Strength Properties of Floor Finish Films

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ABSTRACT

Unsupported floor finish films were prepared by deposition on glass and removal after soaking in water. The films were then studied for tensile properties, using an Instron Tester. Measurements were attempted and developed for tensile strength, yield strength, elongation, and tearing strength. Differences in film forming characteristics were observed for various floor finishes. Attempts were made to explore film properties, and it was possible to measure differences in film strength properties resulting from scrubbing with detergent-stripper systems.

INTRODUCTION

Because many articles on floor finishes or waxes deal mainly with qualitative or, at best, semiquantitative results, efforts in this research laboratory have focused on quantitative and systematic investigations of floor finish properties. This had led to 2 publications in the analysis of the powdering of floor finishes (1,2). A logical extension of this work is the attempt to isolate floor finish films, free from the substrate, and deal with these in a quantitative fashion. The substrates for floor finishes, e.g., vinyl asbestos or terrazzo, are important to the net appearance of a film, yet such substrates make it difficult to examine properties because another variable is introduced, and this makes reproducibility difficult. Therefore, this study was made to develop methods for quantitative investigations of floor finish films.

An Instron Tensile Tester, which is located in the Alberto-Culver analytical laboratories, was used in this work. This device has been used to measure the tensile properties of hair fibers treated with shampoos and resin sprays (3,4).

EXPERIMENTAL PROCEDURES

Preparation of Film Samples

In this investigation, 40 ml floor finish were poured onto level 8 x 8 in. window glass plates. The liquid spread evenly to the periphery of the plate and then was permitted to dry in a draft free area for 24 hr at 68-72 F and 15-25% relative humidity. After drying, the film and plate were soaked ca. 30 min in a basin of deionized water to loosen the film from the plate.

The film edges were freed from the glass and film was removed carefully from the surface. It should be noted that certain films or floor finishes do not lend themselves to this formation and removal process. For example, it was found that some floor finishes did not form a uniform film, i.e., they were underplasticized and gave an "orange-peel result," or the resulting films were so brittle they spontaneously shattered in efforts to remove them from the glass. It was found that for most of our products, it was possible to develop isolated films which were transparent and uniformly free of distortion.

Film Strength Measurements

The tensile strength, elongation, and stress relaxation were measured via an Instron Tensile Tester, Model TM 1101. The tester was fitted with a 200 pound capacity tensile load cell, Model CT (Instron G-01-5). The film specimens were secured with screw action grips with 1 x 1½ in. smooth ground grip faces. The tester was calibrated by means of a 5 pound wt.

The procedure followed the general provisions of ASTM Method D-882-67 (5), Method A, Static Weighing, Constant Rate-of-Grip Separation Test for thin plastic sheeting.

The test specimens were cut into 3 x ½ in. strips by means of an X-Acto No. 11 blade. Grip slippage was avoided by laminating both sides of each end of the strips with 3M Scotch Magic Transparent Tape No. 810. The resultant gage or test length was 1 in. Film thickness was measured to within 0.1 mil using an Oditest dial micrometer. The thicknesses ranged from 3 to 11 mil depending on the formulation and quantity applied to the glass. In general, the films were tested wtihin 2 weeks after intial preparation. Two films which had aged one year also were tested. Prior to measurement, the films were conditioned 24 hr at 75-78 F and 16-22% relative humidity.

Recorder amplification was adjusted to yield full scale sensitivity equivalent to 5 pounds. The chart speed varied from 2 to 50 in. per min to permit documentation of applicable tensile data. The crosshead speed, or constant rate of grip separation, was maintained at 0.2 in. per min (20% per min rate of elongation) for all samples.

Calculations

The following calculations were used in this study.

a) Percentage elongation at break =

$$\frac{\text{Elongation of specimen at moment of rupture (in.)} \times 100}{\text{Initial gage length (in.)}}$$

b) Tensile strength at break =

$$\frac{\text{Load at break (lb)}}{\text{Original minimum cross-sectional area (in.}^2\text{)}}$$

c) Percentage relaxation at constant strain at time$_t$ =

$$\frac{(\text{Maximum stress at } t_o - \text{stress at } t_t) \times 100}{\text{Maximum stress at } t_o}$$

d) Yield strength =

$$\frac{\text{Load at yield point (lb)}}{\text{Original minimum cross-sectional area (in.}^2\text{)}}$$

TABLE I

Floor Finishes Examined

Code[a]	Average film thickness (mils)	Apparent film character
WBS-1	3.0	Soft, elastic
WBS-2	4.9	Hard, brittle
SBDB-1	3.2	Soft, slightly elastic
SBMI-1	4.3	Soft, very slightly elastic
SBMI-2	10.4	Soft, tough, flexible
NBMI-1	3.1	Moderately hard, inelastic
NBMI-2	4.1	Moderately hard, inelastic
NBMI-3	4.2	Moderately hard, flexible, tough
NBMI-4	6.8	Very hard
NBMI-5	9.7	Very hard, tough, flexible
NBMI-6	10.8	Very hard

[a]WBS = Water based sealer; SBDB = semi-buffable dry bright; SBMI = semi-buffable metal interlock; NBMI = non-buffable metal interlock. Number following code refers to the number tested in each category.

