Experimental Analysis of Elastoplastic Behavior of Corten Steel using FEM

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Abstract- Analysis of Elastoplastic behavior is an important engineering procedure to characterize mechanical properties of the materials. While observing the response of the material during the actual loading conditions, it is necessary to consider the variations in geometry of the specimen. Although it is of great importance to consider the behavior of the material in elastic limit but the knowledge beyond elastic limit is also relevant since plastic effects with large deformation takes place in number of manufacturing processes. Corten Steel is used in manufacturing of railway coaches so the analysis of mechanical behaviour is important. It is also used in the crash analysis of the component. Finite Element Method being a widely used tool for analysis due to revolution in computer field is used for the analysis of the components. The present work describes the behavior of Corten Steel sheet specimens in plastic range. Finite element method was employed for the analysis of tensile test.

Keywords – Corten Steel, Elastoplastic Behavior (Tensile Test), FEM Analysis.

I. INTRODUCTION

The present work deals with the experimental and numerical analysis of tensile test on Corten Steel material which is used in rail coaches.Tensile Test is a useful important standard engineering procedure to characterize elastoplastic variables related to the mechanical behavior of materials. Due to the non-uniform stress and strain distributions existing at the neck of the specimen for axial deformation at high levels, it has been 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 material involved, but the knowledge of their behavior beyond the elastic limit is relevant since plastic effects with large deformations take place in the manufacturing processes such as metal forming example: drawing, forging, extrusion, deep drawing, rolling, magnetic pulse forming etc. Other important applications of elastoplastic models for Crashworthiness, impact problems, inelastic buckling of thin-walled structures, super plastic forming etc. Finite element analysis is very useful in designing and testing of various components and materials, which are constantly under different types of loads and under different conditions such as bending, torsion, tension or compression. FEM is based on matrices and they require less time and memory of computers.

A finite element analysis involves three stages of activity: preprocessing, processing and post processing. Preprocessing involves the preparation of data, such as nodal coordinates, connectivity, boundary conditions, and loading and material information. The processing stage involves mesh generation, stiffness generation, stiffness modification, and solution of equations, resulting in the evaluation of nodal variables. Other derived quantities, such as gradients or stresses may be evaluated in this stage. The post processing stage with the preparation of results. Typically, the deformed configuration, mode shapes, temperature, and stress distribution are computed and displayed at this stage. A complete finite element analysis is a logical interaction of the three stages.

II. PROPOSED WORK

Chemical composition of test specimen: -

Analysis of Corten Steel test specimen was carried out by Optical Spectrometer and the percentage of average chemical composition is given in the table below-

Table1: Average Chemical Composition (%)

C <0.10	Mn 0.25-0.45	Si 0.28-0.72	Ni 0.20-0.47	Cu 0.30-0.60
Cr 0.35-0.60	S <0.03	P 0.075-0.140	Mo <0.05	V <0.05
Al <0.08	Nb <0.04	Fe 98.2		

Preparation of Test Specimen:-
The material (Corten Steel) was cut into sheet specimens. Specifications are shown below-

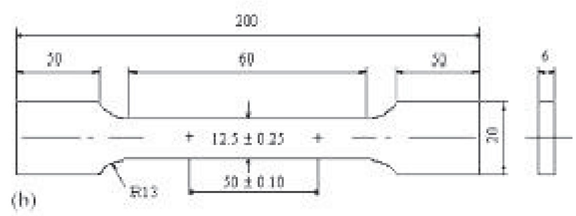

Fig.1: Sheet Specimen of Corten steel.

Mechanical Tensile Test-
The specimen was uploaded on UTM to conduct tensile test, during test the load cell speed was 2.5mm/min.

Table 2: Analysis of the tensile test: average experimentally measured values.

Material/Sample	Maximum Load(KN)	Maximum Engineering stress(MPa)	Elongation at the Fracture Stage (%)
Corten Steel/Sheet	33.9	470.9	28.4

Characterization of the plastic behavior

After tensile test the characterization of the plastic behavior was done. At high level of elongation, the stress strain distributions are no longer uniform along the specimen due to the necking formation that takes place for sheet specimens. Therefore, the stress–strain curve obtain after tensile test cannot provide a proper description of the physical phenomena involved in the test. So the mechanical response can be adequately described by an alternative stress–strain curve defined

In terms of the mean equivalent stress σeq versus an equivalent deformation εeq (composed of an elastic and plastic contributions) respectively given by σeq=FBP/A, and εeq= σeq/E+ εp. Where FB(εp)≤1 is an assumed known correction factor applied to the mean true axial stress P/A. A is the transversal area at the necking zone. E is the Young's modulus and εp=ln(Ao/A) is the true (Logarithmic) deformation.

The correction factor to be applied for this case depends not only on the type of the samples used but also on the strain, εp which is the maximum logarithmic deformation at which the strain and strain distribution are normal along the specimen.

Finite Element Analysis:-

The finite element mesh and methodology is used in order to describe correctly the large stress and deformation expected in the necking zone. The sheet specimen is discretized with a one-dimensional finite element mesh with a height of 50mm (initial extensometer length).

III. EXPERIMENT AND RESULT

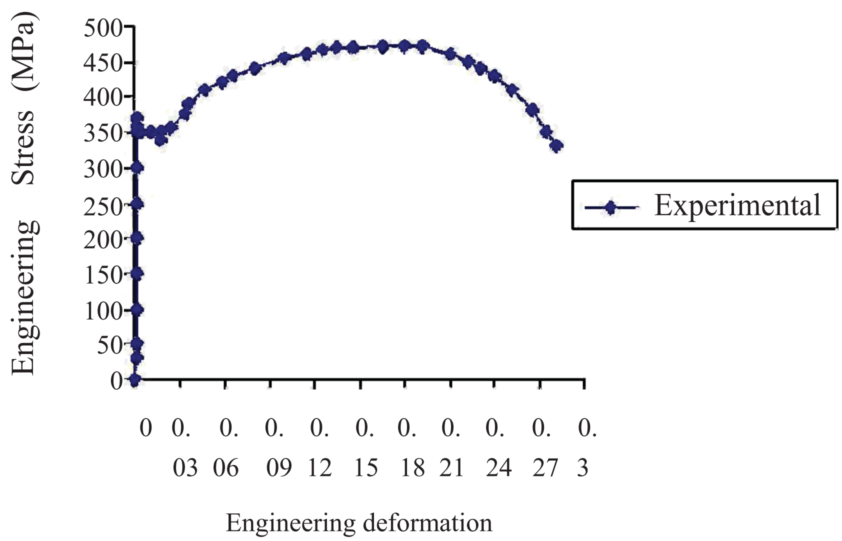

Fig.2: Analysis of sheet specimen: experimental values of average stress-strain curve

