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The measurement of biaxial strains in coated fabric materials using the disc-replica method

- by -

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Summary

A method of measuring biaxial strains in coated fabric type materials is presented whereby the strain is deduced from the distortion of a circular impression made on the material. The impression is placed on the material when loaded, enabling all measurements to be made with the material in its relaxed, unloaded, state.

The method is simple to use, and requires a minimum of equipment.

Notation

	x, y	reference or fabric axes
	x', y'	apparent principal strain axes
	$\epsilon_{Rx}', \epsilon_{Ry}'$	residual strains in the $x'y'$ directions
	$\epsilon_{Tx}', \epsilon_{Ty}'$	true strains in the $x'y'$ directions
	$\epsilon_{Tx}, \epsilon_{Ty}$	true strains in the xy directions
	θ	apparent angle between xy and $x'y'$ axes
	θ'	true angle between xy and $x'y'$ axes
	d	correction angle to θ for residual effects
See	d	basic impression diameter
Fig.	a_1b_1	sizes of datum spot in the y,x directions
3	a_2b_2	sizes of reference spot in the x,y directions
	l_1l_2	initial sizes of grid in y,x directions
	$l_1'l_2'$	final sizes of grid in y', x' directions
	f,c,r',r	see Fig. 4
	A =	$l_1'l_2 - l_2'l_1$

1.1 Introduction

Conventional methods of measuring strain become unsuitable when dealing with fabric, or similar materials, because not only are the strains involved generally very large, but also the presence of a bonded strain gauge may seriously influence the local stiffness of the material.

Although grids marked directly onto the fabric have been employed to measure strains in these materials, these have the disadvantage that the grid distortions must be measured with the structure in its loaded state, which may be difficult on curved surfaces.

The 'Disc Replica' method, presented here, overcomes these difficulties. It will cope with large strains, does not influence the stiffness of the material, and all measurements are taken with the structure unloaded. Furthermore, the method is simple to use: and the only specialised measuring equipment required is a low-powered travelling microscope.

2.1 Disc Replica Method

Two techniques are available:-

i) 'Double Spot' technique
ii) 'Spot and Grid' technique.

The most suitable technique to use in a given case will depend on the initial (no load) stiffness of the material, and the rapidity with which the strain changes from point to point in the loaded structure.

2.1.2. Double Spot Technique

The method is shown diagrammatically in Fig. 1. The steps involved are:-

(a) Small circular discs of, say, 0.25 ins. diameter are cut from adhesive plastic tape, using a hollow punch.

(b) In the region of the structure where strain is to be measured, an orthogonal grid is marked, (in the case of a single ply fabric material, it is convenient if the grid axes coincides with the fabric axes).

(c) With the structure unloaded, and unpressurised in the case of an inflated structure, a disc is stuck into place, approximately over a grid intersection previously marked. French chalk is now brushed over the disc onto the surrounding material, and the disc removed, leaving a circular impression.

(d) The structure is now pressurised and loaded, and allowed to stand for a few minutes to allow creep strains to settle. A further circular impression is marked on the structure as above, adjacent to the original (reference) impression.

(e) Finally, the structure is unloaded and depressurised. The impressions from steps (c) and (d) will now be elliptical in shape, and the major and minor axes of these ellipses are measured, using, say, a travelling microscope. The angle between the marked axes and the principal ellipse axes of the second (loaded state) impression is also measured. Note that all measurements are taken with the material laid flat, and unloaded. The initial (unloaded state) impression provides a measure of the residual strain in the structure. Creep recovery becomes unimportant, therefore, providing that any pair of impressions is measured within a reasonably short time interval.

For low initial stiffness materials, it may be better to preload the structure slightly before making the first impression, since this removes uncertainties with regard to gauge length. In this case, the preloaded state becomes the datum state for strain measurement.

2.1.2 'Spot and Grid' Technique

The method is shown diagrammatically in Fig. 2. The steps in the technique are:-

(a) With the structure in its unloaded and unpressurised state, a grid is marked out on it locally in the region where the strain is to be measured. The grid size is then measured. (Note: for single ply fabrics it is convenient if the grid coincides with the fabric axes).

(b) The structure is now pressurised and loaded, and allowed to stand for a few minutes to allow creep strains to settle. A disc is now placed on the structure at a grid intersection, and using french chalk, an impression is made. The disc is now removed.

(c) The structure is now unloaded and depressurised, and the major and minor axes of the ellipse resulting from the disc impression measured. The angle between the ellipse axes and grid is also measured, and finally the grid size itself is measured again as a check on residual strains. As in the previous method, all measurements are taken with the material laid flat.

3.0 Analysis of Results

3.1 Double Spot Technique

Fig. 3 illustrates the appearance of the two spots after testing. Fig. 3(a) showing the final state of the first (datum) impression, and Fig. 3(b) the final state of the second (loaded) impression.

Using the notation of Fig. 3, it can be shown that the residual strains in the x' and y' directions are respectively: