Experimental and Finite Element Study of the Mechanical Properties of IS 3074:2005 ERW-1 Tube with Variable Thickness

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Abstract- *This project provides an experimental and finite element study of mechanical behaviour of IS -3074:2005-ERW-1 tube material under tensile testing. The mechanical properties of material limit the application of such material in an automobile industry. It is because one cannot use low strength material in load carrying path, whenever there is some kind of accident it leads to breakage of that part and cause injuries to the occupant. The main intension of any automobile industry is to protect the occupant during accidents. So it is necessary to test materials and be aware of their mechanical properties before using them in the building up of automobile or vehicle.This project focuses on the tensile testing of tube material used in manufacturing of car seats. Physical test is carried out with three variables, i.e. three different thickness values-1.2mm, 1.6mm and 2.0mm maintaining same outer diameter 25.4mm for all. Further 3-4 samples are used from each thickness. Specimen prepared is as per IS 1608 standard. The equipment used for all physical tests is Instron UTM Model5582. Load cell of 100kN capacity and Extensometer with 50mm original gauge length. Then same tensile test is carried out in LS-Dyna software with same specimen specifications. Physical test results are validated by results obtained from LS-Dyna tool.*

Keywords- Tubular materials, Mechanical properties, Tensile Strength, FEM.

I. INTRODUCTION

The tensile test is an essential standard engineering technique beneficial to characterize some relevant elastic and plastic variables related to the mechanical behaviour of materials. Due to the non-uniform stress and strain distributions existing at the neck for high levels of axial deformation, it has been long recognized that significant changes in the geometric configuration of the specimen have to be considered in order to properly describe the material response during the whole deformation process up to the fracture stage.

Although in many engineering applications the design of structural parts is restricted to the elastic response of the materials involved, the knowledge of their behaviour beyond the elastic limit is relevant since plastic effects with usually large deformations take place in the previous manufacturing processes such as forming, forging, etc.

A. Requirements of the different materials in Automotive

The materials used in automotive industry need to fulfil many criteria before being approved. Some of the criteria are related to regulation and legislation with the environmental and safety concerns and some are the requirements according to the customers. In many occasions different factors are conflicting and therefore a successful design would only be possible through an optimized and balanced solution: lightweight, cost, crashworthiness, crash worthiness test and recycling and life cycle considerations.

The finite element method (FEM) or finite element analysis (FEA) is a computational technique used to obtain approximate solutions of boundary value problems in engineering. Boundary value problems are also called field problems. The field is the domain of interest and most often represents a physical structure. The field variables are the dependent variables of interest governed by the differential equation. The boundary conditions are the specified values of the field variables (or related variables such as derivatives) on the boundaries of the field. Objective of this paper is to analyse the stress v/s strain curve of experimental results & stress v/s strain curve of FEA results and determine the effect of varying thickness on mechanical properties.

II. METHODOLOGY

This project includes two separate methods of carrying out tensile test. i.e, experimental and FEA test.

Experimental method:

Material selection.: The material selected in this project is used in a car seat frame. ERW-1 tube material. The actual mechanical properties of this material will be compared with final results from this experimental and FEA test. Specimen preparation according to IS 1608 standards.Except gauge length everything else has been flattened in order to hold in the UTM holders.

Test conduction: The equipment used for all physical tests is Instron UTM Model5582. Load cell of 100kN capacity and Extensometer with 50mm original gauge length. After conducting the test obtain results like load v/s deflection curve. Resample the experimental test data.Get average stress-strain curve from resample data. Plot engineering stress v/s engineering strain curve. Convert engineering stress-strain data to true stress-strain.

FEA test:

FEA test includes CAD Model preparation. Discretization of model. Defining material properties. Boundary conditions and external load. Define cross section and gauge length. Define the input curve by loading true stress and true strain data.Post processing-: Plot curves. Results & discussion

III. EXPERIMENTAL METHOD

This includes carrying out tensile test using universal testing machine (UTM).

(a) Material selection

The material selected in this project is used in a car seat frame. ERW-1 tube material. The actual mechanical properties of this material will be compared with final results from this experimental and FEA test.
Actual mechanical properties of ERW-1 material are as follows:

Table 1 Material name and actual properties

Sl. no	Material Specification	Yield strength MPa	Tensile Strength MPa	% Elongation	Thickness mm	OD mm
1	IS - 3074-2005 ERW-1	160	310.00	0.200	1.2,1.6,2.0	25.4

ERW-1 tube material of outer diameter 25.4mm with three variations in thickness is selected.

