Technical

EPDM grade offers improved auto hoses

By Sunny Jacob and Mark F. Welker
ExxonMobil Chemical Co.
Eric Jourdain and Guy Wouters
ExxonMobil Chemical Europe Inc.
Milind Joshi
ExxonMobil Co. India Pvt. Ltd.

Ethylene-propylene-diene elastomers (EPDM elastomers) have been established as the primary polymer choice for many automotive and industrial applications due to their outstanding weathering and heat resistance properties.[1-4]

Since the commercial introduction in the early 1960s, EPDM elastomers have encountered continuous development in the market and ranks third in synthetic elastomers, and first in technical applications out of tire markets, with about 1.3 millions tons of installed capacity.[5]

Executive summary

Ethylene-propylene copolymers (EPDM) continue to be one of the most widely used and fastest growing synthetic rubbers.

EPDM elastomer compounds are widely used in many automotive and industrial hose products, taking advantage of their outstanding thermal and oxidative stability, and their excellent chemical resistance to polar organic and aqueous inorganic fluids. Higher under-hood temperatures (as a result of lower hood lines), reduced air flow within the engine area, and turbo chargers have brought about the need for greater heat-resistant compounds for items such as coolant, emission, brake hoses and air ducts.

Although EPDM elastomers have been commercially available for 50 years, advancements in the area of catalyst and process technology have made it possible to design polymers with tailored properties to meet the increasingly demanding market requirements.

In this paper we will review the performance of a recently commercialized EPDM elastomer grade particularly suitable for hose applications. Our studies indicate that this new grade offers an improved balance of processing, mechanical and elastic properties for automotive hose applications.

TECHNICAL NOTEBOOK

Edited by Harold Herzlich

EPDM rubber compounds are widely used in many automotive and industrial hose products such as under-the-hood hoses, belts, and brake components, taking advantage of their outstanding thermal and oxidative stability, and their excellent chemical resistance to polar organic and aqueous inorganic fluids.[6,7]

EPDM rubber can be compounded to achieve the broad range of tensile strength and durometer required in this application segment. In addition to meeting the typical requirements for mechanical properties, heat resistance and compression set, EPDM coolant hoses offer good low temperature (-40°C) sealing properties and electrochemical resistance.

Collapse resistance and dimensional stability required for hose fabrication processes, extruding the inner tube, braiding the tube with yarn to provide pressure resistance followed by co-extrusion of the cover stock and forming and curing on a mandrel can be achieved by selecting EPDM with tuned microstructure for this application.

In general, the basic material properties needed to meet the performance requirements for automotive coolant, air and heater hoses, and air conditioning (A/C) and brake hose formulations include high green and tear strength, good retention of properties after aging with a balance of low temperature flexibility and compression set, and easy mixing and processing properties.

EPDM elastomers offer these properties and have been widely accepted as a reliable material of choice for a broad range of applications such as general purpose hose (up to 125°C type of service), heat resistant hose (up to 150°C type of service) and high-heat resistant hose (above 150°C type of service); however silicone rubbers are preferred for very high-heat resistant hoses (170°C and above).

The performance standard for the automotive coolant system hoses is specified in SAE J20, which classifies according to the type of service, i.e., SAE 20R3 for heater hoses and SAE R4 for radiator hoses.

Based on physical property and end use performance requirements there are three classes of hose materials specified, Class D-1 (70 hr aging at 125°C and compression set at 125°C), Class-D3 (70 hr aging at 150°C and compression set at 125°C), and Class-A (70 hr aging at 175°C and compression set at 125°C).[6,8]

Class D-1 performance requirements are easily achievable from sulfur cured EPDM elastomers with medium molecular weight, relatively high ethylene content (>70 wt percent, examples Vistalon 7001, Vistalon 5601 EPDM rubber, etc.). To achieve the stringent requirements of the Class-D3, often a blend of amorphous and crystalline EPDM with high molecular weight is cured using peroxide cure systems.

Bimodal EPDM elastomers have been found to be a suitable blend component to meet many of the Class D-3 requirements (examples Vistalon 7500 or 8700 EPDM rubber with a high ethylene EPDM such as Vistalon 5601 or 7001 EPDM rubber).

Class A requirements are hard to achieve using EPDM elastomers but blending an EPM copolymer or a very high molecular weight EPDM with a bimodal or crystalline EPDM along with advanced heat stabilizers may help in meeting these requirements. For brake hoses, compounds should be prepared without plasticizers to prevent extraction by the brake fluid.

Thus blends of low molecular weight and broad molecular weight distribution (MWD) EPDM are commonly used to achieve the necessary green strength for processing the compounds.

Bimodal EPDM elastomers, where the major polymer fraction has a narrow MWD along with a controlled level of very high molecular weight component (**Fig. 1**), have been successful in these application segments due to some of its key properties.

The attributes of the bimodal EPDM elastomers has helped to reduce the need for blending elastomers to maximize physical properties and excellent processing characteristics with a single polymer compounding approach.[9-11]

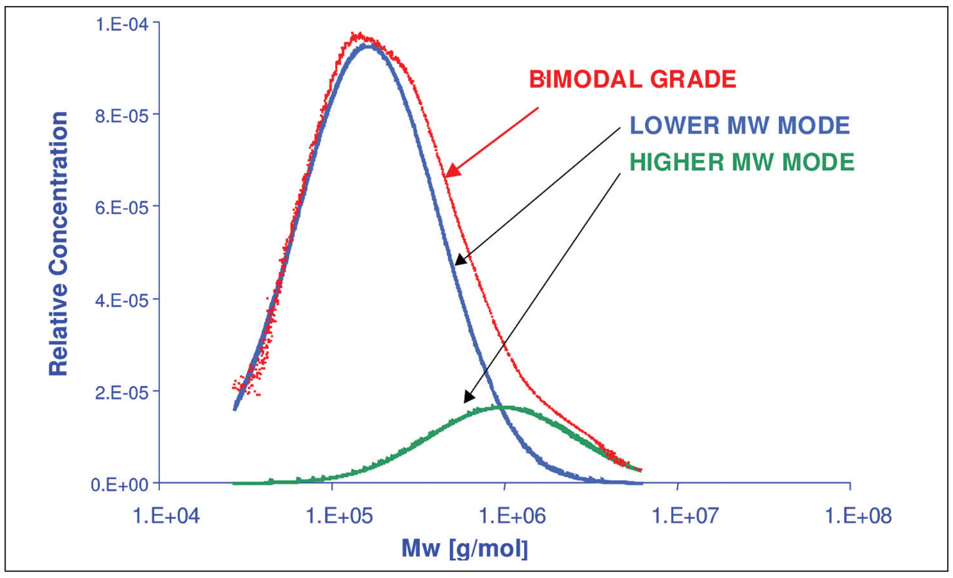
The presence of a discrete very high molecular weight and different composition component in the bimodal EPDM has a large impact on polymer elastic behavior and also improves significantly its processability. Bimodal EPDMs offer the performance of high molecular weight EPDM with

See **Hoses,** *page 16*

Table I. Typical properties of EPDM elastomers studied.

