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Tensile Test and CAE Correlation of ABS Polymer

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Abstract—*This paper presents tensile behaviour of ABS polymer. Tensile deformation behaviour of Acrylonitrile Butadine Styrene (ABS) was experimentally investigated, following a practice guideline by ASTM. Material was tested for various strain rates. Test specimen was prepossessed using FEA software Hypermesh. Results obtained by experimentation were validated using analysis software Abaqus. During preparation of material card, tested Stress – Strain curve had negative slope after ultimate stress. As solver couldn't accept negative slope, curve was smoothen by establishing a procedure. There was problem with Young's modulus from Stress vs. Strain curve of test results. Some assumptions were made for Young's modulus from test results. It was seen that, specimen thickness contract at higher rate than its width. As strain rate for tensile test increases, its yield stress also increases. Tensile strain rate was maximum in necking region.*

1. INTRODUCTION

Engineering plastics are used in instrument panels, interior trim, fuel tanks and other vehicle applications. Due to their viscoelastic nature, plastics exhibit important rate dependence in their stress–strain responses. The strain rate dependent stress–strain curves of these materials are mandatory input in dynamic finite element (FE) analysis for crashworthiness prediction [9].

The experimental technique to generate data at these strain rates is a research topic of practical importance [9]. Modelling and predicting the behaviour of these structures made of polymers require the knowledge of mechanical response of the materials [1].

To obtain valid stress–strain data in a material test, the specimen should be in a state of stress equilibrium, and undergo homogeneous deformation in the gage section. Usually, necking in the polymeric specimen occurs at relatively small strain, which results in the inhomogeneous deformation of polymers [1].

2. MATERIAL AND SPECIMEN

Polymeric material used in this study was Acrylonitrile Butadine Styrene (ABS). Material was specified according to ASTM D638, Type I [14]. It has variation in thickness from 3.2 mm to 3.8 mm across the length. The specimen has dumbbell shape. The straight gauge section has length of 50mm and width of 13mm [14]. The test dumbbells were injection moulded by the material supplier. The nominal thickness of the specimens was 3.2 mm. Fig. 1 shows the geometric dimensions of the test specimen as per ASTM D638 standards [14].

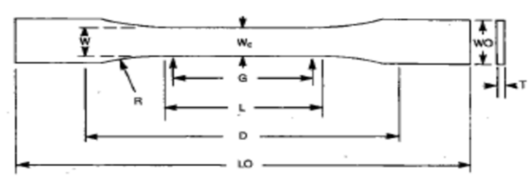

Fig. 1: Geometry and Dimensions of specimen[14].

Table 1: Dimensions for specimen as per ASTM D638 [14].

Dimensions	Type I Specimen	Tolerances
W – Width of narrow section	13	±0.5(±0.02)
L – Length of narrow section	57	±0.5(±0.02)
W/O – width overall, min	19	+3.18(+0.125)
LO – Length overall	165	No max
G – Gauge length	50	±0.25(±0.010)
D – Distance between grips	115	±5(±0.2)
R – Radius of fillet	76	±1(±0.04)
T - Thickness	3.2	±0.4

3. EXPERIMENTATION

ABS dumbbells were tested with UTM machine. Test was conducted according to ASTM D638, which is standard for tensile test of Plastics [14]. Dumbbells were tested with variable strain rate of 1mm/min, 10mm/min, 20mm/min and 50mm/min. For each strain rate three specimens were tested. Results obtained are Load (N) and Deflection (mm) for each specimen. From results obtained calculation performed for Engineering Stress, Engineering Strain, True Stress, and True Strain. Experimentation gives load (N) and Deflection (mm) only. This curve is then converted in to Engg. Stress vs. Engg. Strain and True Stress vs. True Strain curve. Once Young's modulus was finalized, True stress vs. Plastic strain curve was obtained.

4. CALCULATIONS

$$Engg.Stress(s) = \frac{Load(N)}{Cross\ Sectional\ Area(Sq.mm)}$$ Equation 1

$$Engg.Strain(e) = \frac{Change\ in\ length}{Original\ Length}$$ Equation 2

$$True\ Strss(\sigma) = Engg.Stress(s)[1 + Engg.Strain(e)]$$ Equation 3

$$True\ Strain(\varepsilon) = \ln[1 + Engg.Strain(e)]$$ Equation 4

$$Plastic\ Starin = True\ Strain - \frac{True\ Stress}{Young's\ Mod.}$$ Equation 5

For calculation of engineering stress cross sectional area of each specimen after break was used. Then calculated Stress for each specimen and averaged it. Curves were plotted with average engineering stress values obtained by calculation.