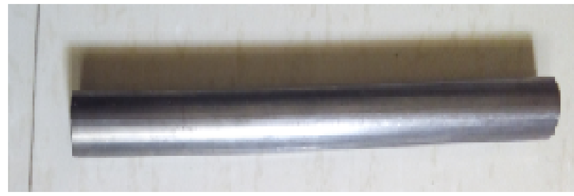


Fig.1 ERW-1 material

(b) Specimen preparation

The test specimen is prepared as per IS 1608 standards.

Fig.2 Specimen prepared

Except gauge length everything else has been flattened in order to hold in the UTM holders.

(c) Test conduction

The equipment used for all physical tests is Instron UTM Model5582. Load cell of 100kN capacity and Extensometer with 50mm original gauge length.

Procedure:

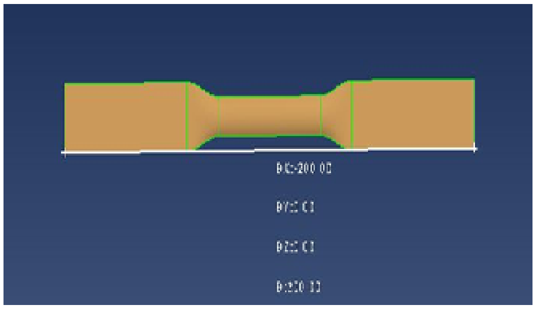
- Measure the gauge length of specimen and mark the gauge length end points.
- Fix the specimen between fixed crosshead and moving crosshead of machine..
- During the test note down the maximum load.
- Test should be conducted until fracture takes place.
- After fracture stop the machine and measure the final gauge length.

Fig.3Tested specimen

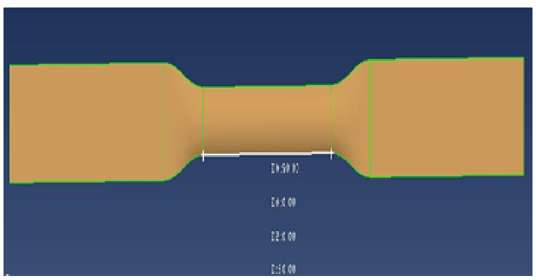
IV. SOLUTION BY FEM SOFTWARE

(i)Model preparation:

The first step in the FEM solution procedure is to prepare specimen model as per the specified geometry using a design software tool. Tool used in this project is CATIA V5. Figures 4.a,b,c&d.



(a)



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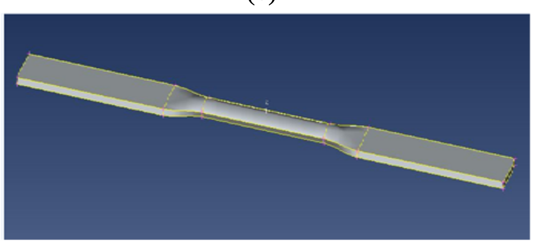

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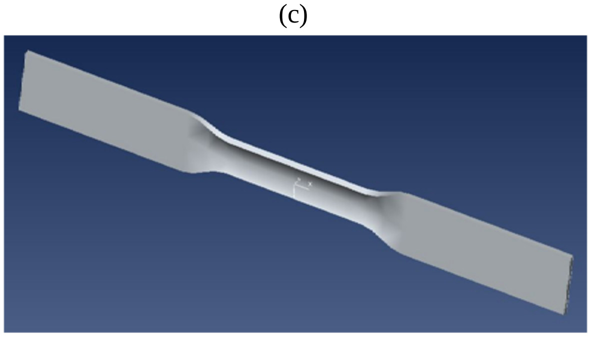
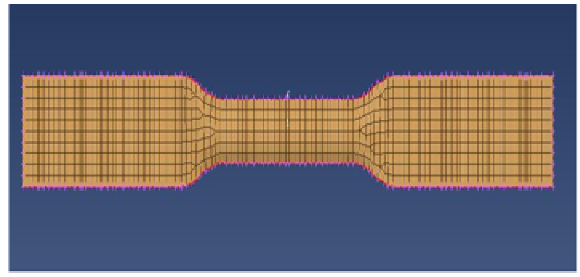


(d)Geometry of specimen

(ii) Discretization of the model prepared

The built up model is imported into ANSA software. Discretization refers to the dividing model into finite number of small elements also called as meshing. Meshing is a basic step in all types of FEA analysis and CFD analysis problems. Figure 5 shows meshed model.



(a) Meshed model

(iii) Define material properties

It is necessary to define the material properties in order to get similar results as of physical tensile test. These include the Young's modulus, density and Poisson's ratio of the material.

