Laminating FEPM fluoroelastomers to other rubbers for automotive hose applications

by Keisuke Yagi, AGC Chemicals Americas

For 180 years, elastomers have been used around the world to provide important performance qualities to industrial parts and components, including sealing, friction, and thermal and electrical insulation. Natural rubber accounts for approximately 47% of the global rubber trade, but there are many applications where it cannot be used because of its limited performance characteristics. For example, natural rubber does not hold up in high temperatures.

Because of these limitations, many grades of synthetic rubber have been developed that can retain their performance in high temperature applications. Fluoroelastomers have the highest heat resistance of all synthetic rubbers, which gives them a distinct advantage in challenging applications. Today's newest fluoroelastomer grades can even co-cure with other rubbers, making it possible to cost-effectively manufacture multilayered automotive hoses that can withstand the demanding underhood environment.

The rise of FEPM type fluoroelastomers

In 1975, AGC developed unique fully saturated fluoroelastomers composed of alternating units of tetrafluoroethylene (TFE) and propylene. Their saturation puts them under the classification of FEPM type elastomers. These fluoroelastomers, branded AFLAS, are often confused with FKM type rubbers because they are similar in function, but they are very different when it comes to price and performance characteristics (figure 1).

Due to their outstanding chemical and heat resistance, including a continuous service temperature of 200°C (392°F), FEPM type fluoroelastomers can be used for parts and components in chemical plants, food processing plants, cars, wires, cables and downhole applications for oil and gas.

These fluoroelastomers have excellent acid resistance and are also much more resistant to aqueous caustic soda, ammonia water and alkaline chemicals like tetramethylamonium hydroxide (TMAH) and n-methylpyrrolidome (NMP). They are also more suitable than FKM-type rubbers for use on liquid crystal and semiconductor manufacturing lines (figure 2).

FEPM fluoroelastomers have outstanding electrical insulation properties (10^{16} Ω.cm) and mechanical strength. These qualities make it possible to manufacture cables that can conduct high electrical currents with relatively thin insulation layers. An example of this type of application is the engine cables in Shinkansen high-speed trains.

Shinkansen bullet trains (figure 3), which travel all over Japan at speeds up to 199 mph, use engine cables insulated with AFLAS fluoroelastomers.

As demands on internal combustion engines become stronger and conditions become harsher, engine components will

