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MICROSTRUCTURE AND STRAIN DISTRIBUTION INFLUENCE ON FAILURE PROPERTIES IN FORMABLE STEEL SHEETS

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ABSTRACT

Formable steel sheets (FSS), alloys exhibit plastic strains to failure (usually in the range of 1%-5%), that those of conventional structural steel alloys. We have developed a technique to measure strains at the scale of the microstructure and have used this method to assess the variation in failure properties with microstructure. This method is capable of using the greyscale information in the image of a gridded sample to obtain sub-pixel marker displacement, and can therefore accurately determine small strain values. Microstructures that exhibit large variation in local strain distribution tend to have higher variability in tensile properties, particularly tensile ductility, compared to microstructures that accumulate strain more uniformly. Orientation and morphology of lamellar plates in lamellar colonies play, also, a role in influencing the distribution of strain.
Local grain orientation, phase distribution and segregation are factors influencing the strain distribution, and therefore the properties of these materials.

KEYWORDS: FSS, microstructure; strain; steel, SEM

INTRODUCTION

The combination of specific stiffness, good oxidation resistance and fire-resistant steel performance at intermediate temperatures can provide significant weight saving for certain components. One of the obstacles to the application of FSS alloys components is the relatively low ductility of these materials in tension. Because, this property is not clear explicitly dealt with in component design, some degree of damage tolerance and ductility in generally required so that stress concentrations can be blunted and minor levels of damage do not produce immediate failure. Some scientist [1], have shown that a plastic strain to failure of 2.8%, is sufficient to blunt relatively large stress concentration in FSS alloys, and many of the currently plastic deformation steel alloys being considered have average strains to failure that meet this relatively low requirement [2].
Much investigated FSS alloys samples, exhibit a large variations in failure stress and strain, but the results of some samples do not reach the desired 2.8%, [3].
The aim of this work is to examine the influence of microstructure on variations in strength and ductility in FSS steel alloys. This work describes the investigations in INAV-S.A. Bucharest and laboratories F.S.I.M.-U.P.B.

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EXPERIMENTAL PROCEDURE

Master ingots, with chemical composition given in Table 1,were elaborated in vacuum induction furnace by melting high-purity metals under argon atmosphere and were casting into graphite rods [4]. These ingots were machined into small- bars and placed in high purity alumina crucible of $57/47x10^{-3}$, outside/inner diameter [4]. Thin samples of FSS alloys, were elaborated by directional solidification in XTAL-VAR 97 installation [4], at a constant growth of R_{vl} and a constant temperature gradient at solid/liquid interface of G_l.

TABLE 1. Chemical composition of FSS alloys

Alloy	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	V	Nb	Al	N
FSS1	0,10	0,98	0,008	0,027	0,31	0,39	0,15	0.09	0,45	-	-	0,018	0.003	0,01
FSS2	0,08	1,13	0,005	0,03	0,26	0,33	0,12	0,12	0.03	0,01	0,05	0,022	0,002	-

In order, to eliminate the nucleation and growth of mis-orientated grains along the specimen length, all thin samples were grown from seeds defined structure and crystallographic orientation [4].
Sheet samples with an olmet geometry and a gage volume of $160mm^3$ were prepared from each alloy. The surfaces of olmet samples were prepared by a low stress grinding procedure followed by hand treatment through 680 grit. The samples were electropolished at temperature (-30°C), to obtain a surface mirror finish and avoid hydride formation [5]. The polished samples were gridded by evaporating gold through a 1400 line per inch titan mesh and then tested to failure in Kammrath-Weiss in-situ tensile stage in Philips SEM 515-EDS. It was selected the microscope magnification around 92 grains and 2300 to 3000 markers [FSS 1-120x; FSS 2-120x]were present in each acquired 706 by 468 pixel image. Tested was interrupted at regular load intervals to allow for image collection. The image resolution of the technique depends on a number of experimental parameters including a higher resolution, signal to noise ratio, and the number of greyscales present, captured .

RESULTS

The results obtained for samples with chemical compositions in Table 1, are shown in Table 2 :

TABLE 2. Results of tensile testing

Alloy	*Samples test*	*Plastic strain to failure*	*Peak strain before to failure*
FSS 1	7	1.9-2.4 % (2.6%)	~5.5%
FSS 2	9	1.2-1.8% (2.0%)	~3.2%

The value for mapped samples are indicated in parentheses. The surface displacement mapping technique is an accurate technique for measuring in plane displacements of less than a pixel, which allows the local strains in a sample to be measured with a high level of accuracy. Stress-strain curves obtained by averaging strains at each load interval for both eutectic samples are shown in Figure 1.

