USING THE VIDEOEXTENSOMETRY AND UCI - HARDNESS FOR MONITORING OF AUTOMOTIVE STEEL SHEETS

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Resume

The paper deals with examination of relation between the hardness and the size of plastic zone during the tensile loading. UCI (Ultrasonic Contact Impedance) micro-hardness method was used for hardness measurements. Deformation was evaluated by non-contact extensometry method – videoextensometry. The result present existence of the power law relation between hardness and plastic deformation: $HV = HV_p + k\varepsilon^a$. Hot rolled sheet and thin automotive sheet were investigated.

Article info

Article history:
Received 12 July 2011
Accepted 14 August 2011
Online 1 September 2011

Keywords:
Hardness
Videoextensometry
Mechanical properties
Automotive steel sheets
Increment deformation

ISSN 1335-0803

1. Introduction

Steel constructions from point of view of safety, reliability and economic durability require materials with good strength and deformation properties. To achieve an optimal combination of these properties it is needed to know the relation between microstructure, deformation and strength of the material [1-4].

For determination of mechanical properties are available well known methods like hardness test as well as new technique for non contact measuring of strain – videoextensometry. The advantage of the videoextensometry is possibility to measure deformation on surface without the contact with the specimen. Experimental equipment consists of camera and computer with particular software. Contrast marks (dots) are placed on the scanned specimen surface. The software records x and y coordinates of center of gravity of each dot during the loading and records all framed pictures too. The post-processing evaluation allows to determine longitudinal and transversal deformations and the others parameters. The deformations of segment are possible to evaluate between 2 scanned dots, between 4 dots is possible to determine deformation of elements. Deformations determined on segments are better to use if we are interested in one component of deformation in relation to the area position on specimen. If we are interested in comparison of particular components of deformation or taking the deformation to the relation to another properties it is preferable to work with elements. Definition of segments and elements are presented in Fig. 1. The value of deformation belonging to element is assigned to center of dots (Fig.1, dots 11-12-21-22) as an average value of deformation ε_L of segments 11-21, 21-22.

Deformation of segments in Y direction (loading direction) for element 11 is determined by following equation:

$$\varepsilon_{(Y,11,t)} = \frac{1}{2}\left[\left(\frac{Y_{(12s,t)} - Y_{(11s,t)}}{Y_{(12s,t0)} - Y_{(11s,t0)}} - 1\right) + \left(\frac{Y_{(22s,t)} - Y_{(21s,t)}}{Y_{(22s,t0)} - Y_{(21s,t0)}} - 1\right)\right] \tag{1}$$

where Y are coordinates of centers of gravity of dots in the loading time t and in the time start of loading t_0 [1-2].

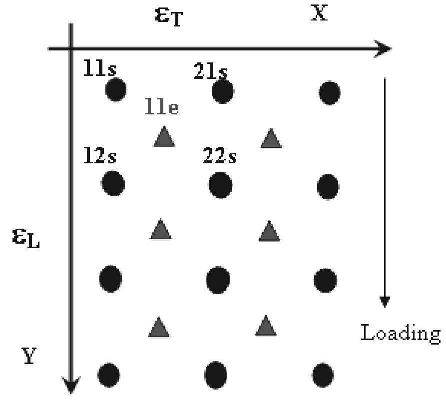

Fig. 1. Definition of normal longitudinal ε_L(11-12, 21-22) and transversal deformation ε_T (11-21, 12-22) for the segment and for the elements (11-12-21-22)

UCI testers are portable electro-mechanic devices that use a spring to apply a known force to a Vickers diamond indenter which is attached to the end of a resonating rod. As the resonating rod and Vickers diamond pyramid indenter penetrate the test sample the resultant indentation creates a clamping force to the tip of the indenter that is proportional to its size and causes a frequency shift to the rod. The amount of the frequency shift is measured and related to the size of the Vickers indentation. Results are converted to hardness scales such as Vickers and Rockwell and Brinell [5-8].

