XIV International Conference on Computational Plasticity. Fundamentals and Applications
COMPLAS 2017
E. Oñate, D.R.J. Owen, D. Peric and M. Chiumenti (Eds)

MEASUREMENT OF STRAIN DISTRIBUTION ON SHEET SPECIMEN IN TENSION TEST VALIDATING TRANSITION OF STRAIN DISTRIBUTION PREDICTED BY FEM

MASAYOSHI AKIYAMA*, RYO MORIMOTO†

* Research Institute for Applied Science (RIAS),
49 Tanaka-Ooi-cho, Sakyo-ku, Kyoto, 606-8202, Japan
e-mail: makiyama@rias.or.jp, web page: http://www.rias.or.jp/

† 2-20-9, Tomatsucho, Amagasaki-shi, Hyogo, 661-0003, Japan
e-mail: rmorimoto0@gmail.com

Key words: Stress-Strain Curve, Tension Test, Sheet Specimen, FEA, Strain Distribution, Transition of Strain, .

Summary *In the present research work the authors tried to measure the non-uniformity of strain on the specimen throughout tension test to validate the results of FEA. Flat specimen of JIS5 was used to investigate the transition process of strain distribution. The material was pure iron. A cast ingot was elongated by hot forging to make a round bar which is 4 times as long as the ingot. The bar was subjected to thermal treatment to homogenize the grain size before flat specimens were sectioned from the bar. Strain gauges were placed on the specimen to monitor the transition of largest strain. An extensometer was also placed to measure the average strain between the two gauge points. Result of FEA analysis predicted that the largest value of strain is observable at the shoulder portion at the initial stage of yielding. The position of largest strain moved to an intermediate portion when the average strain increased and finally moved to the centre portion. The result validated the predicted result by FEA.*

1 INTRODUCTION

Tension test has a long history and has been widely acknowledged as the most common method for evaluating the mechanical properties of materials and it has been used on both academia and industry sides [1]. Major purpose of tension test is obtaining mechanical properties of the material such as a stress-strain curve of the material. Yield stress or Elastic characteristics such as Young's modulus are measured depending upon the customers' request. Stress is calculated by dividing force by the cross sectional area of specimen and strain is calculated by measuring the change in gauge length of the measuring device such as a strain gauge or an extensometer. It is important to note that uniform distribution is assumed of the stress on the cross sectional plane and of the strain in the two gauge points, and the cross sectional plain and the segment connecting two gauge points cross each other. The authors showed that there are cases where these assumptions do not apply**.** Uniformity of stress and strain distribution is important to ensure the precision of measured curve of stress-strain. The authors showed by using FEA that there is a non-uniform distribution of stress and strain in tension test and there is a transition of peak stress and strain according to the progress of tension test [2]. In COMPLAS2015 the authors presented experimental results to show that these peak shifts might affect the shift of rupture point in tension test and proposed a geometry to ensure the centre rupture [3]. In the present work experimental result is shown to validate the result of FEA on tension test of sheet specimen. Strain gauges were placed on the specimen and transition of the intensity of strain on the specimen was compared with the numerical result.

2 NUMERICAL ANALYSIS

Elastic-plastic FEA was carried out on a sheet specimen subjected to tension test focusing attention on the transition of stress and strain distribution according to the progress of the test. The code used was ELFEN [4] developed at Swansea University.

2.1 Preparations

The geometry of sheet specimen is illustrated in Figure 1. It is basically a JIS5 specimen. Symmetry was taken into consideration and only a quarter in the first quadrant was subjected to the analysis. It was a plane-stress analysis and displacement in X-direction was applied on the nodes in the gripping portion.

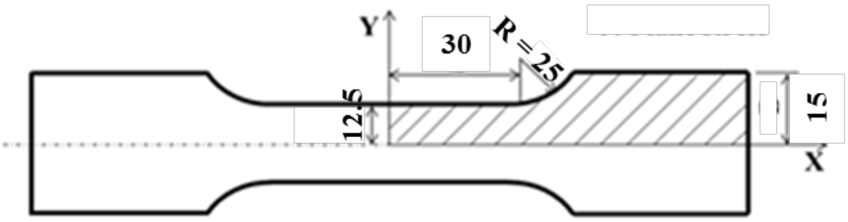


Figure 1: Geometry of specimen and first quadrant subjected to FEA.

Four types of stress-strain curve adopted in the analysis are shown in Figure 2; two types of yield stress and two types of work-hardening ratio. Young's modulus E and Poisson's ratio ν were 210Gpa and 0.3 respectively and were not changed throughout the analysis. Influences of yield stress and work-hardening ratio on the transition of the distributions of stress and strain on the specimen were evaluated.

