# RESEARCH SUMMARY ON FRACTURE OF SWOLLEN RUBBER

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Crack propagation tests with swollen Solithane 50/50 were performed in order to investigate the qualitative influence of the internal viscosity of a material on the fracture process.

The solubility parameter $\delta$ of Solithane 50/50 was experimentally determined as $\delta = 9.0 \quad cal/cm^3$. This result led to the selection of Toluene($\delta = 8.9$) as a swelling agent for Solithane 50/50. Toluene swelling increases the volume of Solithane by 145%; i. e., the linear increase is 35%.

Rough checks showed that the sol-fraction of Solithane is less than 1 weight percent.

The next step was the material characterization of swollen Solithane 50/50 at room temperature. The test specimens were completely submerged during the tests, which were carried out in the Instron tester. Stress-strain curves at strain-rates from 0.00875 in./in. min. to 8.75 in./in.min. were obtained this way. The tests revealed excellent agreement with Neo-Hookean material behavior up to failure at all strain-rates.

The constant $C_1$ in the equation $\sigma = 2C_1[\alpha - \alpha^{-2}]$ turned out to be $C_1 = 77.5$ psi (Fig. 1) if $\sigma$ is based on the cross-section of the swollen specimen (corresponds to a Youngs modulus of E=465 psi for small extension ratios); or $\overline{C}_1 = 104$ psi if $\sigma$ is based on the cross-section of the unswollen specimen ($\overline{E} = 846$ psi for small $\alpha$). For unswollen Solithane $81.0 < C_1 < 88.6$ psi (2) up to $\alpha = 1.13$. The material behavior of unswollen Solithane was not Neo-Hookean for higher extension ratios. Using $C_1$ the effective number of chains was calculated to be $5.89 \times 10^{-4}$ moles/ml, which would correspond to a Sol-fraction of $\sim 0.6\%$ and a modulus of $\sim 500$ psi according to the measurements of L. Smith and A. B. Magnusson (3).

Assuming the Sol-fraction to be zero the polymer-solvent interaction parameter $\mu$ was determined from an equation given by Bueche and Dudek (1). This calculation gave $\mu = 0.492$, which means the concentration of urethane groups is about 2.8 moles/1000 gr (3).

The failure data which were obtained in the course of the material characterization showed that the influence of the strain rate is almost completely removed (Fig. 2). Not enough data has been collected to say if the strain rate has no effect at all any more on the failure stress and strain. The failure envelope degenerates in this case to a point.

These results lead to the conclusion that the internal viscosity is largely reduced by swelling. No changes of the material structure which could result in a difference in the material response of a swollen-deswollen sample are caused by swelling as stress-strain tests with deswollen samples proved.

Crack propagation tests in the swollen state are under way now. The specimen used for these tests are the common strip-type specimens with an initial crack. These tests are not yet completed and only the following can be said so far.

There is a critical strain at which the crack starts to propagate at high speed and the strain history effects this critical strain inspite of the largely removed internal viscosity of the material. Fig. 3 shows the experimentally found dependence of the critical strain on the strain rate.

Another indication of the strain history effect is the observation that the critical strain could be raised by 10 to 15% if the strain was held constant at a level slightly below the critical strain for a longer period of time (e.g. 60 minutes).

The largely removed influence of the strain rate on the failure properties of an uncracked specimen and the still present effect of the strain history on the fracture behavior of a cracked sheet hint at a difference between the crack propagation and initiation mechanisms.

It is planned to modify the testing device so that experiments at different controlled temperatures can be carried out and to go over to high-speed motion pictures to pick up the acceleration and final speed of the crack.

