Thermochimica Acta, 226 (1993) 363–368
Elsevier Science Publishers B.V., Amsterdam

Automatic transmission fluid compatibility with nylon components by thermomechanical analysis and thermogravimetry[1]

A.T. Riga *, G.H. Patterson, W.R. Pistillo, C.R. Scharf and W.C. Ward
The Lubrizol Corporation, 29400 Lakeland Boulevard, Wickliffe, OH 44092 (USA)

(Received 31 May 1993; accepted 16 June 1993)

Abstract

Oxidation testing during automatic transmission fluid (ATF) development showed various degrees of nylon component degradation by thermal mechanical analysis (TMA) and thermogravimetric analysis (TGA). The especially sensitive nylon components were the pump rotor guides and thrust washers. ATFs formulated to contain "basic reserve" additives (overbased calcium sulfonates) were observed to inhibit nylon transmission component degradation. The inhibition is hypothesized to occur by neutralization of acidic oxidation by-products and formation of stabilizing chemical films on the surface of the nylon components. Nylon parts tested with ATFs not containing "basic reserve" additives were susceptible to aggressive degradation.

INTRODUCTION

DEXRON®-IIE oxidation tests were run with different ATFs [1, 2]. Tests showed differences in the surface condition of nylon components. The nylon pump rotor guide and thrust washers were extremely sensitive to the AFT's oxidation products. Nylon or polyamides are known to degrade by various mechanisms, including acidolysis and hydrolysis [3–6]. Nylon transmission components in contact with ATFs containing calcium overbased sulfonates exhibited thermomechanical stability. Overbased sulfonates classically can act as anti-corrosion agents and basic lubricants for various metals. They function by neutralizing acidic by-products produced in lubricating oils. They also form an anti-corrosive barrier layer on metal surfaces. Recent studies suggest that this layer could provide lubrication during metal working processes [7, 8].

---

* Corresponding author.

[1] Presented at the 21st Annual NATAS Conference, Atlanta, GA, 13–16 September 1992.

Our working hypothesis for the stabilization of nylon parts by ATFs containing overbased calcium sulfonate is as follows; a stabilizing carbonate film is formed on the surface of the nylon ATF components which protects against by-product attack by neutralizing acidic oxidation products.

EXPERIMENTAL

The nylon parts used in this study were: (A) a new, unused nylon thrust washer from a transmission, which was light tan and opaque in appearance; (B) a nylon thrust washer exposed to an ATF containing calcium sulfonate in the turbohydromatic oxidation test THOT (the nylon color has darkened but there was no mechanical degradation); (C) a nylon thrust washer exposed to a non-calcium sulfonate containing ATF in the THOT (severe physical and mechanical degradation of this black part were observed). The three thrust washers were examined with an Olympus BH-2 microscope. Furthermore, the samples were characterized by thermogravimetric analysis (TGA) (Model 951 available from TA instruments, Inc., New Castle, DE, USA) and thermomechanical analysis (TMA) (Model 943 available from TA Instruments, Inc., New Castle, DE, USA). The experimental conditions included a heating rate of 10°C min^{-1}, nitrogen atmosphere, and a flow rate of 50 ml min^{-1}.

RESULTS

The TGA profiles of a new nylon component (A) and a part exposed to an ATF containing a calcium sulfonate additive (B) were similar in decomposition temperatures and composition (Fig. 1). Two of the samples

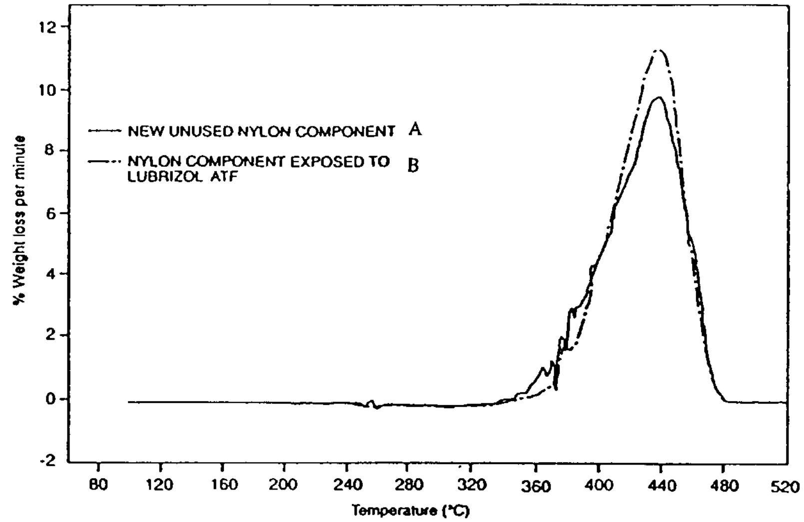

Fig. 1. Derivative TGA of nylon transmission components.

