Effect of Thermal Aging on the Mechanical and Optical Properties of a Polyester Resin

RIADTH J. A. SHALASH and MUSTAFA M. F. AL-JARRAH, *Petroleum Research Centre, Scientific Research Council, P.O. Box 10039, Iraq*

Synopsis

Thermal aging of an unsaturated polyester resin at 150°C was followed for a period of 960 h. The mechanical properties of cured polyester resin were enhanced at the start of aging, followed by slight deterioration. However, some improvement in the tensile strength and modulus were observed at the end of aging. The optical properties, viz., absorbance, transmittance, and reflectance, exhibited the usual change in polymer degradation; the absorbance showed an increase as a function of aging time, whereas the transmittance and reflectance decreased.

INTRODUCTION

Unsaturated polyester resins are one of the widely used thermosetting polymers in the fiber-reinforced plastics industry. In certain applications such as the use of fiber-reinforced polyesters as covers for solar energy collectors,[1] it is important to evaluate the performance of these resins on prolonged high temperature exposure. Indeed, there is very little published work on the durability of mechanical and optical properties of polyester resins upon thermal aging.[2] Optical spectroscopy, especially in the visible region, is known to provide very useful information on the degradation of several industrial polymers.[3–7] Since polymer deterioration usually starts at the surface and penetrates into the bulk, it is also important to study the reflection and transmission properties of the polymeric material.

EXPERIMENTAL

Preparation of Specimens

Resin, catalyst and promoter were supplied by Vianova Kunstharz, Austria. The resin used in this work was Viapal H265 unsaturated polyester based on tetrahydrophthalic acid and appropriate blends of ethylene glycol, propylene glycol, di(propylene glycol), and di(ethylene glycol), dissolved in styrene. The curing reaction was initiated by mixing the resin with 1% (w/w) cobalt–octoate in xylene, containing 6% active cobalt and 1% (w/w) methyl ethyl ketone peroxide as catalyst. The mixture was degassed by centrifuging, and then cast between two glass sheets (300 × 300 mm) treated with wax and poly(vinyl alcohol) solutions as release agents. Great care was taken in the casting process to avoid introducting air bubbles. Case thickness was controlled, using feeler gauges. The cast resin was then cured at room

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temperature for 48 h. Tensile test specimens were prepared from the cured resin sheet according to ISO 3268-1978 (E) (type III test specimens) and machined by diamond wheel into strips of 230 × 25 × 1.3 mm in dimensions.

THERMAL AGING

Specimens were aged in an air-circulating oven at 150°C for 960 h. Five specimens were drawn from the oven every 96 h, and conditioned at 23 ± 2°C and 50 ± 5% relative humidity, prior testing.

MECHANICAL MEASUREMENTS

Tensile testing was conducted using a Zwick 1434 universal testing machine at test speed of 2 mm/min.

OPTICAL MEASUREMENTS

The same specimens after mechanical testing were used to measure their absorbance, transmittance, and reflectance properties using a Pye-Unicam SP 8 250 UV-visible spectrophotometer. Air was used as a reference for absorbance and transmittance, whereas a Pye-Unicam white standard was used in the reflectance measurements.

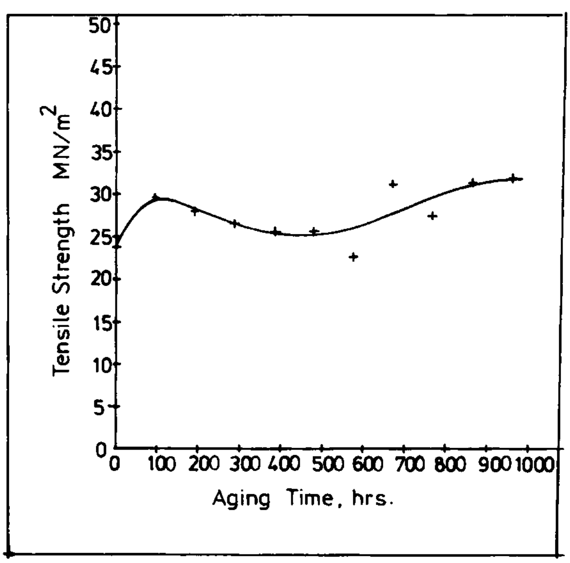

Fig. 1. Tensile strength as a function of aging time.

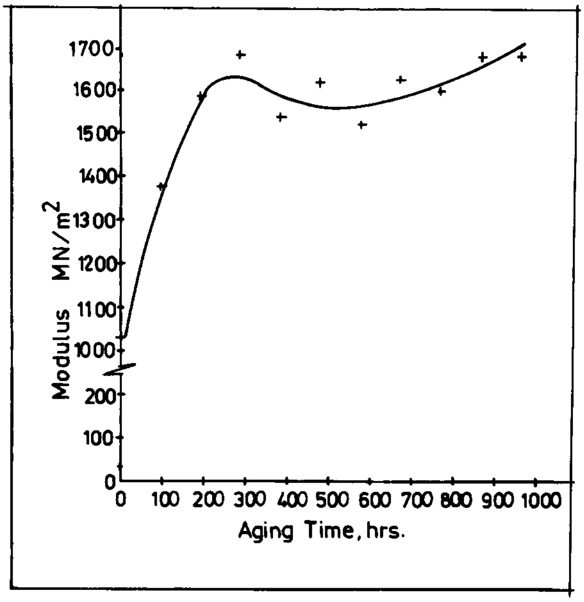

Fig. 2. Modulus as a function of aging time.