Typical Properties	Method	Unit	Vistalon™ EPDM rubber 6602	Vistalon™ EPDM rubber 7500	comp. EDPM
Mooney Viscosity ML (1+4,125 °C)	ASTM 1646 mod.	MU	80	90	70
MLRA,125°C	ASTM 1646 mod.	MU.s	344	1110	209
Ethylene content	ASTM D 3900 A	wt %	55	56	54
ENB content	ASTM D 6047	wt %	5.2	5.7	5.0
MWD			Medium	Bimodal	Narrow

Fig. 1. Mathematical resolution of EPDM elastomers with varying molecular weight distributions.



The authors

Sunny Jacob joined ExxonMobil Corp. in 1998 and has worked there at a variety of roles, including thermoplastic vulcanizate product development, polyolefin elastomers, and EPDM and butyl rubber applications development.

Jacob

He graduated from the University of Akron's Department of Polymer Science and Engineering. He has written more than 20 publications and has been granted several U.S. patents.

Mark F. Welker serves as a senior staff chemist at ExxonMobil Chemical in Baytown, Texas, where he has worked the last 13 years. Prior to that, he spent four years as the North America technology manager for Shin-Etsu Silicones.

Welker

Welker earned his undergraduate degree at the University of North Carolina and his graduate degree at Penn State University.

Eric Jourdain is a senior engineering adviser for specialty elastomers in automotive applications at ExxonMobil Chemical Europe in Brussels, where he has worked for the last seven years.

He specializes in EPDM and thermoplastic elastomers, including product development, formulation and compounding, processing, application technology and innovation, and market strategy. His responsibilities include automotive applications of elastomers in North America, China, Japan and South Korea.

Jourdain was educated in France, where he started his career. He took a role in technical service and development at ExxonMobil Chemical in 1984 in Brussels, and then he became a polymer technology engineer at ExxonMobil Chemical in Texas before returning to Brussels.

Guy Wouters currently is a managing director for Macro Chem Consult Sprl in Brussels. Prior to that, he spent 31 years at ExxonMobil Chemical in Brussels, serving as a senior staff chemist and new polymers development technical leader.

Wouters

Milind Joshi is the application development manager at ExxonMobil Co. India Pvt. Ltd., where he has worked for more than six years.

His expertise is in the development of rubber and plastics products in automotive and industrial applications.

Hoses

Continued from page 15

processing of a middle molecular weight, critical in these polymer rich compounds.[10, 11]

The main objective of this paper is to review the properties of a new grade of EPDM elastomer produced using a single site metallocene catalyst system. We will also discuss the results of a benchmarking study with a competitive metallocene grade and a conventional vanadium based EPDM grade with a primary focus for hose applications.

Unlike the previously commercialized metallocene catalyzed EPDM polymers, this elastomer has shown improved processing performance and comparable property performances to conventional EPDM elastomers.

Fig. 2. Plot showing the variation of complex viscosity η* with frequency measured at 125°C and 14 percent deformation of the three EPDM elastomers studied.

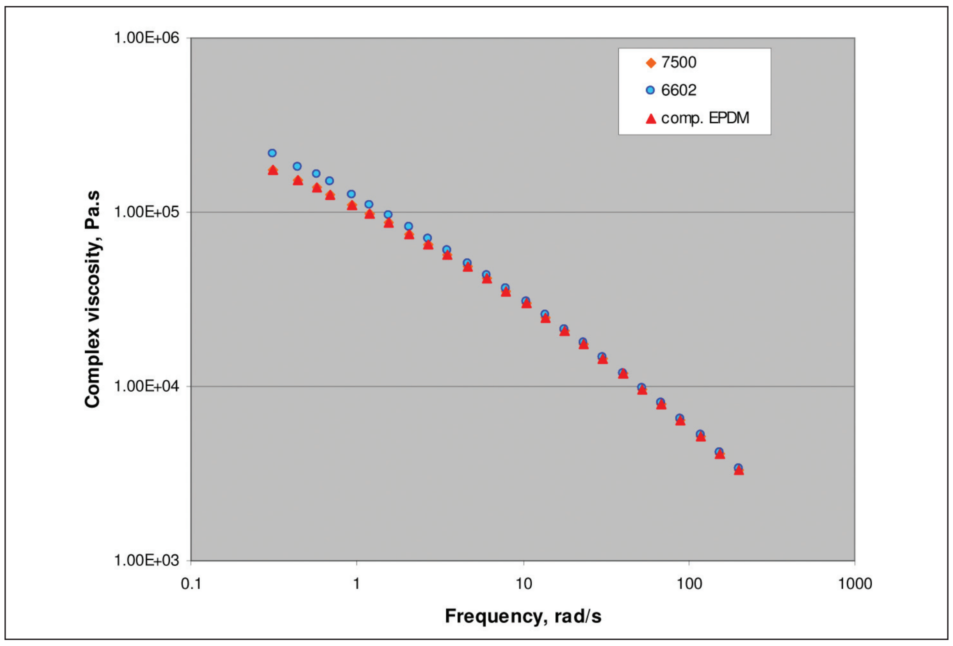


Fig. 3. Plot showing the change in tan δ with frequency for the three EPDM elastomers studied.

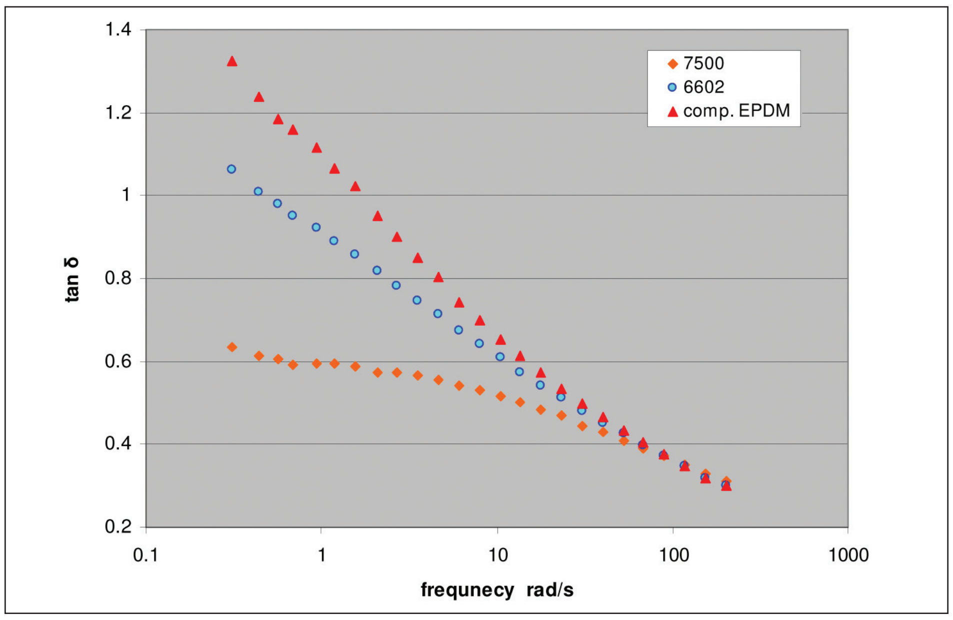


Fig. 4. Correlation MLRA/ML and tan δ at low frequency compound rheological properties.

