

Technical

Most effective viscoelastic properties from the rubber process analyzer for measuring factory quality of mix

By John Dick and
Richard Hanzlik
Alpha Technologies
(First of two parts)

During the mixing process for a rubber compound, the base elastomer is masticated while the other ingredients, such as carbon black, begin to incorporate. As this process continues, the filler agglomerates are deagglomerated and dispersed as primary aggregates while the base raw elastomer(s) simultaneously is masticated and “broken down,” usually through some degree of

TECHNICAL NOTEBOOK

Edited by John Dick

depolymerization.^{1,2}

We constructed simple model recipes of selected fillers with SBR and studied the rheological effects on these experimental compounds from controlled amounts of applied work history during BR Banbury mixing in the laboratory.

The ASTM RPA processability tests

The rubber process analyzer (or RPA) evolved from the MDR (moving die rheometer) in 1992.

The RPA, introduced in 1992 by Monsanto (now Alpha Technologies), has the same die design that the MDR has except the RPA has a high-tech, direct-drive robotic motor and computer-controlled forced-air cooling, which allowed the RPA to function not only as a rotorless curemeter, but also as an effective dynamic mechanical analyzer (DMA) for raw rubber characterization and QA. It also serves as a processability tester for uncured mixed stocks in the factory, as well as after-cure dynamic properties of final mixed stocks (containing curatives). **Fig. 1** shows the Premier-brand RPA from Alpha Technologies.

Over the last 20 years, much work has been performed in the ASTM task groups of D11.12 Subcommittee on rubber processability measurements with the RPA. As a result, nine new standards have been developed and routinely used by the rubber industry to test different raw elastomers and measure and control compound masterbatches and finals with curatives, for various mixing processes all over the world.³⁻⁵

1. ASTM D5289—The original MDR curemeter standard on which a significant amount of modern-day RPA technology is based.

2. ASTM D6204 Part A—Simple 1 point per decade frequency sweep at $\pm 7\%$ strain (usually in the linear viscoelastic range) at 100°C for testing either raw rubbers or mixed stocks in the factory.

3. ASTM D6204 Part B—Simple 2 point frequency sweep at 0.1 and 1 Hz at ± 100 and/or $\pm 200\%$ strain at 100°C for testing in the non-linear viscoelastic range for either raw rubber or mixed stocks in the factory.

4. ASTM D6204 Part C—A variable temperature analysis (VTA) thermal ramp typically

Executive summary

Over the last three decades, the rubber process analyzer has evolved as the processability test instrument of choice for measuring and solving many rubber factory problems. Now there are several different RPA ASTM International methods that are used routinely by the rubber industry to measure the quality-of-mix of different rubber compounds for predictions of downstream processability differences. Of course, there are comparative advantages and disadvantages for using each of these viscoelastic properties, depending on the quality differences of the raw rubber and quality differences among factory recipes (including fillers), even among compounds that are used for the same purpose.

This paper discusses the statistical comparative advantages found from the results of a new RPA special laboratory study with specially mixed rubber compounds to compare the relative advantages of each of the viscoelastic properties which are measured by the RPA through sinusoidal deformation.

from 100°C to 180°C, for better test sensitivity to changes in scorch safety for “finals” (uncured compounds containing curatives).

5. ASTM D6601—An isothermal cure test followed by one or two back-to-back strain sweeps to measure quickly cured dynamic properties of the rubber compound at a lower temperature.

6. ASTM D7050—Consisting of high strain sweep tests to quickly distinguish the differences between “tough” natural rubber and “soft” natural rubber.

7. ASTM D6048—A stress relaxation test for quickly determining the state-of-mix of a mixed stock or viscoelastic characterization of raw rubber regarding AMW, MWD, LCB and gel.

8. ASTM D8059—Using the RPA with extended dynamic range (EDRTM), after a conditioning time, starting with a very low applied strain at $\pm 0.07\%$ and increasing quickly to $\pm 300\%$, measuring the Payne Effect for quickly determining the state-of-mix and percent dispersion of a rubber compound filled with a colloidal particle size filler such as carbon black or precipitated

silica.

9. ASTM D7605—Using the RPA with parallel plate dies to measure both the processing characteristics and congealed properties of thermoplastic vulcanizates (TPVs) and thermoplastic elastomers (TPEs).

Measuring different fillers incorporation and deagglomeration profiles

This part of the study involved measuring rheologically the effects of different filler incorporation and deagglomeration at different states-of-mix during the Banbury mixing process.

In this design of experiment, SBR 1502 was mixed with 35 percent by volume of the fillers shown in **Table 1**.

The table shows the weight

amounts of each of the different fillers that were used in this study to approximate a 35 percent by volume ratio of each of these fillers with the respective SBR 1502 base.

During the BR Banbury mixing process, 20g aliquot samples were taken from the mixer after three, four, five, six, seven, eight, nine, 10 and 12 minutes for sampling intervals. Each of these samples were tested on the RPA by the new ASTM D8059 Standard for the Payne Effect as well as ASTM D6204 Parts A and B Frequency sweeps (at 7 percent and 100 percent strains, respectively) and ASTM D6048 with stress relaxation.

For this portion of the experimental study, we used the ASTM D6204 method, Parts A and B, with two back-to-back frequency

Table 1: Recipes for the filler dispersion sensitivity study.

	1	2	3	4	5	6	7	8	9
SBR 1502	100	100	100	100	100	100	100	100	100
N234	68							68	68
N660		68							
N990			68						
Hard Clay				98.2					
Whiting					102				
VN3 ppt.						75.6	75.6		
hydrated Silica									
X50 (50:50									
TESPT and								12.5	
Carbon Bk)									
Ground Rubber								20	50
(30 Mesh)									
TOTAL PHR	168	168	168	198.2	202	175.6	188.1	188	218

Fig. 1: Premier-brand RPA from Alpha Technologies.



Fig. 2: Brabender torque curve.

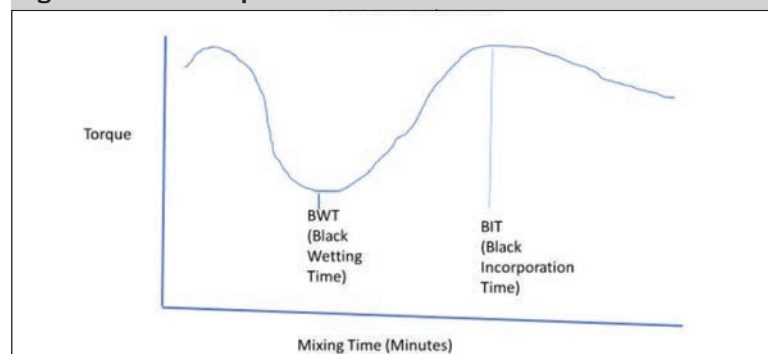


Fig. 3: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of N234 carbon black.

