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# Water Vapour Permeability and Wet Rub Fastness of Finished Leathers - Effect of Acrylic Polymer Dispersion Formulations

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**Abstract:** The water vapourpermeability and wet rub fastness of leathers finished with acrylic polymer based resin binder was carried out using the popular water vapour permeability cup method and the VESLIC test method respectively. Five formulations (125 g, 150 g, 175 g, 200 g and 250 g) of the binder which was the factor varied in this experiment, was prepared and then was applied on the originally retanned leathers from which five samples was generated. The effect of the finish formulations on water vapour permeability and wet rub fastness of the originally retanned leathers were investigated. Water vapour permeability test was also carried out for the unfinished (originally retanned) leathers as control samples. The results indicated that the water vapour permeability of the finished leather samples was significantly lower when compared to that of the unfinished (control) leather samples. However, for the finished leather samples, water vapour permeability increases as the quantity of the binder varied in this experiment was increased. The result of the VESLIC test indicated the resistance of the finished leather samples improves as the quantity of the binder varied in this experiment was increased. The overall results showed that the formulations containing the 200 g and 250 g of the acrylic polymer binder are good for leather finishing applications where suitable water vapour permeability and excellent rub fastness are both required.

**Keywords:** Water Vapour Permeability, Wet Rub Fastness, Finished Leathers, Acrylic Polymer Dispersion

## 1. Introduction

Polymer binders are the main components of aqueous finishing preparations. The three chemically different synthetic types of binders widely used in leather finishing include acrylates, butadiene, and urethanes. Acrylic polymers have found extensive use in leather finishing as a result of their basic properties such as softness, heat and light stability, and favourable economics [1]. Acrylic polymer emulsions have been widely used for leather coatings, with interest in polyurethane dispersions increasing because they are environmentally friendly material [2-4]. A blend of the two systems and synthesis of the polyurethane/polyacrylate (PUA) composite latex particles has also been reported [5]. These systems can be tailored to form a unique core shell and interpenetrating network structures, a technique which has been widely practiced in recent years [6-9].

The synthesis of acrylic polymer dispersions is obtained by free radical polymerization. A free radical polymerization has three principal steps which include: the initiation of the active monomer, propagation or growth of the active (or free radical) chain by sequential addition of monomers, and termination of the active chain to give the final polymer product. Acrylate based block copolymes have been synthesized by atom transfer radical polymerization (ATRP) process [10]. The polymers were multiblock copolymers consisting of poly(butyl acrylate) or poly(lauryl acrylate) soft blocks and hard blocks composed of poly (methymethacrylate), poly (isoborny acrylate), or poly (styrene) homo- or copolymers.

Water vapour permeability of finish on leather substrate controls the escape of moisture and is responsible for foot comfort when shod. It is one of the most precious physical properties of leathers, which may greatly affect the breathability and the comfortable feelings of leather goods [11]. The numerous capillaries among collagen fibres in leathers as well as lots of hydrophilic groups on the collagen chains might have endowed leathers with good water vapour permeability, compared with other synthetic clothing materials [12]. Different methods of measuring water vapour permeability of leathers have been reported by a couple of researchers [13-15]. Analysis of the results indicated that the thickness, density, water-absorbing ability, and aperture ratio of the samples are the main factors that may affect the water vapour permeability of leathers [15].

Also, finishing play an important role in affecting the water vapour permeability of leathers as reported by [16] Tang et al., 2002, who studied the water vapour permeability of unfinished leather, polyurethane finished leather, filmed leather and synthetic leather. Their reports showed that the water vapour permeability of unfinished leather is far better than the other three. It was also found that the water vapour pressure difference between the two sides of the sample and the transferring action of hydrophilic groups on collagen chains are two main factors affecting the water vapour permeability for unfinished leathers. In cases of finished leather, filmed leather and synthetic leather, however, the mechanism of water vapour permeability is only the transporting of water molecules through capillaries in leathers driven by the water vapour pressure difference between the two sides of the leather samples [16]. Traditional processes of tanning, retanning, and fatliquoring may greatly affect the water vapour permeability of leathers [17, 18]. Besides, the water vapour permeability of leathers may vary greatly with changing temperature and relative humidity of the environment when the experiment is conducted. Because of the complexity of leathers and the uncertainty of affecting factors on the water vapour permeability of leathers, it is difficult to study the water vapour permeability of leathers, and few studies are reported in this field [15].

