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Experimental Studies on Tensile Properties of Various Steels Using Miniature Specimens

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Abstract : This paper presents the design, development and application of a miniature specimen test technology for predicting the tensile properties of structural steels using rectangular miniature specimens. For the present investigation rectangular shaped miniature specimens of dimensions $10mm \times 2mm \times 1mm$ are carefully prepared from five varieties of structural steels viz. EN8, EN19, EN24, EN31, EN36. Specimens were subjected to Small Punch Testing at room temperature using Universal Testing Machine (UTM). A specially designed and fabricated fixture was used to hold the specimens in the UTM and the load vs load point displacement measurements were taken during the test. The experimental data obtained from miniature specimen tests were further analyzed to obtain the standard mechanical properties of the structural steels. Further, a relation is developed between the ultimate tensile strength of the standard specimens and peak loads of the corresponding miniature specimens using Mini-tab statistical analysis software. By using this relationship one can determine the tensile strength of the structural steel.

Keywords : Tensile property, Miniature specimen, Structural steel, Small Punch Test, Regression Equation.

Introduction

The present study deals with the design, development and application of a miniature specimen test technology for predicting the tensile properties of structural steels using rectangular miniature specimens. The miniature specimen technique can be especially appealing in investigating the effect of uniformity of steel tensile properties. In order to find the behavior of material, it is essential to have a thorough understanding of the compositions of alloying elements. Small punch test technique (using miniature specimens) has been extensively employed for the evaluation of tensile properties in metallic alloys. This is used to extract mechanical properties (tensile properties and fracture toughness *etc.*) from disk type specimens. In this technique, a supported disk or coupon is loaded with a penetrator of particular geometry until the failure occurs. The output of the test is in the form of a load-displacement curve which is analyzed for getting the mechanical properties. Although different researchers attempted with different penetrator geometry, the use of spherical and cylindrical geometries are quite common. The test carried out with the spherical indenter is called “ball punch test” and the one with the cylindrical indenter is called “shear punch test”. Ball punch test is of two types: “disk bend test” and “bulge test”. In general, disk bend refers to a test in which the disk specimen is simply supported and in bulge test the specimen is clamped between the two dies using a fixed number of screws.

Foulds *et al.*[1] used the miniature disk bend test to successfully estimate the conventional tensile and fracture properties of steel reactor pressure vessel using specimens of 6.35 mm diameter and 0.5 mm thickness.

Husain[2] employed small punch test on different steels (H11steel, D3steel, structural steel) having varying strength to establish a general relationship to obtain yield strength using circular, rectangular and square shaped specimens with three different hemispherical punches.

Wang et *al.*[3] conducted small punch test on reactor vessel steel using miniature specimens of varying thickness i.e. 0.4mm, 0.5mm, 0.63mm, 0.75mm, 0.86mm and 1mm.

Hu and Ling[4] conducted small punch test on Zirconium using disc specimens of diameter=10mm and thickness=0.5mm to evaluate the mechanical properties. They had also implemented 3D finite element simulation to model the plastic damage of Zirconium. They observed a good agreement between load-displacement curves of finite element simulation and small punch tests.

P.Vineeth Kumar et al.[6] the finite element analysis is conducted to simulate the life of spot welded joints when subjected to fatigue loading. A numerical study to predict the fatigue life of spot-weld joint under imposed loading conditions is presented. The work has been carried out to observe the effect of sheet thickness spot diameter on the fatigue life of spot welded joints and it is seen that fatigue life of the specimen increases with the increase in spot diameter and sheet thickness. But the model clearly needs to be tested against more set of data of different dimensions and more importantly need to be tested experimentally in a variety of situations, so that the ansys results can be validated.

Subramanian K et al.[7] the finite element study was performed on the voided slab of thickness 100 mm and varied spacing of void formers. The results have concluded that voided slabs performed similar to that of solid slab, either by plate theory or finite element analysis.

Vikram G Kamble et al.[8] the natural frequency of beam drops from 550Hz for undamped to 300Hz for damped condition, this is due to the presence of MRFluid in the beam under magnetic field and it has really good damping effect.

K Logesh et al.[9] this study proposed and analyzed a new cantilever design which shows high deflection with less reduction in resonant frequency when compared to standard rectangular cantilever beam. The proposed design shows 140% increase in deflection value with of 32% decrease in resonant frequency value when compared to standard rectangular cantilever beam.

