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Band-deformation in PVC tubes: a material or processing property?

The testing of commercial-grade materials is an essential step in the rational utilization of plastic materials. Such testing is thwart with surprises of a type not normally encountered when using custom-made laboratory materials. This note discusses observations made when a cylindrical tube specimen of a red commercial-grade PVC was subjected to a slowly-increasing internal pressure. It also demonstrates the usefulness of a technique which might, by direct analogy, be termed "metallography" of plastic materials.

Fifty-millimetre long tube specimens of 37.5 mm i.d. and 0.375 mm wall thickness, were machined from red extruded rod and subsequently deformed by slowly increasing internal pressurization at a loading rate of 30 N mm^{-2} min^{-1}. The load was applied in such a way that the specimen was subjected to a hoop stress only. Deformation was carried out under increasing hoop stress and was essentially viscoelastic until yield occurred at a strain of 2%. Further increase in hoop strain beyond 2% resulted in plastic deformation in a mode that, to our knowledge, has not been previously reported.

After yield, wide bands of plastically-deformed material exhibiting stress whitening were formed, separated by narrow linear boundaries of essentially undeformed material (Fig. 1a).

The white bands were 6.8 mm wide, parallel to the axis of the tube specimens (and also the extrusion axis) and the boundaries were at regular 20° intervals around its circumference. Fig. 2 shows a close-up of one such band in which clearly visible "chevron" type markings are evident. The chevron markings intersect in the middle of the deformation bands, along a generator of the tube at an angle of $43° \pm 2°$, suggesting that the material deformed by shearing.

The regular positioning of the bands suggested initially, that they were caused by some mechanical means either in the machining of the extruded rod or by regular pinning of the specimen in the experimental apparatus. The deformation bands were observed in specimens made by two different techniques on two different machines, which indicates that the bands were not produced by

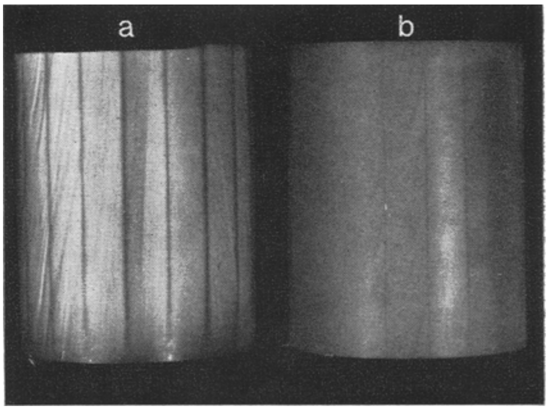

Figure 1 Band structure on (a) deformed specimen, (b) undeformed but etched specimen.

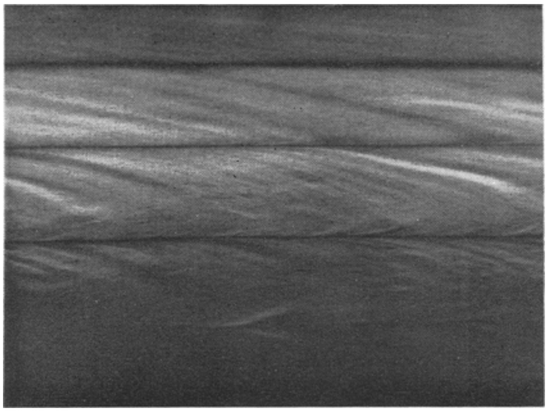

Figure 2 "Chevron" type markings in deformation bands.

some anomalous effect of the machining. In addition, no feature of the experimental apparatus was found that could cause 20° pinning or any multiple of 20° pinning. It became clear that the band formation was a feature of the material itself. The cause of the regular band formation was eventually revealed by a technique which might be called "metallographic".

Samples of the raw unmachined extruded rod were machine faced, polished, and finally etched in acetone. After etching, a regular hexagonal honeycomb structure was observed on the cross-section of the extruded rod (Fig. 3). Subsequently, similar features were revealed by acetone-etching on undeformed tube specimens cut from the rod (Fig. 1b). Further enquiries revealed that this regular structure was produced during the initial extrusion process by extruding the rod through a multi-holed breaker plate.

The macroscopic structure generated in the raw material during production, as revealed by the polishing and etching techniques, obviously led to the deformation mode observed during testing. This observation highlights the necessity to characterize the test specimens not only for molecular-structural properties (for example, molecular weight distribution) but also macroscopic structures. The polishing and etching technique, which has proved of immense value in metallurgical studies, may also be of use in rheological investigations of plastics.

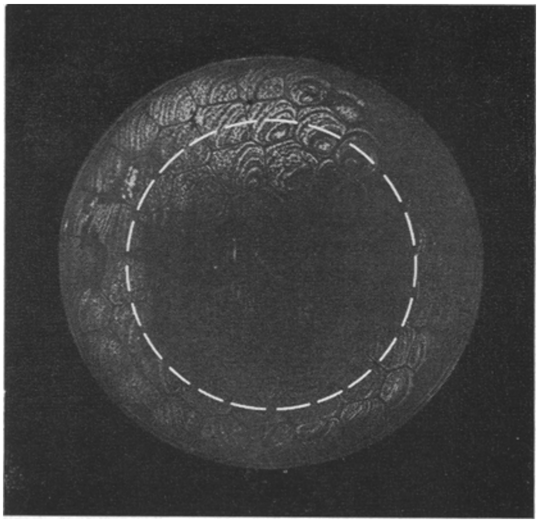

Figure 3 Etched surface of raw PVC rod; dotted line indicating position from which specimens are machined.

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Reaction zones in Ti/W composites

This letter describes microscopic, kinetic, and microhardness observations of solid-state interfacial reactions between tungsten filament and titanium, made as part of an experimental study on metal-matrix composites. The solid-state region of the titanium/tungsten system is characterized by a β eutectoid decomposition at 715°C that forms two phases of tungsten and α titanium solid solutions [1].

Composite specimens were prepared using 0.2 mm commercial lamp-grade W filament and 0.41 mm thick sheets of commercially pure Ti75A. These components were diffusion bonded at 1000 psi (6.9 MNm^{-2}) for 1 h at 875°C under 10^{-4} mm Hg vacuum. Reaction-zone studies were carried out by vacuum annealing in the temperature range 760 to 930°C and by furnace cooling to produce measurable reaction zones.

On slow cooling from the diffusion annealing temperature, the Ti/W interfacial region forms