Key Polyurethane Attributes & Their Effect on Electro Photographic Roller Life & Performance

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Abstract

This paper will cover in details, 1) What types of polyurethane should be considered for Charge roller, Transfer roller, Developer roller & Paper transport feed roller application. 2) Important polyurethane properties consideration based on roller application. 3) Effects of PU properties & its impact on performance. 4) Effect of electrical properties on different PU structure – impact on roller life & performance.

Introduction

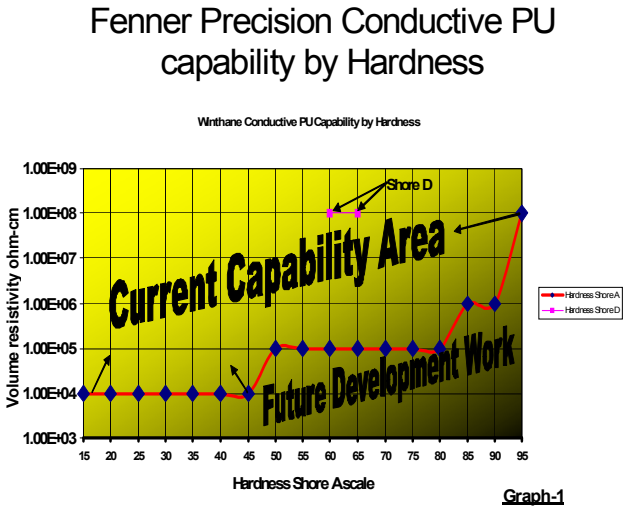
Quite often for printer OEM it becomes difficult to define the right PU material for rollers for a given roller function. Most often they totally rely on manufacturer's expertise. This presentation will highlight some of the known important PU properties, which must be considered when asking the roller manufacturer for making prototype rollers for them. Defining properties ahead of time helps OEM to know upfront what they are expecting from a manufacturer & also helps printer OEM to filter out supplier's capabilities.

We will discuss types of polyurethane and its advantages & disadvantages, compression modulus stability @ various temp, compression set, solvent resistant, surface morphology, humidity impact on electrical properties, surface coating, abrasion resistance…etc.

Experiment

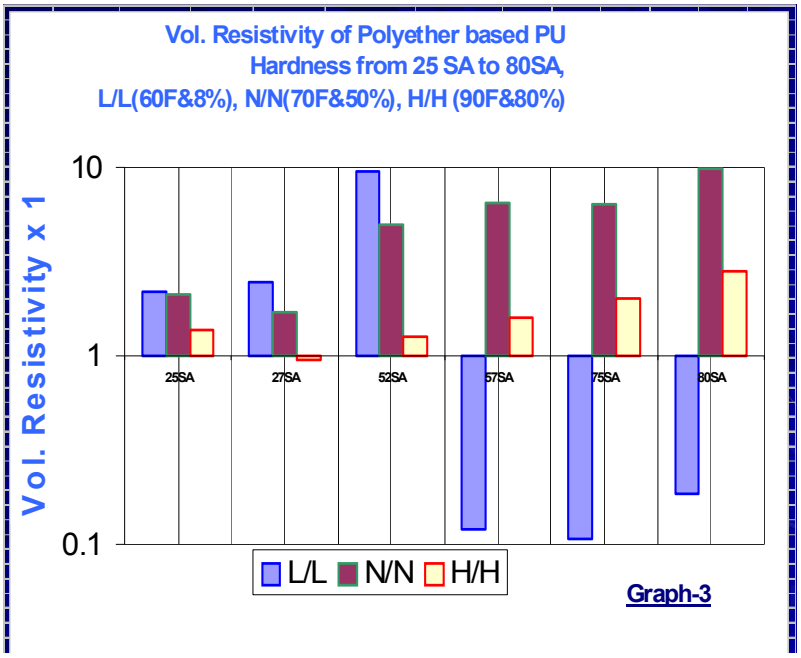
MDI ester, MDI ether, TDI ester & TDI ether based Polyurethane chemistry was used to make test sheets, test slab & buttons to test required properties. Also, mini rollers at different PU wall thickness were made to measure electrical properties @ different environmental conditions—@ L/L (60F & 8% Rh), H/H (90F & 80%Rh) and N/N (70F & 50%Rh). All physical & mechanical test specimens & test parameters were according to ASTM. Volume Resistivity was measured on 0.25" thick Pu specimen using Kiethly PicoAmpmeter by applying DC voltage of 100V to 500V. All samples were kept in the above conditions in an environmental chamber for 1week before VR measurement.