Figure 1 - benefits of FEPM versus other elastomers

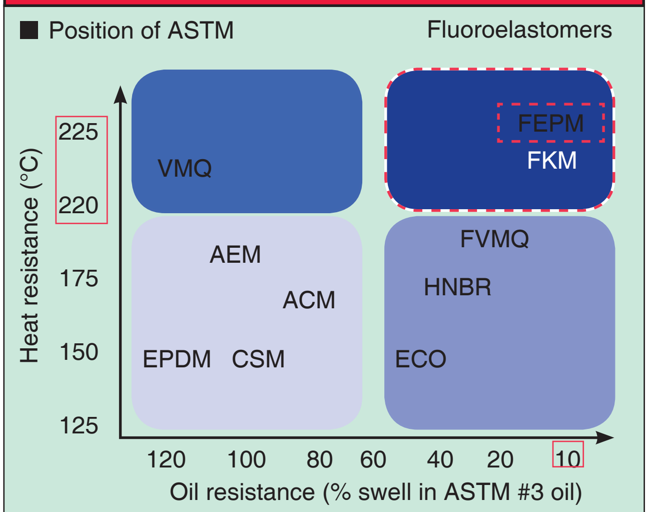


Figure 2 - comparison of FEPM and FKM

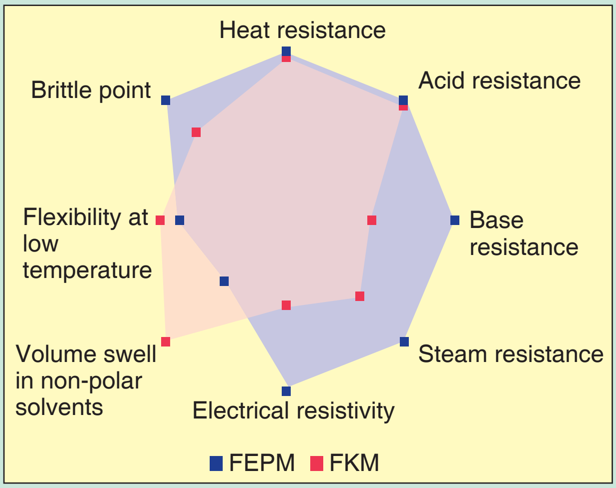
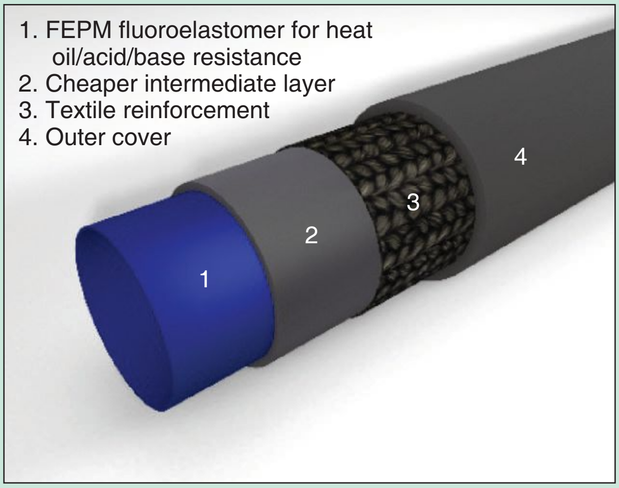


Figure 3 - Shinkansen bullet train

Figure 4 - multilayer hose concept



need more protection from aggressive materials and environments. For example, engine oils contain amine-based additives that act as antioxidants. When they contact hot metals, these oils break down into undesirable products that can damage engine components. FEPM-type fluoroelastomers provide excellent resistance to alkaline substances, making them ideal materials for oil seals that need to resist high temperatures.

FEPM elastomers sit in a niche area of the market, falling between FKMs and the far more expensive FFKMs. They are widely used in the energy industry, particularly in downhole applications, because of their excellent resistance to oil, heat and pressure. They also perform well in sour gas (H_2S-rich) environments, and some grades are routinely used in areas where rapid gas decompression (RGD/ED) is a serious consideration.

Although FEPMs are slightly more expensive than FKMs, their performance in harsh environments warrants the added price. However, when lifetime is not an issue because maintenance is easy, these materials become “nice to haves” rather than essential.

New developments and applications for FEPM elastomers

Recently, AGC developed a new FEPM elastomer grade that is ideal for compression molding into seals and gaskets. Another new FEPM grade is more suited to extrusion applications like cable and hose. These new grades were designed to offer performance improvements, including compression set, tear strength and mold release. Also, because the grades are white, they create more vibrantly colored parts when compounded with pigments.

The new FEPM elastomers also cure far more rapidly. Cure times (T_{90}) for their predecessors were in the region of nine minutes (ref. 1), making their handling unfamiliar to producers of more conventional rubber components. The new grades exhibit T_{90} around three minutes (ref. 1), which is very similar to EPDMs, AEMs and VMQs.

FEPMs are very well suited for applications like air, oil, fluid and coolant hoses. Some grades are also able to co-cure with other materials, making it possible to use a multilayer construction instead of a full fluoroelastomer hose, without sacrificing the technical performance or the lifetime of the part. This is particularly important for price-sensitive applications like automotive parts.

Adhesion has also been improved over the previous grades. For example, when measuring its adhesion to ACM, AEM, VMQ and EPDM rubbers at an operating temperature of 150°C without using adhesive primers (ref. 2), the result was >9 N/in for the new FEPM grade versus <2 N/in for conventional fluoroelastomers.

Today’s automotive industry is focused on efficiency: getting the most out of as little as possible. Strategies like lightweighting and engine downsizing are driven by legislation and environmental concerns. Smaller engines are traditionally associated with low power. However, there has been a shift in the industry to introduce turbochargers to more gas engines and to increase the effectiveness of the turbos. While this increases power output, the turbocharger systems have much higher temperatures and pressures. This accelerates the oxidation of oils and fluids, and amplifies the chemical and physical stress on the components.

