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EXPERIMENTAL STUDY OF LIMIT STRAINS IN THE CASE OF MARCINIAK TEST

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Abstract. One of the most important problems of manufacturers and users of deep drawing sheets is to know whether the sheet characteristics are sufficient to allow manufacturing of a given part. This presumes the knowledge of material properties and of its deformability. By determining the limit-deformations one can identify sheet deformability in view of their deep drawing. The paper presents the variation of the main deformations, ε_1, ε_2 şi ε_3 at 10 mm from either side of the crack for different stress states of the material. The sheet itself is deep drawing steel A5 STAS 10318-80, manufactured by Mittal Steel Romania, with a thickness of 0.73 mm and 1.23 mm.

1. INTRODUCTION

In the category of the plastic strain processes an important place is taken by the sheet strains. The main users of sheet are the automotive industry and the electrical engineering one. In the case in which the pieces made from sheet are big or complex the only way to obtain them is through the process of deep drawing. One of the main issues of those who make and use sheet in the deep drawing process is to know whether the sheet's features are good enough in order to produce a given piece. This aspect presupposes to know the features and strains of the sheet material. Sheet strains can be established by determining the limit strains for the deep drawing process.

For a cupped piece there are several types of strains. Several types of strains can be obtained with the help of the deep drawing process with a cylindrical flat bottomed punch (Marciniak test) by using blanks with different widths. In the case of the deep drawing process with a flat bottomed punch the piece usually cracks in the joining area of the piece's bottom with the cylindrical area. In order to avoid the cracking of the piece a driving plate is used in this area (figure1).

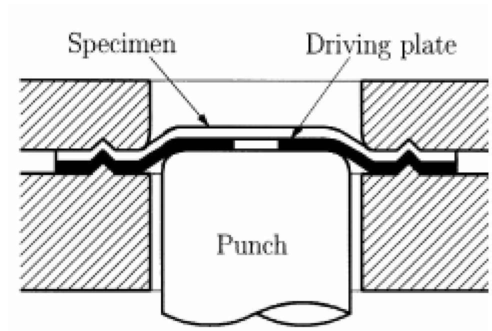


Fig. 1. Marciniak test

This work presents the variation of the main strains ε1, ε2 and ε3 at 10 mm on both sides of the crack for different stages of material application. The test used is the Marciniak test. The material of the sheet used for the deep drawing is steel A5 STAS 10318-80, produced by Mittal Steel Romania being 0, 73 mm and 1.23 mm thick. The chemical composition and mechanical features STAS are presented in table 1.

Tab. 1

Chemical composition, %, max.				
C	Mn	Si	P	S
0,08	0,40	0,10	0,025	0,03

The limit strains were determined through the digital image correlation method. The strain in thickness determined through the digital image correlation method will be compared to the measured one.

2. EXPERIMENTAL PROCEDURE

2.1 The specimens used

The used specimens are 200 mm long and have different widths in order to obtain various types of strain: l= 80 mm (single axial traction), l= 140mm (plane traction) and l= 200 mm (biaxial traction).

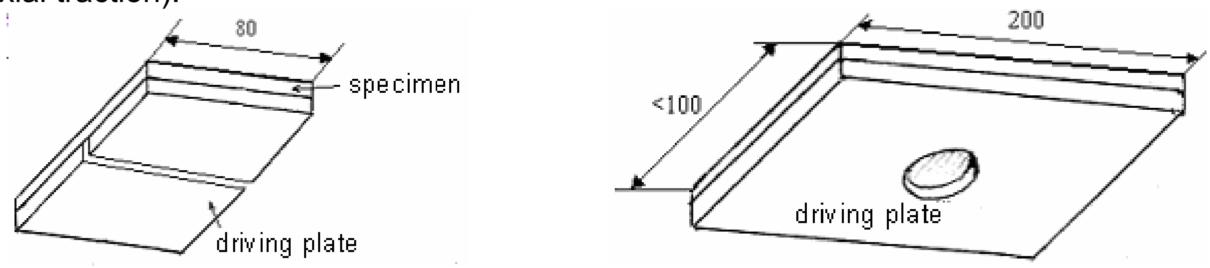


Fig. 2. Specimens

The tests were done by using a driving plate placed between the specimen and the punch, fig. 2. The driving plate had similar heights with the tested specimen which was meant to avoid the appearance of the crack in the joining area of the punch.

2.2 The equipment used

In order to determine the limit strains when using the deep drawing process with a cylindrical flat bottomed punch we used: a traction-compression machine, computer commanded; the deep drawing modulus; a camera; a computer with data acquisition programme to correlate images; a black paint blower; an air pump; material to deposit the random grid.