(iv) Boundary conditions

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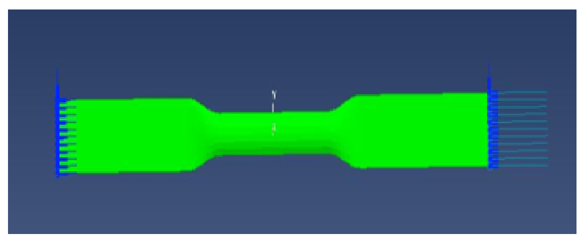
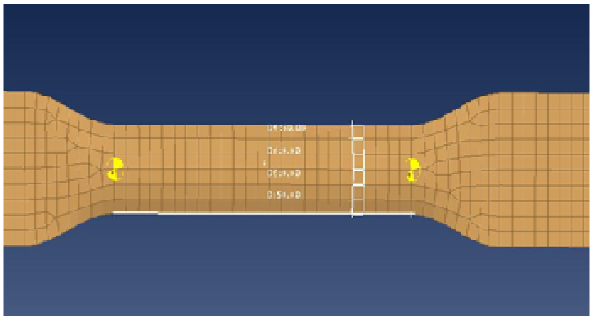
Define boundary conditions. i.e, constraining all 6 degrees of freedom at one end and on other end except X-direction all other 5 degrees of freedom are also constrained. And apply an external load along X-axis.



(a) Boundary conditions and external loads

(v) Define database cross section and history nodes

Database cross section of the gauge length is prescribed by selecting nodes and their adjacent elements. This will be original cross sectional area to calculate engineering stress. Similarly nodes at both ends of gauge length are defined as history nodes. This is original or initial gauge length. From these nodes it is easy to calculate final gauge length. Used to calculate engineering strain.



(a)Database cross section and history nodes

(vi)Define input curve

Input curve has to be defined in order to specify behaviour of material being tested. The input curve to be defined is data of true stress and true strain obtained from physical test. The input curve is different for each thickness model.

Then control cards need to be defined. After this the model has to be debugged to check the errors present in the model, then once the model is free of errors it has to be run.

(vii)Analysis

The data obtained after running the model is used to analyse the required solutions. In this section the displacement, true stress and true strain analysed will be reported. This includes all three models.

- Analysis from 1.2mm thick tube model
- Analysis from 1.6mm thick tube model
- Analysis from 2.0mm thick tube model

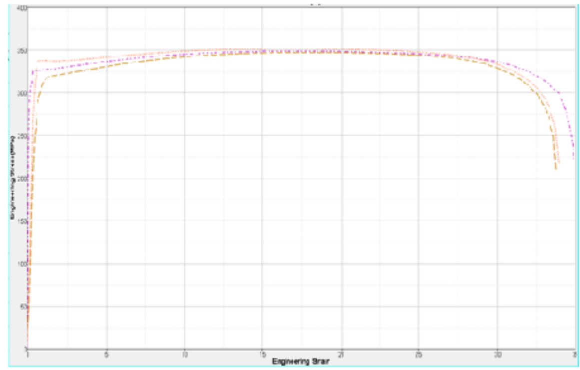
V. RESULTS AND DISCUSSION

Results from physical test:

Physical tensile test has been conducted on 3 samples of 1.2 thickness and 4 samples from 1.6 and 2.0 mm thickness.

(i)Results from 1.2mm thick tube

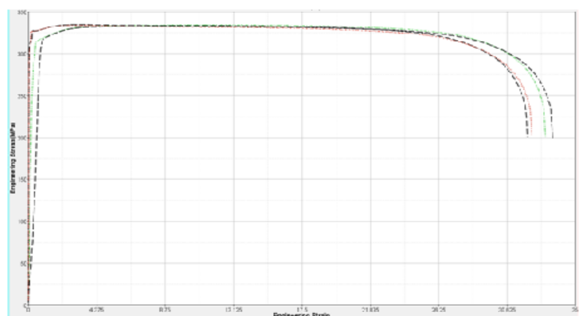
SI.No	0.2% Offset YS (MPa)	UTS (MPa)	Elongation at break (%)
1	325.1	348.6	34.8
2	287.9	347.2	33.7
3	335.5	351.5	33.9



Graph.1 Engineering Stress v/s Engineering strain curves of 1.2mm thick tube samples