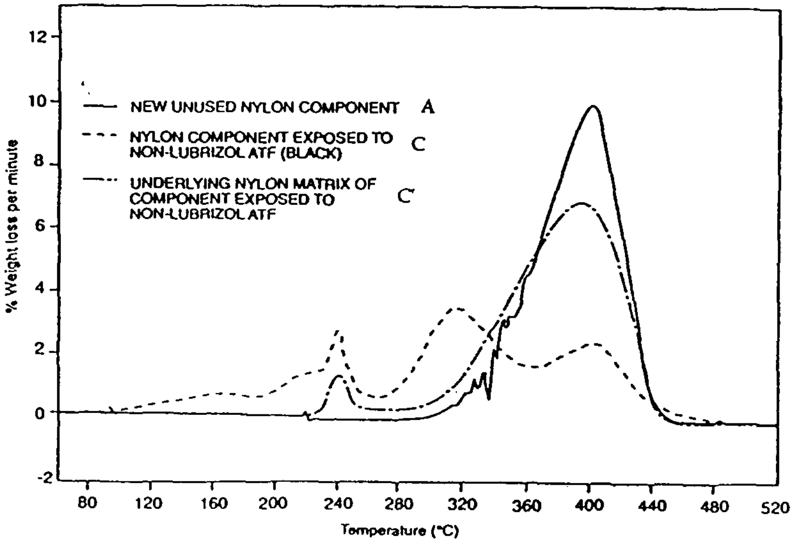

Fig. 2. Derivative TGA of exposed nylon transmission components.

characterized in this oxidation study, samples A and C, are seen in Fig. 2. The TGA of sample C was significantly different from the TGA of samples A and B. Multiple degradation peaks were noted for sample C; however, the underlying nylon matrix of C appeared to be identical to A.

The characteristic TMA profile of a new unused nylon ATF component (sample A) is illustrated in Fig. 3. The positive coefficient of linear

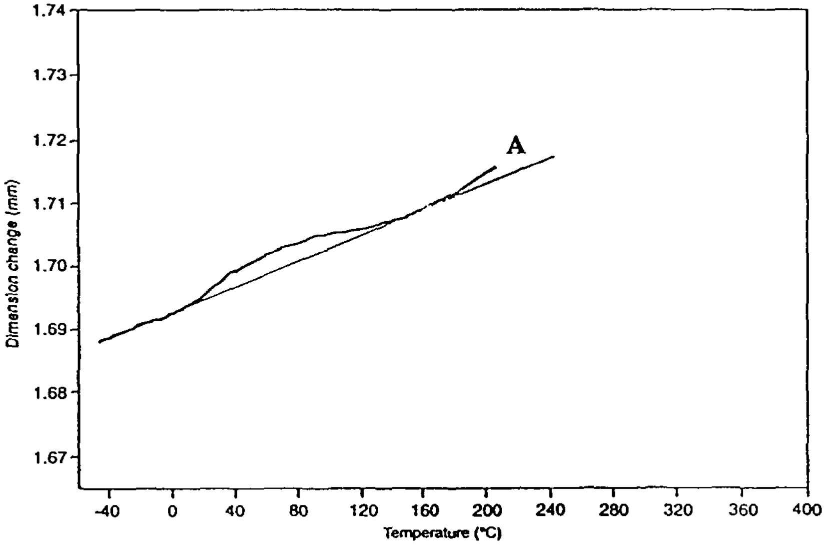

Fig. 3. TMA of new/unused nylon transmission components.

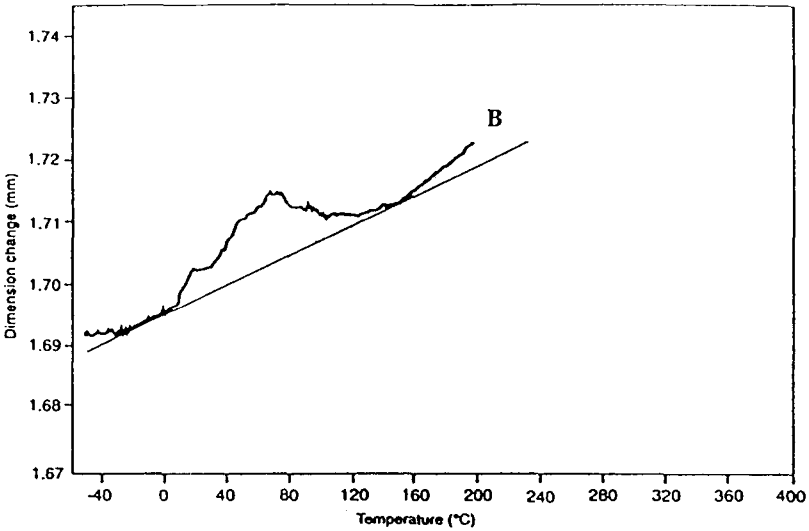

Fig. 4. TMA of a used nylon part exposed to ATF with calcium sulfonate.

expansion is indicative of a dimensionally stable nylon material over the temperature range studied, −40°C to 200°C. As shown in Fig. 4 the expansion profile is indicative of a nylon part exposed to an ATF containing the overbased sulfonate after a transmission oxidation test (sample B). The overall positive slope is similar to the unused nylon component. Figure 5 shows the TMA expansion profile of a degraded part (sample C). The accelerated nonlinear expansion at −40°C and at higher temperatures the