2. Experimental and testing methods

The experiments were performed on two types of steels. Steel sheets were investigated: XSG is deep drawing interstitial free steel with ferrite microstructure. Absence of interstices causes low yield, high ductility and high normal plastic anisotropy as well as normal anisotropy. The thickness of used sheet is 1.9 mm [4]. The steel KX70 are high strength micro-alloyed hot rolled steels with ferrite-pearlite microstructure with small amount of alloying components [5]. The thickness of used sheet is 1.9 mm . The steel KX70 are high strength micro-alloyed hot rolled steels with ferrite-pearlite microstructure with small amount of alloying components. The thickness of steels was 8 mm. The chemical compositions of steels are presented in Table 1. The mechanical properties are presented in Table 2 .

Flat tensile specimens were used for tensile tests. A grid of 3x33 dots was prepared on the surface of the working part of thin sheet specimens, on the thick sheets was grid of 50x3 dots prepared. Distances between the dots were 3 mm in longitudinal direction and 2 mm in transversal direction, respectively. The specimens were loaded with the crosshead speed of 1.3 mm/min while the surfaces of specimen were scanned.

After the loading to appropriate plastic deformation the specimens were unloaded and hardness (HV1) was measured. In the case of thin sheets the procedure was repeated to the extension close to rupture. Thick sheets were loaded only in the range between the yield strength and tensile strength. Number of loadings and corresponding forces are presented in the Table 3.

Table 1

The chemical composition of investigated steels (in. wt.%)

Steel	C	Mn	Si	P	S	Al	Ti	Nb	V
KX70	0.08	1.66	0.25	0.01	0.01	0.03	0.02	0.06	0.05
XSG	0.0013	0.08	0.006	0.011	0.01	0.055	0.04	0.001	0.002

Table 2

The mechanical properties of investigated steels

Steel	R_e (MPa)	R_m (MPa)	A (%)
KX70	540	618	22
XSG	189	300	36

Table 3

Number of loadings and corresponding force before the hardness testing

Load force (kN)	1	2	3	4	5
KX70	69	70	72	74	76
XSG	7.7	9.5	10.5	12.1*	10*

*values correspond loading in localized deformation area

3. Results and discussions

The aim of the experiments was to describe the homogeneity of deformation distribution after the particular loading and find out the relation between the hardness and deformation.

Distributions of deformations along the length of all tested specimens are presented in the Fig. 2-3. The homogeneity of deformation distribution increases with increasing loading for all investigating materials. The homogeneity of deformation decrease due to localization of deformation in the neck when loading after the tensile strength Fig. 3-4. The maximum local deformation of XSG is 163% before the total crack initiation. These results are good corresponding with literature [9-13].

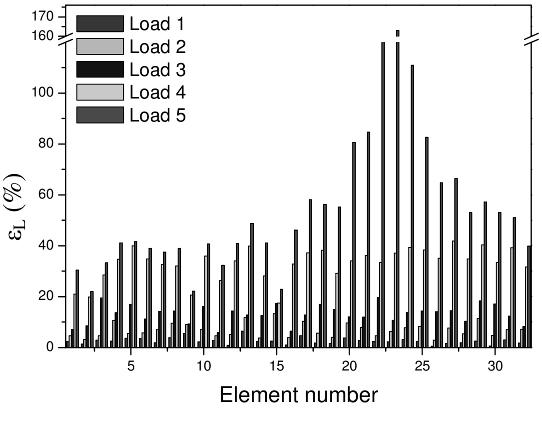

Fig. 2 Distribution of longitudinal strain along the specimen length of material XSG

The hardness tests were performed after each loading in the center of elements. Distance between measuring positions was 0.5 mm. This distance is sufficient to not to be affected the measurements by previous one. UCI-hardness test is easy to use, portable method of hardness test. Disadvantage of this method is that the tested object should be heavy. The weight of the measuring object should be more than 200g. This is the reason why thin sheets specimens were fixed on another bulk piece of steel. The scatter of hardness values in the case of thin sheets is due to specimen preparation.