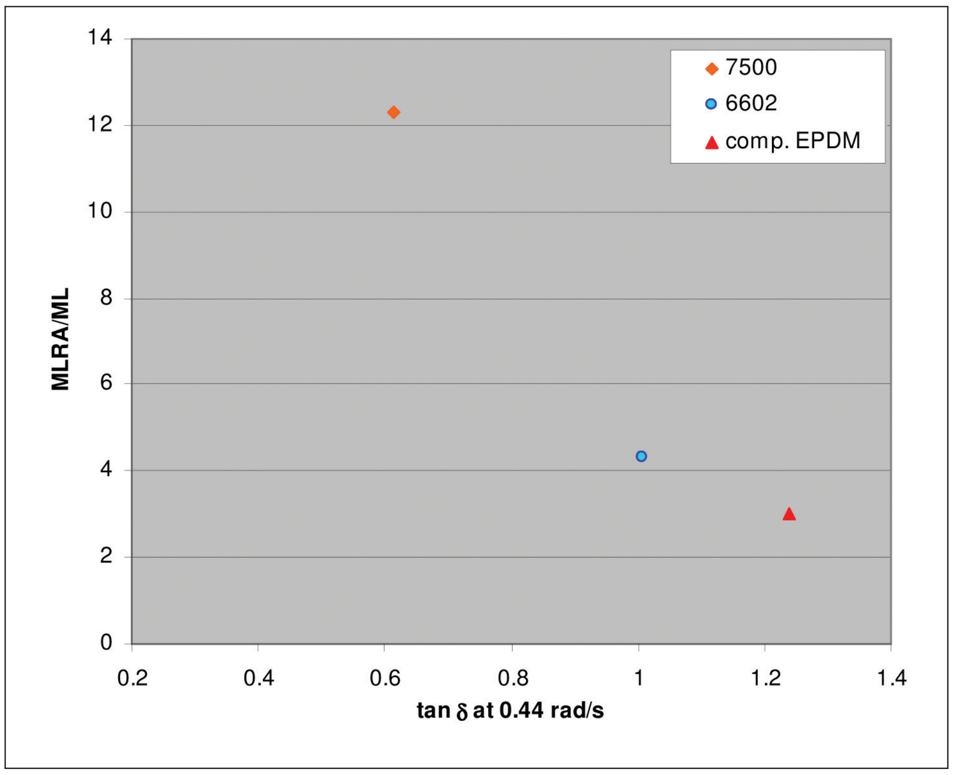


Fig. 5. Plot of complex viscosity η* with frequency of sulfur compounds (316 phr model compound) measured at 80°C and 14 percent deformation.

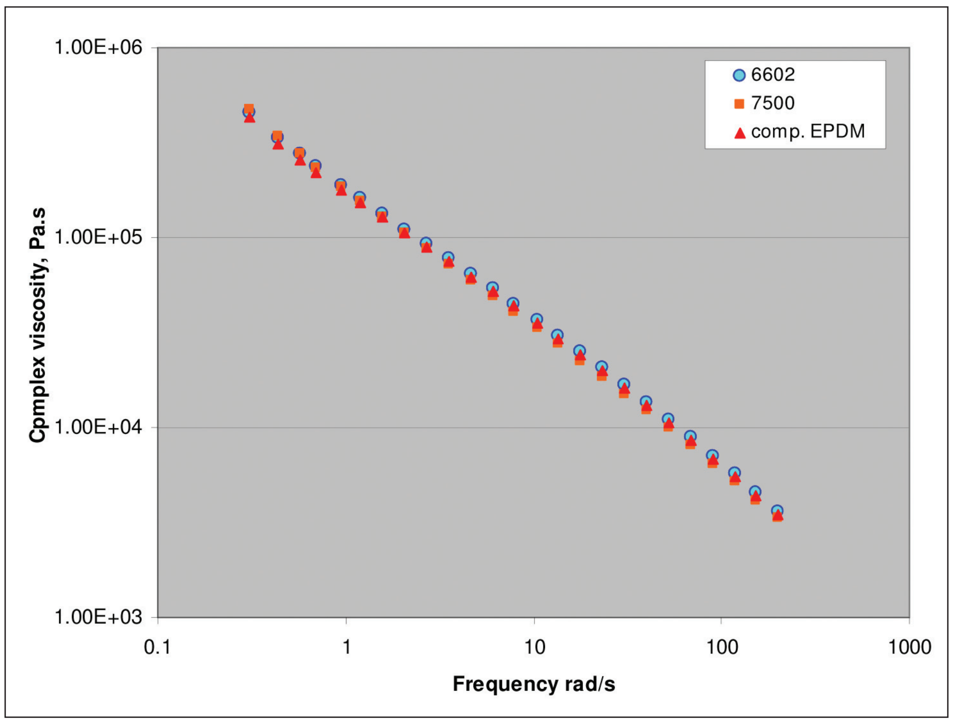


Fig. 6. Plot showing the change in tan δ with frequency for sulfur compounds (316 phr model compound).

