Evaluation for Mechanical Strength of Aluminium Tubes Filled with Polymers

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Abstract - *Safety is one of the most important criteria in design of vehicle structures. In general, a crashworthy vehicle must meet the impact energy management criteria that require the passenger compartment structure to withstand crash loads without excessive deformation while absorbing and dissipating the kinetic energy of impact. Many devices have been designed to study impact energy absorption during collision and hence protect the passengers and vehicle components. These energy absorption tubes act as mechanical fuses to limit the loads, which may act on the main structure immediately after a collision. The objective of this study is to evaluate the mechanical strength performance of empty circular Aluminium tubes, polyester and elastomer filled circular Aluminium tubes of different shore number for Quasi static loading conditions. The study have been undertaken experimentally for Quasi static loading condition using UTM in laboratory and numerically using Finite Element code ANSYS AUTODYN 3D. The results can be helpful to guide the design of crash worthy structures.*

Key Words*: Quasi static, Aluminium 6063-T6, Elastomers, Polyester.*

1. INTRODUCTION

Number of vehicles on road has been quickly increasing every year due to the continuous development of both transportation and automobile industry. Subsequently, vehicle accidents have now become major and important worldwide concern and continuous focus is on to address safety requirements. This is especially in case for road vehicles such as cars, trucks, vans and heavy vehicles. Motor vehicles can be undergone in a variety of crash events and accidents, each causing human injury of various severities. In general, a crashworthy vehicle must meet the impact energy management criteria that require the passenger compartment structure to withstand crash loads without excessive deformation while absorbing and dissipating the kinetic energy of impact. These energy absorption tubes act as mechanical fuses. Analysis of crashworthy structures has become a primary area of interest for some researchers for quite a few years now. The pursuit for a better energy absorbing or a better crashworthy structure has led researchers to carry out various analysis experimentally and also by simulating the characteristics. In response to this, a comprehensive study have been undertaken experimentally & numerically to evaluate the behavior of mechanical strength performance of empty circular Aluminium tubes, polyester, vinyl ester, polyurethane foam, silicone rubber and elastomer filled circular Aluminium tubes of different shore number for Quasi static loading conditions.

2. PROBLEM DESCRIPTION

The circular Aluminium tubes empty and filled with polyester, vinyl ester, polyurethane foam, silicone rubber and elastomer of different shore number was investigated by quasi static using experimental setup and finite element analysis software. The finite element software used in this study was Ansys Autodyn. The complicated response of aluminum tubes filled with different polymers along with the high cost of fabrication limits the number of Aluminium filled polymer considered for experimentation. In order to overcome this issue, finite element analysis can be used to find out the responses for a number of Aluminium tubes filled polymers, and to obtain the various information on the parameters that affects the quasi static phenomena.

3. OBJECTIVE OF THE RESEARCH

The main focus of this research is to study the response of empty and different polymer filled Aluminium tubes when subjected to quasi static analysis using both experimental and finite element analysis. The objectives of this research are:

- To determine the empty and polymer such as polyester, vinyl ester, polyurethane foam, silicone rubber and elastomer (polyurethane) of different shore numbers filled Aluminium tubes for energy absorption and failure response.
- To determine the mechanical behavior of empty and polymers filled Aluminium tubes.
- To evaluate the deformation and compressive strength for the empty and polymer filled Aluminium tubes when tested under quasi static loading conditions.
- This investigation is done experimentally for quasi static facility using UTM and numerically through FEM. Outcome of this project is used to guide the design of crash worthy structure.

4. FEM MODELLING DETAILS

The test specimens are designed using NX CAD software. A hollow circular Aluminium tube of inner diameter 47.5mm and outer diameter 51mm and a length of 140mm are used. The boundary condition includes the crosshead travel at 8mm/minute. The cross head is considered as a rigid body and no deformation is taken into account, and flexible body consideration is used for the test specimen. To save computational time the distance between the cross head and the specimen is reduced in the modeling.

The model is imported into Ansys and meshed. The empty Aluminium tube has 846 elements and 5765 nodes; the polymer filled Aluminium tube has 1590 elements and 9487 nodes.