The VESLIC type test adopted in this study, contain two independent factors that need to be considered. One is the ability to prevent discolouration or transfer of colour onto the cloth or felt pad, and the other is the ability of the finish to resist damage. Polymers that form a good film and are hydrophobic give good performance in preventing discolouration. However, when it comes to resisting finish damage, harder or high $T_g$ polymers perform better that soft polymers in acrylics and polyurethanes [1]. These factors are important in achieving a good rub resistance and were considered in this experiment.

Watervapour permeability and wet rub fastness of finished leathers are two opposing physical properties. Therefore, any attempt to improve on one could jeopardize the performance of the other. Hence the leather finisher would have to decide on the type of finish and formulation of the mix in order to strike a balance for optimal performance. And talking of choice, acrylics are used in top coats, mostly in admixture with urethanes, indicating an on-going interest for their further development as a versatile resin binder. There is a number of aqueous dispersed resin binders based on acrylics, polyurethanes, synthetic rubbers available commercially in the market. After selection of the proper binders the formulation of the finish is worked out according to requirements. This article presents results of the effect of acrylic based commercial resin binder on the water vapour permeability and wet rub fastness of finished leather.

## 2. Experimental

### 2.1. Material

Wet blue sheep skins, acrylic resin binder (Nycil, AE 558), wax (Lepton- Wax A, Basf), penetrating agent (EE 8044, Pixel Colour), liquid syntan (Syntan-SA, Smit Zoom), powdered syntan (syntan-SA, smit zoom) were used as supplied. Bagaruwa (vegetable tannin), fatliquor and sodium carbonate were obtained from the research and development unit of the Nigerian Institute of Leather and Science Technology, (NILEST), Zaria, Nigeria.

### 2.2. Sample Preparation

Five (5) pieces of the sheep skins in the blue state was weighed and then soaked in 200% water at 50°C for 15 minutes. The leather samples were then neutralized under this condition with 1% sodium carbonate ($NaHCO_3$) for 45 minutes and the resulting pH of the bath was determined at the end of the operation. The samples were then rinsed with 200% water at 50°C for 15 minutes. The leather samples were then retanned using the following retanning agents: liquid syntan (4%) for 20 minutes, powdered syntan (6%) for 10 minutes, and bagaruwa (6%) for 60 minutes in that order in 200% water at 60°C. Finally, 6% fatliquor was added with 80% water at 60°C temperature for 30 minutes. The leathers were then horsed up overnight, hanged to dry at room temperature for 45 minutes. The samples were then conditioned and hand staked before finishing. The leathers were cut into two groups of five leathers each where one group labeled A1 to A5 had the finish formulations (table 1) applied on them, while the other group labeled B1 to B5 was left unfinished.

***Table 1.*** *Typical finish formulation for leather.*

| Additives/Ingredients | Formulations | | | | |
|---|---|---|---|---|---|
| (g) | A1 | A2 | A3 | A4 | A5 |
| Acrylic Resin | 125 | 150 | 175 | 200 | 250 |
| Pigment | 6.25 | 6.25 | 6.25 | 6.25 | 6.25 |
| Water | 50 | 50 | 50 | 50 | 50 |
| Penetrator | 6.25 | 6.25 | 6.25 | 6.25 | 6.25 |
| Wax dispersions | 8.75 | 8.75 | 8.75 | 8.75 | 8.75 |

### 2.3. Water Vapour Permeability Measurement

The water vapour permeability cup method [13] was employed in this experiment. Circular shapes of the finished leathers were cut, weighed and then placed inside thermostated sample holders containing 20 $cm^3$ of water positioned in a water vapour permeabilimeter (Muver model 5011) for 1 hr. The test sample capsules together with the leathers were weighed again and the difference between the first and the second weighings was obtained. This was repeated also for the unfinished leather. Water vapour permeability is calculated as $Pwv\ (\frac{mg/cm^2}{hr}) = \frac{7460\ M}{d^2 t}$, where, M = mass gain between weighings in milligrams; $d^2$ = area of diameter of sample in $cm^2$, t = time in minutes between the first and second weighing.

