An Experimental Study of the Transient Deformation Work in Front of a Sharp Notch in a Polymer

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Introduction

The study of irreversible deformation processes as plastic and viscous flow in materials is of considerable interest both for the understanding of basic material properties and for technical applications. However, it is no simple task to measure and map transient local deformations. In this work an indirect method has been used to do this. The main part of dissipated work of deformation is transformed into heat causing the temperature to raise. Recording of the temperature field consequently gives valuable information about the deformation work.

Measuring equipment

The technique indicated above requires an equipment with fast response to temperature changes. This is especially the case when one wants to measure local plastic deformation, since in this case the thermal effects are rapidly smoothened out due to the thermal conductivity. Measurement of the infrared radiation from the surface of the body seemed to meet these requirements.

The infrared radiation from the body is focused via a rotating prism furnished with four mirrors upon an InSb-detector. A line on the specimen is scanned. The detector output signal is amplified and fed into the vertical amplifier of an oscilloscope and/or into a tape recorder. A cooled InSb-detector was chosen. This is a detector insensitive to mechanical shock and which can be cooled easily using liquidized air. It also has a suitable spectral distribution of its sensitivity and a frequency response which is high enough.

The optical system consists of a plano-concave silicon lens and the above mentioned prism. The mirrors are overlaid with a thin layer of aluminium to make them reflect IR-radiation. By appropriate choice of the geometry a 40 mm long line on the target is scanned with a nearly constant speed and with correct focusing. The rotation speed can be altered so that the line is scanned in 0.8-4.8 ms and with a line frequency of 33-200 Hz.

The amplifier has a noise factor of only a few decibels. The upper cut-off frequency can be adjusted to obtain the best signal to noise ratio at each scanning speed. The high quality detector-amplifier combination makes the signal to noise ratio depend on the randomness of the IR-radiation (photon noise). The sensitivity can consequently only be increased by a better optical system or by a detector with a better spectral response. There is a close relationship between temperature resolution, geometrical resolution and bandwidth. As an example a higher temperature resolution can be obtained at lower scanning rates. The equipment can sense a temperature difference of about 0.1^{o}C at a scanning speed of 10 m/s. 10 m/s is obtained at a line frequency of 33 Hz which has been used during the tests. A trigger pulse is obtained from the prism each time a line on the target is scanned. The trigger pulses are fed to one channel of a tape recorder, the temperature signal to another. When the signals are to be reproduced they are fed into a storage oscilloscope, the trigger pulses via a special, counting device. This makes it possible to number the scanned lines and to study every desired line on the oscilloscope screen. Of course, the tape

recorder can be used to record other quantities, e.g. load, simultaneously.

Some experimental results

Test specimens

A PC polymer (makrolon) has been used. Its low thermal conductivity is the main reason for choosing it. If a circular zone (diameter 1 mm) has a temperature difference to the surrounding material of T^{o}C the temperature in the middle of that zone after 0.3 s will have decreased by 0.05T^{o}C and after 0.5 s about 0.15T^{o}C. A corresponding value for steel is 0.05T^{o}C after only 1 ms. The physical dimensions of the test specimens are shown in fig. 1. They were fastened to two torque-free grips.

Performance of the tests

Two different experiments have been carried out. In the first one a step load was applied to the test specimen. The load was low enough to give only elastic deformations. The temperature decreased due to the adiabatic dilatation. The temperature distribution along four lines perpendicular to and at different distances from the notch was measured. The results are shown in fig. 2 where isotherms are also shown. Note that the scales of the two axis are not the same.

In the second experiment the grips were displaced at a constant speed of 1 mm/s. Also in this case lines at different distances from the notch were scanned. The temperature distribution along these lines at three different load levels are shown in fig. 3. At the first load level the temperature has begun to raise close to the tip of the notch and at the third load level the highest temperature has been reached. (A crack is beginning to propagate.)

It is obvious that in this case the temperature increases mainly in two narrow parallel bands in front of and on the sides of the notch. When the deformation increases the two bands seem to merge into one. This may partly be explained by thermal conduction. In front of the area with increasing temperature the temperature decreases due to local adiabatic dilatation. It has been observed that the conditions in front of a propagating crack in the test specimens used are very similar to those in front of the notch.

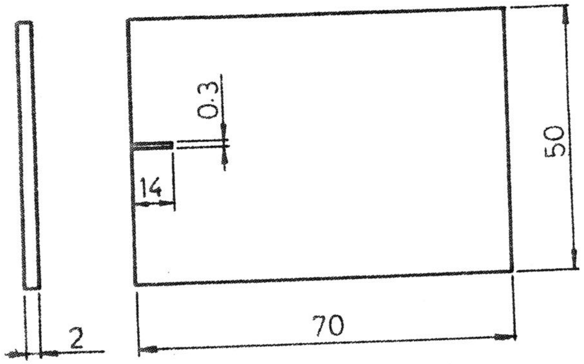

Fig. 1. Test specimen.

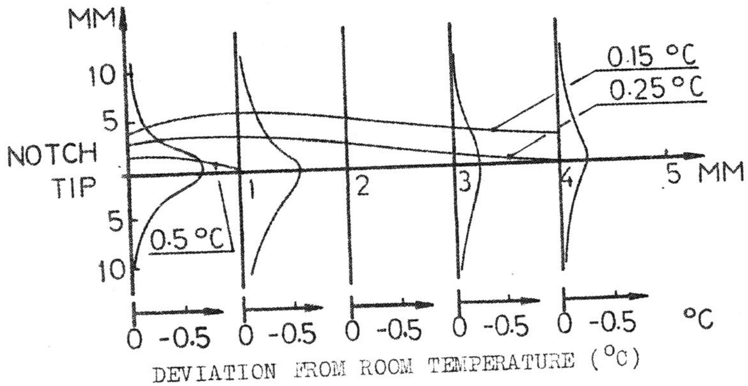

Fig. 2. Isotherms in front of a notch and temperature distribution along lines perpendicular to the notch and at different distances from this. Load: 2000N.

Fig. 3. The temperature distribution along lines perpendicular to the notch.

3A. Load: 4000N. Displacement: d mm.

3B. Load: 4350N. Displacement: d+0,45 mm.

3C. Load: 4650N. Displacement: d+0,83 mm.