## REFERENCES


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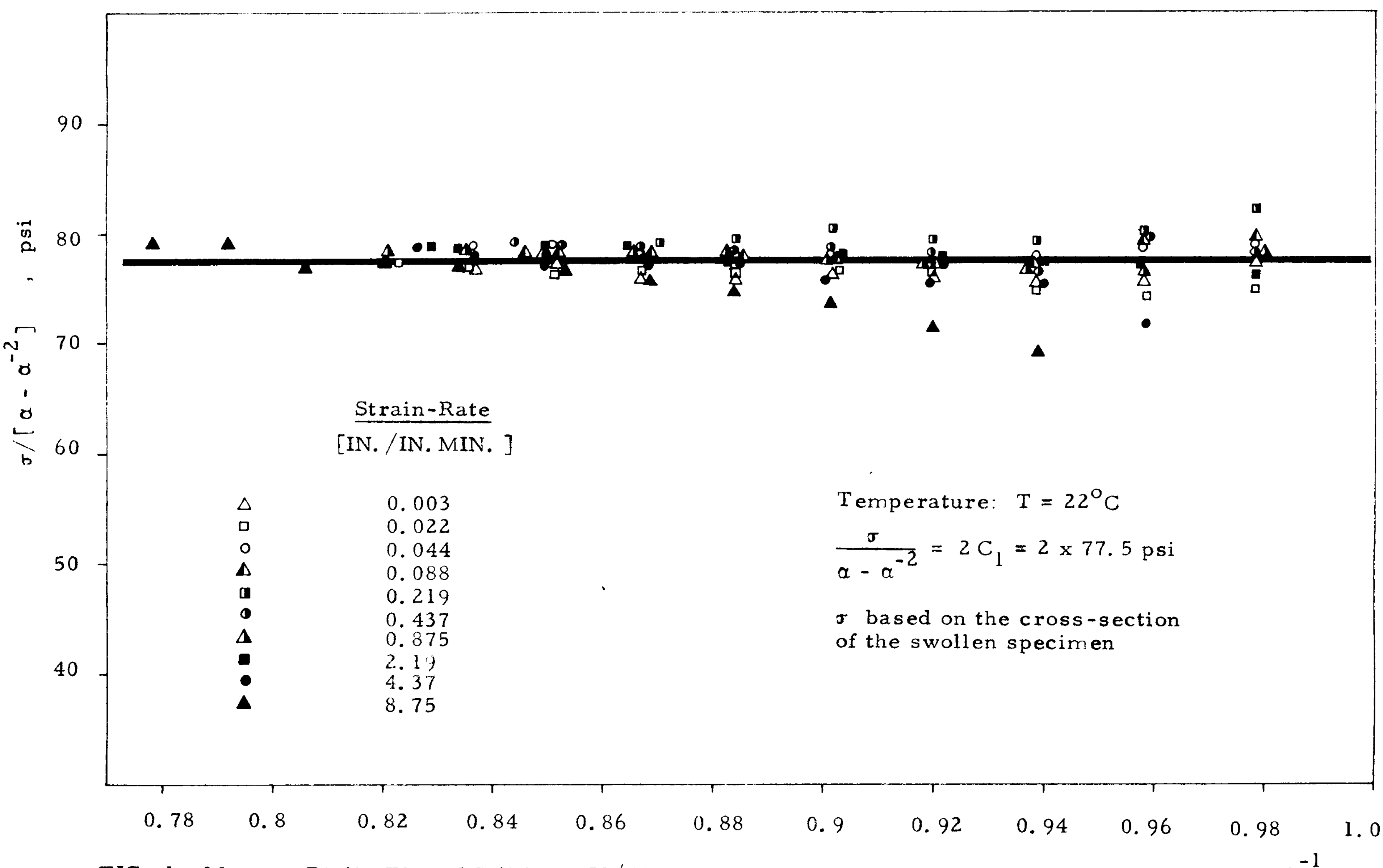


