The effect of PVC's resin K-value on the mechanical properties of the artificial leather

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ABSTRACT

Artificial leather offer wide variety of application thus the demand is increased over time. The variation of the product needs different properties that can be achieved using resin with suitable k-value. This works reports the influence of the resin k-value on the mechanical properties of the artificial leather. The combination of various resin with different k-value (66, 68, 72, 74, and 76) is used and the tensile strength and elongation at break of the product were evaluated. The results show that blending the PVC resin with different k-value can be used to adjust the easier processing of the lower k-value and better mechanical properties of the higher k-value. Larger k-value differences between two resin make more difficulties of resin blending thus give more defect. For the blending of two resin, the tensile strength and elongation value would be between both of the resin initial properties. The final properties will be closer to the resin with a higher percentage in the resin blending.

Keywords: artificial leather, elongation, K-value, tensile.

INTRODUCTION

Nowadays, artificial leather has become important materials that widely used to substitute genuine leather in the automotive interior, clothing, footwear, sofa fabric, decoration, and other application (Pimapunsri *et al.*, 2017). Comparing to genuine leather, these materials have stable production and lower production price, thus have obtained a good market (Gurera & Bhushan, 2018). Artificial leather usually consists of top coat, middle coat, base coat, and backing cloth.

Spreading is most widely used in the manufacturing of artificial leather. This method consists of coating plastisol on a moving fabric using a roller or a knife (Pimapunsri *et al.*, 2017; Rybachuk *et al.*, 2007). The processing through plastisol is one of the most efficient procedures since its ease processing and low equipment costs (Rybachuk *et al.*, 2007; Zadhoush *et al.*, 2004). Plastisol is prepared by mixing the components (polyvinyl chloride resin, fillers, pigments, plasticizers, adhesives, and other additives) in

certain sequences.

The processing using plastisol is close related to a fluid system. A fluid can be anything from substance of water-like consistency to high viscosity, plastic-like mass. There are many parameters that can influence the rheological behavior, such as processing conditions, temperature, plastisol contents, K-value and plastisol type (Zadhoush *et al.*, 2004). Flow parameter and paste rheology are important parameters during coating processing and influences the properties of the final product (Du *et al.*, 2012).

The rheological, mechanical and thermal properties of the polyvinyl chloride (PVC) are dependent on the K-value and the various additives used in the formulation (Marceneiro *et al.*, 2018; Sholeh & Rochani, 2018). K-value or viscosity number is an indicator of their molecular weight and degree of polymerization for the PVC used (Marceneiro *et al.*, 2018). In the making of artificial leather, emulsion PVC resin is used. When E-PVC resins are mixed with a liquid plasticizer, a paste

(plastisol) is produced due to the surfactant layer around the grain surface preventing plasticizer adsorption at room temperature. Consequently, these resins are called paste resins which are used in a wide range of specialty applications such as coating, dipping or spreading. Resins are available commercially for differing molecular weight, porosity, viscosity, speed of gelation, clarity and gloss level. For example, K-values range between 64 to 80 are suitable for automotive interior materials corresponding to medium to high molecular weight (Marceneiro *et al.*, 2018).

Fikentscher K-value is the molecular weight distribution of PVC that estimated from the dilute solution viscosity measurements (Coelho *et al.*, 2006; Mehdipour *et al.*, 2017). The K-value can be calculated from equation 1.

$$\ln\left(\frac{\eta}{\eta_0}\right) = \frac{cK}{1000} \left(\frac{75K}{1.5cK+1000} + 1 \right) \dots\dots(1)$$

Where η , η_0 , and c are the solvent viscosity, PVC solution viscosity, and concentration, respectively.

Sometimes, resins with optimal K-value for specific processing needs are not available commercially. Therefore, the blending of PVC resins with different K-values can be used to adjusting the melt rheology of a compound to processing machinery. Another advantages of the blending are to combine the better fusion properties of the lower Molecular Weight (MW) component with the better mechanical properties of the higher MW materials (Pepperl, 2000).

There is some research that already discussed on artificial leather such as on surface modification (Sakmat *et al.*, 2015), processing (Roh *et al.*, 2014), thermal and mechanical properties modification (Ma *et al.*, 2019; Maia *et al.*, 2017; Pimapunsri *et al.*, 2017; Yang *et al.*, 2017). And some paper has also studied the effect of k-value into the rheological behavior of plastisol (Zadhoush *et al.*,

Table 1. Plastisol Formulation.