(ii) Results from 1.6mm thick tube

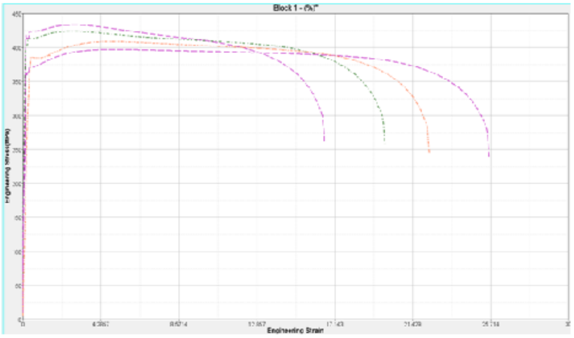
SI.NO	0.2% Offset YS (MPa)	UTS (MPa)	Elongation at break (%)
1	313.4	334.3	33.0
2	318.4	332.4	33.4
3	316.2	334.7	31.8
4	314.3	334.0	32.1



Graph.2 Engineering Stress v/s Engineering strain curves of 1.6mm thick tube samples.

(iii) Results from 2.0mm thick tube

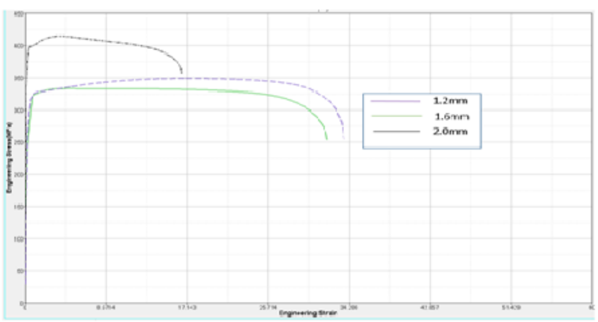
SI.NO	0.2% Offset YS (MPa)	UTS (MPa)	Elongation at break (%)
1	423.6	433.6	16.4
2	413.3	423.9	19.8
3	370.5	397.4	25.5
4	385.7	408.9	22.2



Graph.3 Engineering Stress v/s Engineering strain curves of 2.0mm thick tube sample.

(iv) Results from average curves of each thickness samples

Average curve of	Yield stress(MPa)	UTS(MPa)
1.2 mm	339.987	348.843
1.6 mm	328.896	333.01
2.0 mm	404.964	414.557



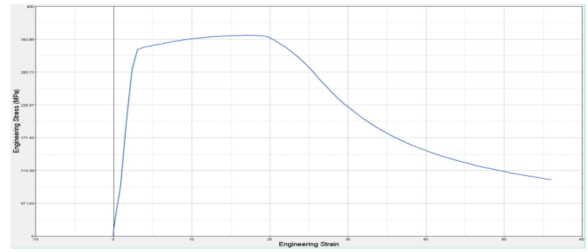
Graph.4 Average curve from 1.2, 1.6 & 2.0mm thickness samples

From Graph.4 it is can be noted that for 1.2mm thick sample the stress&strain values increase in proportional manner till 339.98 MPa and later the strain increases in drastic manner keeping stress in constant condition. This case is similar to all other samples.

Results from FEA solution:

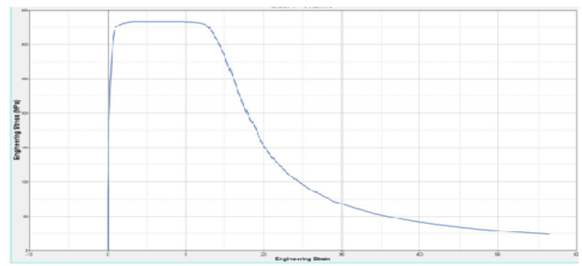
FEA Model	Yield stress(MPa)	UTS(MPa)
1.2 mm	340.186	349.852
1.6 mm	325.26	333.526
2.0 mm	405.273	415.009

(i) Results from 1.2mm thickness model



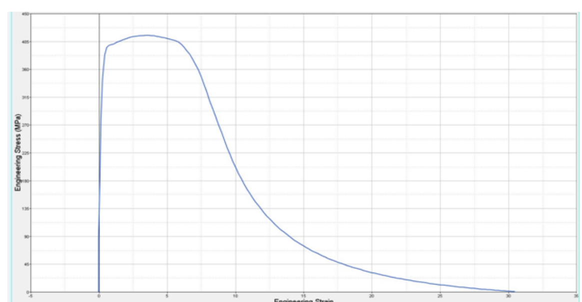
Graph.1 Engineering stress v/s Engineering strain curve of 1.2mm thick model