FIG. 1: Mooney-Rivlin Plot of Solithane 50/50 swollen in Toluene

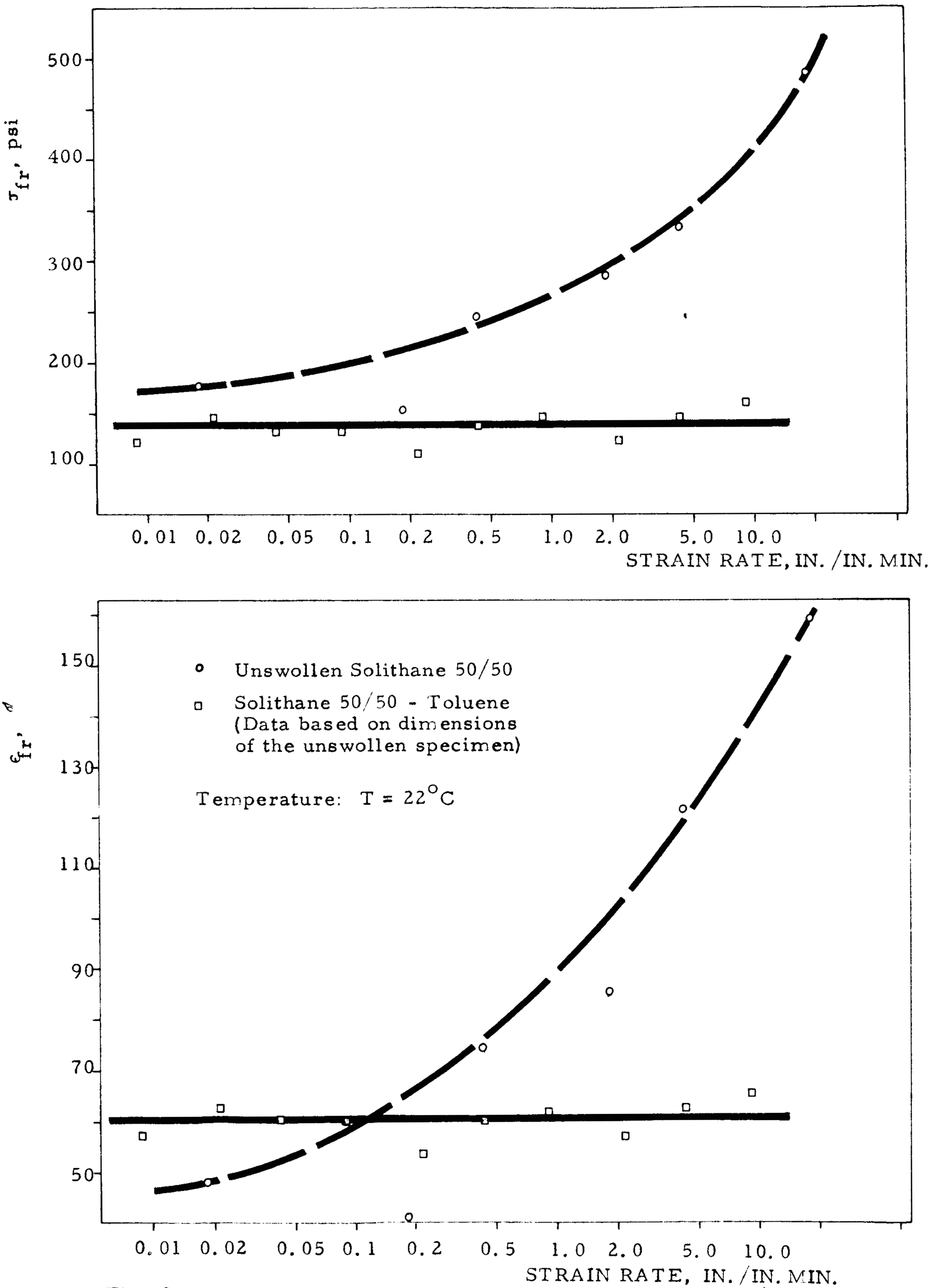


Fig. 2: Failure Data for swollen and unswollen Solithane 50/50

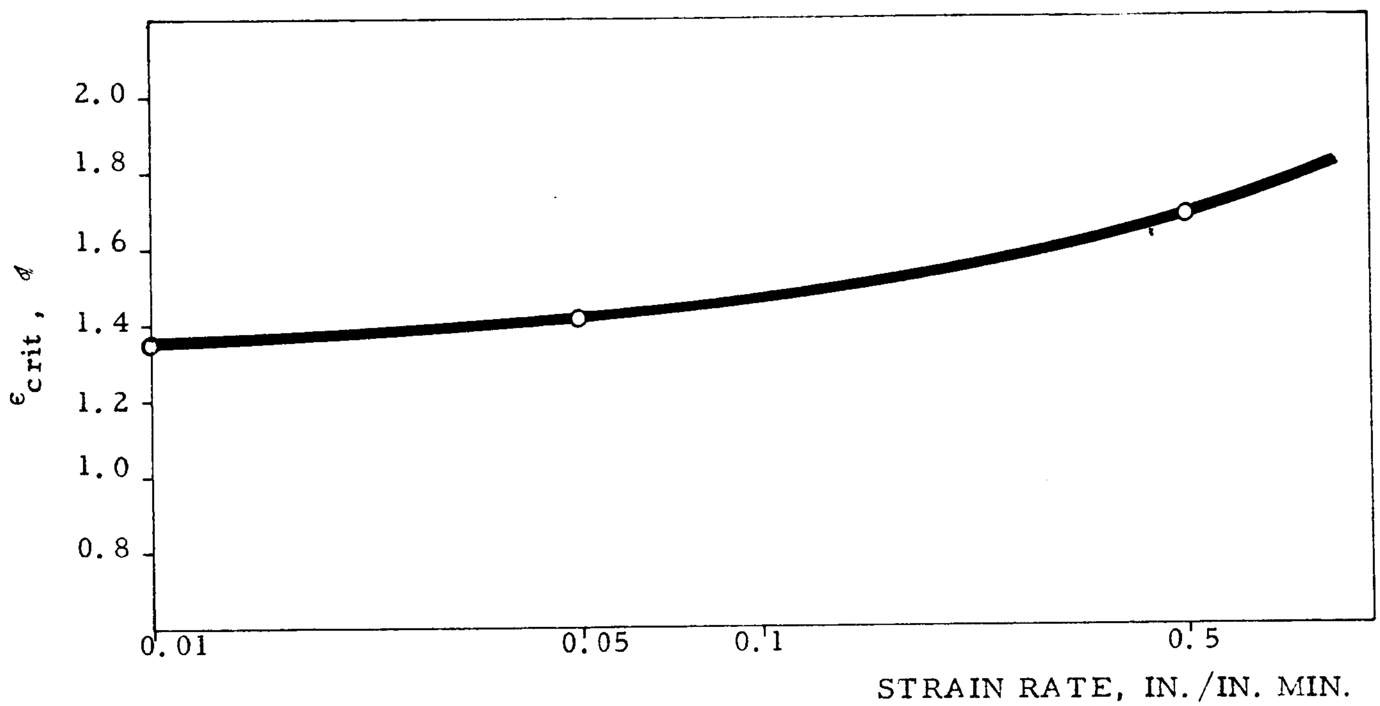


FIG. 3: Experimental Dependence of the Critical Strain on the Strain Rate. Each point represents the average of 5 tests.