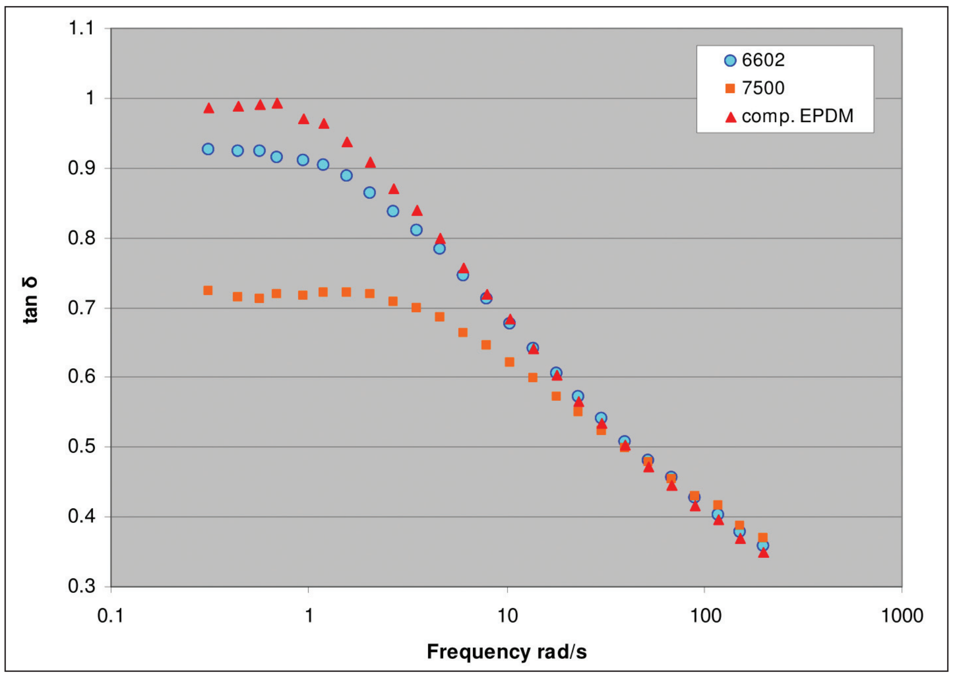
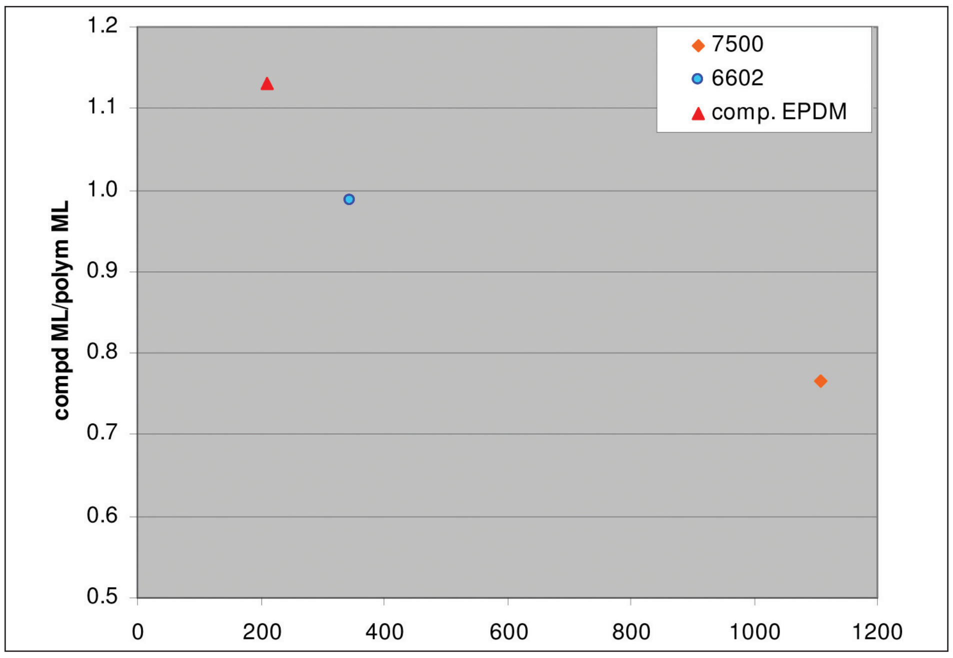


Fig. 7. Influence of EPDM MLRA on compound Mooney.



Experimental; Materials used

Three commercially available EPDM elastomers were used in this study. The EPDM elastomers used are commercially available under the trade names Vistalon 6602 EPDM rubber (new EPDM), Vistalon 7500 EPDM rubber (bimodal EPDM), and Nordel IP 4570 (comp. EPDM).

The typical properties of the EPDM polymers studied are shown in **Table I**. A typical model hose formulation with sulfur and peroxide cure system were used in the study to understand the compound performance (see **Table II**). Compounding of the formulation was done by a two-pass upside-down mixing procedure. A laboratory Farrell BR Banbury mixer, 1600 cc chamber volume, with variable rotor speed was used for preparing compounds.

Testing

The methods used for the testing of the typical properties of the EPDM elastomers are listed in **Table I**. The rheological properties of the EPDM elastomers and the compounds were studied using a rubber process analyzer instrument using a method developed at ExxonMobil labs.

Compound Mooney viscosity and Mooney scorch properties were tested at 100°C and 125°C, respectively according to ASTM D1646 guidelines. A moving disc rheometer (MDR) was used to test the cure characteristics of the compounds according to ASTM D2084 guidelines.

The original and aged physical properties of the compounds were tested according to ASTM D 2240, D412, 395(B) guideline for durometer hardness, tensile properties, and compression set, respectively. The test specimens were prepared by press curing at 170°C for t90+5 minutes for sulfur cure and at 180°C for t90*1.4 minutes for peroxide cure compounds. Garvey die extrusion test was conducted for understanding the processing characteristics of the compounds.

Results and discussion

The new grade of EPDM elastomers (Vistalon 6602 EPDM rubber) described in this paper is a high molecular weight amorphous polymer (ethylene content is 55 weight percent) with a medium level of ENB content designed to meet the application requirements for continuous curing processes.

The new grade was produced commercially using a single site metallocene catalyst system. The new grade of EPDM has exhibited several improved properties compared to previously commercial EPDM elastomers produced using single site metallocene catalyst technology.

The new grade is developed by considering the processing advantages of conventional Ziegler Natta EPDM elastomers and the flexibility of metallocene catalyst to tailor make EPDM elastomers with very uniform architecture.

Through product design we were able to achieve properties comparable to the conventional bimodal elastomers with good elastic performance for both high and low temperature applications, although the new grade of elastomers shows molecular weight distribution generally narrower than the conventional EPDM elastomers.

The polymer properties and the fast curing characteristic (faster cure rate and higher cure state) of the new grade of EPDM with both sulfur and peroxide, will be illustrated in the following discussion.

EPDM polymer rheological properties

The rheological properties of the EPDM elastomers studied using RPA are shown in **Figs. 2** and **3**.

These three elastomers have comparable properties with respect to ethylene content and ENB content except the Mooney viscosity (ML) values. As described earlier, the 6602 and the competitive EPDM elastomers were produced using a metallocene catalyst whereas the bimodal grade 7500 was produced using a conventional Ziegler Natta Catalyst.

As expected, the bimodal grade (due to the bimodal distribution of molecular weights) showed lower complex viscosities although it has the highest Mooney values.[11] Although the Vistalon 6602 EPDM rubber showed the highest viscosity values at low frequencies, it showed comparable shear thinning behavior to competitive grade at high frequencies. **Fig. 3** shows the change in tan δ with frequency of deformation for the three EPDM elastomers.

The tan δ values at low frequencies are an indicator of elastic properties of elastomers. It is noteworthy the tan δ values for the 6602 is lower than the competitive grade indicating improved elastic performance compared to the competitive grade.

This data also indicates that the compounds of the new grade is expected to exhibit improved elastic performance and processing characteristics that are closer to the bimodal 7500, which is well known for its processing advantages.[11]

Again this characteristic of the 6602 grade is highlighted in **Fig. 4**, where the ratio of Mooney relaxation area to Mooney (MLRA/ML) is plotted against tan δ at a low frequency. The higher value of MLRA/ML means broader polydispersity than the competitive EPDM and thus improved processing characteristics for 6602.

The MLRA value integrates the molecular weight of the EPDM, its branching and its fraction of high molecular weight ends. The higher the MLRA, the broader the molecular weight distribution at given Mooney viscosity.