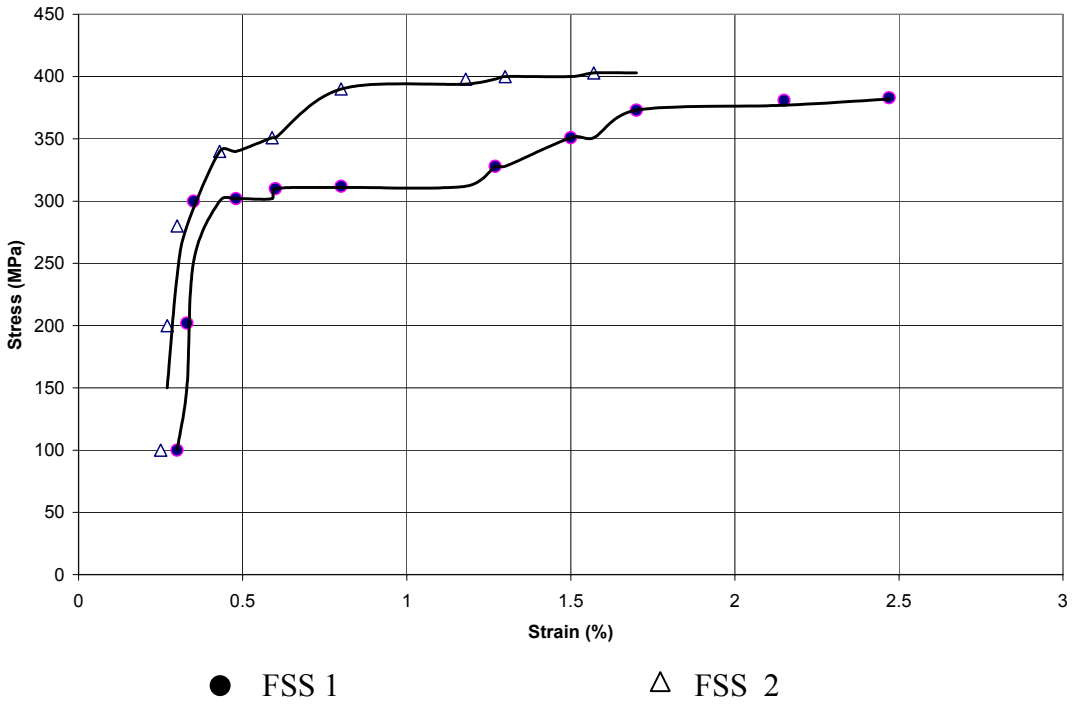

Fig.1.Stress – strain curve from strain mapping, calculated for displacement mapped samples.

These curve appear in a good shape, despite being measured over only $0.67mm^2$ of the surface area of the FSS 1,and $0.58mm^2$ of the FSS 2. Like the first conclusion, the results become more consistent as the level of strain in sample increases, and that there is considerable variation at low strain levels. The error bars used in the graph represent the variation in the strains in the four quadrants of the analyzed area. The large variation in strain at each load level indicates that these areas are too small to provide an accurate measurement of average strain for the entire sample. This local variation in strain increased as the load and average strain increased for both eutectic alloys.

For measuring small strain during in-situ tensile tests in SEM -Microscopy, we introduced a method which use pattern recognition algorithms to locate markers on a gridded sample before and after deformation. The distorsions in the grid are used to calculate the strains at each markers. Gold grids with a mesh size of 20μm were evaporated onto the samples though titanium grids affixed with adhesive tape. Electron back-scatter images of the samples taken during testing were analyzed using a set of interactive routines written in the Operative Data Language (ODL).After all displacement have been determinated in this fashion, a polynomial fit maps the locations of a marker and its surrounding markers in the distorted image to the corresponding in the reference image. The strains of the sample surface are then simply the coefficients of the polynomial expansion, and they are then contour plotted to show a map of the strains in the sample .The strain maps can be overlaid on the original image or plotted separately.

Some strain maps obtained by this method can be seen in (Figure 2). This technique is to capture the development of strain in our sample, and the progression can be followed as the load increase.The magnitudes of the strains are similar to those predicted by a continuum model, but the shape of the strain contours depends on the microstructure of the sample, in main manner.