P. Jaishankar et al.[10] flexural behaviour of laminated annealed and laminated toughened glass beams samples are tested by varying the reinforcement percentage. The strength of toughened glass is 58.5 % more than that of annealed glass. The cost of toughened glass is 15.47 % more than that of annealed glass.

Subramanian K et al.[11] the finite element study was performed on the voided slab of thickness 100 mm and varied spacing of void formers. The results have concluded that voided slabs performed similar to that of solid slab, either by plate theory or finite element analysis.

M.Pavithra et al.[12] this research work is mainly designed for modeling and characterizing the nonlinear coupled MEMS resonator. This paper focuses on nonlinear coupled MEMS resonator for electrostatic actuation. In this study laterally driven an electrostatic force comb drive, is designed for capacitance sensing and nonlinear MEMS resonator can exhibited for the hard spring response. Hence the analytical calculation and simulation analysis are described. However the working principle and dimensional parameters of the coupled MEMS resonator are determined and simulated by COMSOL Multiphysics 4.4. The solution of quality factor is very well, capacitance sensing range 4.425fF and the resonance frequency is 1.6 GHz is use for mobile satellite communication application.

M.Vasubabu et al.[13] the present work is concerned with effect of alkaline treatment on the mechanical properties of Tectona grandis wood species. Mass loss, Tensile strength, compression strength, elongation and hardness were measured at different alkaline (NaOH) concentrations (5%, 10%, and 15%). The result shows that variation in mechanical properties with alkali treatment on Tectona grandis wood species at different concentrations. Optimum mechanical properties were obtained at 10% of alkaline treatment is discussed with its structure critically.

S.Karthikeyan et al.[14] the introductions of Zinc- Ni alloy coatings on Al 7075 PDC samples were successfully demonstrated. Also the coatings were found to improve the hardness, wear and corrosion resistance of the Al surfaces. The application of laser texturing on Al 7075 PDC could improve the adhesion of coatings which significantly contribute improvement of mechanical properties of air craft machineries.

Alvaro Realpe et al.[15] In the present project were evaluated the mechanical properties of residual polyester resin laminate reinforced with recycled newspaper, such as tensile, flexural and hardness. The catalyst / resin ratio and the number of layers of recycled newspaper were manipulating in order to establish the effect of these variables on the mechanical properties of the residual resin laminate, and comparing these properties with those obtained from virgin resin laminates. The results show that the average tensile strength of the laminates (0,5%) with residual and virgin resin were 71,8 and 73 MPa, respectively; and it decreases with increasing percentage of catalyst and increases with the addition of layers of recycled newspaper. The flexure strength of residual resin laminates (214,7 MPa) was higher than the virgin resin (210,5 MPa) at 0,5%, and it decreases with increasing percentage of catalyst and the number of layers of recycled newspaper. The number of layers of newspaper does not affect significantly the Shore D hardness of laminates; while, the hardness of laminates increases with increasing the catalytic percentage. On the other hand, hardness of laminates with virgin resin is higher than recycled resin.

A thorough study of past literature reveals that there is no study reported on testing of various steels using miniature specimens. Hence the objectives of present study are

1. Designing simple and efficient specimen geometry for the miniature test on steel specimens and also developing a small punch test setup for the proposed miniature specimen testing.
2. Determining the load vs displacement diagram on the miniature specimens.

Design and development of miniature specimen test setup

The essential elements of the miniature specimen test technique are punch and specimen holders known as dies (lower and upper dies), punch holder for load application and load vs displacement measuring devices. The miniature specimen is supported by a rectangular slot of a lower die and the upper die with screws would keep the specimen in position. The load is applied by a punch which is attached to the punch holder. This assembly is gripped in universal testing machine. Appropriate load cells are chosen to accurately record the load applied through the punch on the specimen. Miniature specimen lower and upper die holders are depicted in Fig. 1 and Fig. 2. Punch and punch holder assembly used for experimentation is shown in Fig. 3. Entire assembly of Small punch test fixture is shown in Fig. 4. The entire miniature specimen tests have been carried out on the computerized UTM of 100ton capacity is shown in Fig. 5.