In fact, the whole engine system is affected. For example, the evolution of acidic nitrous (NO_x) and sulphurous oxides (SO_x) in the oil is a challenge for many components. Alkaline additives are an essential part of the oil chemistry used to combat this acid evolution.

Combining harsh additives with high pressures and high temperatures puts conventional elastomer hoses at risk of failure. Similarly, the degradation of coolant media such as ethylene or propylene glycol can generate acidic species that can cause engine corrosion. This combined with steam presents a challenge for rubber hoses (figure 4).

Resistance to oils

To demonstrate the capabilities of FEPM-type elastomers in such conditions, AGC tested its grades to a standard specification (ref. 3) in two engine oils. First, 0W/20 (ref. 4) and 10W/60 (ref. 5) were tested in conjunction with an FKM dipolymer and an FKM terpolymer. The oil resistance test followed ISO 1817, and involved immersing the materials at 150°C for 70 hours. In the first oil, all materials showed less than 5% change in tensile strength (TS) and elongation to break (E2B). In the second oil, the FKM dipolymer suffered a 32% decrease in TS and 20% decrease in E2B, whereas the FEPM grades and FKM terpolymer samples showed <5% drop in TS and <10% drop in E2B.

The test was repeated with oil that had been aged at 175°C for 72 hours to better represent everyday usage conditions. Fresh material samples were immersed at 175°C for 168 hours. Again, in the first oil, changes in mechanical performance were small (<10%) for all materials. In the second oil, however, there were significant changes for both FKM dipolymer and FKM terpolymer. They sustained 64% and 48% drops in TS, and 42% and 30% drops in E2B, respectively; whereas, both FEPM grades exhibited less than 5% change. It became clear that the higher concentration of anticorrosion additives in the second oil had a notable effect on the FKMs (figure 5).