### 2.4. Wet Rub Fastness Measurement

The SATRA machine (VESLIC) test method was used to measure the wet rub fastness of the finished leathers [1]. Rectangular piece of the finished leather samples was cut, and for each track 20 mm wide. The side the leather to be tested was rubbed along the given track with pieces of wool felt under pressure in forward and backward motions. Each sample was examined for discolouration or transfer of colour to the felt, and/or for finish damage after 32, 64, 128, 256, 512 and 1024 revolutions. After every examination, scores ranging from '0' (poor resistance) to '5' (excellent wet rub resistance) was assigned when compared with a standard grey scale. Score of '0' was assigned for damaged finish.

## 3. Results and Discussion

### 3.1. Water Vapour Permeability

The values of the water vapour permeability measurement for both finished and the unfinished leathers are shown in table 2 (figure 1). Results indicate that the water vapour permeability of the unfinished leathers is better than that of the acrylic finished leathers which is in order according to literature [16].

***Table 2.*** *Effect of acrylic dispersion on water vapour permeability of leather.*

| Sample (finished leather) | Resin (g) | Mean mass (g) | Mean Wvp ($mg/cm^2/hr$) | WVP per unit thickness ($mg/cm^2/hr/mm$) |
|---|---|---|---|---|
| A1 | 125 | 0.18 | 18.71 | 11.62 |
| A2 | 150 | 0.28 | 29.10 | 23.28 |
| A3 | 175 | 0.25 | 25.98 | 22.39 |
| A4 | 200 | 0.62 | 64.45 | 43.54 |
| A5 | 250 | 1.10 | 114.34 | 47.84 |
| (unfinished) | | | | |
| B1 | - | 3.20 | 332.6 | 220.26 |
| B2 | - | 4.08 | 424.1 | 350.49 |
| B3 | - | 3.18 | 330.54 | 277.76 |
| B4 | - | 4.00 | 415.78 | 349.39 |
| B5 | - | 3.25 | 337.82 | 268.11 |

Figure 1 shows a plot of the water vapour permeability of the unfinished leather samples and the corresponding finished leather samples against the resin finish formulations. The results obtained showed that the water vapour permeability of the unfinished leather is significantly higher than that of the finished leather samples. It has been reported by [16] Tang et al., 2002 that finishing plays an important role in affecting the water vapour permeability of leathers. They [16] showed that the water vapour permeability of unfinished leather was far better than polyurethane finished leather, filmed leather and synthetic leather. For the finished leather samples the water vapour permeability increases from A1 to A5 as the resin offer (g) present in the formulations is increased. The values obtained are typical for uncrosslinked acrylates when used as basecoats. When crosslinked and used as topcoats on the other hand, the water vapour permeability could be as low as 0.9 $mg/cm^2/hr$ [19]. However, the unfinished leather samples give values that are consistent for unfinished shoe upper and lining leathers [20]. By scientific fitting, the calculated water vapour permeability of the leather samples may serve as a reference in leather making and leather goods making to get leather goods with good water vapour permeability.

