On Experimental Testing Methods for Anisotropic Sheet-Steel

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Abstract

The aim of this work is to develop new experimental testing methods, in order to obtain proper measurements of the mechanical properties of anisotropic rolled sheet-steel. It is shown that the classical testing procedures lead to erroneous experimental data and to non-realistic specifications of the constitutive laws. A proposed new testing device, associated with the stereophotogrammetry method for measuring kinematic fields, gives a solution to the essential problem of obtaining reliable experimental data for the directional properties of anisotropic sheet-steel.

1. Stereophotogrammetric method for measuring displacement and strain fields

First, we developed and improved the method of stereophotogrammetry with deformation parallaxes, in order to determine with high accuracy the whole displacement and strain fields in specimens subjected to mechanical tests. The method consists in taking from a fixed position two photographs at a certain time interval. The analysis in a "stereoplotter" of the two photos permits to measure at any point the components of the displacement vector corresponding to the deformation undergone by the specimen during the time interval. These components could be measured with an accuracy of from 1 to 2 μm at the scale of the photos. The main problem in the stereophotogrammetric method is to determine displacement functions associated with the obtained data, in order to derive the nets of isodisplacement lines and, by derivation, the strain fields. This could be achieved with the help of an interpolation procedure employing "spline functions".

2. Heterogeneous kinematic fields obtained with the classical testing procedure

A number of simple tensile tests were performed on specimens of orthotropic rolled sheet-steel with different inclinations θ with respect to the rolling direction. When the inclination angle θ is different from 0° and 90° ("off-axis" tests), it can be shown that the principal directions of the stress and plastic strain tensors do not coincide. The result is that homogeneous stress and strain fields are incompatible with the boundary conditions imposed in the classical testing procedure with rigidly clamped heads. Thus, heterogeneous fields of stress and strain develop during the axial straining and the off-axis specimens tend to assume a S-shape. This is confirmed experimentally by the obtained isodisplacement lines (Figure 1a) and plastic strain fields. As the classical off-axis tests are generally interpreted with the hypothesis of homogeneity, the so-obtained experimental data are erroneous and unsuitable for the specification of constitutive laws.

3. Displacement and strain fields obtained with the new testing device

In order to obtain homogeneous stress and strain fields, the ideal testing procedure should assure non-constrained deformation of the specimens. Such an ideal procedure cannot be achieved practically. In order to approach the ideal case, we propose a new testing device consisting of hinged fixtures with knife-edges permitting the ends of the specimens to rotate. With this new device, the experimentally obtained isodisplacement lines are parallel straight lines (Figure 1b) and the plastic strain fields are perfectly homogeneous in almost the whole working length of the off-axis specimens. Thus, the proposed new testing device permits to measure properly the mechanical properties of anisotropic sheet-steel.

When the off-axis specimens are strained up to the appearance of localized deformations, the results obtained with the new testing device show that the field of the axial plastic strain remains perfectly homogeneous (Figure 2a). Finally, it is shown that localized plastic deformations produced by axial straining induce heterogeneities only in the fields of the transverse and shear strains (Figure 2c,d,e).