(ii) Results from 1.6mm thickness model



Graph.2 Engineering stress v/s Engineering strain curve of 1.6mm thick model

(iii) Results from 2.0mm thickness model



Graph.3 Engineering stress v/s Engineering strain curve of 2.0mm thick model

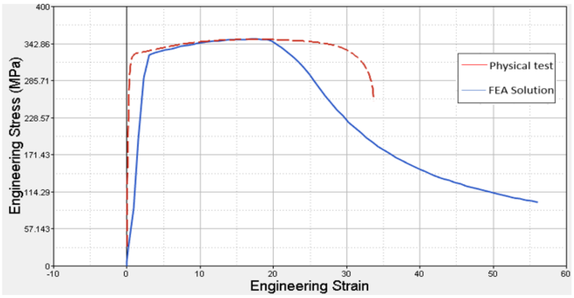
VI.COMPARISON OF PHYSICAL AND FEA TEST RESULTS

(i)1.2 mm THICKNESS MODEL

Table.1 Results of physical and FEA test of 1.2 model

	Yield stress(MPa)	UTS(MPa)
Physical test	339.987	348.843
FEA solution	340.186	349.852
Correlation (%)	99.94	99.71

The engineering stress v/s engineering strain curves of physical and FEA solution are shown in Graph.1



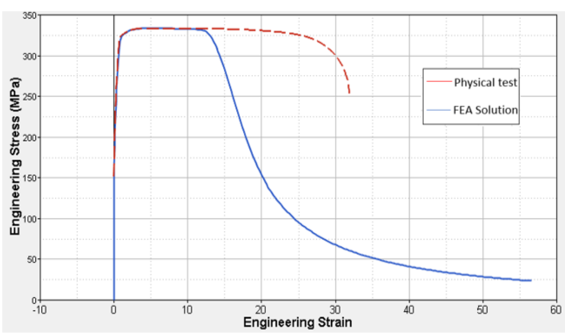
Graph.1 The engineering stress v/s engineering strain curve of physical and FEA solution of 1.2mm model.

The Graph.1 shows that curves obtained from physical test and FEA solution are similar to one another. Both curves run one on one till necking starts. Also from table 1 it is clear that yield stress and UTS are also similar. The results of physical test match with FEA solution results.

(ii)1.6 mm THICKNESS MODEL

Table 2 Results of physical and FEA test of 1.6 model

	Yield stress(MPa)	UTS(MPa)
Physical test	328.896	333.01
FEA solution	325.26	333.526
Correlation (%)	98.89	99.84



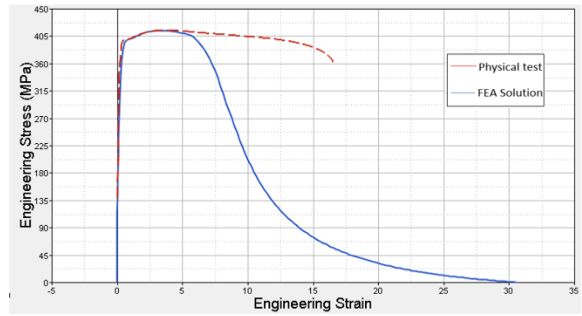
Graph 2 The engineering stress v/s engineering strain curve of physical and FEA solution of 1.6 model.

The Graph 2 shows that curves obtained from physical test and FEA solution are similar to one another. Both curves run one on one till necking starts. Also from table 2 it is clear that yield stress and UTS are similar too. The results of physical test match with FEA solution results.

(iii)2.0 mm THICKNESS MODEL

Table 3 Results of physical and FEA test of 2.0 model

	Yield stress(MPa)	UTS(MPa)
Physical test	404.964	414.557
FEA solution	405.273	415.009
Correlation (%)	99.92	99.89



Graph 3The engineering stress v/s engineering strain curve of physical and FEA solution of 2.0 model

The Graph 3 shows that curves obtained from physical test and FEA solution are similar to one another. Both curves run one on one till necking starts. Also from table 3 it is clear that yield stress and UTS are similar too. The results of physical test match with FEA solution results.

VII.CONCLUSION

The mechanical properties of IS3074-2004 ERW-1 tube material with variable thickness and constant outer diameter are stated and the results are summarized. The results obtained experimentally were compared with the simulation in LS-Dyna software. From comparison the following points can be noted-

1. Correlation percentage shows that there is similarity in results obtained.
2. Both results match till UTS point and further there is more elongation in physical test compared to FEA solution.
3. From the current study it is evident that FEA methods can be used effectively to validate and model Material properties accurately.
4. Validated FEA material curve can be used to improve analysis accuracy, which helps reducing Engineering development cost by reducing number of Prototypes and Physical test.
5. It is also observed from the test data that change in thickness do not affect the strength parameter significantly, however there is a minor change in Yieldstrength.

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