ANALYSIS OF AUTOMOTIVE MATERIALS ON IMPACT LOADS AND ENERGY LEVELS

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Abstract: Most of the automobile materials are subjected to various dynamic loadings under various sets of performance parameters such as air resistance, grade resistance and tractive and traction efforts and many more. Thus it is very necessary for any automobile manufacturer to have a keen knowledge on the materials selection for the specific automotive application. The impact or failure analysis ensures the optimum results of the failure rate at specific energy levels or under specific loading conditions. To ensure the safety of the occupants as well as the pedestrians it is very important to have a proper selection of the material for the automobile body. For proper selection of materials there is a need of impact test under various energy levels and impact loads. With the ease of materials test under various sets of impact test, the most reliable material is obtained which will ensure the safety of the occupants during impact.
Index Terms: Impact, GI Sheet, Reinforced Plastic,

I. INTRODUCTION

Safety of an automobile can be ensured by two main considerations. Firstly, the design should be such that chances of accident happening are minimum and secondly, if the accidents does take place, the injury to the occupants should be minimum. The details is as discussed below:
Preventive Design.
This should aim at driver comfort and safety design of various vehicle systems. Such vehicle features which help prevent crash by providing the driver with better ways of controlling the vehicle and avoiding hazards are called active safety features.

- There should be largest possible glass area with minimum blind spots caused by body pillars. This will increase the driver's efficiency in heavy traffic conditions.
- Good mirrors will enable the driver to see potential hazards when reversing, parking or changing the lanes.
- Headlights must be of good design and adequate intensity of the lights. They should give the driver a good view of road ahead and roadside without distracting.
- The instrument panel should be so designed that the driver should be able to read all the parameters without any distractions.

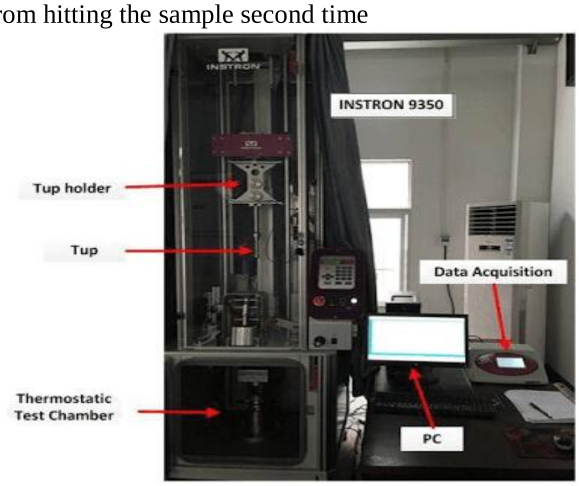
Designing for minimum injury in case of accident.
Passive safety features are the features which prevent or minimise injury to the vehicle's occupants in a crash. Some of these help absorb the crash forces, some restrain the occupants from colliding the vehicle interior, while others prevent objects inside the vehicle from striking the occupants.
Thus it is very important from the point of safety to analyse the various materials to be used in automobile to check under various safety limits to ensure best results

II. EXPERIMENTAL METHODOLOGY

The experimental analysis was conducted on INSTRON CEAST 9350. The CEAST 9350 is a floor standing impact system designed to deliver 0.59 to 757 J or up to 1,800 J with optional high energy system. The CEAST 9350 works with impact software and data acquisition system. The details of the INSTRON CEAST 9350 is as follows:

Sr.No.	Specifications	Range
1.	Energy	0.59 to 1800 J
2.	Speed	0.77 to 24 m/s
3.	Drop Height (Simulated)	0.03 to 29.4 m

The machine is equipped with weighing system that measures the total weight of the falling mass and tup inserts. Also the specimen feeding system is equipped to perform tests in automatic cycle within the environmental chamber. It also has an environmental chamber that can cool specimen to -70 or heat specimen to + 150 degree Celsius. It is also equipped with high energy configuration setup and an automatic lubrication system eliminates friction effects between the tup insert and the test sample. Also it has the anti-rebound system that can catch the crosshead-preventing it from hitting the sample second time



Setup of INSTRON CEAST 9350

III. THEORIES OF FAILURE

These are five different theories of failures which are generally used

(a) Maximum Principal stress theory (Due to Rankine)
(b) Maximum shear stress theory (Guest - Tresca)
(c) Maximum Principal strain (Saint - venant) Theory
(d) Total strain energy per unit volume (Haigh) Theory
(e) Shear strain energy per unit volume Theory (Von – Mises & Hencky)

In all these theories we shall assume.

σ_{Yp} = stress at the yield point in the simple tensile test.

σ_1, σ_2, σ_3 are the three principal stresses in the three dimensional complex state of stress systems in order of magnitude.

(a) Maximum Principal stress theory:

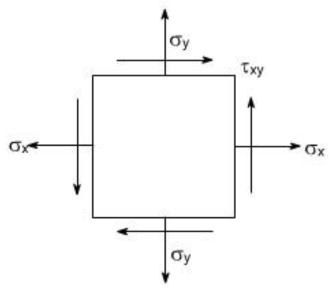
This theory assume that when the maximum principal stress in a complex stress system reaches the elastic limit stress in a simple tension, failure will occur.

