Crazing and shear banding in polymers:-

Engineering design with polymers starts with stiffness, but strength is also important . at least five strength – limiting processes are known in polymers, they are :-

1. Brittle fracture, like that in ordinary glass.
2. Cold drawing, the drawing – out of the molecules in the solid state, giving a large shape change.
3. Shear banding, giving slip bands like those in metal crystal.
4. Crazing, a kind of microcracking, associated with local cold – drawing.
5. Viscous flow, when the secondary bonds in the polymer have melted.

Brittle fracture:-

Polymers are brittle below 0.75 T­g ( approximate ). Unless special care is taken to avoid it, a polymer sample has small surface cracks ( depth C ) left by machining or abrasion, or caused by environmental attack.

Then a tensile stress will cause brittle fracture if:-

, KC = fracture toughness of the polymer.

Approximately, the fracture toughness of most polymers is 1Mpa and the incipient crack size is a few micrometers. Then the fracture strength in the brittle regime is about 100 Mpa. But if deeper cracks or stress concentrations are cut into the polymer, the stress needed to make them propagate is lower.

When designing polymers you must know that below 0.75 Tg they are low toughness materials and anything that concentrates stress is dangerous like (notches – cracks – sharp changes in section). (see fig. (1)).

Crazing :-

Many polymers, among them PE, PP and nylon draw at room temp. other with a higher Tg such as Ps , do not draw well at higher temperatures. If PS is loaded in tension it crazes. Small crack – shaped regions within the polymer draw down, but being constrained by the surrounding undeformed solid, the drawn material ends up as ligaments which link the CraZe surfaces. The CraZes are easily visible as white streaks or as general whitening when cheap injection molded articles are bent (plastic pen tops, plastic Caps). The CraZes are a precursor to fracture. Before drawing, a crack forms at the center of a CraZe and propagates \_ often with a CraZed zone at its tip to give final fracture. ( see fig. (2))

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| Fig. 1- Brittle fracture: the largest crack propagates when the fast fracture criterion is satisfied. |
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| Fig. 2- CraZing in a linear polymer: molecules are drawn, but on a much smaller scale, giving strong strands which bridge the microcracks. |

Shear banding:

When CraZing limits the ductility in tension, large plastic strains may still be possible in compression and called shear banding (fig. 3). Within each band a finite shear has taken place. As the number of bands increases, the total overall strain accumulates.

Viscous flow:

Well above Tg polymers flow in the viscous manner, when this happens the strength falls steeply.

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| Fig. (3) shear banding, an alternative form of polymer plasticity which appears in compression. |