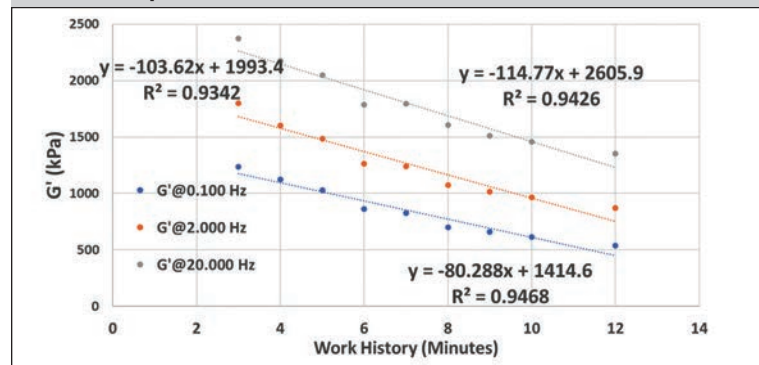
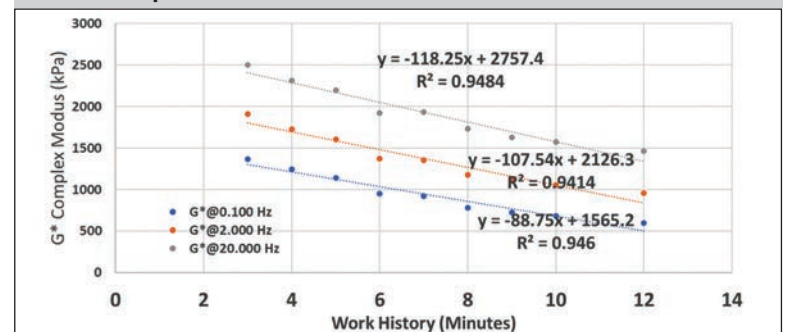


Fig. 4: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of N234 carbon black.



The authors

John Dick has more than 45 years of experience in the rubber industry. He was with BF Goodrich and later Uniroyal Goodrich Tire Co. as a section manager and development scientist in R&D until 1991



Dick

when he joined Monsanto's Rubber Instruments Group (now Alpha Technologies) as a senior scientist for applications until 2016.

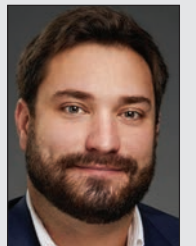
Dick now is an Alpha Technologies Fellow and the technical editor of *Rubber News*.

He teaches more than 10 rubber technology courses each year for the University of Akron, University of Wisconsin in Milwaukee and ASTM International.

He has authored more than 100 journal and magazine publications, including five books on rubber technology. He has consulted and given technical papers and seminars in more than 40 countries. Some of his publications have been translated into nine languages.

Dick is an ASTM Fellow and the chairman of ASTM D11.12 Committee on Rubber Processability Testing.

Richard Hanzlik is a chemical engineer from Cleveland State University with more than seven years of experience in the polymer industry.



Hanzlik

Formerly a formulations chemist dealing with UV curable thermosets, he is now an application engineer with Alpha Technologies. This includes helping customers in the rubber and composite industry by providing solutions and analysis to issues relating to compounding, processing and R&D.

Hanzlik has several publications in the U.S., Latin America and South Korea, and hosts rheology training courses across the continental U.S.

Technical

sweeps which were performed with the RPA. The first frequency sweep was performed at a strain of $\pm 7\%$ for 0.1, 2 and 20 Hz, followed by a second frequency sweep at $\pm 100\%$ strain for 0.1 and 1.0 Hz at 100°C .

So carbon black is much more attracted to the SBR medium used in this study than silica, which is “rubber-phobic.” Economic diluent fillers such as whiting and hard clay are somewhat in between carbon blacks and precipitated hydrated silica for “rubber friendliness.”

Silica actually is “rubber-phobic” in SBR compared to carbon black. Silica is not really that rubber-friendly. When initially mixing silica with organic-based elastomers, the silica particles prefer to agglomerate and associate with each other rather than disperse throughout the rubber hydrocarbon medium. Carbon black, by contrast, is much more “rubber-philic” and is known to disperse much more rapidly than precipitated hydrated silica. So, carbon black is known to have a much better wetting time and incorporation time than a typical precipitated hydrated silica. The data in **Fig. 2** shows the typical black wetting time and black incorporation time. Carbon blacks, because they are relatively “rubber-philic,” typically show significantly shorter BWT and BIT values than what silica displaces.⁶⁻⁸

Certainly, TESPT addition to a silica mix will improve this situation somewhat, however still precipitated hydrated silica with TESPT will not perform the way that carbon black does during mixing. Also, one should not forget that the TESPT silanization is best achieved at batch temperatures between 145°C to 155°C .⁹

Experimental

Formulations shown in **Table 1** were carefully mixed in a laboratory BR Banbury. Aliquots for these mixes, as discussed earlier, were taken at stated time intervals representing the applied “work history” during the mixing process.

All these samples were appropriately labeled and robotically tested by the Premier RPA, which was pre-programmed to perform the following ASTM tests:

- ASTM D6204 Part A (low strain frequency sweep)
- ASTM D6204 Part B (high strain frequency sweep)

One of the purposes of this specific study is to determine which of four RPA viscoelastic parameters (all outputs from ASTM D6204 A and B) relate best to state-of-mix. These four parameters are:

- G' - Elastic modulus under shear (kPa)
- G'' - Viscous modulus under shear (kPa)
- G^* - Complex modulus under shear (kPa) [$(G^*)^2 = (G')^2 + (G'')^2$]
- $\tan \delta$ - The dimensionless ratio of the viscous divided by the elastic ($\tan \delta = G''/G'$)

Dispersion of N234 carbon black

N234 is a fully reinforcing carbon black used to significant-
See **Viscoelastic**, page 28

Fig. 5: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of N234 carbon black.

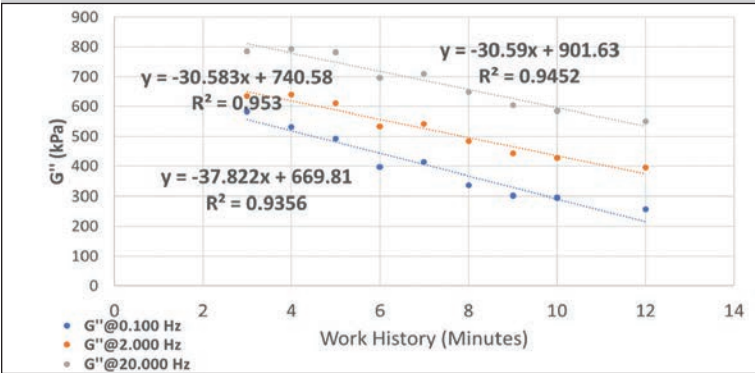


Fig. 6: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of N234 carbon black.