Therefore the criterion for failure would be

$\sigma_1 = \sigma_{yp}$

For a two dimensional complex stress system σ_1 is expressed as

$$\sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \frac{1}{2}\sqrt{(\sigma_x - \sigma_y)^2 + 4.\tau_{xy}^2}$$
$$= \sigma_{yp}$$



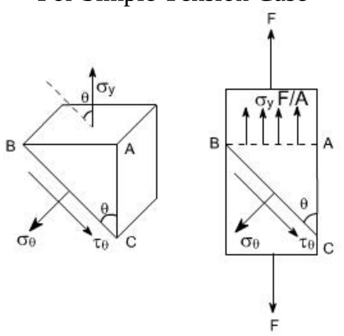
Where σ_x, σ_y and σ_{xy} are the stresses in the any given complex stress system.

(b) Maximum shear stress theory:

This theory states that the failure can be assumed to occur when the maximum shear stress in the complex stress system is equal to the value of maximum shear stress in simple tension.

The criterion for the failure may be established as given below:

For Simple Tension Case



$$\sigma_\theta = \sigma_y \sin^2\theta$$
$$\tau_\theta = \frac{1}{2}\sigma_y \sin 2\theta$$
$$\tau_\theta\big|_{max^m} = \frac{1}{2}\sigma_y \quad \text{or}$$
$$\tau_{max^m} = \frac{1}{2}\sigma_{yp}$$

whereas for the two dimentional complex stress system

$$\tau_{max^m} = \left(\frac{\sigma_1 - \sigma_2}{2}\right)$$

where σ_1 = maximum principle stress

σ_2 = minimum principal stress

$$\text{so} \quad \frac{\sigma_1 - \sigma_2}{2} = \frac{1}{2}\sqrt{(\sigma_x - \sigma_y)^2 + 4\tau^2 xy}$$
$$\frac{\sigma_1 - \sigma_2}{2} = \frac{1}{2}\sigma_{yp} \Rightarrow \sigma_1 - \sigma_2 = \sigma_y$$
$$\Rightarrow \sqrt{(\sigma_x - \sigma_y)^2 + 4\tau^2 xy} = \sigma_{yp}$$

becomes the criterion for the failure.

(c) Maximum Principal strain theory:

This Theory assumes that failure occurs when the maximum strain for a complex state of stress system becomes equals to the strain at yield point in the tensile test for the three dimensional complex state of stress system.

For a 3 - dimensional state of stress system the total strain energy U_t per unit volume in equal to the total work done by the system and given by the equation

$$U_t = 1/2\sigma_1 \in_1 + 1/2\sigma_2 \in_2 + 1/2\sigma_3 \in_3$$

substituting the values of $\in_1, \in_2$ and $\in_3$

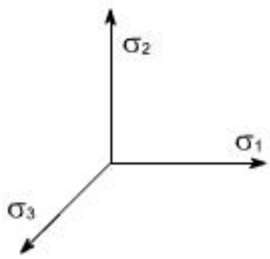
$$\in_1 = \frac{1}{E}[\sigma_1 - \gamma(\sigma_2 + \sigma_3)]$$
$$\in_2 = \frac{1}{E}[\sigma_2 - \gamma(\sigma_1 + \sigma_3)]$$
$$\in_3 = \frac{1}{E}[\sigma_3 - \gamma(\sigma_1 + \sigma_2)]$$

Thus, the failure criterion becomes

$$\left(\frac{\sigma_1}{E} - \gamma\frac{\sigma_2}{E} - \gamma\frac{\sigma_3}{E}\right) = \frac{\sigma_{yp}}{E}$$

or

$$\boxed{\sigma_1 - \gamma\sigma_2 - \gamma\sigma_3 = \sigma_{yp}}$$



(d) Total strain energy per unit volume theory:
The theory assumes that the failure occurs when the total strain energy for a complex state of stress system is equal to that at the yield point a tensile test.

$$\frac{1}{2E}\left[\sigma_1^2+\sigma_2^2+\sigma_3^2-2\gamma(\sigma_1\sigma_2+\sigma_2\sigma_3+\sigma_3\sigma_1)\right]=\frac{\sigma_{yp}^2}{2E}$$

$$\sigma_1^2+\sigma_2^2+\sigma_3^2-2\gamma(\sigma_1\sigma_2+\sigma_2\sigma_3+\sigma_3\sigma_1)=\sigma_{yp}^2$$

It may be noted that this theory gives fair by good results for ductile materials.

