

Fracture Behaviour of Normal and Reinforced Thermoplastic Materials in Liquid Environment

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Besides submicroscopic inhomogeneities of amorphous materials the borders of texture components of semi-crystalline plastics are as well starting points of cracking under load as the bordering areas between filler and matrix of reinforced plastic materials. Crazes as areas of oriented amorphous material and cracks always appear when definite, material-specific deformation values - which define the linear strain-sector - are exceeded.

The presence of well-diffusing liquids, which diminish the surface tension and by this the fracture energy, generally accelerates by means of physical-chemical processes the crack growth rate and leads to increased creep and premature fracture.

These results were found on polymethyl methacrylate (PMMA) and polycarbonate (PC) as well as on polypropylen (PP) and polyacetal (POM) in the environment of distilled water, bedewing liquid, diluted lye and butanol. Furthermore, the influence of liquids on glasfibre reinforced polycarbonate was comparably examined.

According to that, a deformation behaviour, which is shown in Fig. 1, has resulted for all solid-liquid combinations; it yields an increased creeping of the plastic material in the liquid environment.

In air the failure occurs at a strain value of 8 - 10 per cent for amorphous materials. Semi-crystalline materials show a "flow-out" or breaking only at significantly higher strain values. The craze or crack formation, which precedes the break, is dependent on stress and temperature. The curve $\epsilon_p = f(t)$ as an

indication of first damage by crazing or cracking tends asymptotically for long loading times to a strain limit $\epsilon_{F_{00}}$. No irreversible and craze-causing deformation will occur below this value. The strain limit bordering the linear-elastic deformation sector is characteristic for each plastic material and its value is independent on stress-conditions, temperature, and environment as long as no change of the material properties takes place (e.g. softening).

Whereas under laboratory conditions many crazes develop in amorphous thermoplastic materials (leading to a silvery glimmer on the specimen) there generally exist in the presence of fluids only a few crazes, which are growing through the total profile of the specimen. These crazes are regions containing oriented polymer material, which is interconnected with the normal surrounding polymer. Therefore, crazes are able to sustain stresses such that an increasing strain can be absorbed during a balanced temperature and stress behaviour. Basically, a plastic material may become more ductile by liquid-absorption and may fail - on account of lubrication between the macromolecules - only at high strain values (e.g. PMMA in bedewings and at increased temperature). On the other hand, the chance of a nearly brittle failure exists when a polar liquid is connected by hydrogen bridges to the secondary chains of the polymer. Consequently, a handicap for deformation is established which leads to the fact that one of the few developed crazes initiates the fracture (e.g. PMMA in distilled water).

The formation of those crazes and the surface of a nearly brittle-broken specimen is shown in Fig. 2 and Fig. 3.

Equal to the behaviour of reinforced resins diffusional proceedings in the bordering areas of glasfibre reinforced

thermoplastic materials may cause an accelerated creeping and failing such that fillers (considered to be a reinforcement) may thoroughly lower a craze-initiating strain value by favouring absorption. A special importance will have to be paid to those other materials in which the fillers themselves may possibly swell and by this break the cohesive polymer matrix.

In natural environment the fracture of semi-crystalline thermoplastic materials starts from the borders of the structural components in shape of a real crack and moves along these borders till it comes to a stop at a spherulith arranged rectangularly to its direction of growing. Temperature and corrosive liquids enforce a more distinct crack growth, which starts also from adhesion areas but goes straightly through the spheruliths. This growth is rectangular to the greatest normal strain direction and leads to a failure by fracture at lower strain values than those found in air at room temperature.

By considering admissible strain values the influence of liquid environments on plastic materials can well be determined and this allows a simple application in plastic design.

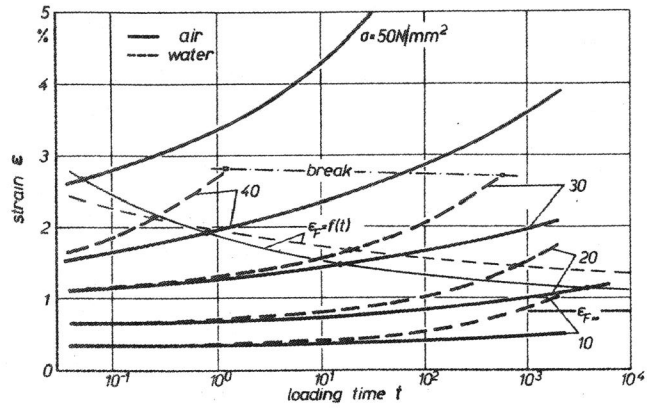


Fig. 1 Stress-crazing in tensile creeps tests of PMMA in air and water at 23°C

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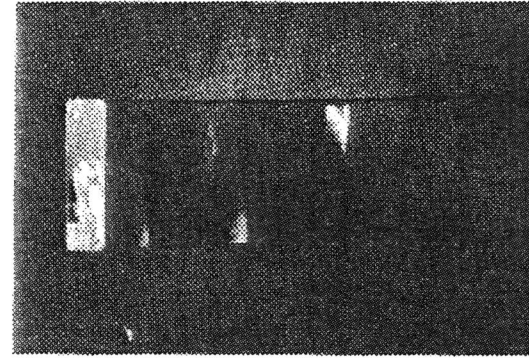


Fig. 2: Craze-formation at a PMMA-specimen in water
 $\sigma = 30 \text{ N/mm}^2$, $T = 23^\circ \text{C}$

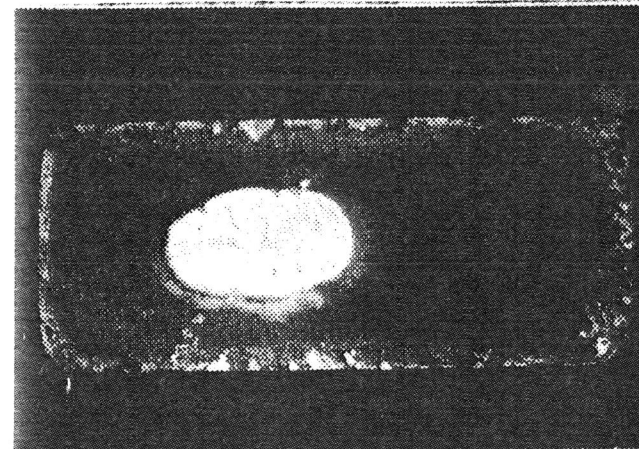


Fig. 3: Fracture surface of a PMMA-specimen in water
 $\sigma = 30 \text{ N/mm}^2$, $T = 23^\circ \text{C}$