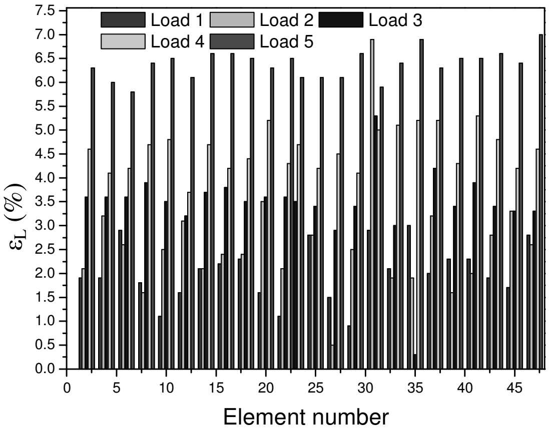

Fig. 3 Distribution of longitudinal strain along the specimen length of KX70

The results of hardness tests were correlated with the deformation measured by videoextensometry Fig. 4-5. The relation between the hardness HV 1 and deformation was found in all investigated steels. The relation was fitted by following power function:

$$HV1 = HV1p + a\varepsilon^{b} \qquad (2)$$

where HV1p is the hardness of material before deformation, ε is tensile longitudinal deformation and **a, b** are fitting coefficients. The coefficients depend on the properties of the steels. The values of coefficients **a** are in order of 10^1-10^2. The values of coefficient **b** are in order of 10^{-1} for all investigated steels.

The fitting function is valid for all investigated steels even the different longitudinal deformation state of measured specimens.

Using the determined relation is possible to predict longitudinal deformation state of steel constructions.

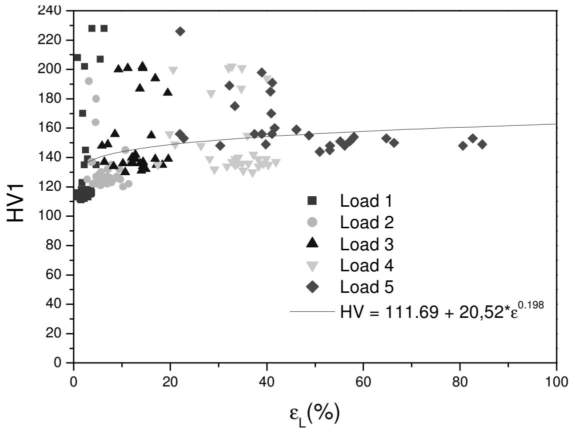

Fig. 4 The relation between hardness and plastic deformation of steel XSG

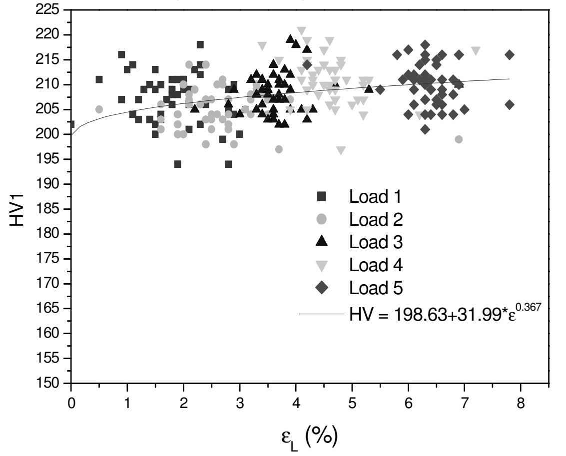

Fig. 5 The relation between hardness and plastic deformation of steel KX70

4. Conclusions

Using the videoextensometry and UCI-hardness test enables to characterize the relation between the hardness and plastic deformation on different steel grades.

Homogeneity of deformation distribution increases with increasing of loading force in macro scale element 3x2 mm while in the neck area localization of deformation occurs.

The power relations between the hardness HV1 and longitudinal deformation was found. This relation is valid for all investigated steels. The coefficients of the relation are changing depending on steel grade.

UCI is practical, portable method appropriate to satisfactory determination of deformation state of materials.

A*cknowledgements*

This study was supported by the grants projects and APVV No. 0326-07, SK – PL 0019 – 09 and VEGA 1/0780/11.

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