(e) Maximum shear strain energy per unit volume theory:
This theory states that the failure occurs when the maximum shear strain energy component for the complex state of stress system is equal to that at the yield point in the tensile test.

$$\frac{1}{12G}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right]=\frac{\sigma_{yp}^2}{6G}$$

Where G = shear modulus of regidity

$$\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right]=2\sigma_{yp}^2$$

As we know that a general state of stress can be broken into two components i.e.,
(i) Hydrostatic state of stress (the strain energy associated with the hydrostatic state of stress is known as the volumetric strain energy)
(ii) Distortional or Deviatoric state of stress (The strain energy due to this is known as the shear strain energy)
As we know that the strain energy due to distortion is given as

$$U_{distortion}=\frac{1}{12G}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right]$$

This is the distortion strain energy for a complex state of stress; this is to be equaled to the maximum distortion energy in the simple tension test. In order to get we may assume that one of the principal stress say (σ_1) reaches the yield point (σ_{yp}) of the material. Thus, putting in above equation $\sigma_2 = \sigma_3 = 0$ we get distortion energy for the simple test i.e.

$$U_d=\frac{2\sigma_1^2}{12G}$$

Futher $\sigma_1 = \sigma_{yp}$

Thus, $\boxed{U_d=\frac{\sigma_{yp}^2}{6G}}$ for a simple tension test.

IV. SIMULATION 1

The result of tested specimens is as follows. The simulation 1 has GI sheet as test specimen.

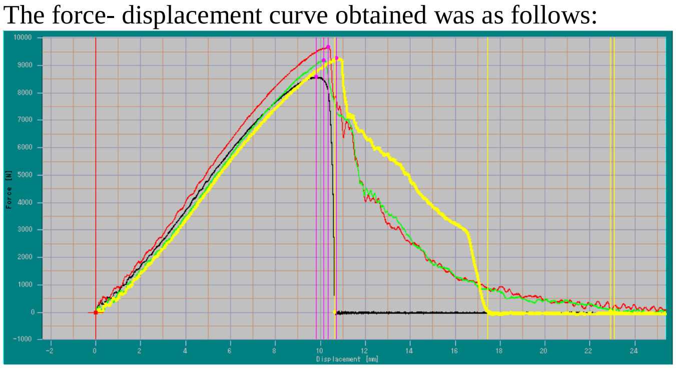
Sr. No.	Impact Energy (J)	Peak Force(N)	Peak Energy (J)	Total Energy (J)
1.	50.00 J	8588.22 N	45.233 J	51.26 J
2.	203.28 J	9668.80 N	53.768 J	79.86 J
3.	150.00 J	9177.88 N	47.306 J	74.95 J
4.	80.00 J	9279.45 N	51.403 J	82.96 J

Tested GI Specimen results

Four GI specimen was been tested on INSTRON CEAST 9350. The detailed report is been tabulated as above. The first specimen was tested for 50 J of energy, the peak force obtained was 85882.22 N, and at this energy level the material showed elastic deformation. Further for next two readings the specimen raptured under loading condition, which clearly indicates that the specimen was unsafe during the impact loading conditions. The final impacted also shows elastic deformation. Thus it is clear from the impact energy values the material (GI Sheet) is safe within limits 50 J to 80 J of energy respectively.

Tested GI Sheets.

The force- displacement curve obtained was as follows:



V. RESULT & CONCLUSION

From the graph it is clear that specimen 1 and specimen 2 is within safe limits beyond the results of the specimen 2 i.e. beyond 80 J of energy the material will start its plastic deformation respectively.

VI. SIMULATION 2

Another material tested was reinforced plastic with reinforcement material as carbon, aramid or basalt. The result of tested reinforced specimen is as below:

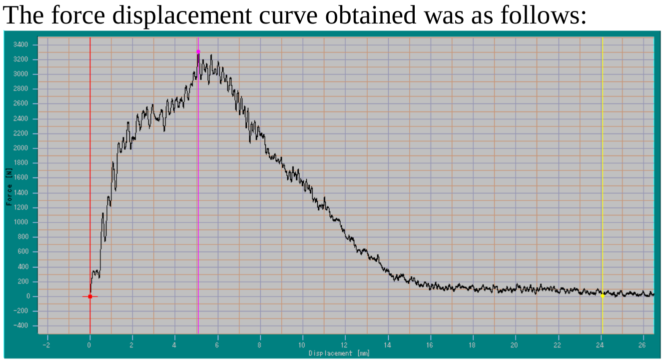
Sr.No.	Impact energy (J)	Peak Force (N)	Peak Energy (J)	Total Energy (J)
1.	30.00 J	3308 N	10.53 J	26.95 J

Tested Reinforced Plastic results.

From the above table it is clear that the material is safe within 30 J of impact energy. Beyond 30J of impact energy the material will start plastic deformation and begin to rapture.

Tested reinforced plastic specimens

The force displacement curve obtained was as follows:



VII. RESULT & CONCLUSION

From the above graph it is clear that the tested specimen is safe within 30J of loading conditions respectively.

VIII. CONCLUSION

The automotive industry in India is on of the largest in the world with an annual production of 23.96 million vehicle in fiscal year 2015-16, following a growth of 2.51 % over the last year. The automobile industry accounts for 1.1 % of country gross domestic product (GDP). The two-wheelers. The two wheelers segment, with 81 % market share, and is the leader in the Indian Automobile market.

The tested material shows various elastic and plastic behaviour at each set of points. The comparative analysis will lead to the safer and more reliable material for the automobile industry, which will safer the use of the automobiles for the occupants.

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