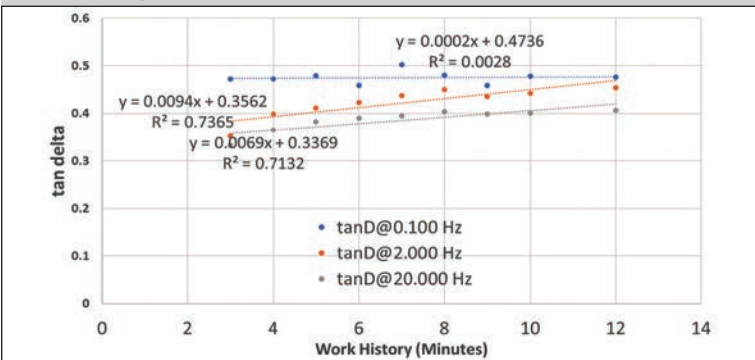


Fig. 7: State-of-mix by ASTM D6204 Part B from frequency sweeps at 100% strain, 100°C for dispersion of N234 carbon black.

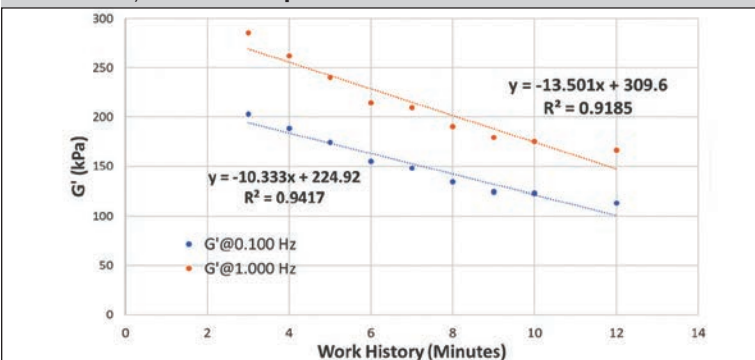


Fig. 8: State-of-mix by ASTM D6204 Part B from frequency sweeps at 100% strain, 100°C for dispersion of N234 carbon black.

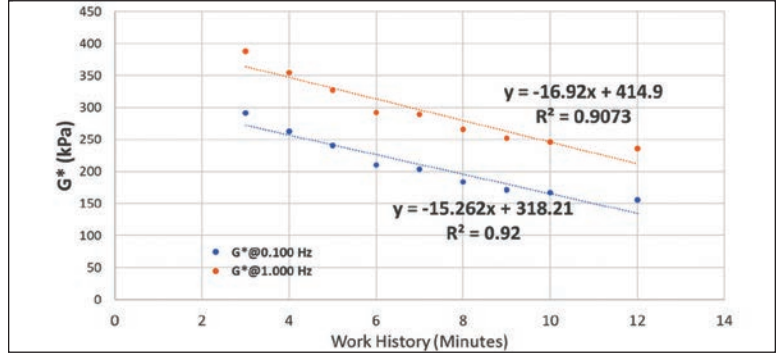


Fig. 9: State-of-mix by ASTM D6204 Part B from frequency sweeps at 100% strain, 100°C for dispersion of N234 carbon black.

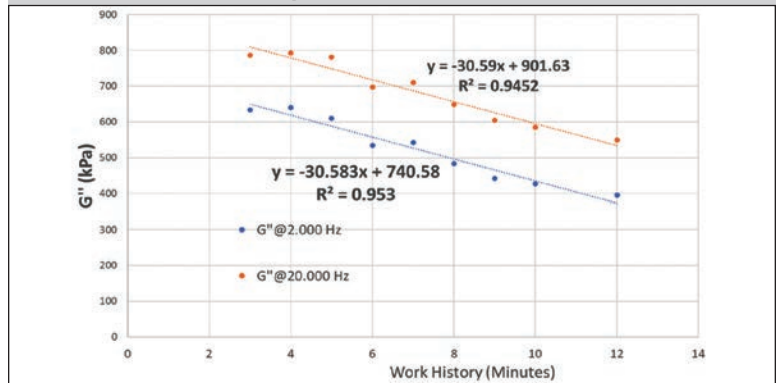
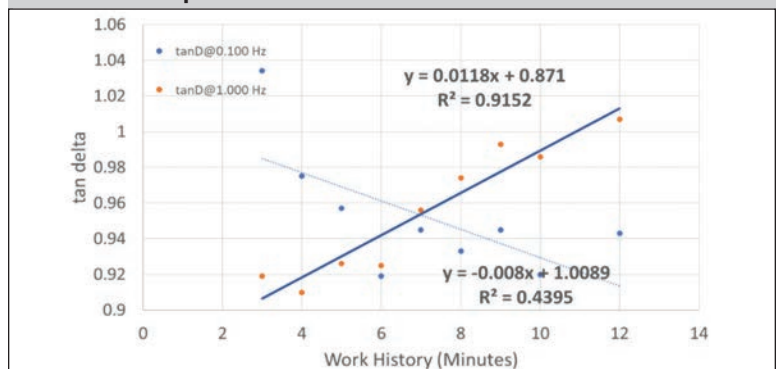


Fig. 10: State-of-mix by ASTM D6204 Part B from frequency sweeps at 7% strain for dispersion of N234 carbon black.



Vanderbilt Chemicals, LLC

A Wholly Owned Subsidiary of R.T. Vanderbilt Holding Company, Inc.

THE CHEMISTRY OF SUCCESS™

INNOVATION | EXPERIENCE | EXPERTISE

Made in the USA

Our Customers

Our People

Our Suppliers

Technical Support

Visit us at the International Elastomer Conference, Booth #410

30 Winfield Street, P.O. Box 5150, Norwalk, CT 06856-5150
(203) 853-1400 | www.vanderbiltchemicals.com



Vanderbilt Chemicals, LLC

A Wholly Owned Subsidiary of R.T. Vanderbilt Holding Company, Inc.

Registered and pending trademarks appearing in these materials are those of Vanderbilt Chemicals, LLC. Tecnoflon is a registered trademark of Solvay.



Fig. 11: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of whiting.

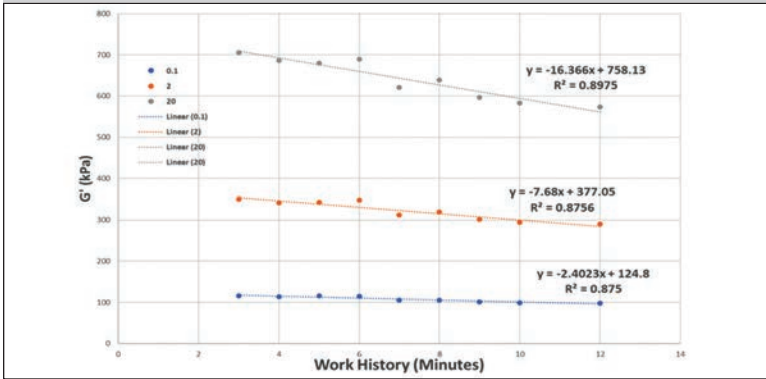


Fig. 12: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of whiting.