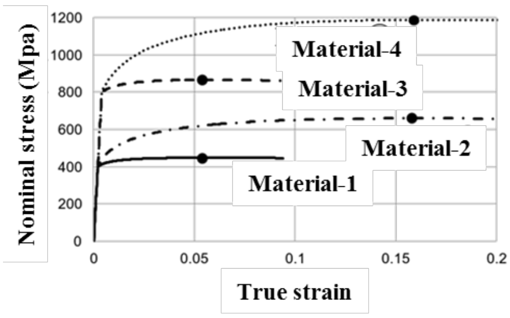


Figure 2: Stress-strain curve used in FEA.

4.2 Result

For the case of material-1 transitions of axial stress and axial strain are illustrated in Figure 3 and 4. Plastic deformation starts in the vicinity of the shoulder portion and new poastic zone suddenly appears on X-axis in between the centre and the shoulder. Finally the highest value of strain moves to the centre and almost uniform distribution of axial stress and axial strain are obtainable in the vicinity of specimen centre. Little influence of work-hardening ratio was observed on the distribution patterns of stress and strain.

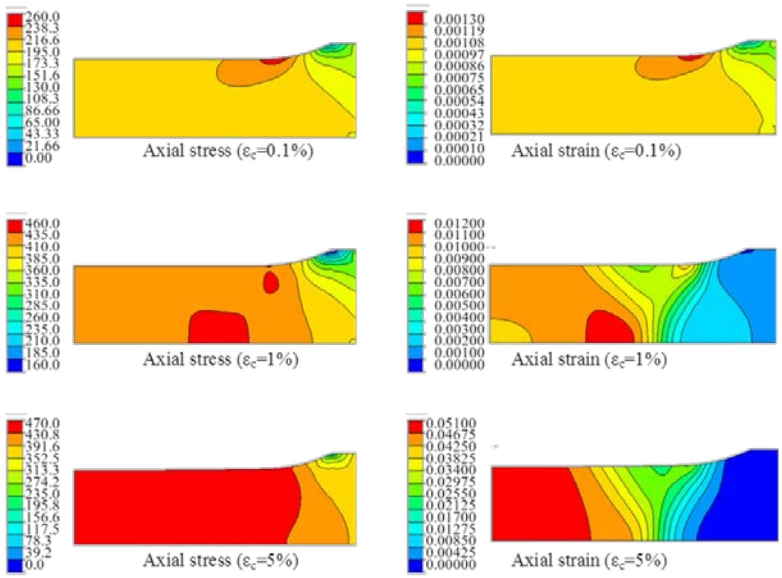


Figure 3: Transition of axial stress and axial strain according to tension test

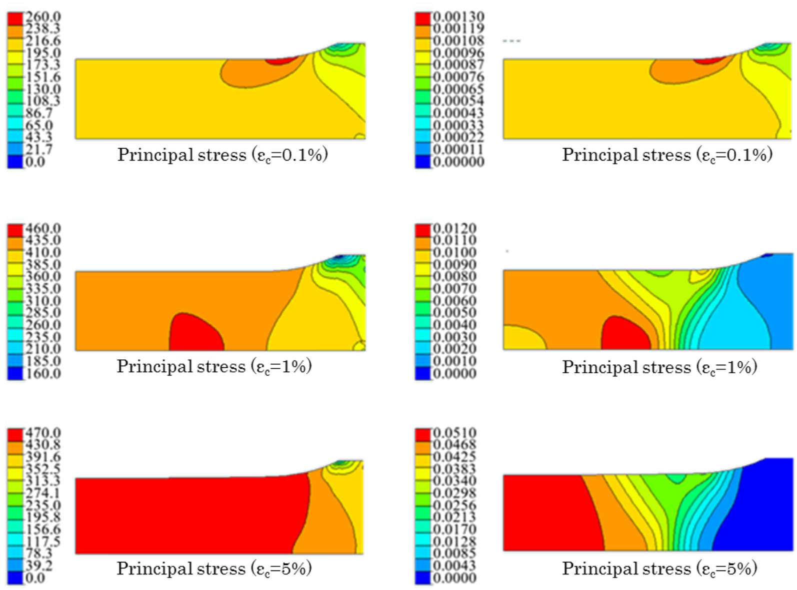


Figure 4: Transition of principal stress and strain according to tenstion test.

3 EXPERIMENT

3.1 Preparations

A 50Kg round ingot of pure iron was cast of which geometry was 310mm in height, 180mm and 130mm in upper and lower diameters. After cooling, the ingot was put in an electric furnace in order to homogenise the grain size. Then specimen for tension test was sectioned from it bu wire cutting. The specimen was JIS5 of which geometry is given in Figure 5. In order to measure the distribution of axial strain, 5 strain gauges were placed in the axial direction on both edges and on the centre line. The number of strain gauges were 15 on both sides of the front and rear surface. The gauges placed on the specimen were plastic gauges which are capable of measuring strain up to 20%. The grid size was 1.5mm wide and 5mm in length and the base size was 3mm wide and 11.5mm in length.

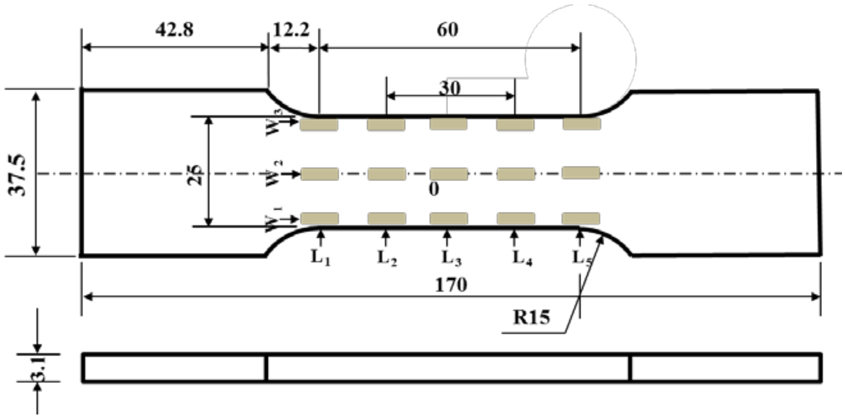


Figure 5: Geometry of sheet specimen of JIS5 and placement positions of strain gauges.

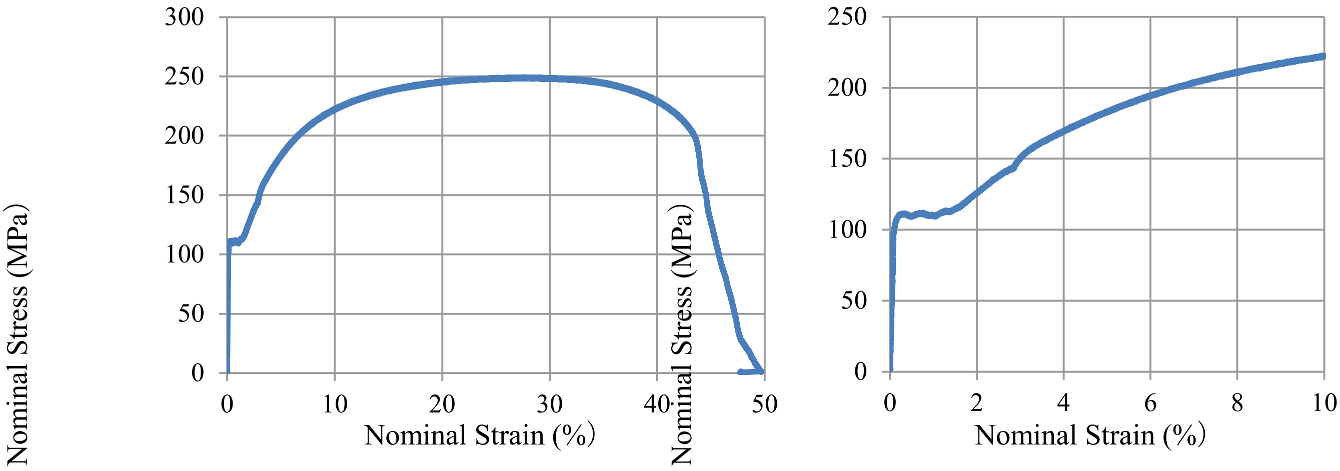
View of the tension test is given in Figure 6. The testing was carried out by using an Instron testing machine with capacity of 200KN. The cross head speed was 2mm/min. The deformation of strain gauges hit 20%, which is the lowest limit of measurable strain of the strain gauge, in the course of the test but the test was carried out until rupture.

Initial setting | Testing | Necking

Figure 6: View of tension test.

3.2 Result

Measured stress-strain curve obtained by extensometer is shown in Figure 7.



Stress-strain curve to rupture Enlargement until 10% strain

Figure 7: Measured stress-strain curve by load and extensometer.

