y= M/I

= M*Y/I

I = 1/12 * b*d^3

I = 1/12 0*4.17*4^3

I = 222.4 mm^4

σ_c = M*Y_c /I

= 49*10^3 * 2 / 222.4

σ_c = 440.64N/mm^2

Y_{max} = PL^3/ 48 EI

= 2.8*10^3*70^3/48*2500*222.4

Y_{max} = 35.98 mm

Elasticity of given material :**E = 2500 Mpa**

E = 2500 N/mm^2

σ=E*e

e= σ_c / E

= 440.64/2500

= 0.1762

e = 17.62 %

% Elongation safe zone= 15 %

We have to change thickness of bumper for reducing plastic strain

Analysis of bumper for F = 7 KN

t = 4 mm

F = 7 KN

Gauge length – 190 mm

Total length = L = 1350 mm

Support length =L_1= 3.5 feet

=3.5*12*25

L_1=1097.28 mm

M_{max} = w*L_1/4

= 7*10^3*190/4

M_{max} = 332.5*10^3 N-mm

σ_c/Y= M/I

= M*Y/I

I = 1/12 * b*d^3

I = 1/12 *280*4^3

I = 1.493*10^3 mm^4

σ_c = M*Y_c /I

= 332.5*10^3 * 2 / 1.493*10^3

σ_c = 445.41N/mm^2

Y_{max} = PL^3/ 48 EI

= 7*10^3*190^3/48*2500*1.493*10^3

Y_{max} = 267.98 mm

Elasticity of given material : E = 2500 Mpa

E = 2500 N/mm^2

σ=E*e

e= σ_c / E

= 445.41/2500

= 0.1781

e = 17.81 %

% Elongation safe zone= 15 %

We have to change thickness of bumper for reducing plastic strain

Calulation for mass;-

1.Density of bumper=ρ=1.75*10^3 Kg/m3

=1.75*10^{-6} Kg/mm3

m= ρ* V

= 1.75*10^{-6} *1330*280*4

m =2.60Kg

Energy absorb=$1/2\ mV2$

=1/2*2.60*2.77^2

=9.974 J

2.Density of bumper=ρ=1.75*10^3 Kg/m^3

=1.75*10^{-6} Kg/mm^3

m= ρ* V

= 1.75*10^{-6} *1330*280*4.5

m =2.93Kg

Energy absorb=1/2 mV^2

=1/2*2.93*2.77^2

=11.24 J

3.Density of bumper=ρ=1.75*10^3 Kg/m3

=1.75*10^{-6} Kg/mm3

m= ρ* V

= 1.75*10^{-6} *1330*280*5

m =3.25Kg

Energy absorb=1/2 mV^2

=1/2*3.25*2.77^2

=12.46 J

VI.RESULT

Velocity	Iteration	Bumper Thikness	Plastic strain(%)	Mass of bumper	Maximum center point Deflection
10 Km/hr Type=3 Compression testing	1	4 mm	17.81	2.6Kg	267.98 mm
	2	4.5mm	Below 16%	2.9Kg	200.00mm
	3	5 mm	Below 15%	3.23Kg	150mm

Velocity	Iteration	Bumper Thikness	Maximum center point Deflection	Plastic strain(%)
4 Km/hr Type=3 Point bending testing	1	4 mm	35.98 mm	17.62%
	2	4.5mm	---	Below 16%
	3	5 mm	---	Below 15%

Velocity	Iteration	Bumper Thikness	Maximum center point Deflection	Plastic strain(%)
10 Km/hr Type=3 Compression testing	1	4 mm	267.98 mm	17.81%
	2	4.5mm	---	Below 16%
	3	5 mm	---	Below 15%

Velocity	Iteration	Bumper Thikness	Mass of bumper	Plastic strain(%)	Energy absorb
10 Km/hr Type=3 Compression testing	1	4 mm	2.6Kg	17.81%	9.974 J
	2	4.5mm	2.9Kg	Below 16%	11.24 J
	3	5 mm	3.23Kg	Below 15%	12.46 J

VII.CONCLUSION

In this presentation the composite material model in LS-DYNA, ANSYS enhanced respectively implemented within the project has been described and their failure parameter has been discussed. Using simple test problem, the general mode of operation was shown. We study and develop front bumper for S.U.V./CARS/TRUCKS segment for Indian market. Experimentation for Modal analysis and any other tests would be carried out at secured Test Labs in ABLE India technologies, pvt.ltd. The development process of automobiles with regard to crashworthiness behavior depends strongly on virtual testing and simulation.

Hence we study and develop existing bumper in testing lab and suggest improvement in design by carry out impact analysis using explicit solver and develop bumper and recommend implementation of enhancement maid in design carry out model analysis for finding out natural frequency to avoid resonance.

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