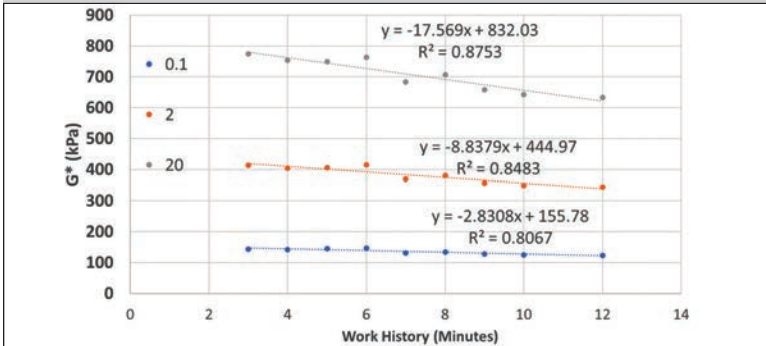
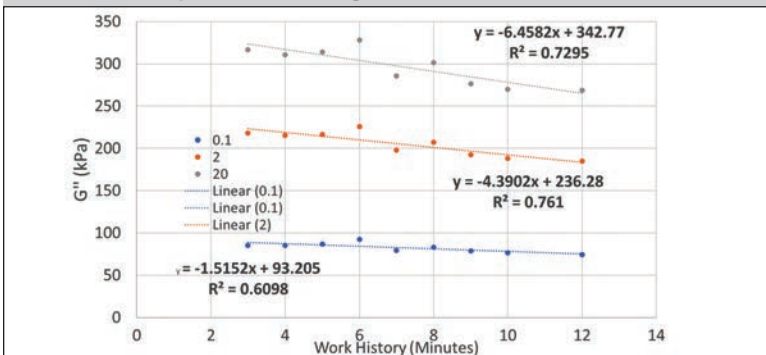


Fig. 13: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of whiting.



Viscoelastic

Continued from page 27

ly improve cured compound properties such as wear resistance and many other physical properties. To achieve these compound property improvements, it is particularly important that good dispersion is achieved. Fig. 3 shows how effective the RPA ASTM D6204 Part A with G' (elastic modulus) measurement is at relating to total work history (total mixing time) for the SBR formulation at low strain.

As can be seen, the R square correlation coefficients with the G' parameter are very good with very reliable predictions of total work history for the dispersion of N234 carbon black in the SBR base for this low strain (7 percent) frequency sweep (Part A) for ASTM D6204.

Also, Fig. 4 shows the discriminating power of the complex modulus G*.

As can be seen with N234 fully reinforcing carbon black dispersion, the complex modulus G* is equivalent to the elastic modulus G' in predicting state-of-mix (percent dispersion).

Fig. 5 for G'' for N234 dispersion shows the same predictive power as well.

So, for measuring state-of-mix with N234, G', G* and G'' are all equally effective in ASTM D6204 Part A at 7-percent strain. However, the situation is somewhat different with tan δ, which is shown in Fig. 6.

In Fig. 6, tan δ is a poorer predictor of state-of-mix for N234 carbon black.

ASTM D6204 Part B (100-percent strain)

Similarly, another comparison was performed with N234 carbon black dispersion using the higher strain of 100 percent with ASTM D6204 Part B. Fig. 7 shows the results of this comparison with the elastic modulus G'.

Once again at the higher strain, the G' gave a very good prediction of the state-of-mix for

N234 mixing.

Fig. 8 shows the results of comparisons with G*.

As can be seen, G* works just as well in predicting quality of mix when compared to G'.

Additional comparisons with method B (100-percent strain) were made for G'' in Fig. 9.

In this case, the higher strain did not give any advantages when using the G'' parameter.

Fig. 14: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of whiting.

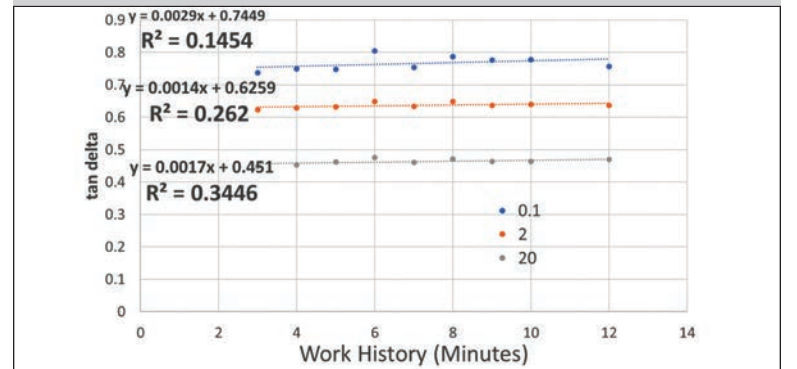


Fig. 15: State-of-mix by ASTM D6204 Part B from frequency sweeps at 100% strain, 100°C for dispersion of whiting.

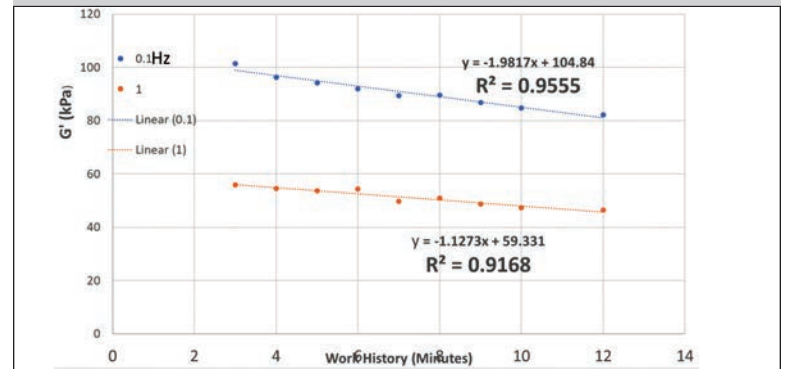


Fig. 16: State-of-mix by ASTM D6204 Part B from frequency sweeps at 100% strain, 100°C for dispersion of whiting.

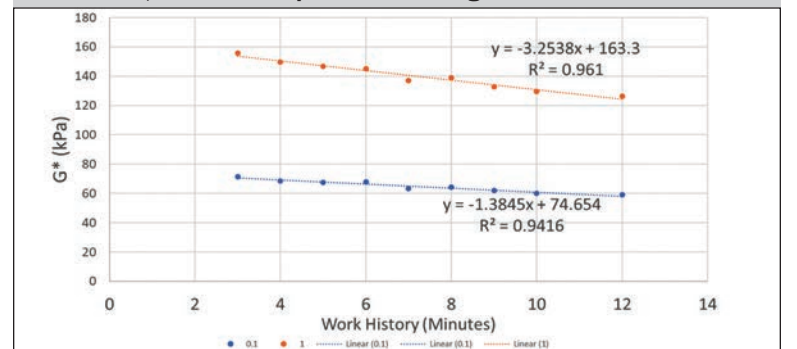


Fig. 17: State-of-mix by ASTM D6204 Part B from frequency sweeps at 100% strain, 100°C for dispersion of whiting.