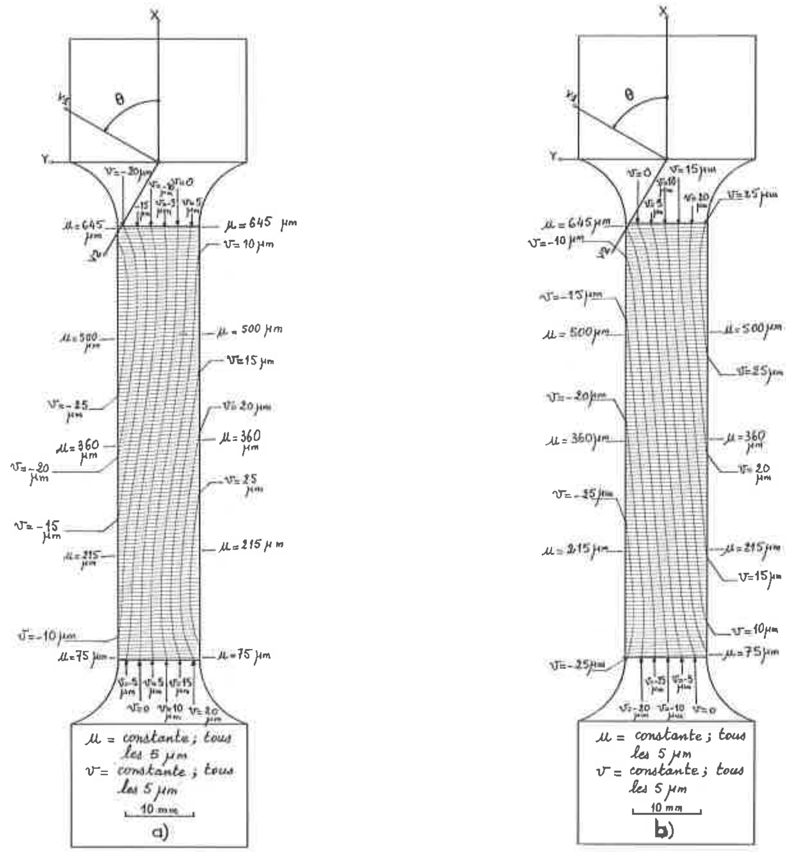

Figure 1

Simple tensile test on off-axis specimens of orthotropic rolled sheet-steel

Axial displacement : 0,72 mm

V1 : rolling direction ; X : direction of axial strain ; (X, V1) = 60°

u = Cste : axial displacement isolines, every 5 μm

v = Cste : transverse displacement isolines, every 5 μm

Fig. 1a : classical testing device

Fig. 2a : proposed new testing device

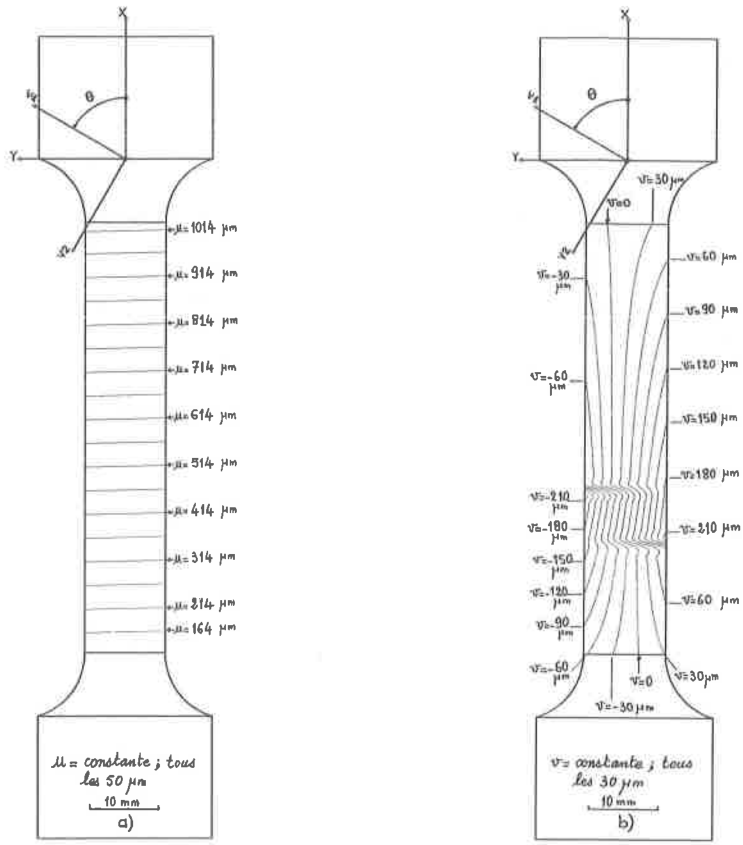

Figure 2

Simple tensile test on an off-axis specimen of orthotropic rolled sheet-steel
Axial displacement : 1,20 mm
V1 : rolling direction ; X : direction of axial strain ; (X, V1) = 60°

Fig. 2a - u = Cste : axial displacement isolines, every 50 µm
Fig. 2b - v = Cste : transverse displacement isolines, every 30 µm

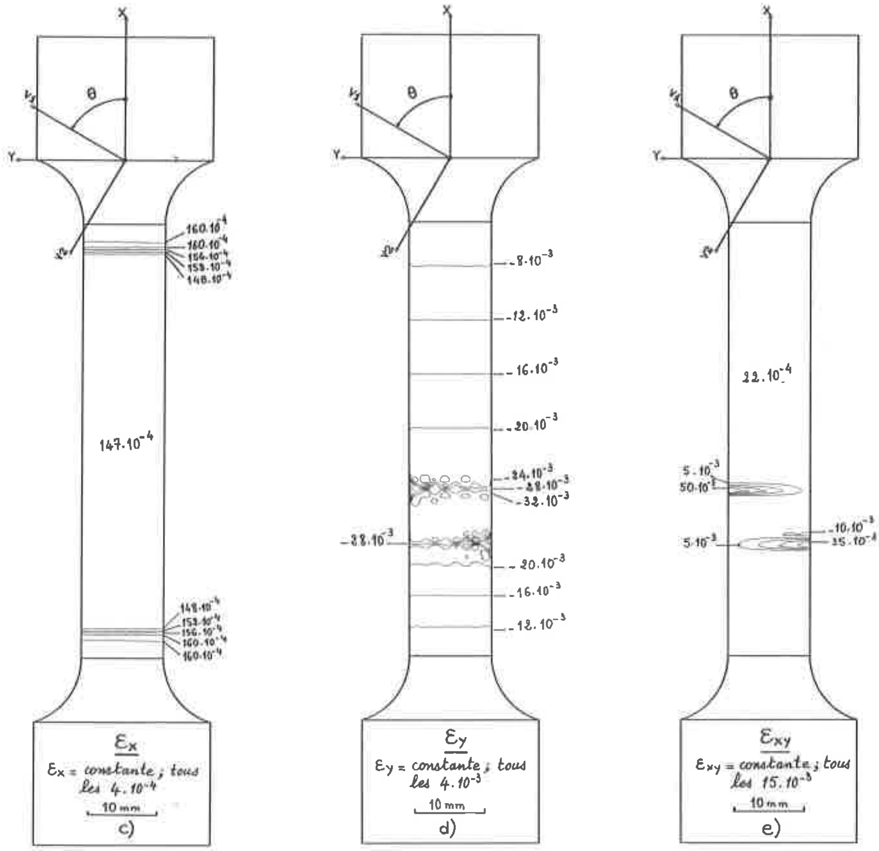

Fig. 2c - ε_x = Cste : axial strain isolines, every 4.10^{-4}

Fig. 2d - ε_Y = Cste : transverse strain isolines, every 4.10^{-3}

Fig. 2e - ε_{XY}= Cste : shear strain isolines, every 15.10^{-3}