Figs. 5 and **6** show rheological properties of model sulfur cured compounds prepared using three EPDM elastomers used in this study. The compounds' rheology shows a similar behavior as the elastomers.

The complex viscosity change with frequency is comparable for all three compounds. The tan δ versus frequency plot

See **Hoses,** *page 18*

Fig. 8. Hose locations under the hood of an automobile.

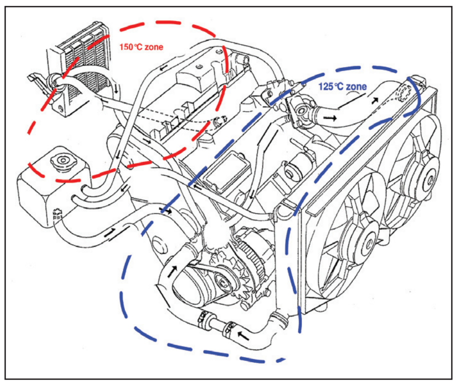


Table II. Formulations studied.

Masterbatch	Ingredient, phr	Sulfur cure	Peroxide cure
	EPDM Polymer	100	100
	Carbon Black N 550	120	110
	Paraffin Oil - High Viscosity	60	45
	ZnO	5	
	Stearic acid	1.5	
	Structol WB16	3	
	TMDQ	1.5	1.5
	EGDMA		2.0
	Total weight	291	256.6
Finalization			
	Masterbatch	291.00	256.5
	Sulfur	0.5	
	TMTD	2	
	DTDM	2	
	ZnMDC	0.9	
	ZDBDC-Butyl Zimate	0.9	
	Ni BDC (NBC)	0.9	
	Luperox F-40		7.0
	Total phr lab	298.2	265.5

Fig. 9. MDR cure curve of peroxide cured formulations.

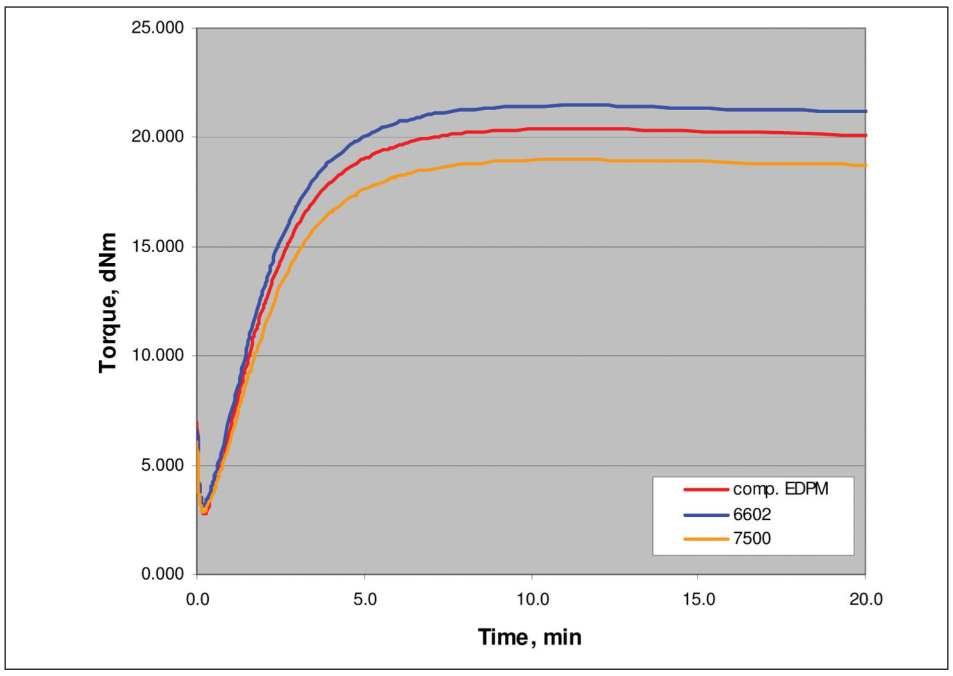
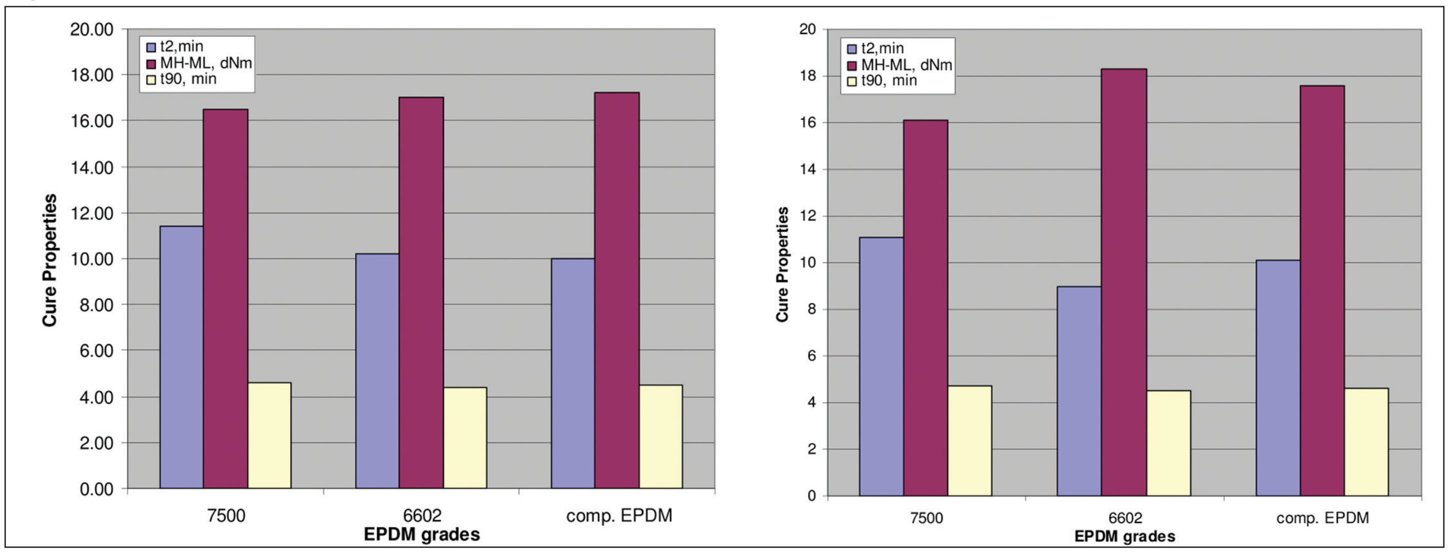


Fig. 10. Cure properties of EPDM compounds studied: (A) Sulfur cure; (B) Peroxide cure.



Hoses

Continued from page 17

shows that the Vistalon 6602 EPDM rubber compound has improved elastic performance indicated by the lower tan δ values at lower frequencies.

This property of the 6602 is illustrated further in **Fig. 7** where the ratio of compound Mooney to polymer Mooney (compound ML/polym ML) is plotted against MLRA of the polymer.