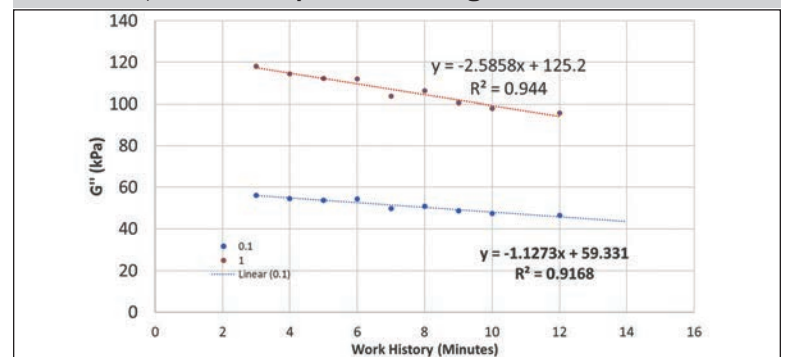
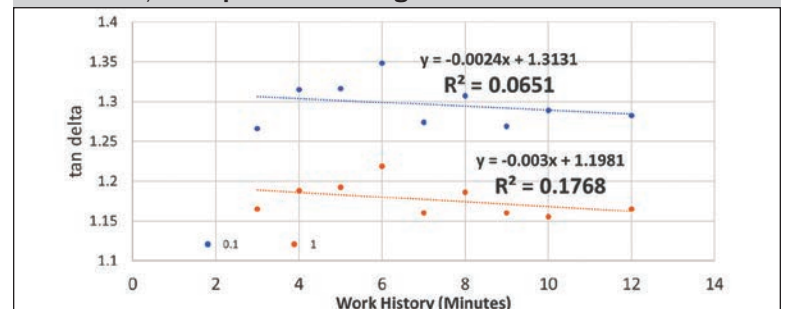


Fig. 18: State-of-mix by ASTM D6204 Part B from frequency sweeps at 100% strain, for dispersion of whiting.



Renoil Process Oil puts the soft in soft-touch TPEs



Bring a luxurious feel and pliability to your soft-touch TPEs with Renoil Low Volatility Process Oils.

These crystal clear mineral oils range in viscosity from 30 to 600 SUS @ 100F. So you can meet requirements, while extending your formulation and reducing the cost of your finished TPE products.

Additional advantages include:

- Highly compatible with rubber polymers
- Extremely stable, low volatility
- Excellent UV color stability, even for bright hues

We offer direct food contact grades as well.

Find out more at RenkertOil.com/products



1 (800) 423-6457 or inquiries@renkertoil.com

Technical

Lastly, for the N234 study, we used $\tan \delta$ at high strain as shown in Fig. 10.

This measure by $\tan \delta$ was effective at 1 Hz in frequency where with additional work history the $\tan \delta$ rises. More applied mastication breaks down the elasticity faster than the viscous quality, which causes the $\tan \delta$ to rise, as reported in the past.¹⁰⁻¹² The low frequency measurement for $\tan \delta$ was very scattered with a very poor correlation.

Dispersion of whiting (ground limestone)

Whiting is almost the exact opposite of N234 carbon black. Whiting has particle sizes between 1,000 and 5,000 nanometers compared to N234, which is around 20 nm. Whiting has no particle-particle interaction in a compound while N234 does through weak Van der Waals forces. Whiting is ground from limestone, while N234 is a highly engineered product designed to impart great reinforcement properties to a rubber compound. So the RPA ASTM tests that we were using to study the state-of-mix of N234 in SBR, we now will use to compare the dispersion characteristics of whiting in SBR.

Fig. 11 shows the predictive power of G' in a low strain frequency sweep by ASTM D6204 Part A.

With whiting, there is very little deagglomeration with increasing work history, but there is some breakdown of the base rubber resulting in a given drop in the G' values. The correlations are good.

In Fig. 12 we see the results of the same measurements given above, except this time we used the G^* parameter.

As one can see, the G^* is only slightly less effective at predicting state-of-mix than the G' . So in this case, with the ground limestone, G^* can also work here as well.

Fig. 13 shows the predictive powers of G'' .

G'' is significantly poorer as a predictor of quality of mix for ground whiting loaded compounds than either G' or G^* .

On the other hand, $\tan \delta$ in ASTM D6204 Part A (low strain) is not effective at measuring quality of mix, as shown in Fig. 14.

ASTM D6204 Part B (100-percent strain)

Here one can see that D6204 Part B for G' is somewhat more sensitive and more repeatable in measuring state-of-mix with whiting than Part A is in comparison.

Fig. 15 shows the results for G' elastic modulus by ASTM D6204 Part B.

With the higher strain of 100 percent, the G' is significantly better at measuring the quality of mix and dispersion than at only 7-percent strain.

Fig. 16 shows a small advantage of G^* in signal to noise ratio compared to the traditional G' elastic modulus shown before.

On the other hand, G'' , as can be seen, is slightly less effective than G^* in predicting state-of-mix, as shown in Fig. 17.

However $\tan \delta$ is much worse in predicting state-of-mix as shown in Fig. 18.

See *Viscoelastic*, page 30

Fig. 19: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of VN3 ppt. hydrated silica.

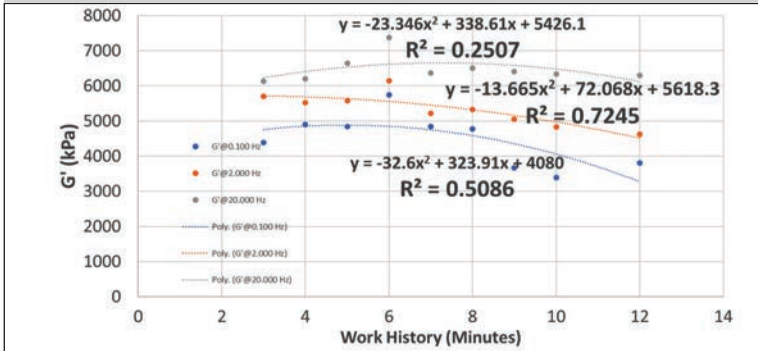


Fig. 20: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of VN3 ppt. hydrated silica.