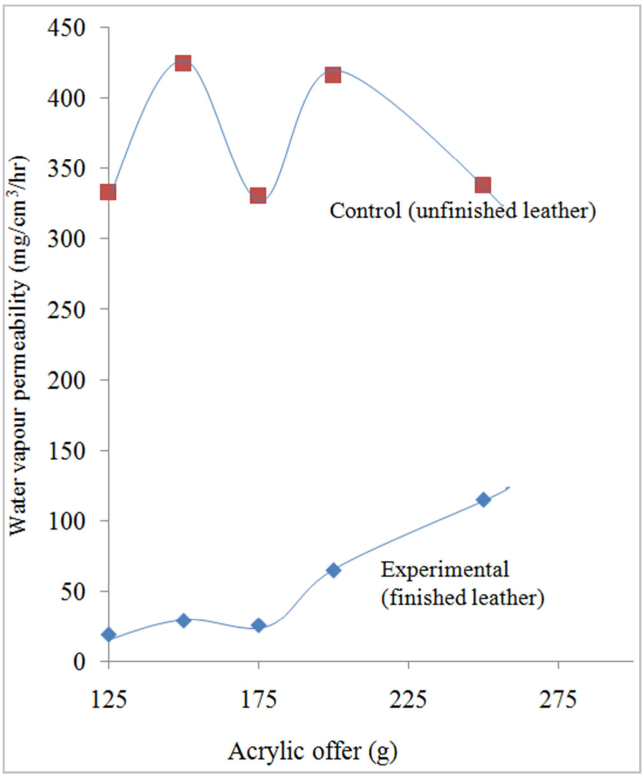


***Fig. 1.*** *Water vapour permeability of finished (experimental) and unfinished (control) leathers.*

Keyong et al., [15] has reported that among the four major contributing factors of water vapour permeability of leathers studied, that water-absorbing capacity affects the water vapour permeability of leathers the mostly, followed by the thickness of the samples. The contributions to the water vapour permeability from the real density and aperture ratio are really less in comparative terms. Therefore, in order to improve the water vapour permeability of leathers, the most efficient way is trying to increase the water-absorbing capacity of leathers. This is demonstrated by the results obtained for the finished leathers (see figure 1). The hydrophilic nature of the binder is able to contribute to the water absorbing capacity of the leather samples; hence increasing the resin offer in the formulation increases the water vapour permeability of the leather samples. It is therefore better to choose leather chemicals with polar group to increase the water affinity of the collagen fibres in leather making. The results can also be guidance in choosing leather materials (such as shoe or garment) with good water vapour permeability. The second contributing factor to the water vapour permeability of leathers is the thickness of the leather samples [15]. This is shown by the results obtained for the unfinished leather samples where the curve is m-shaped. Thin leathers usually have advantages of providing high water vapour permeability.

### 3.2. Wet Rub Fastness

The values of the effect of the finish formulations on the wet rub fastness of the finished leathers are shown in table 3.

***Table 3.*** *Effect of finish formulations on wet rub fastness of the finished leathers.*

| Sample | Acrylic Offer (g) | 32 | 64 | 128 | 256 | 512 | >512<1024 |
|---|---|---|---|---|---|---|---|
| A1 | 125 | 2 | 0 | - | - | - | - |
| A2 | 150 | 3 | ½ or 2 | 3 | 1/2 | 0 | - |
| A3 | 175 | 3 | 3 | 3 | 0 | - | - |
| A4 | 200 | 4 or 4/5 | 4 | 4 | 3 | 0 | - |
| A5 | 250 | 4 or 4/5 | 3 or 3/4 | 3 or 3/4 | 2 | 1 or 1/2 | 0 |

The results indicate that increase in the resin offer improves the resistance of the finished leathers to wet rub action. At low resin offer (125g) for sample A1, the score after 32 rubs (revolution) is rated ‘2’ (poor) when compared to a standard grey scale, and above 32 revolutions the finish is damaged. The leather samples A4 and A5 at high resin offer (200 and 250 g respectively) give very good resistanceto wet rub action with scores of 4 and 3 or ¾ respectively at 128 rubs.

The results obtained are based on their performance in preventing felt discolouration and finish damage when examined. Alexander and Chol-Yoo, 1997 [21] had reported that polymers that form good film and are hydrophobic give good performance in discolouration, but when it comes to resisting finish damage, harder or higher $T_g$ polymers perform better than soft polymers in acrylic and polyurethanes.

## 4. Conclusion

The main objective of this study is to prepare a leather finishing formulation based on acrylic resin binder that has good water vapour permeability and adequate wet rub fastness at the same time. The water vapour permeability and wet rub fastness of the finished leathers are enhanced as the quantity of the resin binder in the finish formulations is increased. The water vapour permeability of the originally retanned (unfinished) leathers is also affected when finishing is applied. This indicates that finishing plays an important role in affecting the water vapour permeability and wet rub fastness of leathers.

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