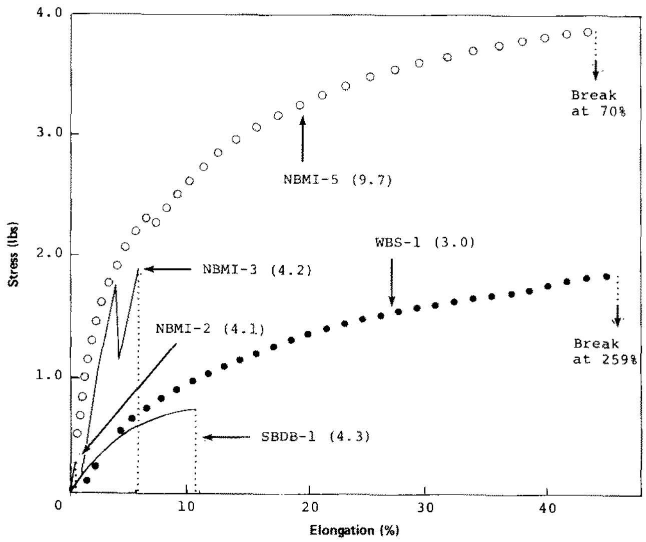

FIG. 1. Stress-elongation curves. NBMI = non-buffable metal interlock; WBS = water-based sealer; SBDB = semi-buffable dry bright.

TABLE II

Tensile Data for Water-based Sealers (NBS)

Sample[a]	Tensile[b] strength (psi)	Elongation (%)
WBS-1 (3.0)	1290	260 ± 30
WBS-2 (4.9)	220	0

[a]( ) = film thickness in mils.
[b]95% confidence limits: ±80.

TABLE III

Tensile Data for Semi-Buffables

Sample[a]	Tensile strength (psi)	Elongation (%)
SBDB-1 (3.2)	420	11 ± 5.0
SBMI-1 (4.3)	220	1 ± 0.4
SBMI-2 (10.4)	1480	90 ± 30.0

[a]SBDB = Semi-buffable dry bright; SBMI = semi-buffable metal interlock. ( ) = film thickness in mils.

Floor Finishes Examined

The floor finishes examined in this study were of 4 types including a) water-based sealers, b) a semi-buffable, dry bright; c) semi-buffable, metal cross-linked types, and d) nonbuffable metal cross-linked systems. The water-based sealers typically contain ca. 13% of an acrylic-styrene copolymer and ca. 0.8% of a leveling resin such as a rosin ester or styrene maleic anhydride. Typically, such sealers do not contain wax. They contain ca. 0.4% of surfactants or emulsifiers such as linear alkylate sulfonate, nonionic surfactants based on ethylene oxide and/or oleate salts such as morpholine oleate. Glycol ethers are present at ca. 4% to coalesce the film, and these are volatile materials. About 0.5% (total) of plasticizing materials also are present, and these consist typically of tributoxyethylphosphate and dibutylphthalate. The balance of the product is water to yield a nonvolatile content of about 15%.

The next type is classified as a semi-buffable, dry bright system. Here, the polymer content is reduced to ca. 8% and the resin content is raised to ca. 2%. A high wax level is present, in the 2.5% range. More emulsifiers, now at 1.5% are needed to stabilize the system, and the coalescent-plasticizers are each typically at 1.5% levels. The nonvolatiles contents of such a system is also in the range of ca. 15%.

Semi-buffable metal cross-linked system is another important category. Such system also are termed metal-interlocks because the metal cross-linking, usually with zinc, renders the polymer more resistant to detergent scrubbing. Removal of such finishes is accomplished by treatment with ammonia to complex the zinc and unlock the polymer. These systems typically contain ca. 11% polymer, 0.8% resin, a high wax level of 2.5% for buffability and appropriate levels of surfactants, coalescents, and plasticizers.

The most common category of floor finishes today, nonbuffable metal interlocks are similar to the semi-buffable metal interlocks, but contain slightly higher polymer levels, less wax, and emulsifiers and higher coalescent proportions to properly soften the polymer particles during film formation.