The lower compound ML/polym ML value for V6602 than the competitive grade indicate that 6602 has broader molecular weight distribution and its compounds are likely to exhibit better elastic properties and processing characteristics than the competitive grade and closer to the bimodal 7500 as described earlier.

It may be desirable in some applications to lower this value, i.e. bring it closer to the Vistalon 7500 EPDM rubber compound value which is achievable by EPDM blending methods which will be a topic of a future paper. The compound rheology data indicate that the 6602 compounds are likely to show similar extrusion behavior as the bimodal 7500 compounds.

Compound properties for hose applications

EPDM elastomers are widely accepted as a material of choice for coolant hose and replaced natural rubber and SBR because of their outstanding resistance to dry heat and coolant fluid. The material requirements for hose application are listed in SAE J20 specification.[6,8]

Some of these requirements are listed in **Table III** and **IV** for reference. EPDM elastomers cured with either sulfur donor cure system (for low to medium service temperatures) and peroxide cure system (high service temperature) exceed many of these requirements. One area where EPDM compounds need advancements is for applications where service temperature is greater than 175°C.

Modern automotive under-the-hood components have to resist such temperature with the development of engines having less fuel consumption and less emission, but offering enough power to satisfy the consumer. This translates into smaller engines, running hotter, with catalyst and filter systems active at high temperatures.

The hotter zone is located in the back of the engine compartment, (**Fig. 8**) where there is less cooling. Therefore the demand for heat resistance has increased for all EPDM hoses, coolant, air conditioning (A/C) and brake hoses.

OEMs demand longer air aging testing time, up to 1,000 hours, excellent electrochemical resistance, and no metallic salt extraction, like zinc salts which may clog the radiator. Some OEMs, such as VW, demand an oil resistance for the EPDM coolant hose. Nowadays, the life goal of the hoses is to perform well over the lifetime of the vehicle.[6]

The properties of Vistalon 6602 EPDM rubber highlighted in the previous sections make it suitable material to meet these demanding requirements for under-the-hood automotive hose applications. In this study we have studied both sulfur and peroxide cured compounds for hose compound performance.

Fig. 9 shows the MDR cure curves of peroxide compounds as an example to illustrate the cure behavior of the elastomers studied.

Fig. 10 compares selected cure properties of the three EPDM elastomers studied. All three EPDM compounds showed comparable cure properties with sulfur cure. But with peroxide cure the 6602 compound showed higher relative crosslink density, often referred to as the "Cure State" (MH-ML), lower ts2 (from Mooney scorch test) and lower t90 values than the other two grades indicating higher the cure efficiency of this grade. The green tear and cured tear properties of the compound are shown in **Fig. 11**.

The 6602 showed comparable green strength to the bimodal 7500 compound and showed the highest cured tear strength.

The physical properties of the sulfur and peroxide cured compounds are given in **Tables III** and **IV**. The 6602 compounds showed slightly better compression set and physical properties. This can be attributed to the uniform molecular architecture combined with an optimum distribution of the ENB along the molecular chains.

All three sulfur cured compounds met the physical property requirements for SAE J20 Class D1. The peroxide cured compounds meet the requirement for SAE J20 Class D3 and GM6250M5 requirements of selected properties studied.

The processing performances of the compounds were studied using a Garvey die extrusion test.

A Garvey die was performed on a 45 mm diameter extruder. All compounds showed good extrusion quality according to rating method A and B for surface smoothness and appearance ratings.

As shown in **Fig. 12**, the 6602 compound showed extrusion output values higher than competitive EPDM compound (although the competitive grade has lower polymer Mooney viscosity than 6602) and values closer to the bimodal 7500 compound. This clearly illustrates that the 6602 has benefits for compound processing. The faster cure rate combined with higher output can bring overall reduction in processing costs.

Conclusion

This study shows the new Vistalon 6602 EPDM rubber grade offers certain attributes that can be exploited for automotive coolant hose applications.

The advancements in the area of metallocene catalysts and process technology open a new regime to EPDM polymers with improved processability without losing the advantages such as high physical and elastic properties, translating in excellent compression set at high temperatures

See **Hoses**, *page 21*

Fig. 11. Green and cured tear properties of EPDM compounds with sulfur.

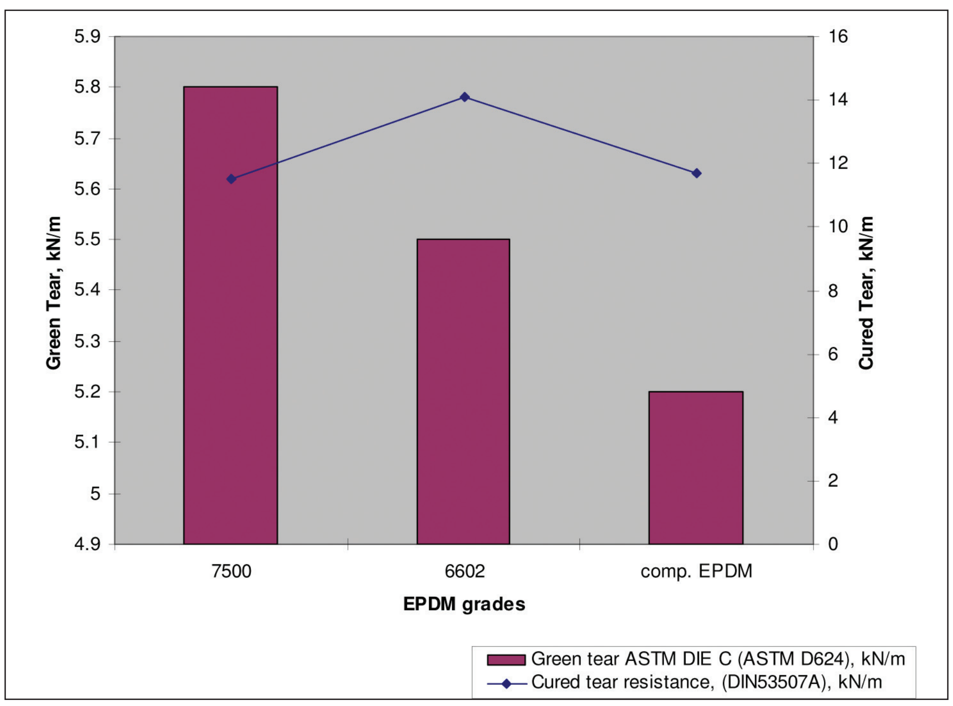


Table III. Original and aged physical properties of sulfur cured compounds.

Properties	Units	Vistalon™ EPDM rubber 6602	Vistalon™ EPDM rubber 7500	comp. EPDM	SAEJ20 Class D1
Original properties					
Durometer, Hardness A	Shore A	71	69	71	55-75
Stress at 100% elongation	MPa	4.0	4.0	4.0	
Tensile strength	MPa	12.0	11.7	10.4	7.0 min
Elongation	%	390	360	360	300 min
Compression Set, 125 °C, 22 hrs	%	51	55	54	75 max
Air aging at 125 °C/168 hrs					
Hardness Change	%	+6	+9	+7	+15 max
Tensile strength Change	%	+5	+9	+13	-20 max
Elongation Change	%	-41	-33	-39	-50 max
ASTM 2 Oil Aging at 100 °C /24hrs					
Hardness Change	%	-38	-35	-35	
Tensile strength Change	%	-32	-27	-27	
Elongation Change	%	-38	-39	-36	

Fig. 12. Garvey die extrusion output data for sulfur and peroxide cured compounds.

