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Replacement of Fischer-Tropsch Waxes with Epolene® N-type Polymers in Hot Melt Adhesive Applications

INTRODUCTION

The adhesive industry continues to experience raw material shortages. Adhesive manufacturers are concerned about the current global shortage of Fischer-Tropsch waxes (F-T waxes). This shortage has been especially challenging for adhesive manufacturers of EVA based hot melt packaging adhesives. As F-T waxes have been placed on allocation, hot melt adhesive manufacturers and end users have found it necessary to find alternative adhesive formulations with reduced F-T wax content.

Westlake Chemical Corporation has evaluated hot melt adhesive formulations with reduced levels of F-T waxes. These adhesive formulations are based on either ***full*** or ***partial*** substitution of F-T waxes. The adhesive formulations presented are intended to be starting point formulations and are not optimized.

Each of these approaches requires the use of Epolene N-type Polymers from Westlake Chemical Corporation. The following information presents test data generated to illustrate the use of these products in an HMA formulation. The Westlake Chemical Corporation products highlighted in this work include:

- ***Epolene*® N-14 Polyethylene -** A nonemulsifiable, medium density, relatively low molecular weight polyethylene homopolymer. Due to its relatively low viscosity, *Epolene* N-14 can be used to modify flow properties and set speed in hot melt adhesives.
- ***Epolene*® N-21 Polyethylene -** A nonemulsifiable, higher density polyethylene wax. Because of its relatively high softening point and relatively low viscosity, *Epolene* N-21 is used as an additive to adjust set speed in hot melt adhesives.

DATA

Table 1: Typical Physical Properties of *Epolene* Polymers

Product Name	*Epolene* N-14	*Epolene* N-21	Typical Fischer-Tropsch
Ring & ball softening point (°C)	108	119	110
Color, Gardner	1	1	1
Penetration hardness (dmm)	3	<1	<1
Density @ 25°C (g/cm^3)	0.920	0.950	0.947
Viscosity @ 125°C (cPs)	150	600	20
Viscosity @ 150°C (cPs)	80	350	18
DSC data (°C)			
Tm (Melting temperature)	104	117	104,80[a]
Tc (Crystallization temperature)	92	105	94,73[a]
Congealing point (°C)	97	109	98
Heat of fusion (J/g)	119	142	180
Crystallinity (%)	41	56	71

[a]*Doublet peak*

Table 2: Molecular Weight Distribution of *Epolene* Polymers

Product Name	*Epolene* N-14	*Epolene* N-21	Typical Fischer-Tropsch
Mz (g/moL)	7,000	12,000	1,160
Mw (g/moL)	3,700	6,400	900
Mn (g/moL)	1,500	2,400	730
Mw/Mn (g/moL)	2.35	2.32	1.22

Table 3: Examples of HMA Formulations with Full and Partial Substitution of Fischer-Tropsch Wax

Component, Weight %	Full *Epolene* N-14	Full *Epolene* N-21	Partial *Epolene* N-14	Partial *Epolene* N-21	Typical Fischer-Tropsch
EVA polymer (28%VA, MI = 150)	30.0	30.0	30.0	30.0	30.0
Permalyn 3100 synthetic resin	34.5	34.5	34.5	34.5	34.5
Parrafin wax (60°C m.p.)	20.0	20.0	20.0	20.0	20.0
Epolene N-14 wax	**15.0**	**---**	**7.5**	**---**	**---**
Epolene N-21 wax	**---**	**15.0**	**---**	**7.5**	**---**
Typical Fischer-Tropsch Wax (Physical properties in Table 1)	**---**	**---**	**7.5**	**7.5**	**15.0**
Antioxidant	0.5	0.5	0.5	0.5	0.5
Total adhesive	100.0	100.0	100.0	100.0	100.0

Table 4: Adhesive Properties of HMA Formulations with Reduced Fischer-Tropsch Wax Content

Test Results	Full *Epolene* N-14	Full *Epolene* N-21	Partial *Epolene* N-14	Partial *Epolene* N-21	Typical Fischer-Tropsch
PAFT[a] (°C) Standard deviation (°C)	52.5 2.3	53.5 3.1	50.8 3.3	52.7 3.0	51.9 2.0
SAFT[b] (°C) Standard deviation (°C)	64.6 3.7	63.6 2.3	68.7 2.7	64.9 3.1	66.7 4.3
Low temperature fiber tear[c] (°C)	<-15	<-15	<-15	<-15	<-15
Open time[d] @ 177°C (sec)	18	19	19	19	13
Set time[d] @ 177°C (sec)	13	14	14	14	12
Brookfield viscosity @ 149°C (cPs)	1,400	1,972	1,110	1,325	930
Brookfield viscosity @ 177°C (cPs)	685	922	562	562	447
DSC data (°C)					
Tm (Melting temperature)	97	112	102	111	101
Tc (Crystallization temperature)	62	64	62	63	61

[a]*PAFT (peel adhesion failure temperature) was determined on 40 lb virgin Kraft paper. ASTM D-4498 was followed.*
[b]*SAFT (shear adhesion failure temperature) was determined on 40 lb virgin Kraft paper. ASTM D-4498 was followed.*
[c]*Low temperature fiber tear was determined on recycled corrugated.*
[d]*Open time and set time were determined using an Olinger Bond Tester.*

DMA Profiles for Adhesives with Reduced Fischer-Tropsch Wax Content

Figure 1: Full Substitution

Figure 2: Partial Substitution

Based on the data shown in Table 4, results suggest that ***full*** or ***partial*** replacement of a Fischer-Tropsch wax with *Epolene* N-14 or *Epolene* N-21 in the proposed EVA adhesive formulation results in similar adhesion and cohesion as evidenced by PAFT, SAFT and low temperature fiber tear results.

As illustrated in Figures 1 and 2, the set time as determined by DMA (dynamic mechanical analysis) correlates very well with set time determined by the use of an Olinger Bond Tester (Table 4). The Fischer-Tropsch wax has the shortest set time, followed by *Epolene* N-14 *and* then *Epolene* N-21. It should be noted that the use of *Epolene* Polymers results in higher formulated viscosity and longer open time. It may be possible to fine tune these parameters by increasing the paraffin wax or tackifier level or by adjusting the adhesive application temperature.

Conclusion

These concepts are intended solely as initial work to evaluate HMAs with properties similar to those of a control formula using 15 wt. % Fischer-Tropsch wax. Based on these concepts, it may be possible to reduce F-T wax content. Full *or* partial substitution of an F-T wax with *Epolene* Polymers results in similar adhesion and cohesion as evidenced by PAFT, SAFT and low temperature fiber tear. In general, the use of *Epolene* Polymers results in higher formulated viscosity and longer open time versus Fischer-Tropsch waxes.

Based on R&BSP, congealing point and viscosity, *Epolene* N-14 *is* the best functional equivalent. *Epolene* N-21 is the best functional equivalent based on density, hardness and heat of fusion.

The formulator should recognize that these are starting point formulations <u>ONLY</u> and they must be further optimized by adjusting the proportions of the adhesive components.