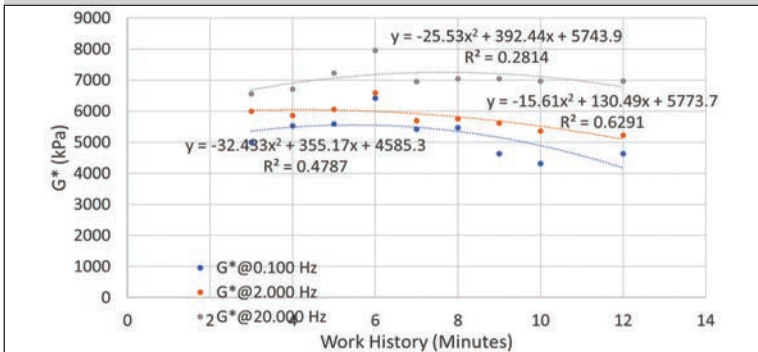


Fig. 21: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of VN3 ppt. hydrated silica.

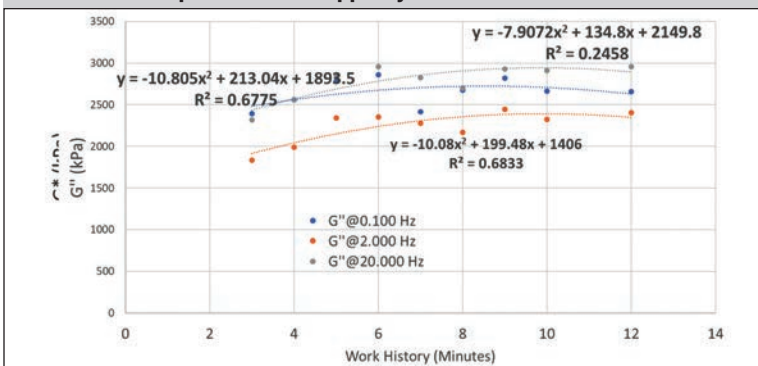


Fig. 22: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of VN3 ppt. hydrated silica.

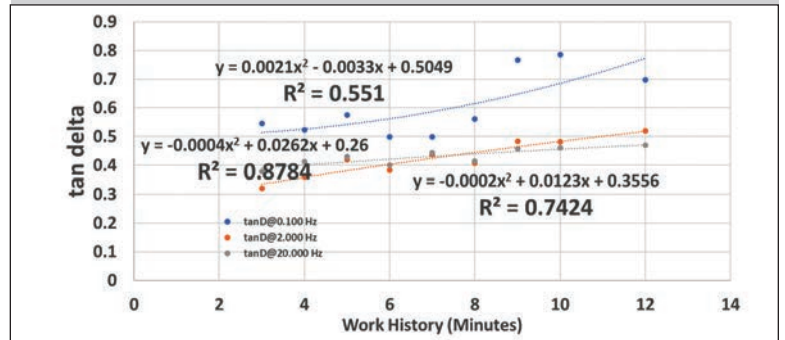


Fig. 23: State-of-mix by ASTM D6204 Part B from frequency sweeps at 100% strain for dispersion of VN3 ppt. hydrated silica.

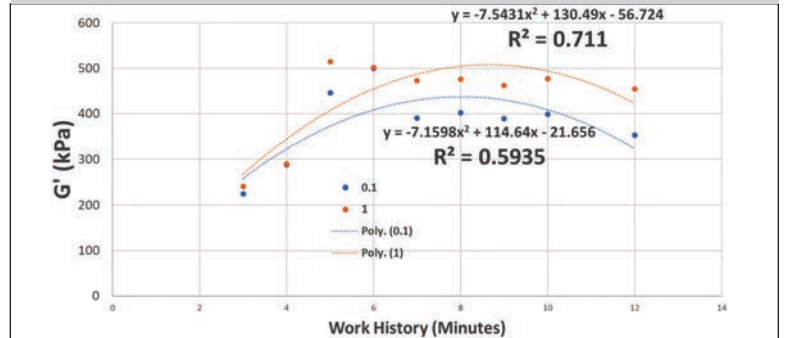
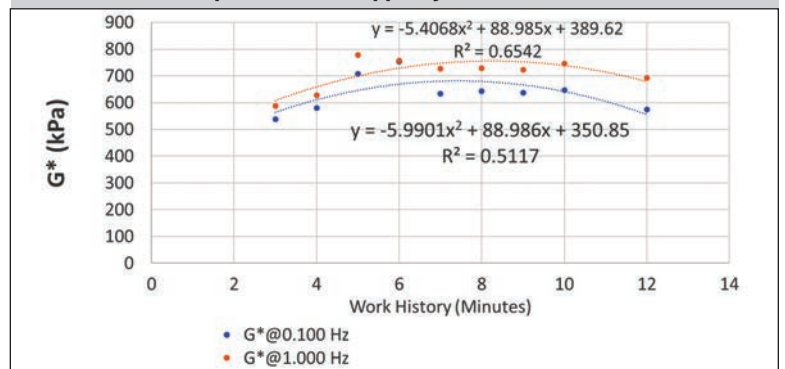


Fig. 24: State-of-mix by ASTM D6204 Part B from frequency sweeps at 100% strain for dispersion of VN3 ppt. hydrated silica.



UNDER PRODUCTION PRESSURE?

Engineering A Solution For Your Toughest Challenges
With Strong Service And Support

We do it all in the Rubber Machinery Industry.

From 30 tons to 10,000 tons, we can complete any custom press job - large or small.



Compression Press

- From 35 tons to over 10,000 tons
- New PLC Control with easy user interface
- Many custom features available
- Patented mold handling system
- Vacuum hood option

Rubber Injection Molding Machine

- FIFO System with precise and accurate rubber flow
- Exact position of mold for flawless repeatability
- Mold handling/part ejection for improved productivity

High Pressure Preformer

- High output - saves on labor and time
- PLC Control with touch screen
- Unique interlocking hydraulic head design
- Available in many sizes - from 2 lbs. to 120 lbs.
- 5,000 PSI (3,000 PSI also available)

Cold Feed Preformer

- Increased output, improved quality
- Three sizes available
- Continuous output - up to 1,000 lbs. per hour

TIRED of your Two Roll Mill? Ask us about our NEW Cold Feed, Screw Fed Preformer!

Call Us Today for
More Information!
330-633-5734



Pan Stone - a technology leader in rubber machinery. Full capability and the largest complete line of rubber molding machinery in the industry.

Polymer Machinery Company
154-B Potomac Ave.,
Tallmadge, OH 44278
www.polymermachineryco.com

Polymer
Machinery
Company



Fig. 25: State-of-mix by ASTM D6204 Part B from frequency sweeps at 100% strain for dispersion of VN3 ppt. hydrated silica.

