Residual stress in plastics

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Objectives

- Development of a QA test method that can assess the level of residual stress in plastic mouldings

- Technique should be:
  - Quick and simple to use
  - Suitable for use on factory floor
  - Provide pass/fail selection criteria
Importance of residual stress in plastics

- Tensile residual stress significantly increase the likelihood of failure in plastics due to Environment Stress Cracking (ESC).
- ESC is fracture that is caused by tensile stress (applied or residual) in the presence of a chemical environment.
- Residual stresses are particularly dangerous in plastics as they are difficult to measure and are therefore often ignored by designers.
- Estimated cost of ESC failures to UK industry £100 million.
Commercial Impact

Failure modes of plastic products

- ESC
- Chemical Attack
- UV attack
- Heat degradation
- Creep/relaxation
- Static (notch)
- Dynamic fatigue
- Wear

30% of failures due to ESC

Estimated cost to UK industry £100 million
In previous programmes NPL have assessed residual stress in plastics using a range of different techniques including:

- Layer removal
- Hole-drilling
- Chemical probe
Layer removal technique
Layer removal results

Residual stress results from the layer removal technique

![Graph showing residual stress vs. depth (mm)]

- **Residual Stress (MPa)**
- **Depth (mm)**

- Blue line: Longitudinal Axis
- Red dashed line: Transverse Axis
Hole-drilling apparatus
Chemical Probe Technique

- Ethanol
- Propanol/Toluene 10:1
- Propanol/Toluene 3:1

Graph showing the relationship between stress (MPa) and time to crazing (minutes) for different chemical probes.
New technique

Chemical probe technique can be used to detect tensile residual stresses on the surface of plastic components.

However, in most plastic mouldings there are compressive residual stresses on the surface which actually inhibit ESC.

New technique will apply tensile stresses to the mouldings and compare the applied stress required to generate crazing in an annealed moulding (no residual stresses) to that in a moulding with residual stresses present.
Plastic Blow Mouldings
ESC Attack

ESC attack following exposure to applied stress and acetone
Conclusions

- Layer-removal technique is the most accurate technique for measuring residual stress in plastics but can only be used with sheets and plates.

- Hole-drilling allows residual stress to be measured in a far wider range of mouldings but is less accurate and requires skilled staff.

- Chemical probe technique is the simplest technique but can only measure tensile residual stresses at the surface.

- The new technique will allow the chemical probe to be used to assess the level of residual stress present in mouldings with compressive residual stresses at the surface.
Publications

◆ Practical Guides
  ◆ Measurement Good Practice Guide -Residual Stress in Polymeric Mouldings

  ◆ Practical Guide for Designers and manufacturers of Mouldings to reduce the Risk of ESC, A.S.Maxwell, NPL Report MATC (A) 05, 2001

◆ Papers
  ◆ Residual Stress in Polymers - Evaluation of Measurement Techniques

  ◆ Measurement of Residual Stress in Polymeric Materials

  ◆ Measurement of Residual Stress in Engineering Plastics using the Hole-drilling

  ◆ Chemical Probe Technique for assessing the Susceptibility of Polymeric Mouldings to Environment Stress Cracking,