Figure 5 - performance in engine oils

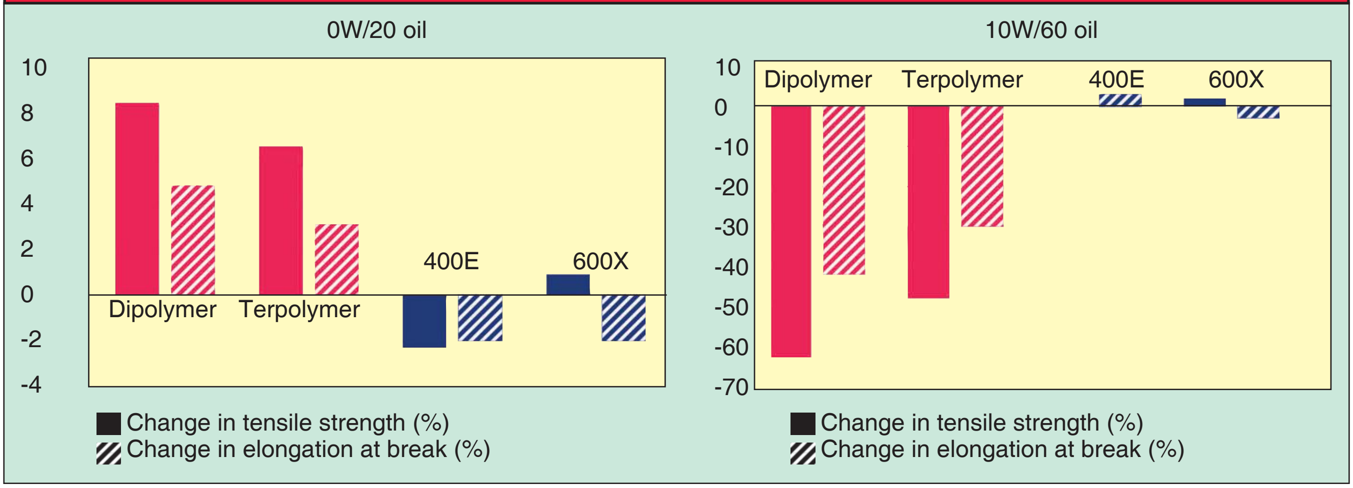
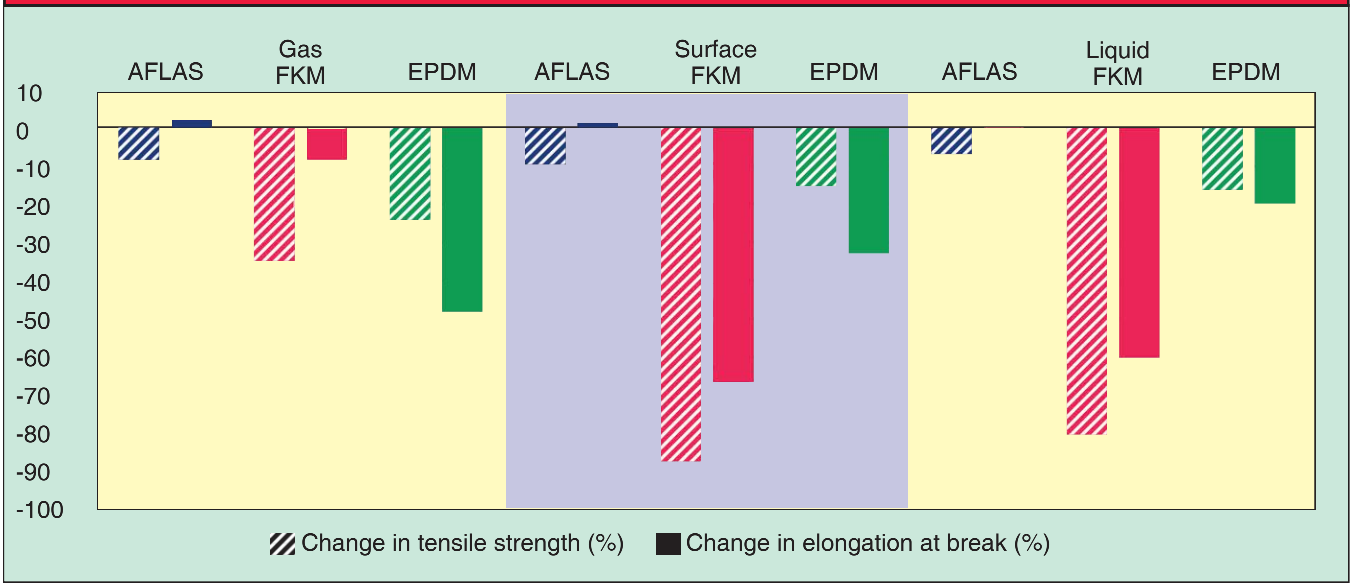


Figure 6 - performance in coolant



Resistance to coolants

In order to test the FEPM grades' suitability for coolant hose constructions, AGC tested the effect of Toyota Super Long Life Coolant at 180°C for 168 hours. The FEPM material was submerged in the gas phase above and at the surface of the coolant. Comparison samples were made from an FKM and EPDM, which are commonly used in coolant hoses.

In all three positions, the FEPM grade showed <10% change in TS and <1% change in E2B. The FKM showed 34%, 87% and 80% drops in TS at gas, surface and liquid phases, respectively, and 9%, 65% and 60% drops in E2B, respectively. The EPDM showed drops of 23%, 16% and 17% in TS, and 49%, 32% and 20% drops in E2B, respectively.

The interaction of the gas and liquid phases is key to the degradation of the coolant into glycolic and formic acids. This interaction caused weakening of the FKM and EPDM, but seemed to impact the integrity of the FEPM grade much less (figure 6).