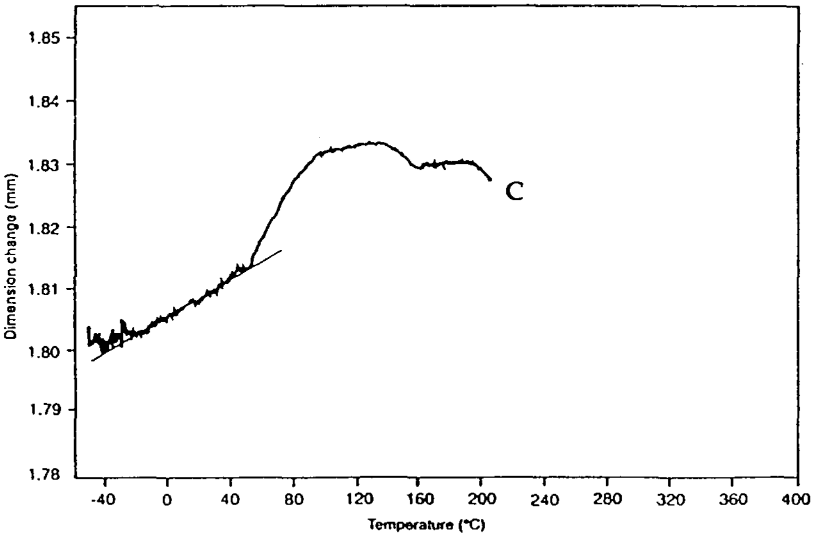

Fig. 5. TMA of a used nylon part exposed to ATF with no calcium sulfonate.

negative (downward slope), penetration profile, is typical of a dimensionally unstable degraded thermoplastic [9]. This dimensional instability parallels at loss of mechanical integrity of the nylon component.

DISCUSSION

The thermal stability and degradation of Nylon 6 or Nylon 66 as well as other polyamides have been well documented [8, 10]. Nylons degrade by thermo-oxidative chain scission as well as hydrolysis [11].

To test the thermal stability of the nylon thrust washers a part was held at 160°C for one month in air. There was no significant variation of the tensile strength or color of this nylon part exposed to air at a moderate temperature. Nylon degradation in our study appears to be due to ATF chemical attack and not thermal-oxidation of the nylon alone. The greatest degradative effects were observed for nylon components exposed to ATF compositions which did not contain overbased calcium sulfonates.

Several mechanisms can explain the inhibition of the nylon by the calcium overbased sulfonate-containing ATF. In the transmission thermal-oxidative processes generate acidic and radical initiator by-products; for example, carboxylic acids and peroxides [11]. The acids can be neutralized by the basic sulfonate, and thus effectively inhibit the oxidation of nylon. Sulfonate additives are surface active and are known to adsorb onto metal or metal oxide surfaces. It is also possible that the ionic overbased sulfonates would adsorb onto the relatively polar nylon surfaces (polar when compared to base oil) and provide a protective barrier which inhibits degradation. A surface film containing carbonates would protect the nylon from acid attack and also stabilize the nylon surface.

CONCLUSIONS

An overbased calcium sulfonate-containing ATF prevented the degradation of nylon parts in a transmission test under THOT conditions. A non-calcium sulfonate containing ATF showed severe degradation toward nylon components in the same transmission test. The degradation of nylon parts caused a loss of mechanical and physical stability. Nylon component degradation will probably affect long term transmission performance.

ACKNOWLEDGMENTS

The authors thank the Lubrizol Corporation for allowing this publication. We also acknowledge the assistance from Tom Taglimonte of the Lubrizol Corporation.

REFERENCES

1 DEXRON II-E Automatic Transmission Fluid Specification, General Motors Corporation, Detroit, MI, 1990.
2 DEXRON II-E Automatic Transmission Fluid Specification, 2nd edn., General Motors Corporation, Detroit, MI, 1978.

3 W. Wendlandt, Thermal Methods of Analysis, Wiley, 1974, p. 428.

4 J. Papay, Ethyl Petroleum Additives, Society of Automotive Engineers, paper 892157 (1989).

5 H. Mark (Ed. in Chief), Encylopedia of Polymer Science and Engineering, 2nd edn., Wiley, 1988, p. 356.

6 V. Moiseev and G. Zaikov, Chemical Resistance of Polymers in Aggressive Media, Plenum, NY, 1982.

7 A. Riga, H. Hong, R. Kornbrekke, J. Cahoon and J. Vinci, Reactions of Overbased Sulfonates and Sulfurized Compounds with Ferric Oxide, Lubrication Engineering (January 1993).

8 H. Hong, A. Riga, J. Cahoon and J. Vinci, Evaluation of Overbased Sulfonates as Extreme Pressure Additives in Metalworking Fluids, Lubrication Engineering (January 1993) 19–23.

9 A. Riga, Heat distortion and mechanical properties of polymers by thermomechanical analysis, Polymer Eng. Sci., 14 (1974) 764.

10 K. Saunders, Organic Polymer Chemistry, Chapman, London, 1976, 185.

11 H. Mark (Ed. in Chief), Encylopedia of Polymer Science and Engineering, 2nd edn. Wiley, 1988, p. 358.