The floor finishes examined in this study are listed in Table I. For simplicity, the finishes have been coded according to the designations: water based sealer (WBS), semi-buffable dry bright (SBDB), semi-buffable metal interlock (SBMI), and nonbuffable metal interlock (NBMI). The numbers following the code refer to the number of the example tested under each category. The thicknesses of the films was measured using an Oditest dial micrometer, with thicknesses ranging from 3 to 11 mils, depending on the nonvolatiles content and the quantity applied to the glass. We also characterized, qualitatively, the resulting films as to their softness or hardness, elasticity, flexibility, and toughness. The sealers were represented by two distinctly different types: soft or elastic versus hard and brittle. The semi-buffables were generally softer, presumably because of their higher wax contents. The non-buff interlocks were generally harder and were inelastic, flexible, or tough, depending on the system.

RESULTS AND DISCUSSION

A composite of curves obtained for selected films is shown in Figure 1. The curves were derived from plotting the stress or pounds of load on the film versus the degree of elongation or stretch obtained at various loadings. The curves illustrated the various results obtained. The first category or type of curve for NBMI-2 is illustrated by the small sharp peak on the lower extreme left corner of the figure. This type of curve was obtained for brittle films and particularly for very thin films from the non-buff-type formulations. The film takes only a small load before it ruptures, and there is very little elongation at break.

The next curve, that for NBMI-3, another non-buff metal interlock type, had a similar film thickness, 4.2 mils compared to 4.1 for NBMI-2. The NBMI-3 product, however, was of a higher solids or nonvolatiles content, 18% versus 15% for NBMI-2. The resulting curve for NBMI-3 showed greater load resistance and significant elongation before film rupture. A yield point also was evident.

The curve for NBMI-5 at 9.7 mils shows that a very hard, tough film can be obtained with a non-buff metal interlock by building up the film thickness. In this case, the breaking strength of ca. 3.9 lbs. load was attained before rupture at 80% elongation.

The curve labeled SBDB-1 is for a semi-buffable dry bright system which is relatively soft, but shows considerable elongation, to ca. 11% before rupture occurs. This formulation is characterized by a high wax content compared to the non-buff products.

And finally, the curve labeled WBS-1, for a water-based sealer represents a flexible or rubbery film which is very tough; and which has an elongation of about 259% at break. Thus we see looking at the various curves for different floor finishes that very substantial differences in stress-strain occur for the films examined.

Table II shows tensile and elongation data for the finishes which were tested. Two types of water-based sealers were tested and two totally different results were obtained. WBS-1, discussed earlier yields a rubbery, strong film with a high tensile strength and a very high elongation at break. It should be noted that the tensile strength data generally has 95% confidence limits of ca. ±80 psi, and these limits were independent of the magnitude of the average tensile strength values. The 95% confidence limits for the % elongation did vary with the extent of elongation, and, therefore, these limits are reported individually.

WBS-2 (4.9) was found to have a much lower tensile strength of ca. 220 psi and virtually no elasticity. The WBS-2 is a styrene-acrylic type sealer with no wax, but it does yield a high gloss undercoating for additional polish. The rubbery WBS-1 is an internally plasticized copolymer system which is readily stretched but which does not impart gloss character to the undercoat seal.

Table III shows results vary substantially for semi-buffable floor finishes. A conventional dry bright system (SBDB-1) with a styrene-acrylic copolymer had moderate tensile strength and substantial elongation of 11%, compared to a slightly lower tensile strength and less elasticity for a semi-buffable metal interlock system. Measurements on a thicker semi-buffable metal interlock film yielded a much higher tensile strength, in the 1500 psi range, and substantially higher elongation, ca. 90%, at break. Thus, while differences in composition affect results, film thickness appears to be a major factor in film strength properties.

Tensile properties for non-buff metal interlocks are shown in Table IV and the results tend to support the above findings. With some exceptions, films in the 3-4 mil thickness range tend to have lower tensile strength and virtually zero elongation. NBMI-3 seems to be somewhat atypical, because it yields a high tensile strength, in the 900 psi range and has some stretchability. It is interesting to note that NBMI-3 at a higher film thickness, i.e., 7 mils, has a similar tensile strength or hardness, but is able to be stretched much further, to ca. 77%, before film rupture occurs. In considering results for these metal interlocks, it also was observed that aging of films for prolonged periods, as much as one year, tended to yield less elastic films for a given film thickness. This result logically would be expected, because as plasticizers become gradually depleted, the film would become more brittle.

Data from stress-relaxation tests is useful in predicting the reduction of stress in materials subjected to constant deformation for long times. Figure 2 shows stress-relaxation (decay) curves for selected films. These decay curves are obtained by stretching the films to a certain length. Then while maintaining this constant deformation, we then follow the gradual decrease in stress which is dependent on the film's elasticity. Figure 2 shows that even with a wide range of strain histories, all of thes tested films exhibit significant stress-relaxation.

Relaxation for various floor finish films, at a constant strain of 50% or less, and after 4 min has been found to be in the 63-80% range. Looking at duplicate measurements on a particular film, NBMI-5, the agreement in % relaxation for 50% strain at 4 min was 65.3 ± 1.5%.

To complete this preliminary investigation, we conducted tensile measurements on a particular film, NBMI-3, after scrubbing with detergent and following a scrub with an ammoniated wax stripper solution. The results are given in Table V. Here we show tensile data for the unwashed film or control compared to corresponding data for 200 cycles of scrubbing with detergent or stripper using a Gardner washability apparatus. The differences observed and the sensitivity of the measurements to these treatments is startling, although the number of cycles (200) would be very roughly equivalent to 10 scrubbings of an actual automatic machine in practical maintenance.

It is interesting to note that the 200 cycles of scrubbing with detergent (1/64) did not affect or reduce the hardness of the film from a maximum elongation of 77% to 4%. Thus, the film remained hard, but lost some elasticity. This result was not attributed to reduction of film thickness but rather maybe caused by a leaching of plasticizer components from the film.

Scrubbing with an ammoniated stripper had a substantial effect in reducing both tensile strength, by ca. 45%, and % elongation, down to a very low value of 1.2%. Thus, the ammoniated stripper yielded the combined result to softening the film and rendering it less elastic or less tough. Because the thicknesses of the film tested were all in the range of 5.5-7.0 mils, the reduction in tensile strength and elasticity is attributed not to film erosion, per se, but

TABLE IV

Tensile Data for Non-Buffable Metal Interlocks

Sample[a]	Yield strength (psi)	Tensile strength (psi)	Elongation (%)
NBMI-1 (3.1)	--	280	0
NBMI-2 (4.1)	--	210	0
NBMI-3 (4.2)	--	940	5.8 ± 1.0
NBMI-3 (7.0)	600	840	76.6 ± 9.2
NBMI-4 (6.8)[b]	--	510	2.4 ± 0.4
NBMI-5 (9.7)	--	860	70 ± 22
NBMI-5 (10.7)	430		
NBMI-6 (10.8)[b]	--	1420	4.4 ± 1.6

[a]NBMI = Non-buffable metal interlocks; ( ) = film thickness in mils.

[b]Films aged 1 year before measurement.

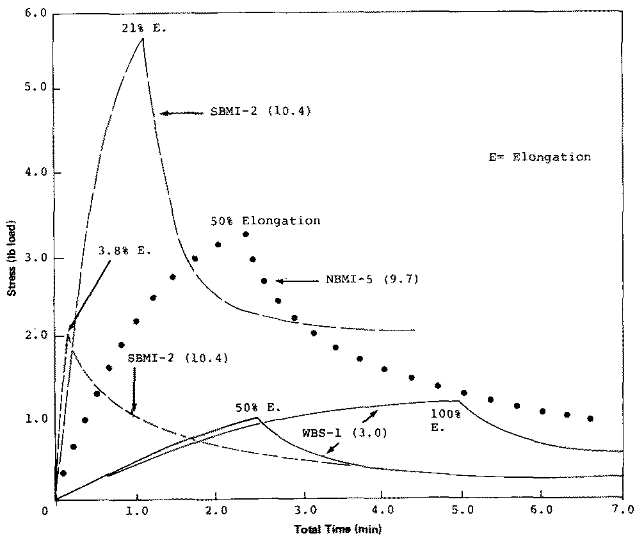

FIG. 2. Decay curves. NMBI = Non-buffable metal interlock; SBMI = semi-buffable metal interlock; WBS = water-based sealer; E = elongation.

TABLE V

Ammonia Detergent-Stripper Effects on Non-Buffable Metal Interlock - 3(7-0) Film

Sample	Tensile strength (psi)	Elongation (%)
Control (No scrub)	840	76.6 ± 9.2
Detergent (1/64) Scrub (200 cycles)	931	4.3 ± 3.0
Stripper (1/16) Scrub (200 cycles)	477	1.2 ± 0.5

primarily to specific chemical effects on the polymer film. In the case of the ammoniated stripper, this apparently would involve the rupture of zinc crosslinking bonds in the polymer.

ACKNOWLEDGMENTS

L. Zalusky supported this research, and T. Wiegind and J. Decker contributed to these experiments.

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[Received November 27, 1974]