Failure investigation – Burst coolant pipes

Several polybutylene pipes used to carry coolant to and from engine blocks were rupturing during use. No particular batch was deemed to be at fault, and the supplier had not changed the grade or manufacturer.

The pipes under normal conditions were expected to carry coolant at temperatures below 90ºC, however during separate investigations spikes in coolant temperature were recorded at temperatures between 108 and 114ºC.

Vehicles were in use for between 8 and 12 hours per day – meaning that pipes were experiencing potentially higher temperatures for prolonged periods of time.

It was queried if exposure to temperatures of 114ºC would result in the bursting of the pipe. Only non-isothermal conditions were used at the request of the customer.

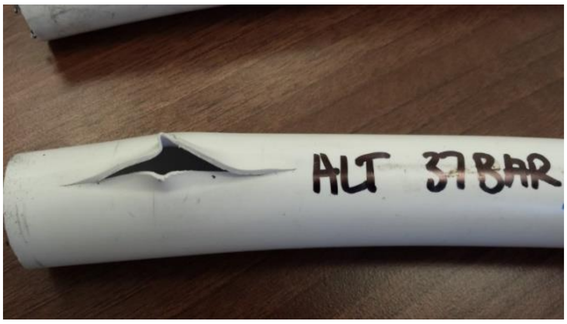

Figure 1: PB Pipe ruptured at PPRC using burst tester to simulate the problem

PPRC investigative approach:

After initially testing samples from the burst pipe material for consistency against good pipe, further thermal analysis was used to determine if the conditions experience by the burst pipe during use could be causing the failure.

Thermal analysis and testing of polymers and plastics across the polymer supply chain and lifecycle is a powerful means of measuring physical properties, transitions, ageing processes, the effect of additives and the influence of diverse production conditions on materials. In semi-crystalline polymers, crystals affect the optical, mechanical, thermal and chemical properties of the polymer. The crystals have strong anisotropy of their mechanical properties along the direction of polymer molecular alignment and perpendicular to it. Therefore, changes in the crystallization will alter the mechanical properties and structural integrity could be compromised given specific conditions.

Differential Scanning Calorimetry (DSC) is a widely-used technique, which here, was used to examine the physical transitions of the pipe during use. PPRC measured any changes to the melting and crystallization phase in accordance with ISO11357-3 - Determination of temperature and enthalpy of melting and crystallization.

Testing methodology:

Both the failed and good pipes had their melting characteristics measured using a standard DSC method, and evidence of secondary metastable crystallites were seen in the presented failed pipe at a melting temperature of 95ºC.

In order to recreate the failure, samples of the good pipe were heated in a DSC to the end temperatures seen in Table 1 and then cooled to room temperature at a rate of 10ºC/min. The samples were then removed from the DSC and left for 7 days for the crystalline structure to settle and any secondary metastable crystallites to form. The samples were reheated to 160ºC at 10ºC/min in order to fully measure the melting characteristics of the pipes.

Any evidence of secondary metastable crystallites; their corresponding temperatures and amount were recorded.

Table 1: Heat termination temperatures for DSC

Heat termination temperature (°C)
108
114
116
118
120
122
124
126
128
130

Heating of the samples to termination temperatures less than 114ºC had no detrimental effect on the overall crystallization of the pipe and no secondary metastable crystallites were formed. However, above this temperature secondary metastable crystallites of varying sizes were seen at every termination temperature with increasing amounts. These crystallites were small and imperfect causing mechanical vulnerability within the pipe and would result in both; an increased amount of PB material phase transitioning from the solid to the liquid state, and a lower overall melting point. The secondary metastable crystallites formed at the 124ºC termination can be seen in Figure 2.

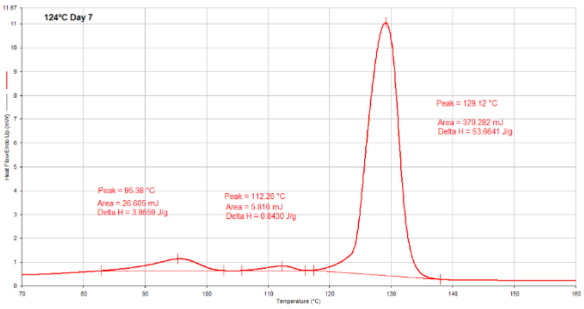

Figure 2: Melting characteristics of pipe with recreated failure

Project conclusion:

Since the lowest melt crystal at 95°C was seen in the burst pipes, it was determined that this section of/or entire pipe had experienced coolant temperatures within the range of 116 - 124°C, which was well in excess of the planned 90ºC and subsequent measured spikes and above the recommended operating temperature advised by the supplier.

The serious implications on the structural performance of the pipe would result in bursting under the internal coolant pressure. The customer installed temperature sensors within the coolant pipes, which alerted the operator when excesses of 90ºC was seen and the engine removed from service to cool down.

If you have any questions relating to troubleshooting or characterisation in general, please get in touch with one of the team:

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