5. MATERIAL CARD PREPARATION

In material card of Hypermesh, material type is MATERIAL and card image is ABAQUS_MATERIAL [13].

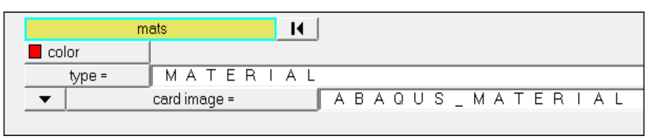

Fig. 2: Material card used in Hypermesh.

In properties of Hypermesh, card image used is SOLIDSECTION. Property type is SOLID SECTION [13].

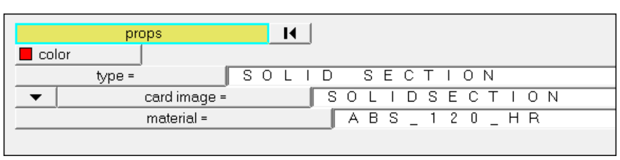

Fig. 3: Property card used in Hypermesh.

Solver demands plastic strain and True Stress values as input [13]. If given curve have negative slope, its error during calculation. To eliminate this error procedure was established. After ultimate stress where curve starts negative slope those stresses were eliminated performing trial and error to establish smooth curve with positive slope.

Density of ABS is 1.05×10^{-09} tonns/mm^3, Poisson's ratio (Nu) is 0.35 for ABS plastic. There was problem with Young's modulus from experimental data. Initially tried young's modules from test results, simulation results obtained with this young's modulus were not as accurate as required. So assumption was made to use standard value of young's modules for simulation, which is 2300.82 MPa.

6. RESULTS

Test results obtained are Load(N) and Deflection(mm). Curves for test results are as:

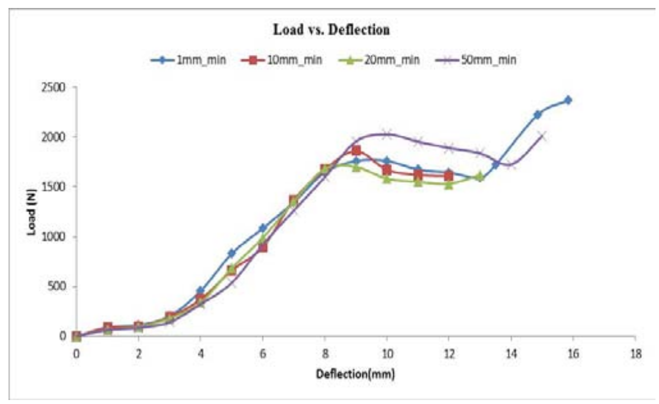

Fig. 4: Load vs. Deflection (Test Results).

Data obtained from test were then calculated and converted into Engg. Stress, Engg. Strain, True stress, True strain, and Plastic strain. Curve plotted are with average of all specimen tested for each strain rate.

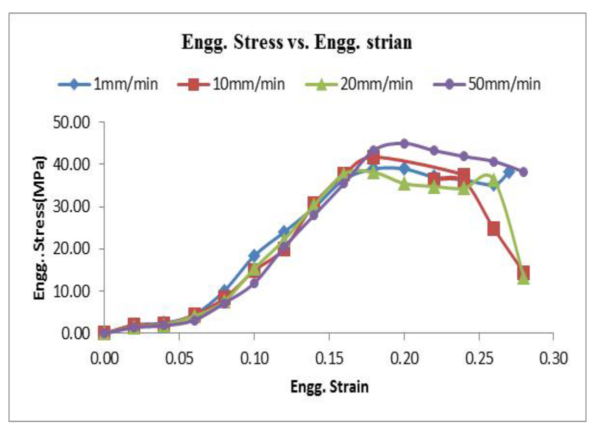

Fig. 5: Engg. Stress vs. Engg. Strain.