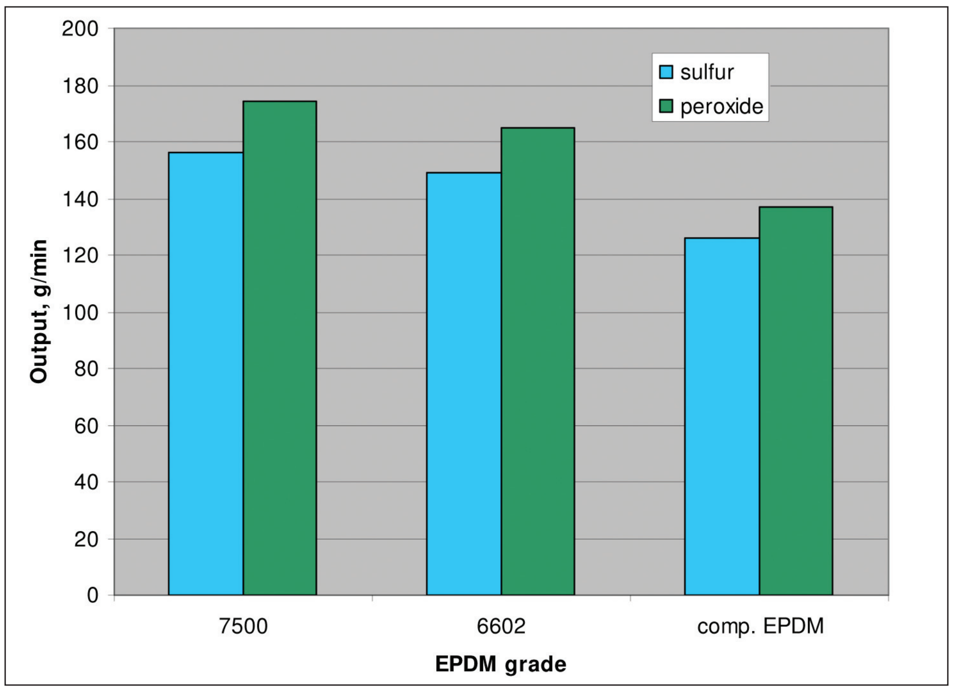


Table IV. Original and aged physical properties of sulfur cured compounds.

	Units	Vistalon™ EPDM rubber 6602	Vistalon™ EPDM rubber 7500	comp. EPDM	SAEJ20 Class D3	GM6250M5
Original properties						
Durometer, Hardness A	Shore A	68	66	68	55-75	50-75
Stress at 100% elongation	MPa	4.1	3.9	3.6		
Tensile strength	MPa	14.8	14.3	14.2	7.0	7.6
Elongation	%	310	280	310	300	250
Compression Set, 150 °C, 22 hrs	%	11	12	8	75 (125 °C)	60
Compression Set, 160 °C, 22hrs		12	18	13		
Air aging at 150 °C/168 hrs						
Hardness Change	%	+10	+11	+10	+15	0-15 (165 °C)
Tensile strength Change	%	-7	-10	-13	-35	-30 (165 °C
Elongation Change	%	-23	-21	-26	-65	-55 (165 °C
ASTM 2 Oil Aging at 100 °C /24hrs						
Hardness Change	%	-35	-32	-38		
Tensile strength Change	%	-26	-34	-34		
Elongation Change	%	-42	-54	-45		

Goodyear's sales decline but tire units climb

By Chris Sweeney
Rubber & Plastics News Staff

AKRON—Goodyear recorded a drop in sales, but increased net income and tire unit volumes during the first quarter, it said April 29.

The firm's sales came in at $4 billion for the quarter, down from $4.5 billion in 2014. Goodyear said it experienced a 2 percent increase in tire unit volumes to 40.8 million for the first quarter. Original equipment volume increased 3 percent while replacement shipments were up 2 percent.

Chairman and CEO Richard J. Kramer said in a statement the firm's volume growth gives Goodyear confidence in its outlook for the remainder of 2015.

Net income was reported at $236 million, up from a net loss of $38 million in 2014. The firm attributed the increase to a non-cash, one-time gain of $155 million ($99 million after taxes and minority interest) for the recognition of deferred royalty income resulting from the termination of a licensing agreement associated with its former Engineered Products business.

That business—which had operated independently as Veyance Technologies Inc.—was solid to Continental A.G.'s non-tire unit ContiTech A.G. in a $1.58 billion transaction that finalized in January.

"Our first quarter performance delivered record operating income of $391 million," Kramer said on a conference call addressing the results. "Segment operating income grew 5 percent, which when adjusted for foreign exchange would have been 16 percent. It's a clear indication of the strength of our underlying business."

Goodyear's North America unit led the way with $1.86 billion in sales, a slight decrease from the $1.88 billion it reported in 2014. Tire unit volumes increased to 14.8 million, up from 14.6 million. Both replacement and OE shipments increased 2 percent.

"By any measure, North America achieved one of its best quarters ever, including record segment operating income of $198 million," Kramer said. According to the executive, this is the 23rd consecutive quarter of year-over-year earnings growth for the segment.

Its Europe, Middle East and Africa segment experienced a 21 percent decrease in sales and a 2 percent decline in tire unit volume, to $1.33 billion and 15.9 units. Replacement tire shipments dropped 1 percent with OE decreasing 2 percent.

Kramer said a weak Euro accounted for almost all of the firm's year-over-year decrease in segment operating income.

Sales declined 9 percent in Asia-Pacific to $450 million, however tire unit volumes increased to 5.7 million units, up 9 percent compared to 2014. OE unit volume increased 20 percent while replacement units remained flat.

"We saw strong growth driven mainly by our consumer businesses in both China and India," Kramer said. "In particular, we saw very strong consumer OE growth in China as local manufacturers, both domestic and foreign, continued to develop their robust production and expansion plans both regionally and globally."

Latin America experienced a 10 percent gain in tire unit volume, to 4.4 million units, but sales dropped 9 percent to $385 million. Kramer said the firm expects the Latin America region to remain volatile for the foreseeable future because of currency, economic and political instability "at levels not seen for years."

However, the CEO said Goodyear remains optimistic about Latin America's long-term prospects, as evidenced by the firm's decision to service the region by investing at least $500 million in a new manufacturing plant to begin operations at San Luis Potosi, Mexico, in 2017.

Mexico

Continued from page 1

including Mexico," the spokesman said. "This location has the infrastructure and the skilled work force necessary to provide our customers high quality tires in a timely manner."