RESULTS AND DISCUSSION

To accelerate the effect of thermal aging on the properties, aging was performed at 150°C, which is well above its glass transition temperature (~80°C). Although at such high temperature an extraneous reaction is expected, yet aging at different temperatures (work in progress), viz., 80, 100,

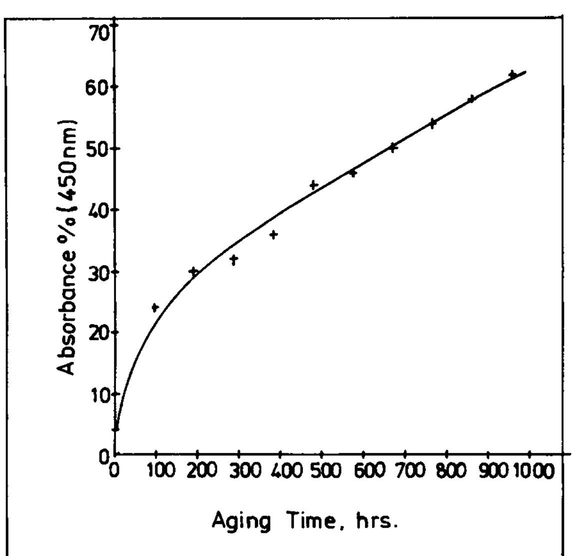

Fig. 3. Absorbance at 450 nm as a function of aging time.

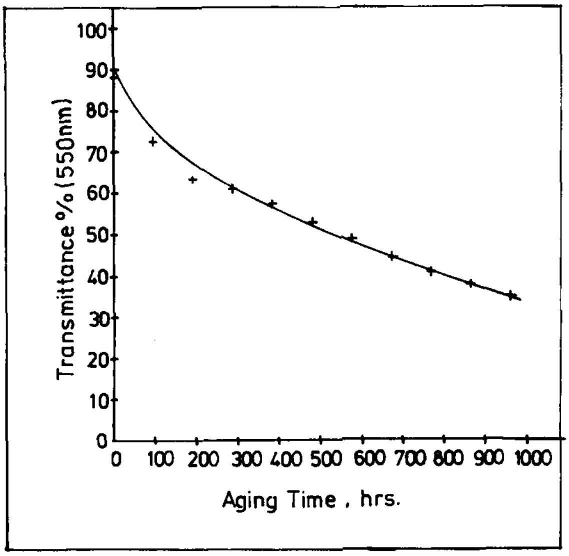

Fig. 4. Transmittance at 550 nm as a function of aging time.

120°C, shows no deviation from the linear dependency of the deterioration in properties with temperature increase.

Results of the mechanical investigation showed some unusual behavior properties which could be explained by assuming that post-curing and degradation reactions take place simultaneously upon aging. Initially, post-curing predominates as demonstrated by the improvement in tensile properties as shown in Figures 1 and 2. Degradation becomes more effective on

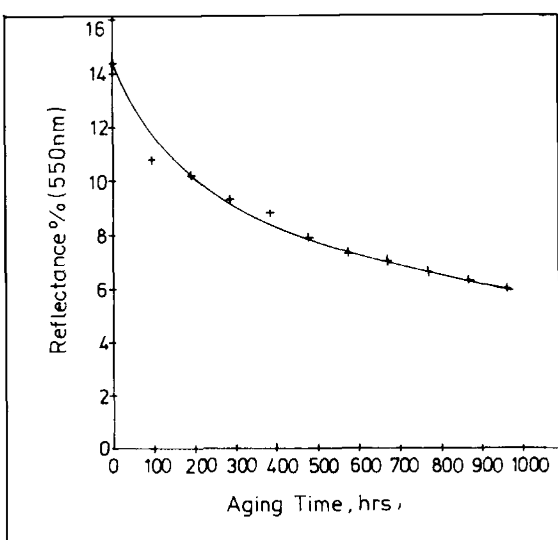

Fig. 5. Reflectance at 550 nm as a function of aging time.

prolonged aging. However, the peculiar improvement in mechanical properties on further aging needs further investigations.

The clear cured polyester specimens caused on thermal aging a very considerable yellowing, which increased with aging time as shown from the increase in absorbance and decrease in transmittance (Figs. 3 and 4). This discoloration is very characteristic of degradation, which occurs as a result of breaking down of crosslinkages and formation of conjugations.

Figure 5 shows the decrease in reflectance property of cured polyester resin during aging. It is believed that this is due to surface oxidation of the resin.

CONCLUSION

Thermal aging of cured polyester resin at 150°C, although it showed a normal discoloration, revealed some unusual behaviour in the mechanical properties. Initially, a substantial improvement in mechanical properties was observed followed by a decline in these properties; then on prolonged aging an improvement in the mechanical properties was observed.

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