Data & discussion

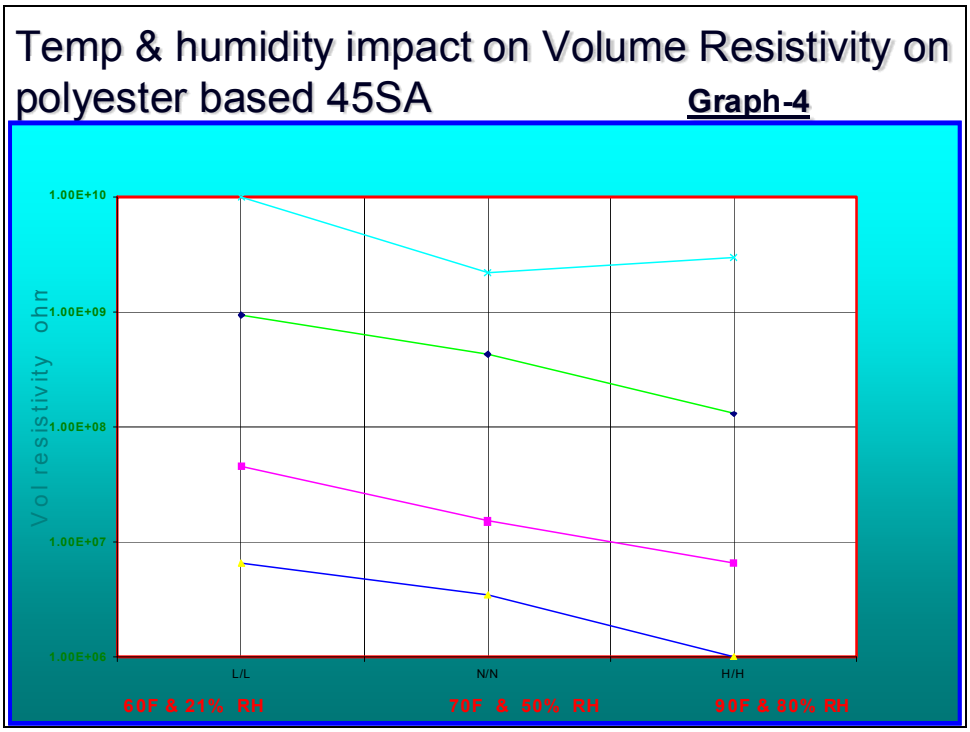


Graph #1: In graph, the "current capability area" indicates that vol Resistivity from 1E4 ohm-cm to 1E9 ohm-cm for Pu hardness from 15SA to 45SA is achievable & so on. It also indicates as hardness increases vol Resistivity increases. Vol resistivty also depends upon PU structure, which can be either linear, cross linked, ether or ester based PU.

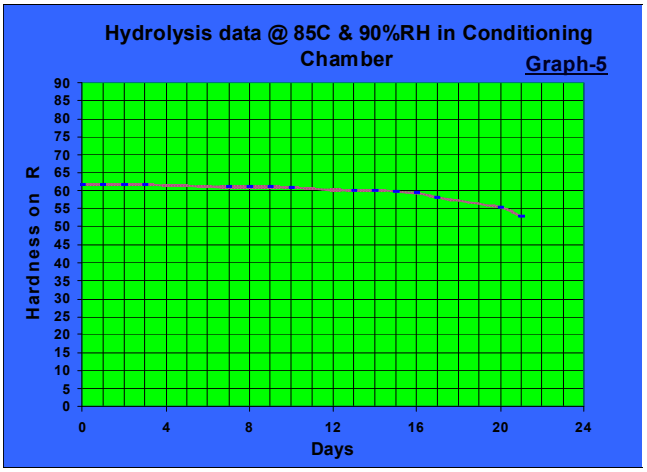
Graph#2: Shows surface Topography of "As cast" roller. A very smooth surface of Ra & Rz is achievable.



