Aging Behavior of Polymeric Absorber Materials for Solar Thermal Collectors

Dissertation

by

Susanne Kahlen

prepared at the

Polymer Competence Center Leoben GmbH

and the

Institute of Materials Science and Testing of Plastics

submitted to the

University of Leoben

Academic Advisor
O.Univ.-Prof. Dr.mont. Reinhold W. Lang
University of Leoben, Austria

Supervisor
Ao.Univ.-Prof. Dr.mont. Gernot M. Wallner
University of Leoben, Austria

Referees
O.Univ.-Prof. Dr.mont. Reinhold W. Lang
University of Leoben, Austria

Univ.-Prof. Dr.phil. John B. Rekstad
University of Oslo, Norway

Leoben, May 2009

ABSTRACT

Plastics offer a high potential for use in solar thermal absorbers, in particular also for flat plate collectors. For such applications, high temperatures in air and water represent the most harmful service conditions. Hence, the investigation of aging phenomena in such materials at elevated temperatures in water and air is of enormous importance to characterize their performance and to identify possible limitations. So far, no comprehensive characterization has been reported, and therefore the main objective of this dissertation was to investigate the aging behavior of plastics for solar thermal absorbers using various methods of polymer science. Special focus was given to the determination of physical and chemical aging processes, and to the establishment of structure-property relationships and of correlations between the results obtained on the level of laboratory specimens, and the sub-component and component level.

For this dissertation, eight different potential polymers for solar thermal absorbers, including four engineering-type plastics (a blend of polyphenylene ether and polystyrene (PPE+PS), polycarbonate (PC), high-impact polyamide 12 (PA12-HI), high-temperature PA12 (PA12-HT)) and four commodity-type plastics (two types of crosslinked polyethylene (PE-X1, PE-X2), two types of polypropylene (PP-1, PP-2)), were selected. According to northern climate conditions, 140 °C in air (during stagnation) and 80 °C in water (during operation) with aging times up to 500 h and 16000 h, respectively, were assumed as typical aging conditions corresponding to an accumulated lifetime of 20 year in service. On the laboratory specimen level, two different analytical methods (differential scanning calorimetry (DSC) and size exclusion chromatography (SEC)) and a mechanical method (monotonic tensile test) were applied to investigate the aging behavior. On the sub-component and component level, DSC and a mechanical indentation test were performed. Furthermore, for three selected polymers (PPE+PS, PC, PP-2) three different lifetime prediction models based on the Arrhenius relationship and results obtained on the laboratory specimen level were used to determine service time endurance limits.

Based on the experimental results generated and the data analysis applied (direct data reduction and/or Arrhenius based lifetime assessment models), only one of the investigated materials, i.e. PA12-HI, was found to be a promising solar thermal absorber material candidate to be applied over the full range of temperatures in air and water as indicated above. Several other materials, offer the potential for absorber applications under more specific conditions. For example, PE-X1 and PP-2 may be applied when proper measures to limit the maximum temperature rise under stagnation are taken (e.g., overheating protection by thermotropic layers). PC was found to be susceptible to hot water, thus constraining its application to air collectors and to components not directly exposed to hot water (e.g., collector glazings). For the investigated PPE+PS, significant chemical aging occurred already during film extrusion step, so that an unambiguous interpretation of the true aging behavior of this material under service near conditions is not possible.

In any case, as this dissertation is the first polymer science based study of the aging behavior of potential material candidates for solar thermal absorbers, further investigations are necessary to substantiate all of the results obtained prior to applying these materials to commercial products. Moreover, future investigations should also broaden the spectrum of material candidates by either proper modification of the polymer material classes included in this dissertation (e.g., stabilization towards the application specific conditions) or by selecting further and new potential polymer types.