Material	phr
resin	100
DOP	60
CP	20
foam activator	2.5
foaming agents	2.75
calcium carbonate	60
pigment	4% of the total formulation

2004) and molecular weight distribution (Pepperl, 2000). But there is limited discussion about the correlation between PVC's k-value with artificial leather properties. In this paper, the influence of PVC resin blending using different k-value on the mechanical properties of the artificial leather were studied.

MATERIALS AND METHOD

Materials

The materials used in this research are polyvinyl chloride emulsion (PVC-E) with k-value of 66, 68, 72, 74 and 76; plasticizer diisooctylphthalate (DOP), chlorinated paraffin (CP); filler (calcium carbonate), foam activator, foaming agent, pigment and backing cloth.

Formulation

The formulation used to make the single-coating artificial leather is shown in table 1. The variable used in this works is the PVC resin blending with different k-value as shown in table 2 below.

Procedure

Skin plastisol was made using DOP, CP, foaming agent, and blowing agent that mixed for 1 minute at speed 30 rpm. Then, filler was added and mixed for 2 minutes at speed 30 rpm. Finally, resin was added using formulation in table 2 and mixed for 5 minutes at 30 rpm. The skin plastisol

Table 2. PVC Resin variables based on k-value.

Resin	k-value	Sample*							
		D5A5	D5B5	D5C5	D10	D5E5	D4B6	D3B7	D2B8
A	66	50							
B	68		50				60	70	80
C	72			50					
D	74	50	50	50	100	50	40	30	20
E	76					50			

*for example, D5A5 means the sample using a blend of resin D 50 phr and A 50 phr

ready for coating. Adhesive plastisol was made using DOP, TXIB, DP 728 and filler that mixed for 1 minute at 30 rpm. Then, resin added and mixed for 5 minutes at 30 rpm.

The released paper is heated at 170-180°C for 20 seconds, then the skin plastisol was coated and heated at 190-200°C for 1 minute. The next step is coating using adhesive plastisol and laminating using backing cloth, then heated at 190-200°C for 1 minute. Finally cooling the coating at room temperature for 3 minutes.

The tensile strength and elongation test was using Universal Tensile Machine (UTM) Gester GT-K02. The specimen is prepared carefully by cutting the PVC sheet in rectangular shape, which measured 3 cm in width and 15 cm in length. Scanning Electron Microscope (SEM) miniSEM is used to study the surface morphology of the sample. Samples were sputtered using gold coating before SEM studies.

RESULTS AND DISCUSSION

The flow character of plastisols may depend on the composition, preparation conditions and shear

rate in the course of their processing (Rybachuk *et al.*, 2007). One of the important factors in artificial leather processing is the plastisol viscosity, thus blending two resin with different k-value will affect the process. In polyvinyl chloride processing, some micro defect would exist such as inclusions, microcrack, microporous, etc (Luo *et al.*, 2012; Yang *et al.*, 2008). Based on the organoleptic test using lamp behind the artificial leather sheet, there are microporous defect that occurs in some of the sample. This defect is also confirmed using SEM analysis as shown in figure 1.

The microporous defect may occur because of the rheological behavior of the paste. The nature of the polymer can have a great influence on the rheological behavior that plays an important role in the coating processes. Higher k-value means higher viscosity, higher molecular weight but also better thermal stability (Coelho *et al.*, 2006). In many instances, its necessary to increased or decreased the viscosity of the coating paste (Zadhoush *et al.*, 2004). And this can be done by selecting the correct choice of PVC k-value. Unfortunately, not all the optimum k-value for processing are

Figure 1. Surface morphology of the sample (a) without lamp test (b) with lamp test and Scanning Electron Micrographs 30x of the sample with (a) few (none of big dots) and (d) many microporous defects (more than 4 big dots).

Table 3. Mechanical test result for the effect of resins k-value blending.

Sample	Microporous defect	Tensile Strength, N/mm ²		Elongation, %	
		Vertical	Horizontal	Vertical	Horizontal
D5A5	none	3.95	1.28	43.61	181.98
D5B5	many	3.28	1.81	41.97	178.44
D5C5	few	3.69	1.51	44.21	197.70
D10	many	4.88	1.35	48.36	173.61
D5E5	few	3.92	1.60	43.65	184.33

available commercially, thus blending two resin may solve the problems.

Effect of Resins K-value on the Mechanical Properties of the Artificial Leather

To studying the mechanical properties of the products, two resin with different k-value are used to make the plastisol. Blending processes allows the combination of the useful and desired properties from different polymers (Du *et al.*, 2012). The mechanical properties of a blend depend on many factors including initial properties of blends material, composition, interfacial interaction and phase morphology (Mehdipour *et al.*, 2017). In this paper, we focused on the variation of blends constituent and composition.