The traction machine used for the deep drawing test, fig. 3, is a Zwick machine with a maximum force of 200 KN (20tf). In order to realise this test the machine was equipped with the deep drawing modulus, fig. 4. The modulus is placed under the mobile beam for the machine to be able to produce the compression force necessary to the deep drawing process. This assemblage with the active plate and the blank holder was made in order to allow the installation of the camera so that the distance specimen-camera would be stable without using a special device.

Fig. 3. Traction machine

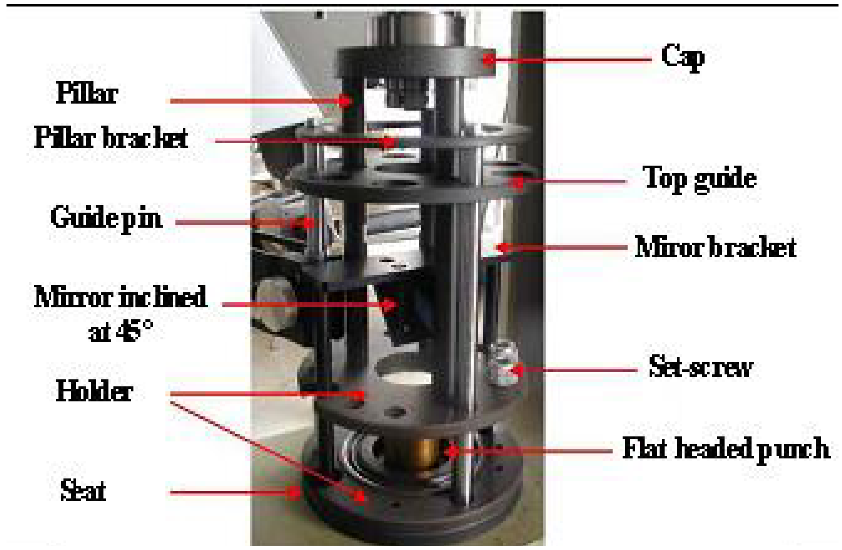


Fig. 4. Experimental device used

In order to measure the cupped specimens' thickness in the crack area at 2, 5, 10 mm from the crack, the cupped specimens were carved and ground to allow the measurement of the thickness with the help of a microscope.

2.3 Strain analysis

This method consists in the overlapping of images that correspond to different stages of material strain. Before starting the deep drawing process different sized paint spots are applied randomly on the specimen. The piece's strains can be measured during the deep drawing process with the help of a camera and of a programme that analyzes images.