5. EXPERIMANTAL DETAILS

For conducting the quasi static test, Universal Testing Machine of 80KN capacity was used at a cross head speed of 8mm/min. The specimen tested is an Aluminium 6063 T6 tube of inner diameter 47.5 and outer diameter 51mm and a span length of 140mm are used. This is done to find out the strength of the specimen. The required data is obtained from the experimentation.

In this study, specimens are prepared by measuring the polymer and adding a calculated amount of catalyst MEKP Methyl Ethyl Ketone Peroxide to it and cured at ambient Temperature and pressure conditions for 24 hours. Similarly other specimens are prepared. The cured specimens are then tested in UTM. The properties of specimens are shown in table I

Table -1: Properties of Specimen

Specimen	Density (Kg/m^3)	Young's Modulus (N/m^2)	Poisson's Ratio
Al-6063 T6	2770	6.89e10	0.33
Polyurethane Shore 45	210	2.1e7	0.248
Polyurethane Shore 60	1100	5.38e8	0.249
Polyurethane Shore 70	1100	5.38e8	0.249
Polyurethane foam	50	10.28e6	0.3
Polyester	1120	8.82e10	0.37
Vinyl ester	1030	3.45e9	0.351
Silicone rubber	1100	1e6	0.47

6. EXPERIMANTAL RESULTS

The parameters such as peak load, total deformation, strain and stress are obtained in the experimentation and the values is given in the table

Fig -1: Empty and Polymer filled specimen

Table -2: Experimental Results

Specimen	Peak Load (KN)	Total Deformation (mm)	Stress (MPa)	Energy Absorption (J)
Al 6063 T6 Annealed	17.45	6.41	64.4	1100
Polyurethane Shore A45	22.45	84	10.99	1525
Polyurethane Shore A60	23.56	76.21	11.53	1575
Polyurethane Shore A70	27.18	80.85	13.4	1675
Al 6063 T6	47.24	7.89	174.46	2520
Polyurethane foam	47.89	4.56	23.44	2895
Polyester	170	11.99	83.2	1040
Vinyl ester	200	10.5	101.2	2120
Silicone Rubber	49.8	54	24.37	2300