Effect of Resins K-value Blending

According to Pepperl (2000), the blending of polymers with k-values differing by less than 10 units will not affect the MW significantly. At the opposite, larger k-value differences between the resin may result in difficulties at homogenizing the plastisol. Furthermore, incompatible polymer blends generally showed lower mechanical properties (Mehdipour *et al.*, 2017). Therefore, in this works, the resin used in the blending process is

from neighboring k-value (the biggest differences is 10 units) in order to adjust the mean k-value of the compound to processing equipments. The resulted mechanical test is shown in table 3 and figure 2.

The blending of 50 phr resin A and 50 phr resin D (sample D5A5) gives none microporous defect since lower viscosity will help the easier spreading of plastisol when processed at the machinery. The defect is contributed to the rejection of the final product, thus should be avoided. This can be the result of inhomogeneities from the bad-fusing resin particles of the high MW by the low shear forces present in the low MW resin (Pepperl, 2000). From figure 2(a) and 2(b), the highest tensile strength (4.88 N/mm²) and longest elongation (48.36 %) achieved by sample D10 (resin D 100 phr) for vertical test but gives many microporous defects. Pure resin D, without blending with other resin give better mechanical properties since there are difficulties in interaction between non-similar long chains in blended polymer system (Mehdipour *et al.*, 2017). Comparing to pure resin, the blending has slightly lower elongation (2.26 – 5.07%), probably because of difficulties in obtained homogenous plastisol when blending two resin with different

Figure 2. Effect of resins k-value blending (a) tensile strength (b) elongation.

Table 4. Mechanical test result for the effect of resins k-value blending.

Sample	Microporous defect	Tensile Strength, N/mm ²		Elongation, %	
		Vertical	Horizontal	Vertical	Horizontal
D10	many	4.88	1.35	48.36	173.61
D5B5	many	3.28	1.81	41.97	178.44
D4B6	few	2.66	1.48	42.82	170.6
D3B7	none	2.62	1.63	39.17	170.38
D2B8	none	2.93	1.48	43.61	166.04

molecular weight. Some paper also shows similar negatives effect of blending inhomogeneity to the tensile strength and elongation (Mehdipour *et al.*, 2017; Selvaraj *et al.*, 2015). Therefore, there is should a compromise between the defect and mechanical properties that still suited the product requirements. The table 3 and figure 2 shows that the best compromise is sample D5A5 that gives none defect with tensile strength value 3.95/1.28 N/mm² (vertical/horizontal) and elongation 43.61/181.89 % (vertical/horizontal).

Effect of Resin Percentage

In this variation, two resin with different k-value (resin B and D) are blended together using a certain combination of phr. For studies of resin percentage effect, the resin D with k-value 74 is chosen because it has good tensile strength and elongation value for common artificial leather article. Whereas resin B has lower k-value but the differences with resin D is in average number (6) comparing to the other resin. The result of the mechanical test are shown in table 4 and figure 3.

As expected, for a combination of two resins, the mechanical properties of the combined resin will be between both of the resin. Since resin D have higher k-value, thus higher phr of this resin

will give product with higher tensile strength and elongation but have higher tendency to make defect. These phenomena can be explained that in general longer polymer chains have less mobility (Mehdipour *et al.*, 2017). On the opposite, a higher proportion of resin B with lower k-value makes it easier to spreading and gives homogenous plastisol that have a lower probability to produce defect but also have lower mechanical properties. In this study, table 3 and 4 shows that the presence of micropores does not have a direct correlation with the mechanical properties, but influence the esthetics value of the product. Some work reported a similar conclusion (Mehdipour *et al.*, 2017), but other papers reported that the internal defect (such as micropores) would make the product damaged, fracture and failure (Luo *et al.*, 2012; Yang *et al.*, 2008). As mentioned above, the combination of two resin with different k-value is effective to choose the optimal product properties if the appropriate resin k-value is not available in the market. Each application produces a different shear to the coating paste at various machines; therefore, coating pastes need to have specific rheological properties to perform well (Du *et al.*, 2012; Zadhoush *et al.*, 2004).

(a)

(b)

Figure 3. Effect of resins formulation (a) tensile strength (b) elongation.

CONCLUSION

Blending PVC resin with different k-value can be used to get the favorable properties of the product by balancing the easier processes of the lower k-value resins and better mechanical properties of the higher k-value. The properties of the product are dependent on the formulation, that the final properties will appear closer to the resin with a higher percentage. Sample D5A5 that consist of 50 phr resin D (k-value 74) and 50 phr resin A (k-value 66) considered good compromise between relatively good mechanical properties and esthetic value since it gives none microporous defect with tensile strength value of 3.95 N/mm² and elongation 43.61%.

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