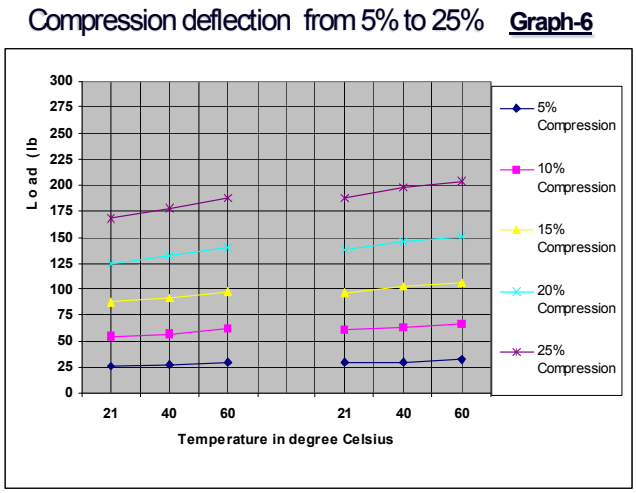
Graph#3: Shows Volume resistivity of Polyether based PU, for hardness ranging from 25SA to 80SA. The target VR for the different hardness of each slab was 5E6 (+/-2E6) ohm-cm. VR was also compared @ L/L (60F & 8% Rh), and H/H (90F & 80%Rh) condition relative to N/N (70F & 50%Rh). For hardness higher than 70SA, the volume resistivty has changed almost half the order of magnitude from L/L to H/H compared to the N/N condition.



Graph#4: Shows "Temperature & humidity effects on Volume resistivty" on the Polyester based PU. Four different slabs were made whose resistivity ranged from 5E6 to 5E9 ohm-cm for a fixed hardness of 45Sa. VR was measured for each category @ L/L, N/N & H/H. As it can be seen, the variations in vol resistivity from L/L to H/H compared to N/N are minimal . No difference in VR was observed when the slab thickness was changed from 0.07" to 0.5".



Graph#5: Shows Hydrolytic stability of 60 Sa Polyester based polyurethane. Pu was subjected to 85C & 90% RH in the conditioning chamber for 3 weeks. No sign of melting or any degradation was observed. In general, Polyester Pu tends to melt @ the above conditions for more than one week

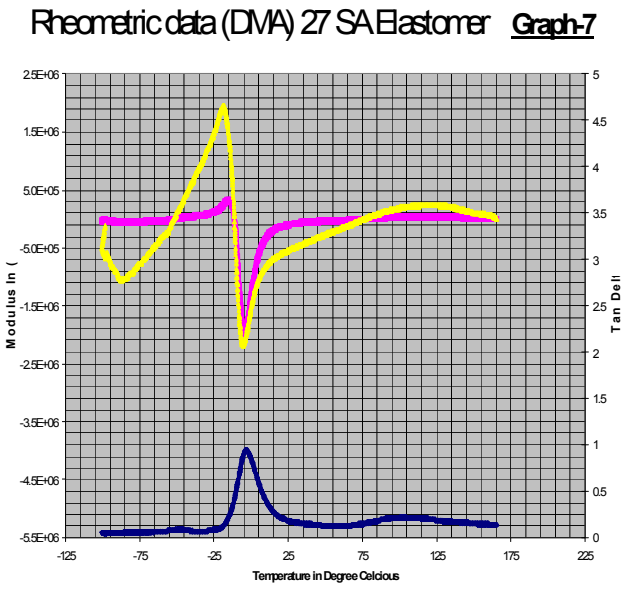


Graph#6: Shows compression modulus stability @ RT, 40C & 60C on 60SA PU. Half inch thick test buttons were stabilized in an oven for 4hr @ 40C & 60C before the testing. Buttons were compressed using the Instron machine. Load was recorded for 5% to 25% compression. As per the data, Compression load didn't drop @ 40C and 60C compared to RT.

Physical & Mechanical Properties of Transport roller, Table-1

Company		ASTM	Fenner precision
Hardness Slab	SA	D2240	55
Tensile Modulus @ 100%	Psi	D412	231
Mod@ 200%	Psi	D412	348
Mod@ 300%	Psi	D412	486
Tensile strength @ Break	Psi	D412	4086
% Elongation @ Break	%	D412	478
Die "C" Tear	Pli	D624	213
Bashore Resiliancy	%	D2632	40
Compression set method B	%	D395-B	<1%
Tabor Abrasion H18 wheel, 1000Cycle, 1000g load each arm.	mg loss	D4060	17 to 30 mg
Load/Deflection data.@ 5% Comp.on 0.5" button @ RT.	load	D575	26.29
COF		FP test method	2.05
TONER Resistance		Std	Pass
Oil swell		Std	No swell
Vol. Resistivity Ohm-cm	ohm-cm		2.00E+09
Hydrolysis Resistance @ 85C/95% RH for 21 days			Pass

Table#1: Physical & mechanical properties of 60SA polyester based PU. The unique properties of this formulation are: compression set is less than 1%, low Tabor abrasion, high Coefficient of friction on recycle paper, resistance to solvent & hydrolysis resistance



Graph#7: *Rheometric data (DMA) on 27SA soft Polyurethane elastomer. This formulated elastomer has good thermal stability & good rebound properties.*

Generally, two types of PU are used as a roller in printing industries, Polyether or Polyester based PU.