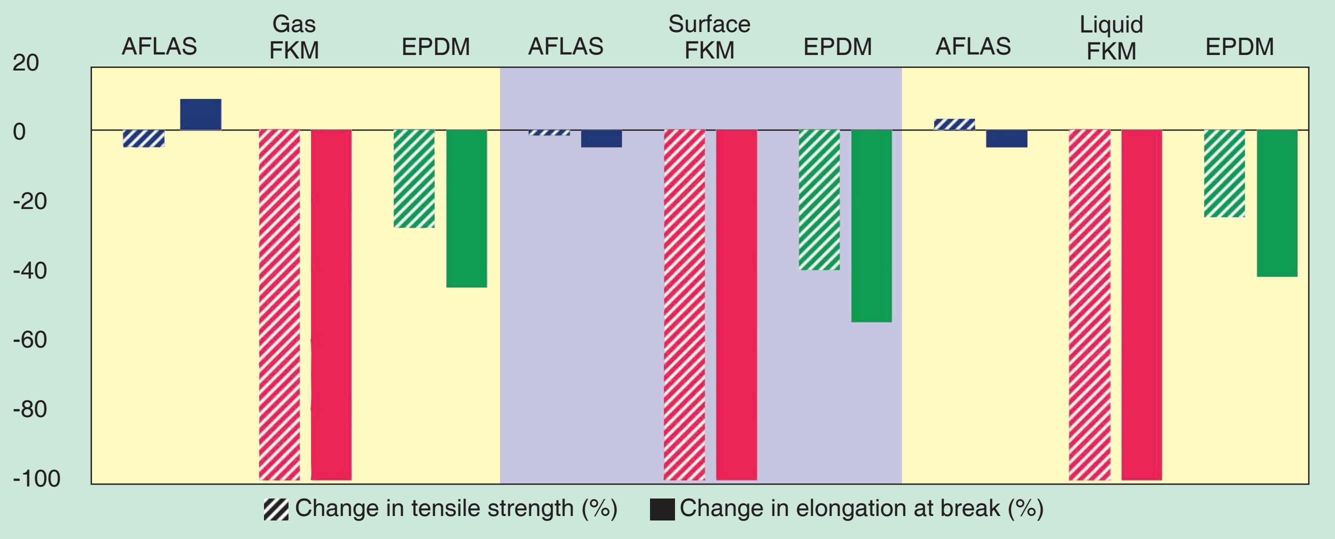
Resistance to ammonia

Because of recent scrutiny into NO_x emissions from diesel-powered vehicles, selective catalytic reduction (SCR) is used more often in the exhaust systems of cars and commercial vehicles. SCR uses diesel exhaust fluid marketed as AdBlue, which is a mixture of water and urea, and is therefore more alkaline than other fluids used in the automotive industry. The combination of high temperatures and high pH can cause problems for some materials, but FEPM fluoroelastomer grades can withstand these conditions. Because of FEPM's excellent barrier properties, they also protect other materials in multilayer constructions.

Similar to the coolant test, the FEPM fluoroelastomer was tested alongside an FKM and EPDM in an ammonia solution. In all cases, the FEPM showed less than 10% change in TS and E2B.

The FKM samples deteriorated and could not be tested. The EPDM showed drops of 28%, 40% and 25% in TS in the gas,

Figure 7 - performance in AdBlue



surface and liquid phases, respectively, and 45%, 55% and 42% drops, respectively, in E2B (figure 7).

Resistance to other media

Besides having excellent resistance to oils and coolants, FEPMs resist other liquids like AdBlue, an ideal common component for many automotive applications that require high-temperature performance and long part life.

FEPM can provide a host of benefits in challenging environments across a number of industrial and commercial applications. New grades allow multilayered systems using FEPM as the principal functional layer, and other materials for structural integrity and flexibility (table 1).

Table 1 - FEPM performance in fluids and steam

	Temperature °C	*FEPM*	*FKM*
Engine oils	150	Excellent	Not recommended
Aged engine oils	175	Excellent	Failed
AT fluids	160	Excellent	Not recommended
Gear oils	135	Excellent	Failed
Brake fluids	135	Good	Good
Coolants 50% LLC	160	Excellent	Not recommended
Sulfuric acid	100	Excellent	Failed
Hot steam	180	Excellent	Failed

References

1. Cure determined by RPA at 170°C, 12 minutes, 100 rpm, 3°.
2. Peel test at 180° at STP and at 150°C to ISO 36:1993.
3. ISO 17324:2014, Rubber Hoses for Automotive Turbochargers specification.
4. Castrol Magnatec API-SN ILSAC GF-5.
5. Castrol Edge API-SN CF Performance ACEA A3/B3 A3/B4.