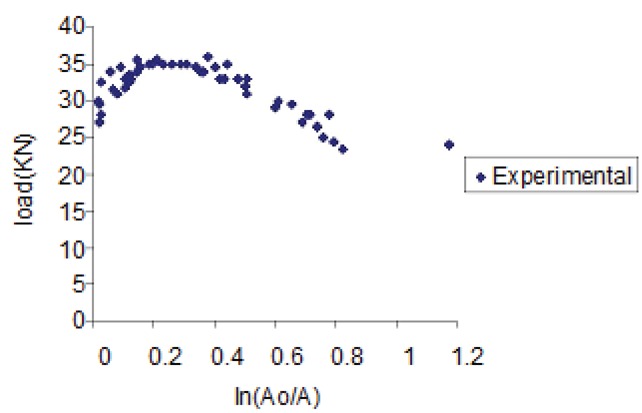

Fig.3(a)analysis of the sheet specimen: load vs true deformation

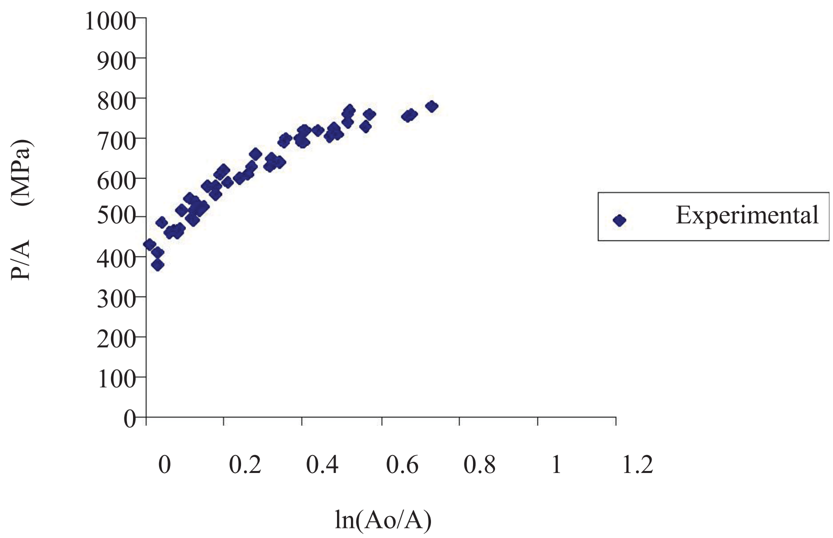

Fig.3 (b) Analysis of the sheet specimen: mean true axial stress versus true deformation.

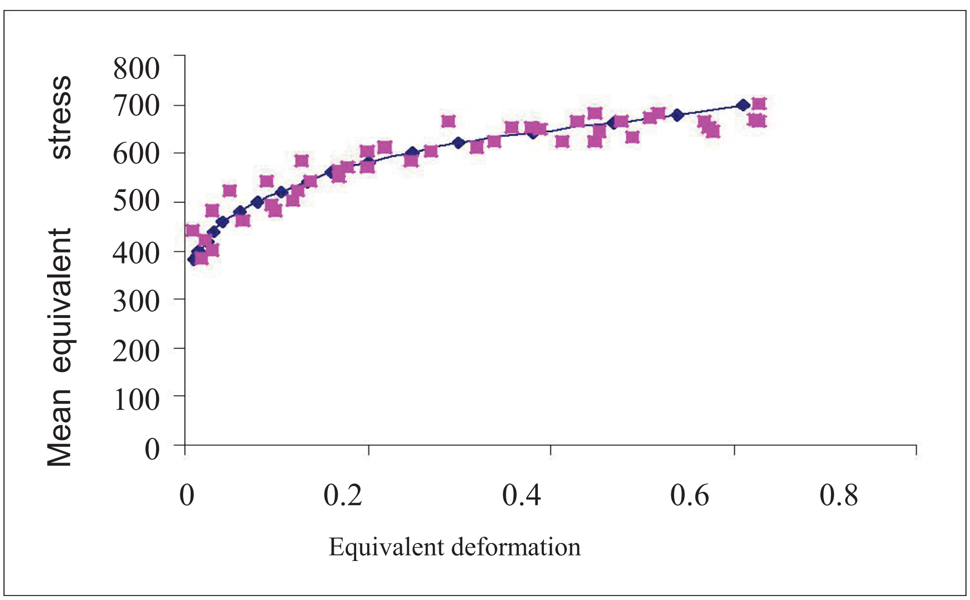

Fig.3(c): Analysis of sheet specimen: mean equivalent stress versus equivalent deformation

Table3: Analysis of the test: correction factor as a function of true deformation

$\ln(A_0 / A)$	Sheet sample correction factor $\varepsilon^*_p = 0.10$
0.00	1.000
0.05	1.000
0.10	1.000
0.20	0.976
0.30	0.955
0.40	0.933
0.50	0.909
0.60	0.884
0.70	0.858
0.80	0.830
0.90	0.800
1.00	0.769