Fig -2: Quasi static test set up using Fine Spavy UTM

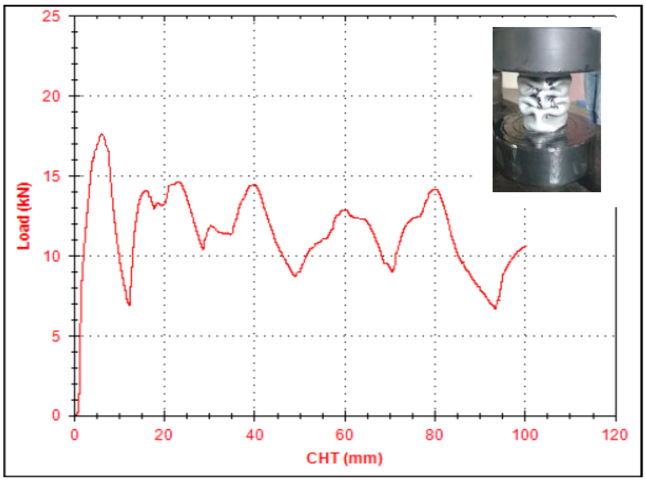

Fig -3: Load vs. Deformation of Empty Annealed Aluminium tube

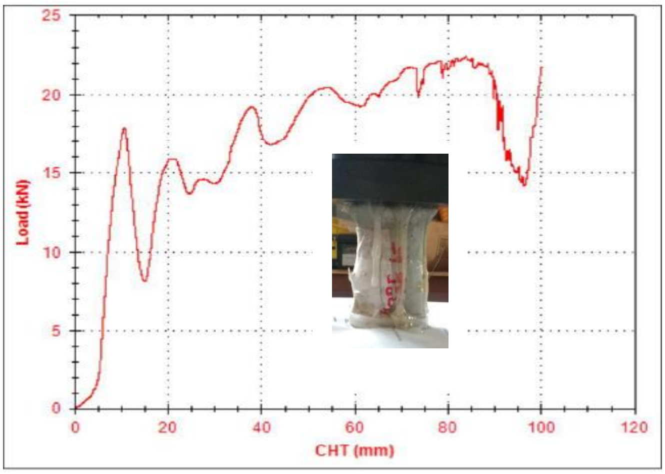

Fig -4: Load vs. Deformation of Aluminium tube filled with Shore A45

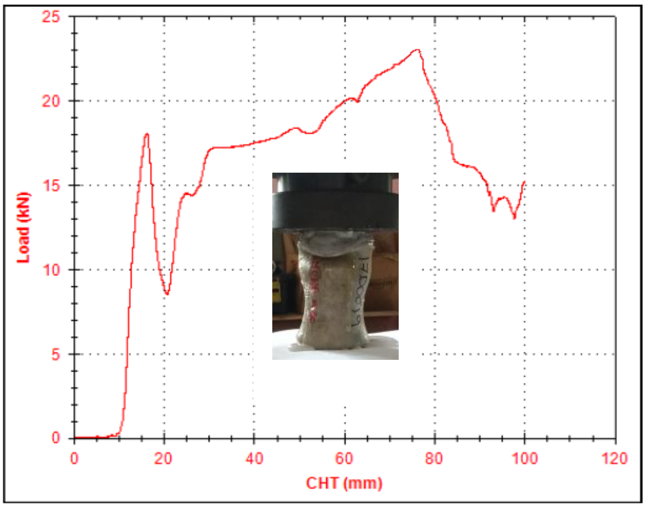

Fig -5: Load vs. Deformation of Aluminium tube filled with Shore A60

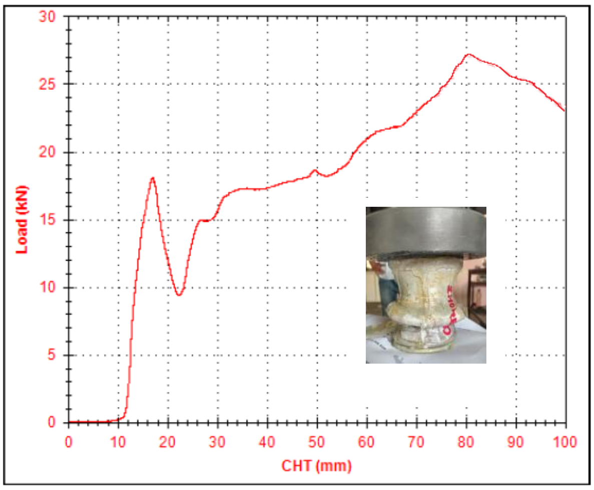

Fig -6: Load vs. Deformation of Aluminium tube filled with Shore A70

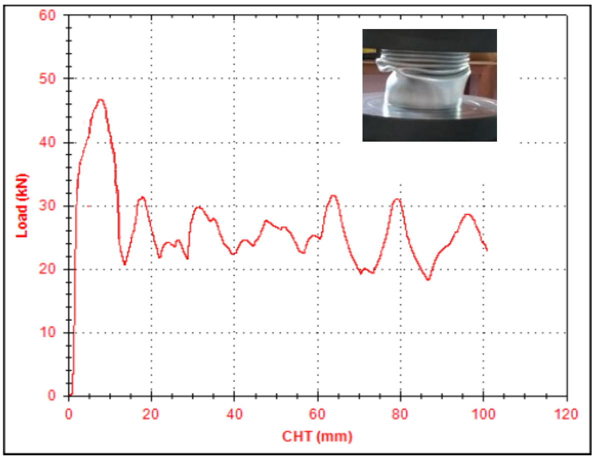

Fig -7: Load vs. Deformation of Aluminium tube

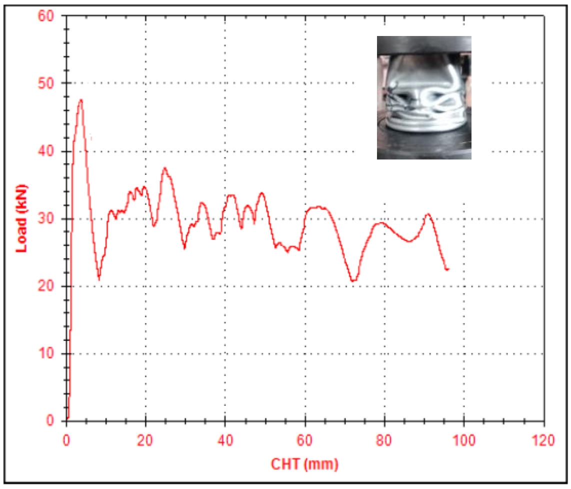

Fig -8: Load vs. Deformation of Aluminium tube filled with PU foam

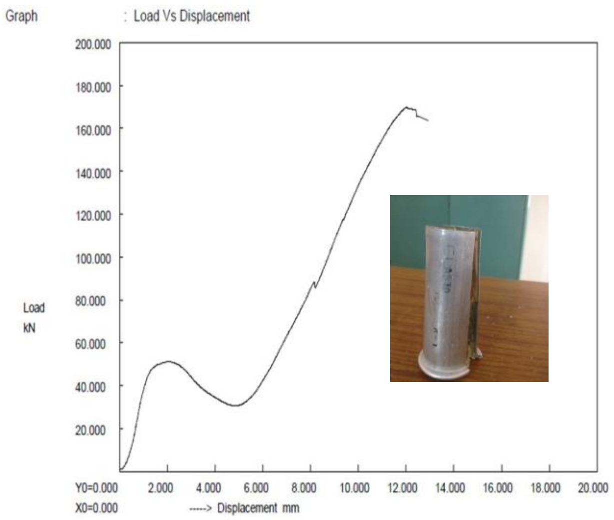

Fig -9: Load vs. Deformation of Aluminium tube filled with Polyester

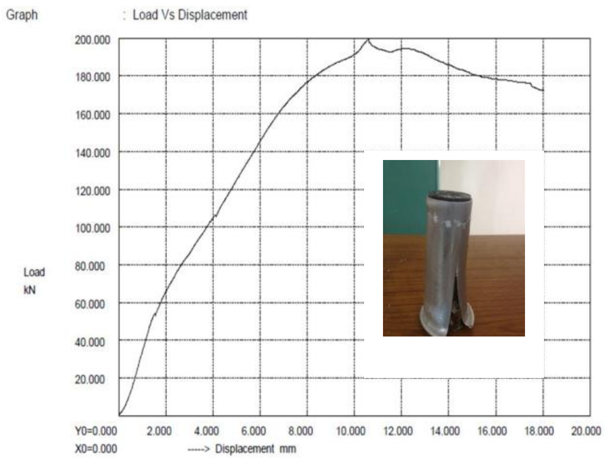

Fig -10: Load vs. Deformation of Aluminium tube filled with Vinyl ester