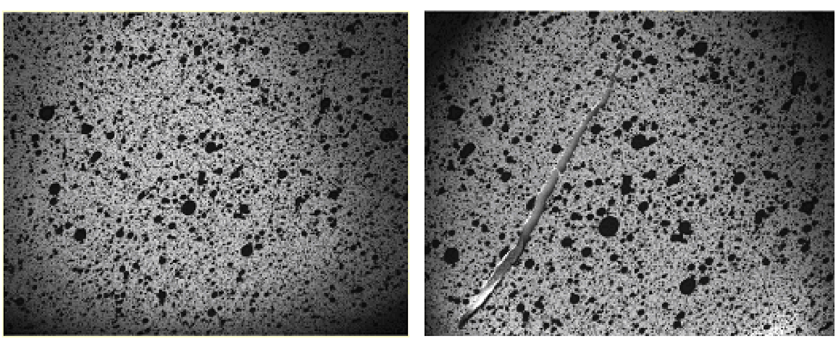


Fig. 5. Speckle aspect at the beginning and at the end of a Marciniak test

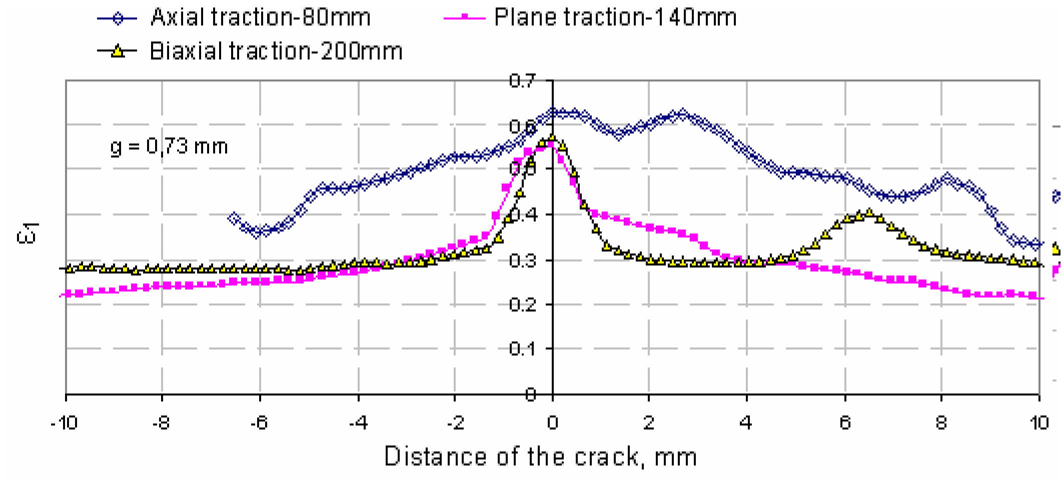
In order to analyze the images and calculate the strains we used the Icasoft programme, the 4.0 version, realised by the INSA University of Lyon. This programme calculates the moves and flat strains with the help of mathematic formula using two *bmp images, fig. 5.

3. THE EXPERIMENTAL RESULTS

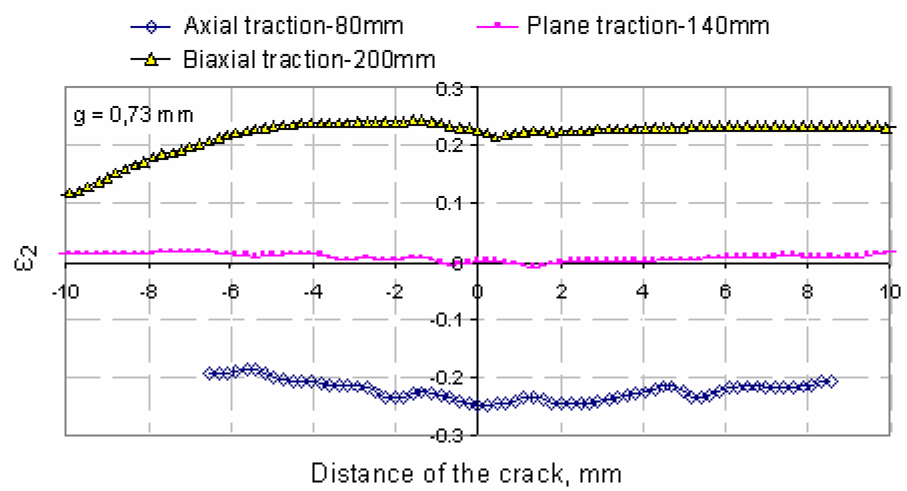
The variation of the main strains ε_1, ε_2 and ε_3 at 10 mm on both sides of the crack for different stages of material application is presented in fig. 7 a, b, c for the specimens being 0.73 mm thick and in fig. 8 a, b, c for the specimens being 1.23 mm thick. The main strains were determined with the Icasoft.

Axial traction-80mm

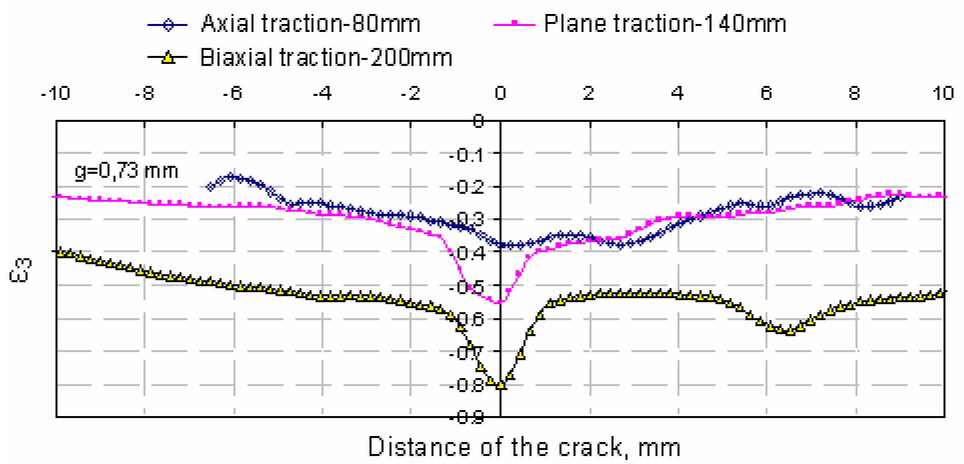
Plane traction-140mm
Biaxial traction-200mm



a.