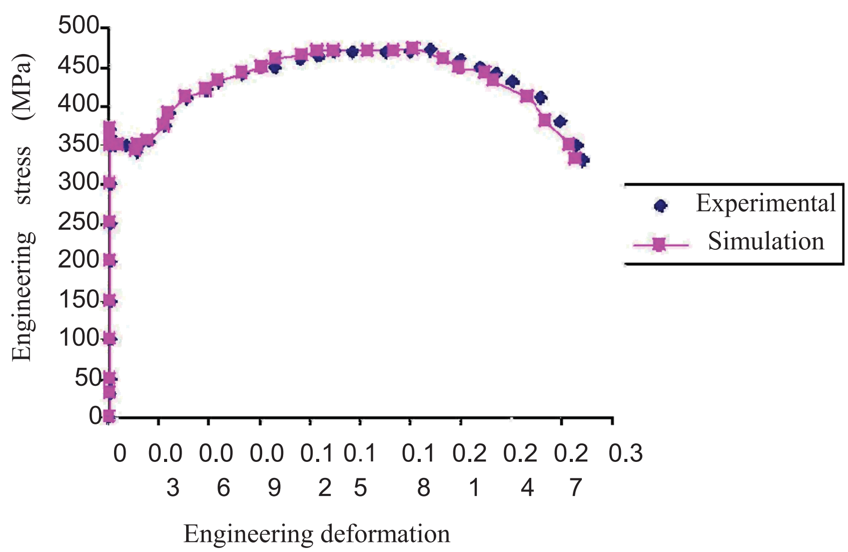

Fig.4: Analysis of sheet specimen: engineering stress strain relationship

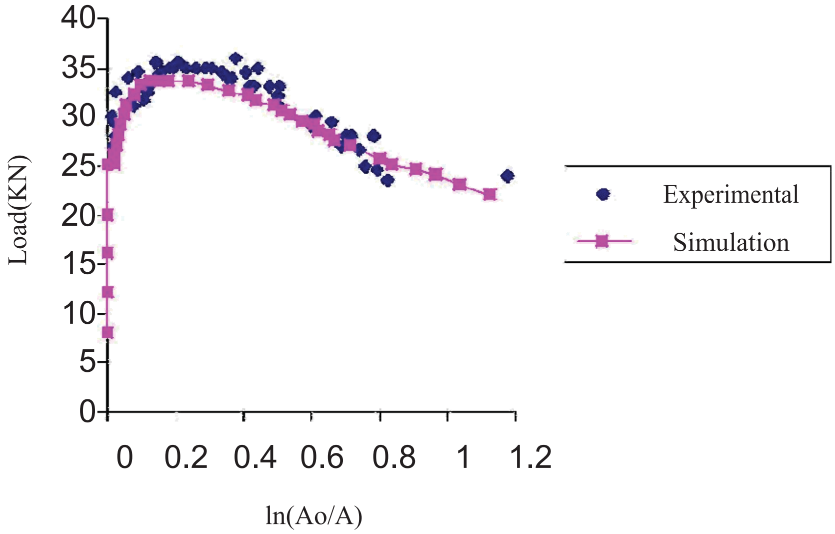

Fig.5: Analysis of sheet specimen, results at the section under going extreme necking: load versus true deformation

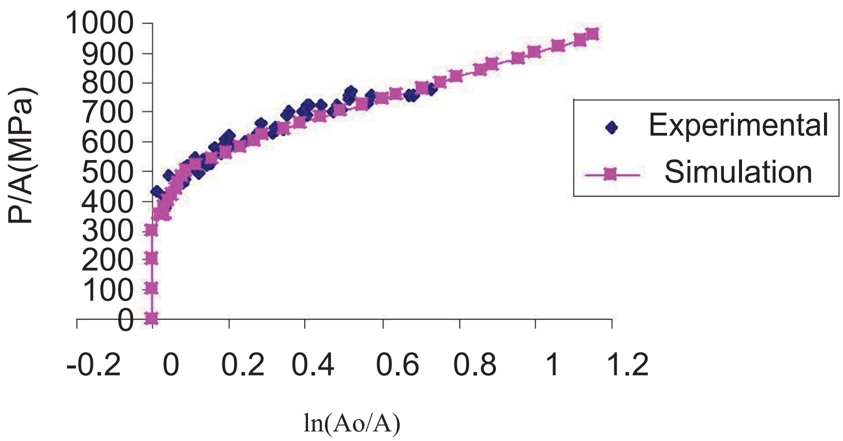

Fig.6: Analysis of sheet specimen, results at the section under going extreme necking: mean true axial stress versus true deformation

IV.CONCLUSION

The study focused on the material reveals that the classical procedure to find the stress distribution at the neck cannot be used directly and it does not provide any information about the mechanical behavior of material in plastic range. The engineering stress-strain relationship and the results at the section undergoing extreme necking shows that the results provided by the simulation have been successfully validated with experimental data. The results also show that the plastic evolution that takes place before and after the necking formation has been described properly. The present finite element based elastoplastic formulation is done using 1D mesh, this work can be extended using 2D and 3D mesh for different geometrical specimens.

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