Fig.1 Miniature specimen holder lower die

Fig.2 Miniature specimen holder upper die

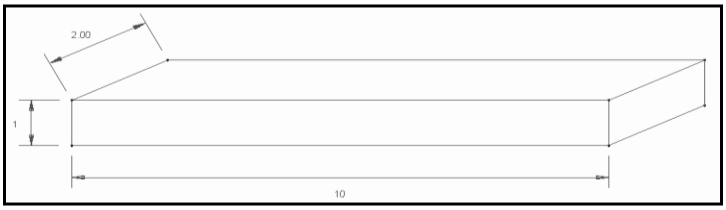
Fig. 3 Punch in a punch holder

Fig. 4 Small punch test fixture

Fig. 5 Universal Testing Machine clamped with Miniature Specimen

Experimentation

Materials considered for experimentation are EN8, EN19, EN24, EN31 and EN36 steels. Miniature specimen considered for experimentation is shown in Fig. 6.



All dimensions are in mm

Fig. 6. Rectangular miniature specimen

In the present investigation, all the miniature specimen tests were carried out on the computerized UTM of 100 ton capacity (Fig. 5). The machine has a versatile feature for varieties of tests. The intelligent system software is connected to the machine using standard interface. The machine has two crossheads, the top crosshead is stationary and the bottom crosshead is movable along the downward vertical axis. All the inputs and the movements of the machine were conducted through the software. The miniature specimen tests were carried out at a crosshead speed of 0.05mm/min. The software had the facility to store the output of the experiment i.e. load - displacement curve in the form of graph and also in the form of data sheet. The output of the miniature specimen test was characterized by the load at breakaway point, peak load and the corresponding displacements, as well as the failure load and the corresponding displacement. Miniature specimens before and after testing are shown in Fig. 7 and Fig. 8 respectively.

Fig. 7 Specimens before testing

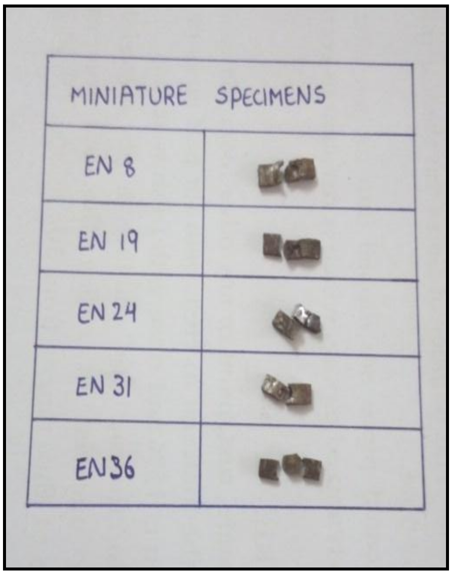


Fig. 8 Specimens after testing

Results

Load-Displacement diagrams for specimens considered are shown in Fig. 9 – 13. The results of miniature small punch test are reported in Table .1. The table also demonstrates the maximum load on the specimen and the corresponding displacement in both longitudinal and transverse directions.