Goodyear said the new factory will be zero waste-to-landfill and a zero solvent facility, use natural gas and energy efficient LED lighting, and state-of-the-art dust collection equipment to meet the firm's commitment to the environment.

The new factory will enable Goodyear to meet the strong and growing market demand for high-value-added consumer tires in North America and Latin America, the company said. Industry demand for these kinds of tires is expected to increase by 10 million tires per year in the Americas from 2014-19.

Goodyear projects HVA tire demand to grow by about 18 million units per year and low-value-added products declining by about 8 million units per year.

"Demand for our high-value-added tires and those throughout the industry, is high and growing," the spokesman said. "Our difficulty has been producing enough of those tires to satisfy demand and meet our customers' needs. This new plant when it comes online, along with the investments we're making at our existing plants, will help us respond to consumer demand."

In its first quarter earnings presentation on April 29, Goodyear projects the regional market for HVA tires to increase by about 90 million units and take up 74 percent of the market by 2019. According to the firm, HVA tires currently account for about 62 percent of the market at about 270 million units.

"Having recently met with many customers in Latin America and North America, their excitement and commitment to Goodyear is palpable," Kramer said on an April 29 conference call discussing the firm's financials. "They view the investment as a tangible sign of Goodyear's commitment to growth. It was a clear demonstration, to me, of the value of being a Goodyear partner."

"The existing domestic supply of tires is insufficient owing to which Mexico imports a substantial quantity of tires into the country."

Karan Chechi

Automotive growth

Karan Chechi, research director at TechSci Research—a global market research and consulting company that operates in a number of industries, including automotive—said in an email that light vehicle production in Mexico reached a new milestone in 2014, surpassing 3 million vehicles.

TechSci projects annual vehicle production to reach 5 million units by 2020, with some of that being exported to neighboring markets.

The increase has led to growth of domestic original equipment tire sales, with passenger car sales growing at a compound annual growth rate of more than 10 percent from 2010-14, Chechi said. The number of passenger cars in use in Mexico crossed the 24 million mark in 2013 and is expected to see continued growth.

"The existing domestic supply of tires is insufficient owing to which Mexico imports a substantial quantity of tires into the country," Chechi said.

There are currently nine tire plants operated by six firms in Mexico—Bridgestone Corp., Continental A.G., Cooper Tire & Rubber Co., JK Tyre & Industries Ltd., Michelin and Pirelli & C. S.p.A.

Automotive OEMs also are expanding in Mexico, most recently Toyota announcing a $1 billion new assembly plant and Ford investing $2.5 billion in two new facilities.

Mexican President Enrique Pena Nieto addresses the crowd at Goodyear's announcement in Mexico City.

Chechi, however, said used tire imports is one issue facing Mexican domestic tire manufacturers. TechSci said 25 percent of the tires sold in Mexico's replacement market are used tires imported from the U.S. Tire makers in Mexico face stiff competition from both authorized and unauthorized used tire imports.

"It is considered to be extremely difficult for the U.S. and Mexican authorities to control the flow of goods from this border," Chechi said of the U.S.-Mexico border that spans about 2,000 miles. "About 5 million units of used/scrap tires enter into Mexico's tire industry every year, which negatively influences the sales of brand new tires in the country."

The analyst said these tires are sold for about one-third of the price of new tires.

Decision disappoints union

The United Steelworkers said it is "disappointing, but not surprising" that Goodyear decided to build its next plant in Mexico, in a statement released April 24.

"USW members at Goodyear have been willing partners and have repeatedly shown their commitment to championing the success of the company," International President Leo W. Gerard said in a statement. "Together we worked hard to help turn the company around, and the USW has led the fight to stop a flood of unfairly priced tires from China."

The USW said when it became clear Goodyear was going to build its plant outside of the U.S., the union began discussions with the company to maximize investments in existing facilities employing USW members here in the U.S.

The union could not be reached to comment further. The USW represents 850,000 workers in North America and has a master labor contract that runs through 2017 with Goodyear's six U.S. manufacturing plants—in Akron; Gadsden, Ala.; Buffalo, N.Y.; Topeka, Kan.; Danville, Va.; and Fayetteville, N.C.

Tom Conway, USW international vice president, leads the union's Goodyear bargaining team.

"Our efforts have significantly contributed to the return to prosperity for the company's North American operations," Secretary-Treasurer Stan Johnson, who also heads the union's rubber and plastics sector, said in a statement.

"That makes Goodyear's decision particularly troubling," he said. "Unfortunately, in today's world of manufacturing and finance, that's increasingly the decision corporations make. Our trade policies drive our companies to produce outside the United States with Wall Street reaping the benefits."

Hoses

Continued from page 18

because of a higher cure state. These expanded properties can be extended to other automotive hose and brake system applications where low temperature flexibility and elastic properties are important.

References

1. S. Jacob, E.P. Jourdain, M.B. Rodgers, The Vanderbilt Rubber Handbook, 14th Ed., M. F. Sheridan (Ed), R. T. Vanderbilt Company, Inc., Norwalk, CT, 2010, p. 138.
2. Ver Strate, G. "Ethylene Propylene Elastomers," Encyclopedia of Polymer Science & Engineering, vol. 6, pp. 522-564 (1986).
3. S. Jacob, Y. Devorest, M. Joshi, E.P. Jourdain, M.F. Welker. Amorphous Metallocene EPDM for Excellent Low Temperature Properties. Presented at a meeting of the American Chemical Society Rubber Division, Pittsburgh, October 2009.
4. M.F. Welker, Insulation Compounds Based on Blends of EPM and EPDM Polymers for Wire and Cable Applications. Presented at a meeting of the American Chemical Society Rubber Division, Pittsburgh, October 2009.
5. IIRSP source.
6. Burrowes, G.; Rodgers, B., "Compound Development and Applications," Rubber Compounding, Rodgers, B. ed., Marcel Dekker, Inc., New York, NY, 2004, p. 577.
7. Sivakumar, A; Sathaye, A., SAE International — Technical Paper (2010-01-1885) Selection of EPDM elastomer in Brake Hose Application for Improved Brake System Performance.
8. SAE Standard J20. Coolant System Hoses, October 1997.9.) G. Stella, N.P. Cheremisinoff. Designing EPDM for production efficiency, Polym.-Plast. Technol. Eng. 28(2), 185-199 (1989).
10. G. Stella, J.R. Schauder. Advances in EPDM structure design, Rubbercon 95, Gothenburg (Sweden), June 1995.
11. S. Jacob, E.P. Jourdain, Advancements in EPDM Sponge Compound Processing Using EPDM Bimodal Polymers, Presented at the fall 178th Technical Meeting of the Rubber Division of the American Chemical Society, Inc. Oct. 12-14, 2010 Milwaukee, Wis. Rubber Chem. & Technol. in print.

Acknowledgements

The authors recognize Mike Bednarik and Neely Nelson for their assistance in reviewing this paper. The authors are also grateful to ExxonMobil Chemical for permission to publish this paper.