7. FEA DETAILS AND RESULTS

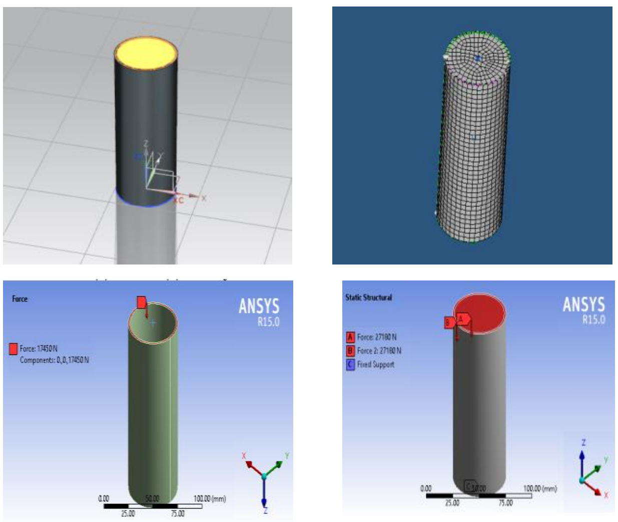

Fig -11: Tube Model, Mesh and Boundary Condition

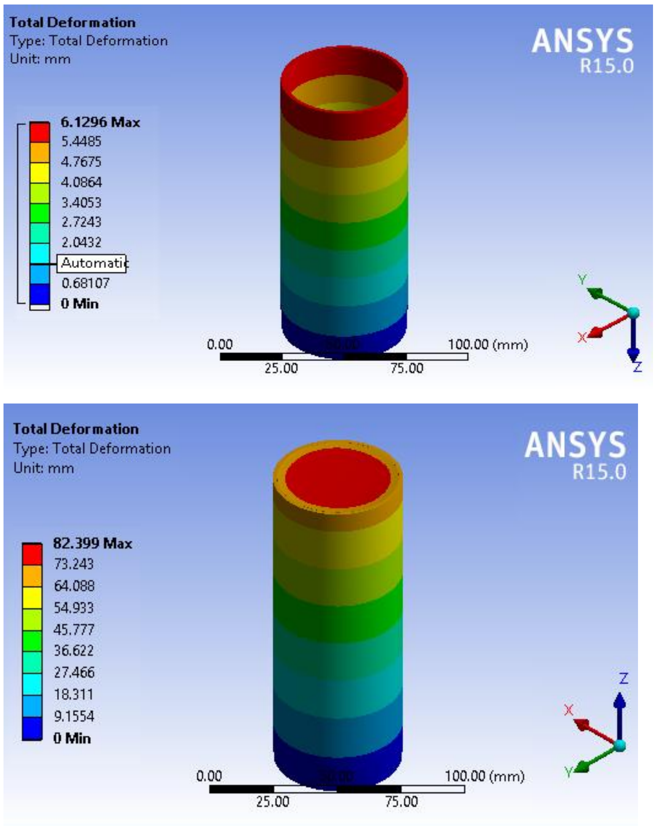

Fig -12: Total deformation of empty and Shore A70 filled tube

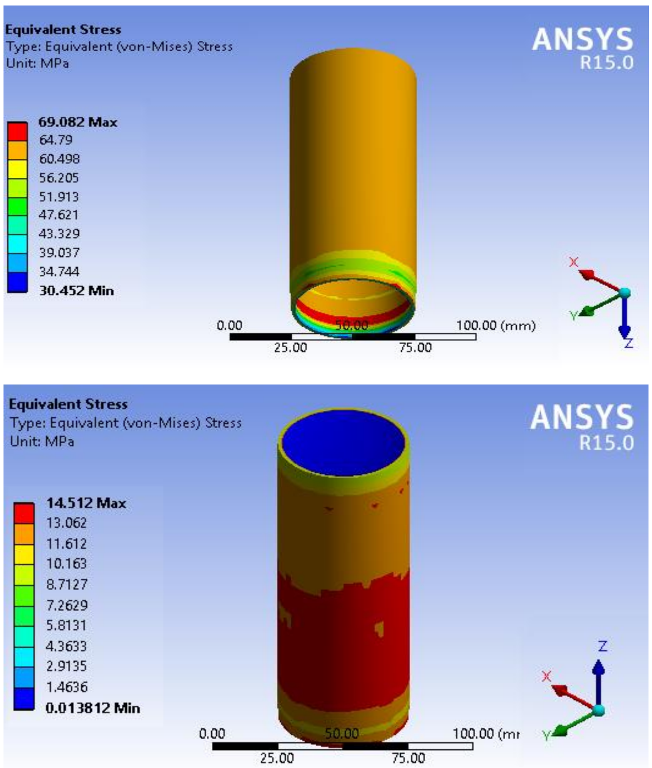

Fig -13: .Compressive Stress of empty and Shore A70 filled tube

Table -3: FEA Results

Specimen	Peak Load (KN)	Total Deformation (mm)	Stress (MPa)
Al 6063 T6 Annealed	17.45	6.12	69.08
Polyurethane Shore A45	22.45	88.776	11.875
Polyurethane Shore A60	23.56	80.12	12.84
Polyurethane Shore A70	27.18	82.39	14.51
Al 6063 T6	47.24	8.59	194.63
Polyurethane foam	47.89	6.62	25.657
Polyester	170	13.484	88.2
Vinyl ester	200	11.5	107.05
Silicone Rubber	49.8	46.059	28.042

8. CONCLUSIONS

The quasi-static crushing behavior of empty and polymer filled Aluminium tubes were investigated experimentally and numerically. The numerical solutions were carried out using the finite element code ANSYS AUTODYN and in general satisfactory agreements were found between the experimental and FEM values in terms of Peak load, Deformation, Energy absorbed and Compressive Stress. It is found that polyurethane shore A70 filled Aluminium tubes will absorb more energy compared to empty aluminum tube. The addition of low density foams does not increase the energy absorption significantly they stabilize the deformation. Whereas high density flexible and rigid foam filled tubes will absorb more.

Whereas the polyester and vinyl ester are not suitable for crashworthy structure because they lead to crack aluminum tube and directly dissipate the impact energy to the vehicle structure. Outcomes from this project might be helpful to guide the design of crashworthy structure.

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