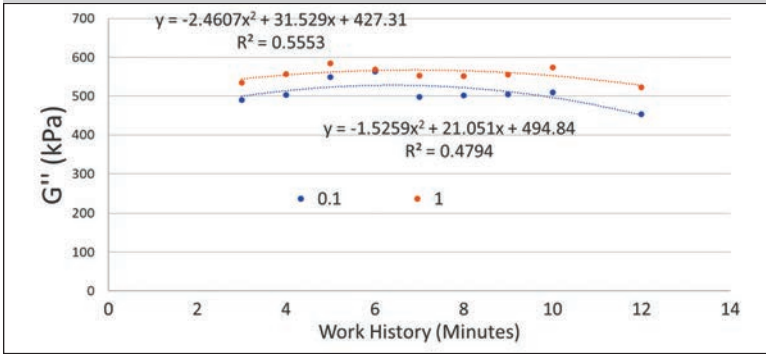


Fig. 26: State-of-mix by ASTM D6204 Part B from frequency sweeps at 100% strain for dispersion of VN3 ppt. hydrated silica.

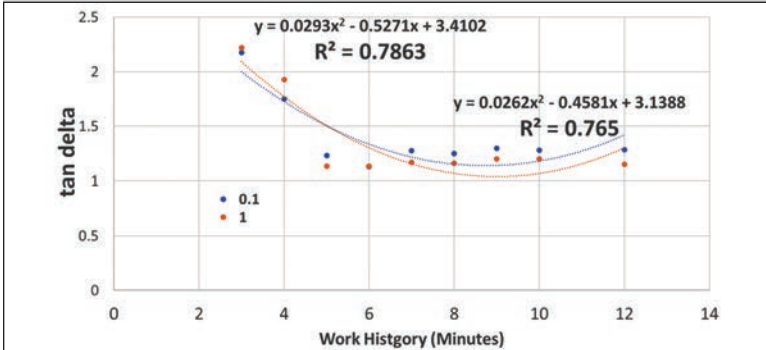


Fig. 27: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of VN3 ppt. silica with TESPT.

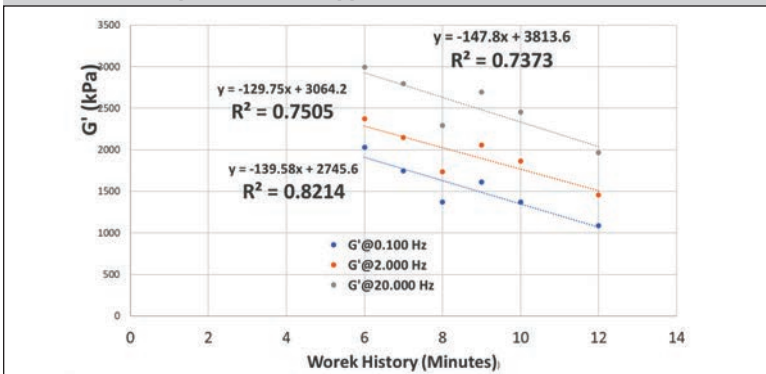


Fig. 28: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of VN3 with TESPT.

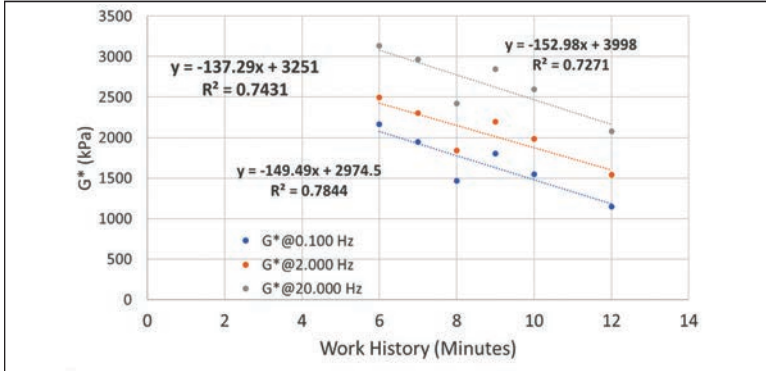


Fig. 29: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of VN3 with TESPT.

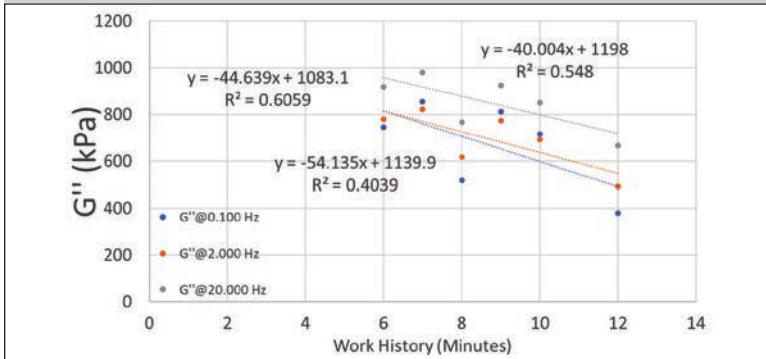
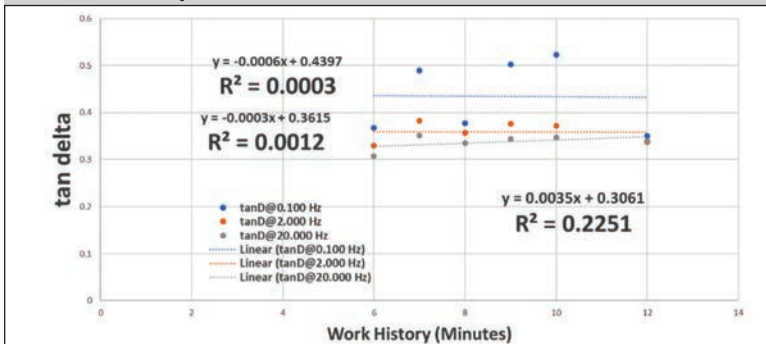


Fig. 30: State-of-mix by ASTM D6204 Part A from frequency sweeps at 7% strain for dispersion of VN3 silica with TESPT.



Viscoelastic

Continued from page 29

Dispersion of precipitated hydrated silica (without organosilane)

It is commonly known that precipitated hydrated silica is difficult to disperse in organic based rubber, especially if there is no organosilane present. Precipitated silica is very “rubber-phobic,” where the individual aggregates are more attracted to themselves than to the rubber medium. Usually the incorporation phase of the mixing of untreated silica lasts much longer than most other fillers.¹³

Fig. 19 shows some of the problems experienced when trying to disperse silica of significant quantity without any organosilane.

Whereas carbon black has a relatively short incorporation phase, silica has a much longer incorporation phase. This is why a curvilinear polynomial regression had to be used here. Even so, there still is a great deal of variation remaining with G' in ASTM D6204 Part A.

Fig. 20 uses G* under the same circumstances to measure the state-of-mix of silica without TESPT by ASTM D6204 Part A.

Here you can see that G* does just as good at predicting state-of-mix as G' does.

In Fig. 21 we see the comparative performance of G''.

As can be seen, G'' performs about the same as G' and G* in this experiment with silica without TESPT.

Fig. 22 shows the effectiveness of tan δ in predicting state-of-mix for untreated silica.