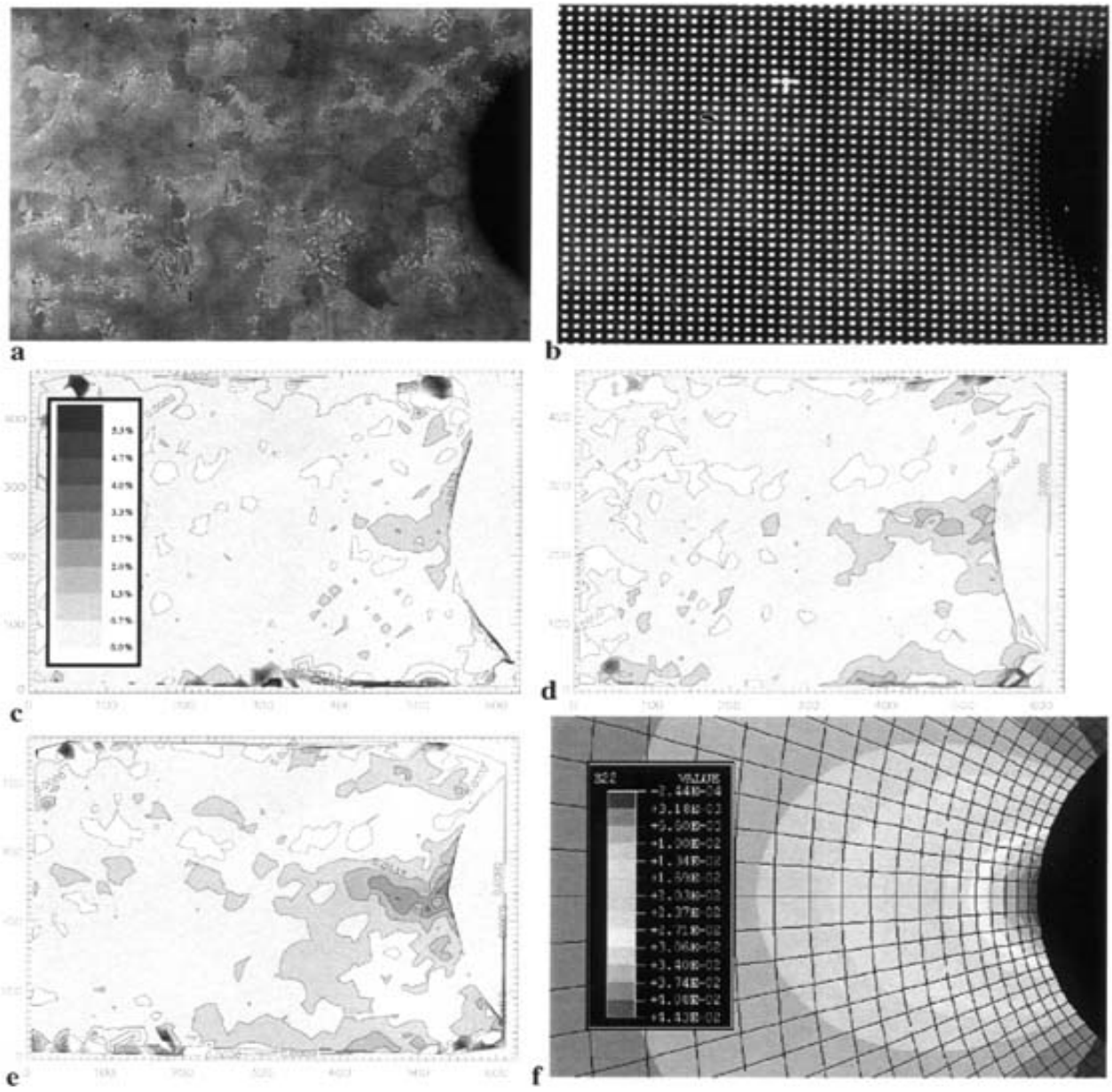

Fig. 2. Strain maps by pattern recognition algorithm method to locate markers on a gridded sample before and after deformation

CONCLUSIONS

This method of measurements useful for isolating the features associated with enhanced local strain. The distribution of these local strain concentrated regions also apparently results in volume effects, where samples with smaller strained volumes higher strength in the absence of extrinsic flaws. The surface displacement mapping technique is essentially a two-dimensional technique, so no information about out of plane displacements can be obtained.
As a finale conclusion, an apparent fracture origin may not be the actual fracture origin, since the real origin may be subsurface.

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