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On the mechanical behaviour of ETFE-films: Elastic range, yielding conditions, break determined by different test methods and the influence of the results on the analysis of ETFE-structures

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Abstract

The analysis of structures made of ETFE-films has been typically limited to the elastic range of the material behaviour. Here the following items are discussed from theoretical and practical aspects: Yield point, yield conditions, hardening, behaviour under cyclic loading and failure. On this base, the most important properties of ETFE-material for analysis will be derived. The respective tests are defined and new test results will be presented

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Keywords: Stress-strain curve, material behaviour, film, foil, hardening, yield point, biaxial test, circular specimen, ETFE, elastic behaviour, plastic behaviour, thickness

1. The Stress-strain behaviour of ETFE films

The stress-strain behavior of ETFE films can at least be divided into two areas:
1. a linear elastic region and
2. a plastic range.

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The state-of-the-art design of structures made of ETFE films considers the elastic range of the working stresses, the plastic region is ignored. [2], [6].

Thus, the yield point limits the maximum stress. The yield stress according to uniaxial tests is in the range of approx. 15 MPa to 17 MPa. These values are also commonly transferred to biaxial stress states without further discussion. The viscous contribution to the stress-strain behavior is not considered. It raises the question whether the yield point should principly be applied as the stress limit, or whether a more detailed investigation based on the theory of plasticity promises benefits. Therefore the elastic-plastic behaviour as it appears with the experiments executed, are presented and discussed firstly. From this discussion one may develop a strategy for the conceptual design, the manufacturing and the design of structures made of ETFE films.

At the beginning, the tests which have been executed to determine the behaviour of ETFE films are reported in a critical manner. Uniaxial tests, biaxial tests on cross specimens and multiaxial tests on circular specimens will be presented, and the results will be discussed. The authors consider that general conclusions for the use in practice can only be derived from accurately conducted and analyzed experiments.

In assessing the deformation behavior of ETFE films it can be assumed that the ETFE film present a semi-crystalline material, as a mixture of crystalline and amorphous regions. The behaviour under mechanical stress will depend on whether uniaxial or biaxial stresses will be applied. By applying uniaxial loads to the material, first the chains in the amorphous regions will be aligned parallel to the load direction. In parallel, the crystalline regions will rotate into the load direction. Thus anisotropic properties will be created: In the stressed direction, the material is getting stiffer.

2. The Behaviour of ETFE films in

2.1. Uniaxial tensile test

The simplest test of ETFE films is the uniaxial tensile test on narrow strips. Such tests are useful to determine the yield point. They give only very poor information on the behavior after yielding. This is getting evident from a microscopical view (Fig. 1) of the surface of a uniaxial tensile strip specimen: The damage structures are clearly shown perpendicular to the tensile test direction. This effect does not occur under biaxial stresses.

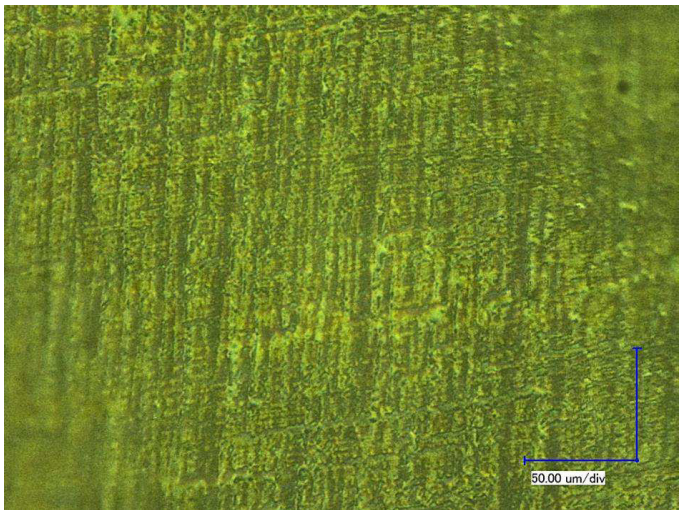

Fig. 1. "Crazes" on the surface of an ETFE specimen after breaking: The test direction is perpendicular to the direction of crazes. (Recording: R. Blum, magnification 1000 times, illumination by polarized light, stacking up from 25 individual shots)

Due to these reasons and for the lack of space uniaxial tests will not be further reported in this paper.