Increase in the strain on each observation point, i.e. point where strain gauge was placed , is shown in Figure 8. It is shown that shoulder portion immediately respond as soon as tension test starts. Then intermediate portion starts to deform and the plastic strain exceeds that of shoulder portion. Finally the centre portion starts to deform. Extensometer picks up the average value which gradually approaches to the strain at the centre portion. It is curious to note that the axial strain at centre is smaller than those of intermediate and edge portions until the time reaches 200 sec.

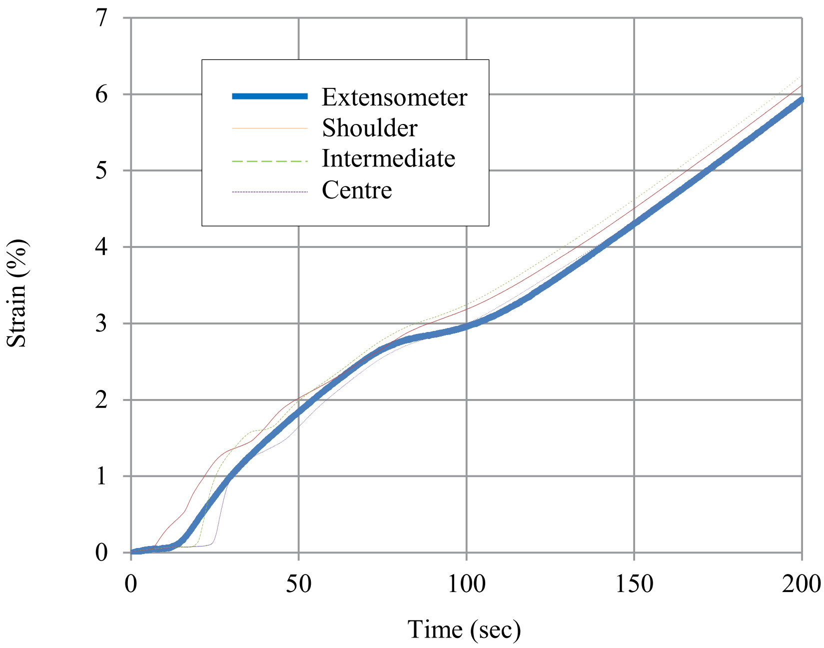


Figure 8: Transition of axial strain according to tension test.

Distribution of strain measured by strain gauges are shown in Table 1. The axial strain on the centre of shoulder portion (b) is 4.45 and is much smaller than those of other observation points, but this is because of the constraint of the gripped portion as it was shown in Figure 4. On the centre plane the distribution of axial strain (Axdial-3(Centre)) is deemed uniform in the width direction, but at the intermediate portion the axial strain on one edge of specimen (c) is considerably smaller than those on the other edge (a) and on the centre line (b). Unfortunately some gauges placed on the intermediate ceentgre plane peeled off after 200 seconds and it was not observed that the peak of strain shifts to the centre. It may be better to carry out more numher of tension test in the same manner.

Table 1: Distribution of axial stress (Time:200sec)

Position	Edge (a)	Centre (b)	Edge (c)
Axial-1(End)	6.39	4.45	5.84
Axial-2(Intermediate)	6.23	6.25	5.75
Axial-3(Centre)	5.82	5.88	5.58

4 CONCLUSIONS

Elastic-plastic FEA was carried out on tension test of sheet speccimen followed by an experiment for validation. Analytical result showed that peak value of axial strain appears at the beginning stage of the test and as soon as the plastic deformation starts on the parallel portion the position of peak strain moves to the intermediate portion, and finally the axial strain at the centre becomes largest. Result of experiment validated that the shoulder portion immediately responds as soon as the test starts but as soon as the plastic strain starts to cover the specimen the peak strain shifts to the intermediate portion as it was predicted by FEA. By repeating tension in the same manner peak shift of axial strain to the centre plane will be observed as was predicted by FEA.

ACKNOWLEDGEMENT

The authors would like to thank Ministry of Economy Trade and Industry, Japan for the experimental part of the present work was supported by the fund titled “Development of a method for the next generation on the measurement and evaluation of steel” in the fiscal year 2016.

REFERENCES

[1] ASTM E8 / E8M - 16a, Standard Test Methods for Tension Testing of Metallic Materials
[2] R. Morimoto and M. Akiyama, Propagation Mechanism of Non-uniform Distribution of Stress and Strain in Tension Test, COMPLAS-XII, 631 (2013).
[3] R. Morimoto and M. Akiyama, Proposal of New Specimen Geometry for Tension Test Restraining Non-Uniform Deformation, COMPLAS-XIII, 968 (2015).
[4] ELFEN : Rockfield Software Limited