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WORKING PARTY ON STRUCTURE AND PROPERTIES OF COMMERCIAL POLYMERS*

THE ONSET OF RUNAWAY CREEP IN HIPS (HIGH IMPACT POLYSTYRENE): A Study in Variability

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The onset of runaway creep in HIPS (high impact polystyrene): a study in variability

Abstract - Previous IUPAC work has shown considerable unexplained variation in the time to the onset of runaway creep in HIPS. Further experiments in seven laboratories have clearly identified the effects of moulding and testing parameters. the chief and most significant effect is that of small variations of stress. A simple reason for this is proposed. By viewing the experiments differently it can be seen that the variation in results are in fact of a level that would normally cause little comment or concern.

BACKGROUND

During an IUPAC collaborative programme on 'Creep measurement on oriented HIPS' (Ref. 1) it was noticed that there was considerable non-systematic variation of the time for onset of runaway creep at high stresses. A small programme by one collaborator on a single set of mouldings gave consistent results. A further collaborative programme was mounted to investigate the cause of the original variations. With hindsight the conclusions drawn from this programme are not surprising, but it could be useful to workers in this area to have them recorded.

THE EXPERIMENTS

Basically a constant load tensile creep experiment was performed at 11.0 MPa stress, and the time to runaway creep measured. Several criteria were used for 'runaway creep', but the final one adopted for convenience was the reaching of 2% strain (Fig. 1.)

The participants were:-

TNO
Cranfield Institute of Technology
Montepolimeri
ICI
BP Chemicals Ltd
BASF
Monsanto

Between these laboratories there were variations in test specimens (bars or dumbells) methods of measuring strain (overall or gauge length) and loading history.

In addition to the 'runaway creep' high stress tests, low stress (3.0 MPa 100 s) creep compliance tests were also performed.

The test specimens were cut from compression moulded sheet. In one series of experiments the effects of cooling rate and position in the sheet were examined, in another preparation of the sheets was carefully controlled (by compression moulding of previously extruded sheet) to achieve consistent mouldings. Specimens were taken from them in such a way as to remove moulding or position in the sheet as a source of variation between laboratories.

RESULTS

In the whole series of tests, results for the same material (HIPS II) (BASF) ranged from below 100 seconds to above 13,000 seconds.

The work on cooling rate and position in sheet plus limited programmes on various testing parameters by individual laboratories showed clearly the effects in Table 1.

Most laboratories gave good agreement on low stress short term compliance.

In the attempt to produce nominally identical specimens (by Monsanto) consistent samples were achieved, i.e. the variability shown within each laboratory was reasonably low. The difference between laboratories was still considerable, the averages for each laboratory spanning the range 3000 seconds to 9000 seconds.