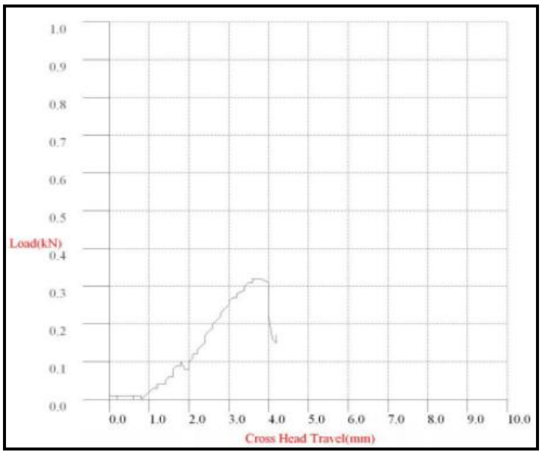


Fig. 9 Load-Displacement diagram for EN8 Steel

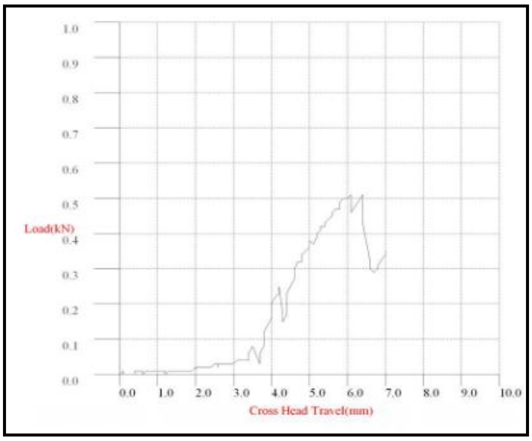


Fig. 10 Load-Displacement diagram for EN19Steel

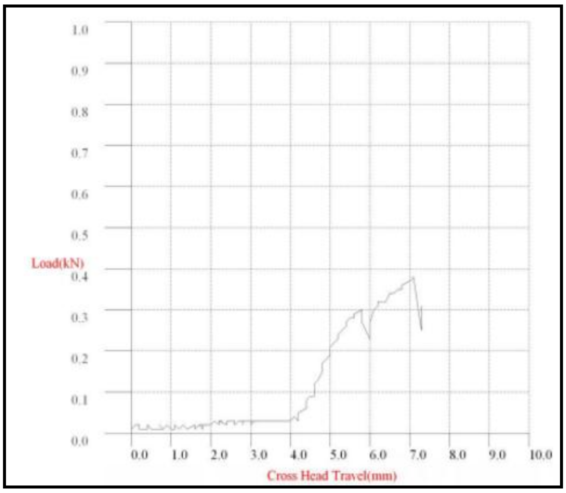


Fig. 11 Load-Displacement diagram for EN24 Steel

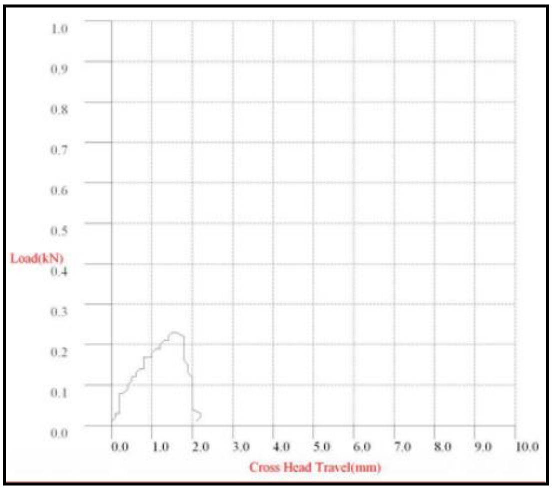


Fig. 12 Load-Displacement diagram for EN31 Steel

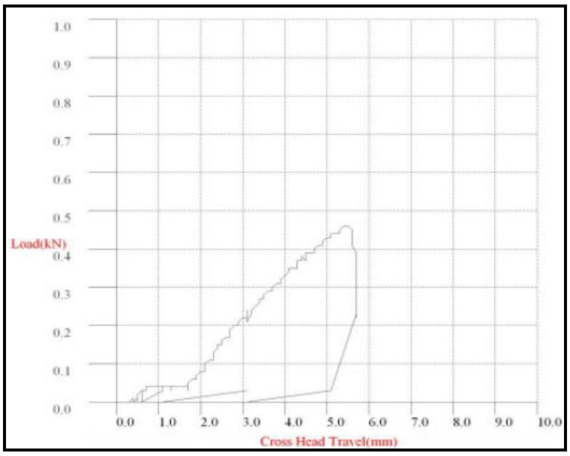


Fig. 13 Load-Displacement diagram for EN36 Steel

Table .1 Miniature specimen test results

	EN-8	**EN-19**	**EN-24**	**EN-31**	**EN-36**
Maximum load (N)	320	510	380	230	460
Displacement at maximum load (mm)	3.8	6.4	7.1	1.6	5.5

Conclusions:

This work presents the experimental studies on tensile properties of structural steels using miniature specimens. The important findings of the present work are as follows:

- A simple rectangular shaped miniature specimen (1 mm thickness) has been designed and proposed for the use in evaluation of tensile properties of structural steels. The specimen preparation requires less number of machining operations and is time saving.
- An experimental setup has been designed and successfully used in the present work to carry out the miniature test using rectangular specimen of thickness 1.0 mm. The development of miniature specimen punch test setup involves designing of dies, punch holder and punch, compression attachment, displacement measuring system etc.

- The experimental values of maximum stresses of standard specimens of EN8, EN19, EN24, EN31, EN36 steels were noted to be 637.23N/mm^2, 895.026N/mm^2, 576.932N/mm^2 ,685.962N/mm^2 ,816.506N/mm^2 and the corresponding strains were 0.288 mm, 0.2mm,0.322mm, 0.222mm and 0.211 mm respectively.
- The experimental values of maximum loads of miniature specimens of EN8, EN19, EN24, EN31, EN36 steels were noted to be 320N, 510N, 380N, 230N, 460N and the corresponding displacements were 3.8mm, 6.4mm, 7.1mm, 1.6mm, 5.5mm respectively.
- The results are found to be in good agreement with those given by standard tensile test data reported in the literature.

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