b



c

Fig. 6. **Plastic strain ε_1(a), ε_2(b) and ε_3(c) for g=*0,73***

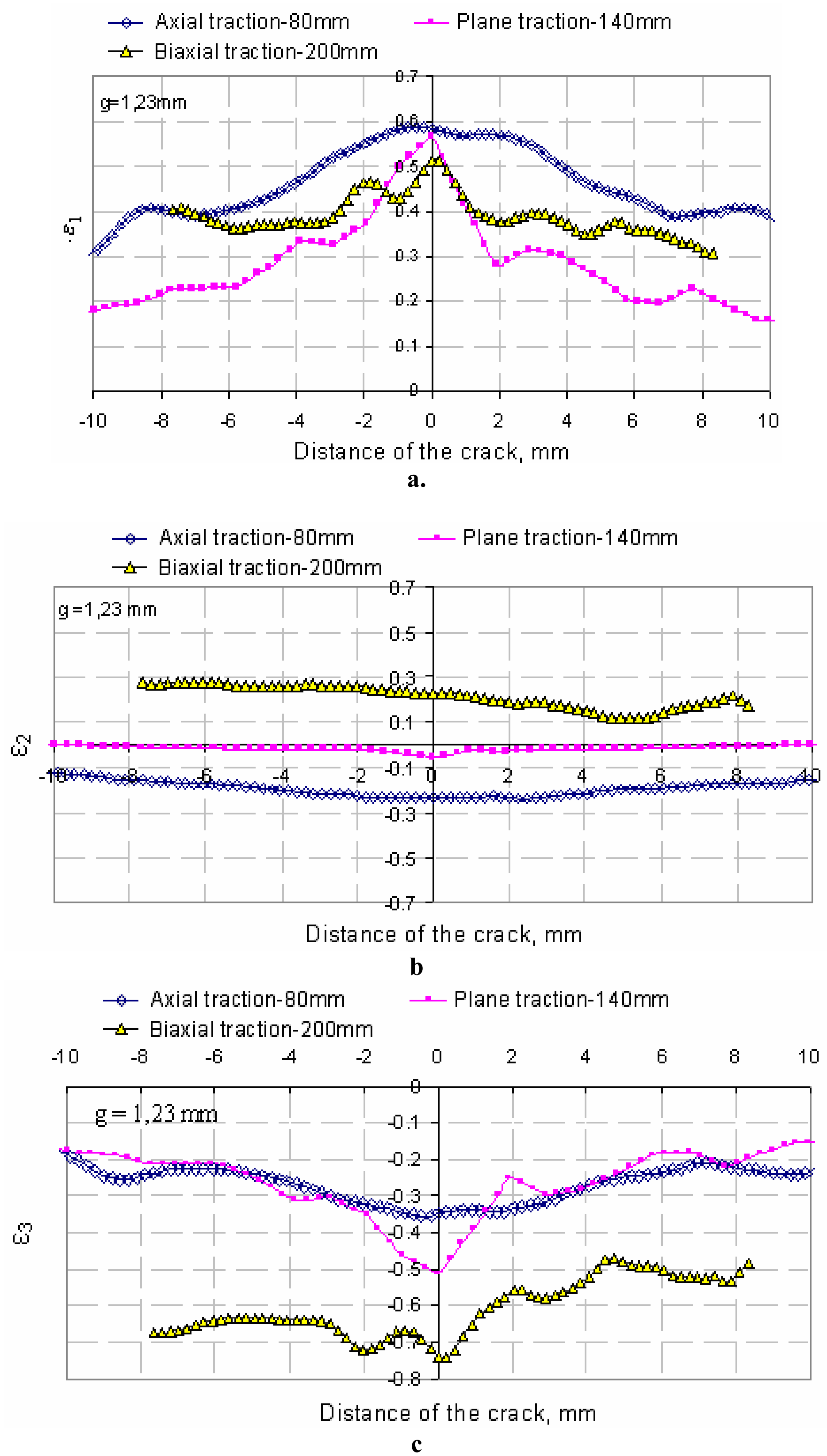


Fig. 7. Plastic strain ε_1(a), ε_2(b) and ε_3(c) for g=1,23

In order to determine the real strain on direction 3 (ε3) we measured the thickness of the cupped specimen near the crack at 2 mm, 5 mm and 10 mm from it for the three types of efforts: single axial traction (l= 80 mm), plane traction (l= 140mm) and biaxial traction (l= 200 mm).