Even though the tan δ moves in the opposite direction, it actually displays a similar degree of effectiveness.

ASTM D6204 Part B (100-percent strain)

Next, we compared the silica testing results via ASTM D6204 Part B at 100-percent strain. Fig. 23 shows how well G' performed when measured at the higher strain of 100 percent strain.

Fig. 24 shows the effectiveness of using complex modulus G* for measuring the state-of-mix of this silica mix. As can be seen, G* at the higher strain of 100 percent (Part B) is not as effective as G' was.

Next, we compare Part B (100-percent strain) against the discriminating power of viscous modulus G'' shown below in Fig. 25.

As can be seen, the G'' is still even less effective.

Lastly, Fig. 26 shows the effectiveness of using tan δ to measure the state-of-mix for untreated silica.

Just as with Part A (at 7-percent strain), tan δ is just as effective (or more effective) than G' elastic modulus by Part B (at 100-percent strain). Of course in the dispersion phase (not the incorporation phase), the tan δ goes up with greater work history, while the moduli values decrease with greater work history.

See *Viscoelastic*, page 31

webinar

Thursday, November 3, 2022
11:00am EDT

Evaluating Viscoelastic Tire Performance Predictors Using the Premier Rubber Process Analyzer with Sub-Zero Technology

Featuring:



RICHARD HANZLIK
Application Engineer
Alpha Technologies

sponsored by



hosted by



Register Here:

RubberNews.com/Alpha/Webinar

SBR market on rise thanks to tires, footwear

Rubber News Staff

NEW YORK—The global styrene butadiene rubber market is set to grow to \$11 billion by 2031, driven by automotive, footwear and construction applications, according to a study released by Kenneth Research.

The high point of \$11 billion will be reached through a CAGR of 4 percent for the SBR market each year moving forward, the institute said.

Participants profiled in the study included Arlanxeo, Asahi Kasei Corp., Goodyear, TSRC, Dynasol Group, Trinseo, Synthos, Chimei, JSR Corp., Sumitomo Chemical Co. Ltd. and Sibur International, among other major companies.

The study took into account market segmentation (both by industry and geography); growth drivers; and market headwinds.

“The rising application of styrene butadiene rubber in sectors including automotive, construction, electrical, footwear, adhesives and sealants, among others, can be accounted for the expansion of the market,” the SBR market study said. “For instance, the U.S. plans to build more than

1 million new housing units each year. The market is expanding as a result of the demand for SBR in the construction sector.”

SBR also is used to alter cement and asphalt in the construction industries. By mixing SBR in concrete, the quality and durability of the material are improved.

“As a result, it is predicted that the rising demand for SBR boosts the market to grow significantly over the forecast period,” according to the study. “Global cement production increased from 4 billion tons in 2020 to over 4.9 billion tons in 2021.”

By geography

The Asia-Pacific region is predicted to be the largest consumer

of SBR, and the tire segment is the largest consumer by industry, the study confirmed.

There exists “growing demand for SBR adhesives and rising trade in cables and insulators” as well.

“SBR adhesives have been carefully developed for attaching synthetic foams, textiles, ceramic tile and insulating materials,” the study notes. “SBR is one of the most commonly used synthetic rubber in adhesives.”

Ceramic tile adhesive is used as a cement extender, binder, shape retention enhancer, stabilizing agent and for other performance characteristics.

Other major segments for the SBR market include North America, Europe, Asia-Pacific, Latin

America, and the Middle East and Africa region.

By industry

While SBR use in automotive remains the largest revenue driver, especially with motorcycle and high-performance tires, footwear is expected to expand in the coming decade, the study forecasts.

“Nearly nine out of 10 pairs of shoes, or 89 percent of the world’s total, are manufactured in Asia, which has a large concentration of the footwear sector,” according to the study.

China produces the most shoes (54.5 percent) in the world. About half of the global consumption of SBR for footwear in 2021 came from Asia. Together, China and In-

dia account for more than one-third of global footwear consumption.

The largest tire demand will come from the North American region, according to Kenneth Research.

By SBR type

Solution SBR is predicted to hold a larger share over the forecast period than emulsion SBR, according to Kenneth Research.

“The widespread application of SSBR in the tire and footwear sectors is contributing to the rise,” the study notes. “As a result of its flexibility, strong anti-slip qualities, durability, strong abrasion properties and density, SBR is frequently utilized in the manufacture of footwear.”

Technical | — Viscoelastic

Continued from page 30

Dispersion of precipitated hydrated silica (with TESPT)

The following test results on compounds containing both silica and TESPT show a big difference. Also, testing compounds with large amounts of silica with TESPT is more realistic.

Fig. 27 shows the G' elastic modulus test results on compounds containing both silica and TESPT by ASTM D6204 Part A.

By having the TESPT present makes the results appear more like the compounds with N234 with linear correlations. This is because the TESPT has significantly reduced the incorporation state-of-mix for silica. Also, the G^* (complex modulus) response via ASTM D6204 Part A is shown in **Fig. 28**.

As shown, the G^* appears to be equally effective at measuring state-of-mix when compared to G' . This is similar to what was observed with the N234 dispersion measurements discussed earlier.

Fig. 29 shows the utility of measuring state-of-mix with G'' (viscous modulus).

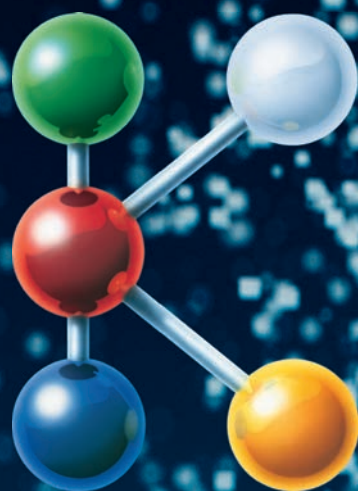
From **Fig. 29**, the G'' (viscous modulus) was not nearly as good an indicator of state-of-mix or dispersion for the silica with TESPT compared to G' or G^* .

Fig. 30 shows the effectiveness of making predictions for state-of-mix using $\tan \delta$.

As can be seen, $\tan \delta$ is quite poor at correlating to state-of-mix compared to the other parameters. This is similar to how $\tan \delta$ performed for measuring the dispersion and state-of-mix for N234 carbon black.

Once again, the $\tan \delta$ is not that sensitive to differences in silica dispersion with TESPT compared to G' .

The conclusion of this technical notebook will appear in the Oct. 31 issue of Rubber News.



AS INNO VATION

k-online.com/k_as_innovation

The World's No.1
Trade Fair for
Plastics and Rubber

19-26 OCTOBER 2022
Düsseldorf, Germany

For show information: Messe Düsseldorf North America
Tel. (312) 781-5180 - info@mdna.com
www.mdna.com
For hotel and travel arrangements: TTI Travel, Inc.
Tel. (866) 674-3476 - info@ttitravel.net


Messe
Düsseldorf
North America