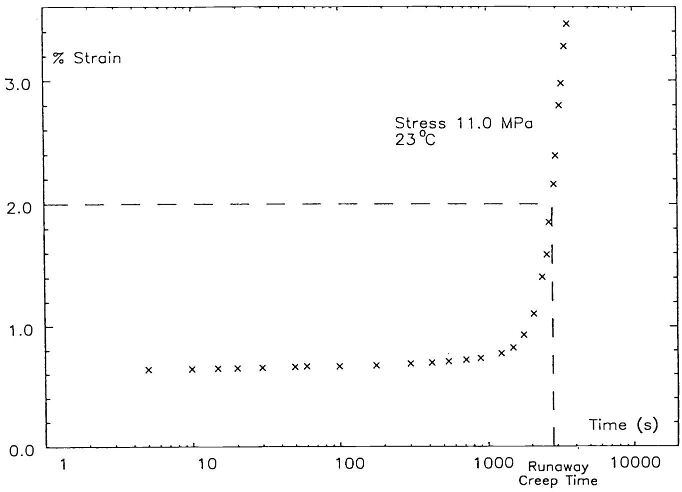

Figure 1: Creep Curve – HIPS II

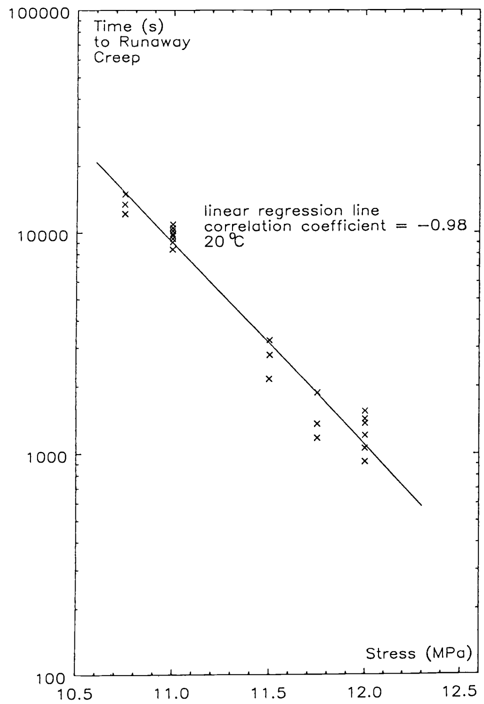

Figure 2: Runaway Creep Time – HIPS II

TABLE 1.

	Low Stress Short Time Compliance	Runaway Creep Variability	Runaway Creep Time
Fast Cooling	Higher		Shorter
High Early Compliance			Shorter
Physical Ageing	Slightly Lower		Longer
Annealing	Lower	No Effect	Longer
Preloading (Prior to Main Creep Load)			Shorter
Surface Roughness		Affects	Affects
Method of Clamping		Affects	Affects
Specimen Geometry (Dumbell or Bar)	Affects	Affects	Affects
Extensometry	Affects	Affects	Affects

Most importantly the sensitivity of creep runaway times to stress was shown definitively by Cranfield (Fig. 2.). This was suggested also by the effect of preloading but here it is quite clear that the difference between 3000 seconds and 9000 seconds could be caused by a difference of only 5% in the true stress level.

This Cranfield work was done at 20°C unlike all other laboratories where 23°C was used. While no experimental work was undertaken, it has been estimated (assuming the yield process to be thermally activated with an activation energy of 125 KJ/mol - Ref. 2.) that the times to yield at 20°C would be a factor of 1.7 longer than at 23°C (this would notionally reduce the variation between laboratories to 3000 seconds to 6000 seconds equivalent to a stress difference of less than 3%).

CONCLUSIONS

Even slight variations in stress can lead to significant differences in runaway creep times. This can occur due to minor variations in loads, dimensions or measurement of these.

Similarly differences in temperature of test can have a pronounced effect on runaway creep. To a lesser extent specimen shape and roughness, clamping and extensometry systems all will affect the results, as will the moulding conditions of the samples.

When the mechanism of runaway creep is considered, none of this is surprising. It was shown in parts of the programme that the time for visible whitening of specimens could be as low as 2000 seconds when the time for 2% strain in the same test was as much as 5000 seconds. Everyone agrees that the yielding mechanism which leads to high strains and runaway conditions is that of crazing. This mechanism which leads to the deformation behaviour that was called 'runaway creep' has commenced much earlier than the time by which we have chosen to measure it.

If indeed, the mechanism is crazing (or even an instability in the continuum mechanics of the material) it is likely to be significantly influenced by stress concentrations and variability is bound to be considerable. Whatever failure mechanism predominates in, for example, pressure testing of pipe, a scatter of over a decade is quite normal. In the work discussed here on specimens made under the same moulding conditions, less than a decade spread has been observed. Such variability is not surprising.

It is clearly unrealistic to expect consistency of results in one laboratory or differences between laboratories of less than one decade in time to runaway for tensile creep experiments. Indeed, if it were not significantly more work, the experiment should be to establish the stress which causes runaway in a certain time (say 2% strain in 1,000 seconds). The results of this experiment should show a consistency well within acceptable experimental error limits which would cause little or no comment.

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