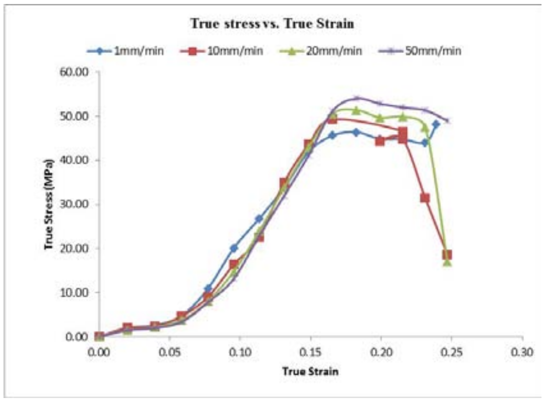

Fig. 6: True stress vs. True strain.

In the True stress vs. True strain curve, curve shows negative slope. Abaqus solver needs True stress and Plastic strain values as input. True stress vs. Plastic strain curve also shows negative slope. This was crucial problem during simulation. As software don't allow negative slope during analysis. To resolve this issue, technique was developed. From the observation of curve, it is clear that curve shows negative slope after ultimate stress value. In actual testing, its region where necking formation starts in the test specimen. For the analysis purpose this was very important region of True stress vs. Plastic strain curve.

From the observation of curve, it is clear that curve starts bending after yield stress. Specimen enters in plastic phase from elastic phase. This bending of curve is still considerable, because it shows still positive curve.

Based on trial and error technic, trials were made with region of curve from ultimate stress to breaking point. Trials were made such that curve shows constant slope/positive slope and it will not affect formation of necking region in simulation.

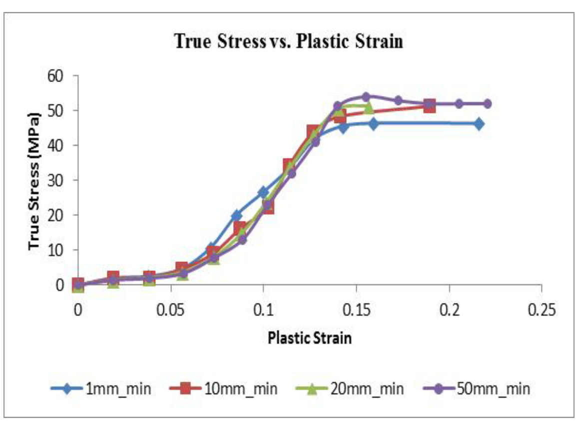

Fig. 7: True Stress vs. Plastic Strain.

Engg. Stress vs. Engg. Strain, True stress vs. True strain and True Stress vs. Plastic Strain curves shows that as strain rate is increasing, its failure value i.e. yield value is also increasing.

7. CORRELATION OF TEST AND CAE RESULTS

Test specimen was first meshed in preprocessor Hypermesh, with profile Abaqus (Standerd3D). Specimen was meshed with solid mesh (Hexa elements) with element size 0.5,1 and 1.5mm. After it, counted number of nodes and elements for each type of mesh. From the simulation results noted values of max. stress, strain and displacement for each type of mesh. Results showed that, it is optimum to use 1mm mesh size. Mesh size of 0.5 mm gives better results but it is time consuming for calculation.

One side of dumbbell was constrained with zero degree of freedom and at another side tensile load was applied with only one degree of freedom, allowing specimen to move in only X – direction. Constraints were applied up to 25 mm from both ends as per ASTM D638 standards.

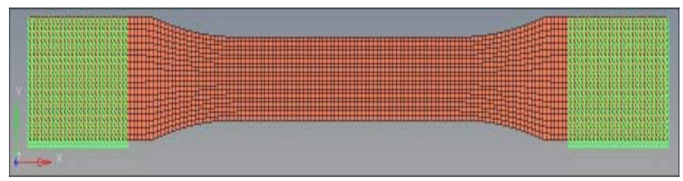

Fig. 8: 1mm element size mesh of dumbbell specimen.

CAE results in Abaqus shows failure of specimen as actual test specimens.

Fig. 9: Correlation of CAE and Test failure of specimen at 1mm/min strain rate.

Fig. 10: Correlation of CAE and Test failure of specimen at 10mm/min strain rate.

Fig. 11: Correlation of CAE and Test failure of specimen at 20mm/min strain rate.

Fig. 12: Correlation of CAE and Test failure of specimen at 50mm/min strain rate.

From above (Fig. 9 to Fig. 12) failure figures, it's clearly seen that as test specimen fails, CAE failure is also in the same region of specimen. CAE failure at each strain rate shows that tensile strain rate is maximum in necking region. From CAE simulation and experimental test it was observed that specimen thickness contract at higher rate than its width.

8. ACKNOWLEDGEMENTS

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