AN EFFECT OF TECHNOLOGICAL NOTCHES ON STRESS AND STRAIN DISTRIBUTION DURING MONOTONIC TENSION

T. Szymczak[1], A. Brodecki[1], Z.L. Kowalewski[1, 2]

[1]Motor Transport Institute, Warsaw, Poland

[2]Institute of Fundamental Technological Research, Warsaw, Poland

1. Introduction

It is widely known that the stress produced by various type of geometric discontinues reduces material resistance. A level of such reduction depends on the loading type.

An influence of notches on material behaviour is usually determined either experimentally [1, 2, 6] or theoretically [3, 5]. The laboratory tests are very often focused on determination of details related to variations of stress-strain curve, fracture force, ultimate tensile strength and lifetime. An effect of hole diameter on the SMC-R50 composite behaviour under tension was investigated by Mallick [4]. He obtained strength decrease from 140 MPa to 60 MPa when the diameter increased tree times. An opposite effect was achieved for the 2024 and 7075 aluminium alloys [6]. Bennett and Weinberg [1] tested the 248-T4 aluminium alloy under cyclic loading applying specimens with two various fillets. An effect of radius change from 1.6 mm to 0.6 mm was manifested by 50% lowering of the strength curve. Another experiments also confirmed a significant influence of notches on high cyclic fatigue life [2]. In order to extend knowledge concerning material behaviour due to geometrical discontinues modern testing devices are necessary such as digital image correlation (DIC) systems for example.

The paper reports results from monotonic tension tests in which the DIC device was applied to measure a distribution of strain components.

2. Experimental procedure

The experimental procedure contained two stages: (a) determination of mechanical properties applying digital image correlation system; (b) examination of an influence of technological notch on the stress-strain curve variations.

The 40H steel widely applied by automotive and machinery branches of industry was selected for investigations. All tests were performed at room temperature, using servo-hydraulic testing machine and DIC measurement system (4M Aramis). The plane specimens of gauge length and thickness equal of 50 mm and 6 mm, respectively, were used. In order to validate axial strain measurements by the Aramis system the 2620 Instron extensometer was applied. Monotonic tension was conducted at constant displacement velocity equal to 0.5 mm/s.

3. Experimental results

The results validation process was performed on the basis of data comparison captured by extensometer and DIC system, Fig. 1. It enabled to distinguish only small differences in the last part of the tensile curve considered. Young's modulus values determined using testing methods were close i.e. 148 672 and 164 866 MPa for extensometer and DIC techniques, respectively.

An influence of technological notches on the steel properties under monotonic tension was investigated for two types of notch, i.e. 3×15 and 5×25 mm, Fig. 2. It was determined on the basis of the Mises strain evolution from the start (Fig. 2a) up to the end of test

(Fig. 2b) and as well as fracture and sub-zones localization (Fig. 2b). A field distribution of the Mises strain calculated on the basis of DIC system measurements was illustrated in Fig. 2a. The maximum values of the effective strain were detected in four zones of the groves edges. A strain increased with increasing tension force and achieved the critical value at zone where decohesion was observed, Fig. 2b. As it is indicated in Fig. 2b besides of the dominant fracture zone one can also notice a subzone, where deformation level is increased with respect to the other places of the specimen.

An effect of technological notch on the tensile characteristic can be evaluated on the basis of taking comparison of tensile characteristic (0) for specimen without artificial defects to stress-strain curves determined by the use of specimens with notches, Fig. 2c. As it is clearly seen both types of notch accelerated material yielding. In the case of notched specimen yield point was equal 350 MPa, what means that it was more than 200 MPa lower than for the standard specimen obtained. The differences between maximum stress from tests performed on the notched and unnotched specimens were almost negligible, less than 5%.
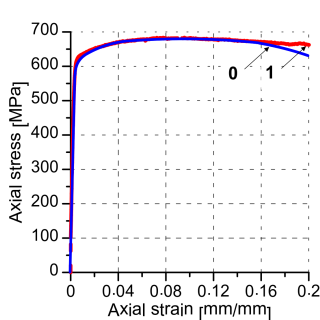

Fig. 1. Comparison of tensile characteristic determined by the use of extensometer (0) and 4M Aramis system (1).
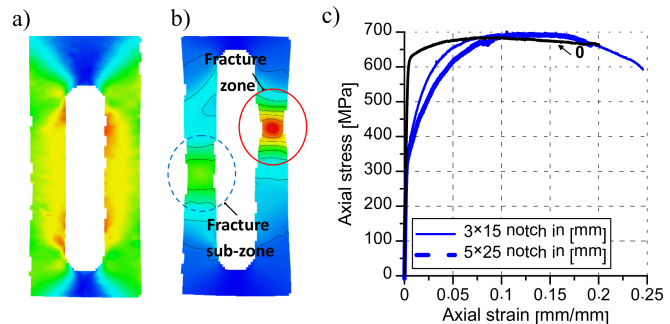
Fig. .2. The results of tensile tests: distribution of Mises's effective strain at the beginning (a) and the final stage of monotonic tension (b); comparison of stress-strain curves for specimens having two types of notch, i.e. 3×15 and 5×25 [mm] to the characteristic (0) captured for unnotched specimen (c).

4. Summary

The digital image correlation (DIC) system may be used to determine not only strain distribution but also to capture data necessary to calculate material mechanical properties e.g. Young's modulus, yield point or ultimate tensile strength. The DIC system allows to identify places of geometrical discontinuities. Although the results exhibited 67% decrease of the yield point due to the notch, the ultimate tensile strength remained almost the same for notched and unnotched specimens.

References

1. J.A. Bennett, J.G. Weinberg (1954). Fatigue notch sensitivity of some aluminium alloys, *Journal of Research of the National Bureau Standards*, **52**, 5, 235–245.

2. A. Fatemi, Z. Zeng, A. Plaseied (2004). Fatigue behavior and life predictions of notched specimens amd of QT and forged microalloyed steels, *Int. J. Fatigue*, **24**, 663–672.

3. M. Fillipini (2000). Stress gradient calculations in notches, *Int. J. Fatigue*, **22**, 397–409.

4. P.K. Mallick (1988). Effect of hole stress concentration and its mitigation on the tensile strength of sheet moulding compound (SMC-R50) composites, *Composites*, **19**, 4, 283–287.

5. N. Noda, Y. Takase (2006). Stress concentration formula useful for all notch shape in a round (comparison between torsion, tension and bending), *Int. J. Fatigue*, **28**, 151–163.

6. R. E. Whaley (1962). Fatigue and static strength of notched and unnotched aluminium-alloy and steel, *Exp. Mech.*, **11**, 329–334.