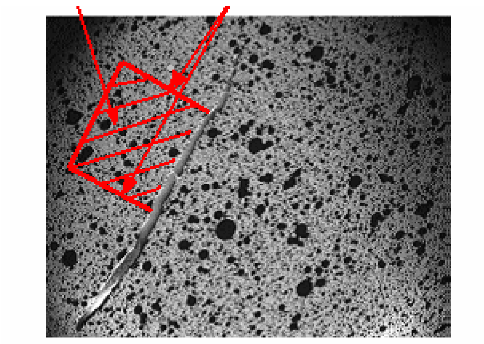


Fig. 8 The position of the carved area

The cupped specimen was carved near the crack in order to measure the thickness, just like in fig. 8.

The specimen's thickness was measured on one of the perpendicular surfaces on the crack, after grinding the edges. The thickness was measured 3 times in every point. The results are presented in table 2 for the initial thickness of 0.73 mm and in table 3 for the initial thickness of 1.23 mm.

Tab. 2

Efforts	The cupped piece's thickness measured at							
	crack	average	2 mm from the crack	average	5 mm from the crack	average	10 mm from the crack	average
Axial traction	0,558	0,482	0,526	0,518	0,537	0,536	0,636	0,596
	0,406		0,512		0,529		0,569	
	0,476		0,517		0,544		0,584	
Plane traction	0,434	0,425	0,514	0,513	0,522	0,532	0,558	0,548
	0,44		0,512		0,533		0,542	
	0,402		0,513		0,543		0,545	
Biaxial traction	0,322	0,315	0,368	0,369	0,38	0,377	0,383	0,384
	0,312		0,369		0,373		0,386	
	0,313		0,372		0,38		0,384	

Tab. 3

Efforts	The cupped piece's thickness measured at							
	crack	average	2 mm from the crack	average	5 mm from the crack	average	10 mm from the crack	average
Axial traction	0,818	0,807	0,849	0,849	0,903	0,922	0,937	0,953
	0,785		0,852		0,944		0,958	
	0.82		0,846		0,921		0,966	
Plane traction	0 ,728	0,757	0,856	0,884	0,943	0,945	1,027	1,019
	0,731		0,906		0,945		1,016	
	0,813		0,891		0,948		1,016	
Biaxial traction	0,613	0,560	0,580	0,588	0,590	0,588	0,604	0,617
	0,544		0,577		0,591		0,665	
	0,525		0,582		0,583		0,583	

ε_3 is presented in tables 4 and 5 and it is calculated according to the thickness measured with the formula:

$$\varepsilon_3 = \ln \frac{g_f}{g} \qquad (1)$$

where: g_f is the cupped specimen's thickness;
g, the specimen's initial thickness.

Tab. 4

Efforts	g = 0,73 mm ε_3							
	crack		2 mm from the crack		5 mm from the crack		10 mm from the crack	
	măs.	icasoft	măs.	icasoft	măs.	icasoft	măs.	icasoft
Axial traction	-0,41	-0,38	-0,34	-0,37	-0,3	-0,36	-0,2	-0,28
Plane traction	-0,54	-0,55	-0,35	-0,36	-0,31	-0,29	-0,28	-0,23
Biaxial traction	-0,83	-0,79	-0,68	-0,52	-0,65	-0,54	-0,64	-0,52

Tab. 5

Efforts	g = 1,23mm ε_3							
	crack		2 mm from the crack		5 mm from the crack		10 mm from the crack	
	măs.	icasoft	măs.	icasoft	măs.	icasoft	măs.	icasoft
Axial traction	-0,42	-0,34	-0,37	-0,33	-0,28	-0,29	-0,25	-0,25
Plane traction	-0,48	-0,51	-0,32	-0,28	-0,26	-0,22	-0,18	-0,15
Biaxial traction	-0,78	-0,74	-0,75	-0,56	-0,73	-0,48	-0,68	-0,47

4. CONCLUSIONS

Limit strains are determined through the image correlation method with a good precision, in a relatively short period of time and using a small number of specimens.

By analysing the graphics we can draw the following conclusions:

- the strain on direction 1, ε_1, has a maximum value for the single axial traction application, regardless of the sheet's thickness;
- the strain on direction 2, ε_2, has values close to 0 for the even strain;
- the strain on direction 3, ε_3, has the maximum value for the biaxial stretch application; along with the growth of the sheet's thickness the values of the limit strains grow, regardless of the application to which the material is submitted;
- the variation of the cupped specimen is similar for the single axial traction and even stretch applications; in the case of the biaxial stretch the specimen's thickness at 10 mm from the crack is 50% of the initial thickness;
- the measured strains on direction 3 have close values to those calculated with Icasoft.

The differences appear due to the real thickness of the material which varies with ±0,01mm.

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