Advantage of Polyether based PU,

PU structure could be linear or cross linked, has Good Resistance to hydrolysis, and the hardness can be from 15 SA to 65D w/o the use of a plasticizer.

Disadvantage of Polyether based PU,

The Elastomer: easily swells in solvents, it tends to wear out (high abrasion), high variations in electrical properties @ LL, HH relative to NN condition, Low dielectric strength, Compression modulus stability @ high temp is poor, Compression set is high.

Advantage of Polyester based PU,

The PU structure can be linear or cross linked, Resistant to solvents, low abrasion, low variation in electrical properties @ LL, HH relative to NN condition, compression modulus stability @ high temp is good, high dielectric strength, Compression set is low.

Disadvantage of Polyester based PU,

Poor resistance to hydrolysis, difficult to make soft elastomer w/o use of plasticizer, hygroscopic in nature. (High level of formulation expertise is required to formulate soft polyester Pu elastomer w/o use of plasticizer & meet all required properties).

Important PU properties for most roller applications

Compression set should be less than 4%, PU must not swell in solvent, Compression modulus should remain constant from RT to 60C, Low Tabor abrasion value for lower wear, High Trouser tear to prevent cut and tear, High storage modulus or low Tan delta value, Surface finish Ra & Rz should be less than 5micron, Resistance to moisture absorption, High Bashore resilience greater than 50 is desirable.

Critical PU Properties for Charge Roller

Hardness: Sufficiently soft to ensure intimate contact with photoconductor for uniform charging

Resiliency: Good rebound response to avoid compression set

Mechanical Properties: Material toughness to minimize mechanical damage

Abrasion: Slow wear rate to extend useful life.

Solvent Resistance: Sufficient chemical stability against other materials used in the process, as well as ozone and other byproducts of charging

Environment Resistance: Limited absorption of moisture to prevent big changes in roll size, and mechanical as well as electrical characteristics.

Key Properties for paper Transport Roller

Coefficient of Friction needs to be higher than 1.7 for superior paper feeding of all types of paper,

Shouldn't loose cof due to paper dust accumulation on tire surface/ surface glazing.

Compression Modulus stability @ high temp should remain constant due to the fact that the roller goes through the fuser zone & must survive 300F environmental temperature. Also, it must not melt & it must maintain hardness @ high temperatures. The most important property is the Compression set which prevents any set on roller; value must be below 2%. It must be resistant to all chemicals that come in contact. For an extended life of roller, Tabor abrasion value should remain less than 20mg. Pu elastomer should be hydrolysis resistant @ 85C & 90%RH for 3 weeks.

Key Properties for Transfer Roller

High abrasion resistance is key, due to the wear on roller edge while feeding paper @ high speed.

Uniform & stable Volume resistivity @ every environmental condition (L/L, N/N & H/H), deviation in the resistivity value should not be greater than 10%, otherwise it affects the generated electrical field and hence the print quality. Medium hardness PU for proper nip width & conformability. Compression modulus stability to maintain proper nip width under load, shift of 20% in modulus leads to problems in paper dynamics & print quality.

Advantages of Secondary Overcoats

A Secondary Overcoat creates a defined electrically resistive layer, Modifies Surface Energy and Coefficient of Friction. It also acts as a protective layer to prevent any contamination.

Conclusion

Based on the results of the experiments, the following table has the important recommended PU properties for rollers used in printing industries.

General properties recommendation for Rollers

Properties	ASTM	Unit	Charge roll	Transport Roll	Transfer Roll	Developer Roll
Hardness	D2240	SA	**Developed Fenner Confidential**	**Developed Fenner Confidential**	**Developed Fenner Confidential**	**Developed Fenner Confidential**
% Elongation @ Break	D412	%	400 to 500	350 to 550	250 to 350	400 to 550
Die "C" tear	D624	Pli	150 to 200	200 to 300	100 to 150	75 to 150
Tabor abrasion	D4060	mg loss	20 to 50	10 to 50	10 to 20	15 to 30
Compression set	D395-B	%	2 to 6	1 to 3	3 to 6	<1.5
Bashore Resisliency	D2632	%	50 to 60	40 to 60	>60	35 to 55
Vol resistivity	STD	Ohm-cm	1E5 to 1E7	1E8 to 1E10	1E8 to 1E9	5E5 to 5E7
Chemical resistance			+++++	+++	+++	+++++