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High Performance Stabilization Systems for PP and PP-Based TPO Automotive Applications

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How can the long-term thermal stabilization (LTTS) of polypropylene be improved so that it meets new, more demanding standards?

Polyolefins, in particular polypropylene (PP), are intrinsically not stable enough to withstand chemical attack by oxygen and consequently they degrade. Antioxidants were developed in the 1960s and 1970s during the industrialization of PP.

The most suitable stabilization chemicals are sterically hindered phenols, which work very efficiently at temperatures varying from low (solid state PP) to very high (300°C – molten state PP).

Current strategies for long-term thermal stability (LTTS)

The principle advantages of sterically hindered phenols are:

- Strong molecular weight protection during melt conversion
- High efficacy at low concentration

Their main drawbacks are:

- A strong tendency to discoloration
- Very limited improvement of LTTS
- Limited solubility and permanence in the substrate

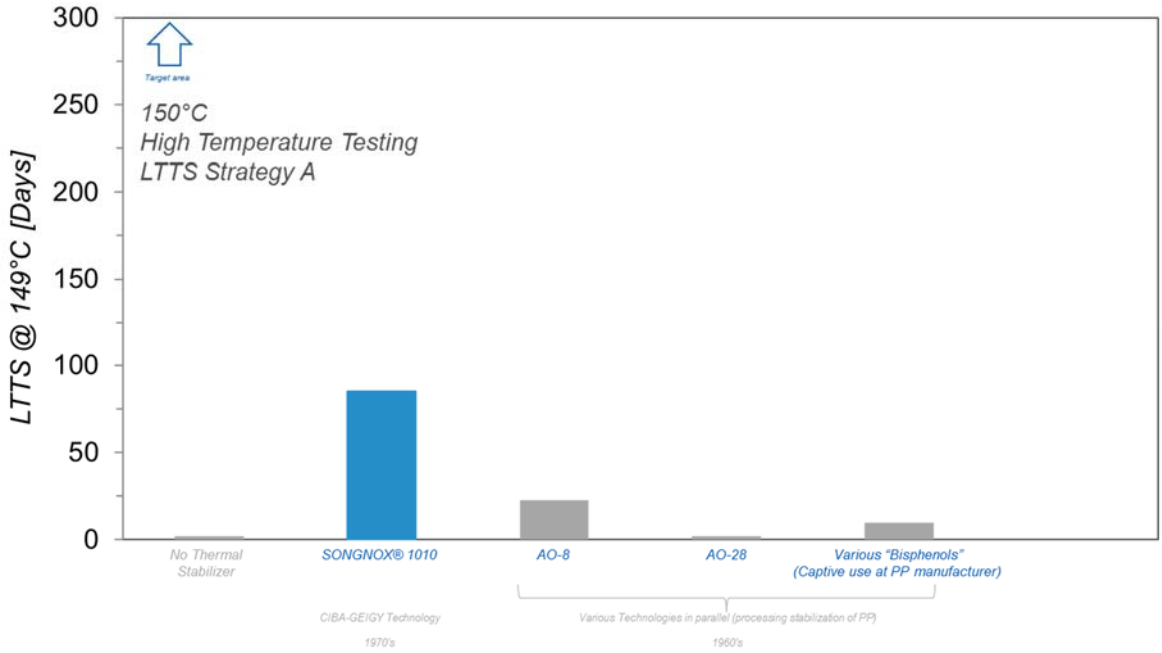

Figure 1: Maximum LTTS achievable with various early hindered phenols
Substrate: PP homopolymer (bulk polymerization)
Sample: 1 mm compression molded plaques
Exposure: 149°C in air
Stabilization: 1000 ppm Ca-stearate + *5000 ppm thermal stabilizer*
Pigmentation: unpigmented

The introduction of SONGNOX® 1010 (under the tradename IRGANOX® 1010) by CIBA-GEIGY in the 1970s moved the antioxidant class of hindered phenols from low to fairly high molecular weights, which are favored for applications requiring FDA approval, minimal discoloration, and long service life at high temperatures. SONGNOX® 1010 was the first antioxidant for PP that could be regarded as a thermal

stabilizer rather than just a processing stabilizer. This product remains the first-choice antioxidant for PP because it provides adequate to good LTTS, combined with acceptable processing stabilization.

The principal advantages of SONGNOX® 1010 in PP are:
- Strong concentration dependence at low concentration
- High efficacy at low concentration
- Good solubility and permanence (in PP homopolymers)

Its principle drawbacks are:
- Some tendency to discoloration in non-pigmented substrates
- Saturation effect already visible at about 2500 ppm

CIBA-GEIGY further enhanced LTTS in the 1970s through the addition of synergistic aliphatic sulfur compounds such as SONGNOX® DSTDP (marketed as IRGANOX® PS 802). A combination of SONGNOX® 1010 and SONGNOX® DSTDP, applied at a ratio of 25:75, nearly doubles the performance of SONGNOX® 1010 on its own, and is today commonly regarded as the LTTS industry standard. As a result of the excellent balance between cost and performance achieved by the combination, the LTTS stabilization strategy for thick section PP at 150°C has not been modified for the last 40 years.

An alternative school of thought

In 2010 a new synergistic mixture based on a different approach was developed and introduced to the market. SONGXTEND® 2124, which was launched in 2016, nearly triples the LTTS effect of SONGNOX® 1010 and today yields by far the best LTTS in the industry.

Its principal advantages are:
- Improvement of LTTS beyond the industry standard, SONGNOX® 1010 + SONGNOX® DSTDP
- Effect approximately tripled
- Outstanding LTTS of PP glass fiber

Its principle drawbacks are:
- Potential organoleptic issues

The single most important benefit of this alternative approach is outstanding LTTS. While SONGXTEND® 2124 shows similar adverse interaction with fillers and sizing agents to the industry standard, and hence a similar relative decrease in LTTS performance, it still yields a good absolute LTTS performance because it benefits from an outstandingly high “starting point”. Like SONGNOX® 1010 + SONGNOX® DSTDP, it is subject to organoleptic issues, making it unsuitable for drinking water applications.

An initial attempt to improve LTTS without the drawback of organoleptic issues resulted in a performance increase of about 30% (SONGXTEND® 2123). This is considered not yet sufficient and further development is underway.

New developments in the pipeline

The significant technical success and subsequent dominant position of SONGNOX® 1010 led to the idea that it is the primary choice in all cases. However, a new system (see Figure 2) approximately triples the performance of the industry standard [SONGNOX® 1010 + SONGNOX® DSTDP] [25:75] at low temperature testing (80°C).

Its principal advantages are:

- Extension of LTTS effect beyond the industry standard [SONGNOX® 1010 + SONGNOX® DSTDP]
- Effect approximately tripled
- Greatly improved organoleptic properties
- Low amount of VOC (Volatile Organic Compounds)

The performance of the new system is currently being tested.

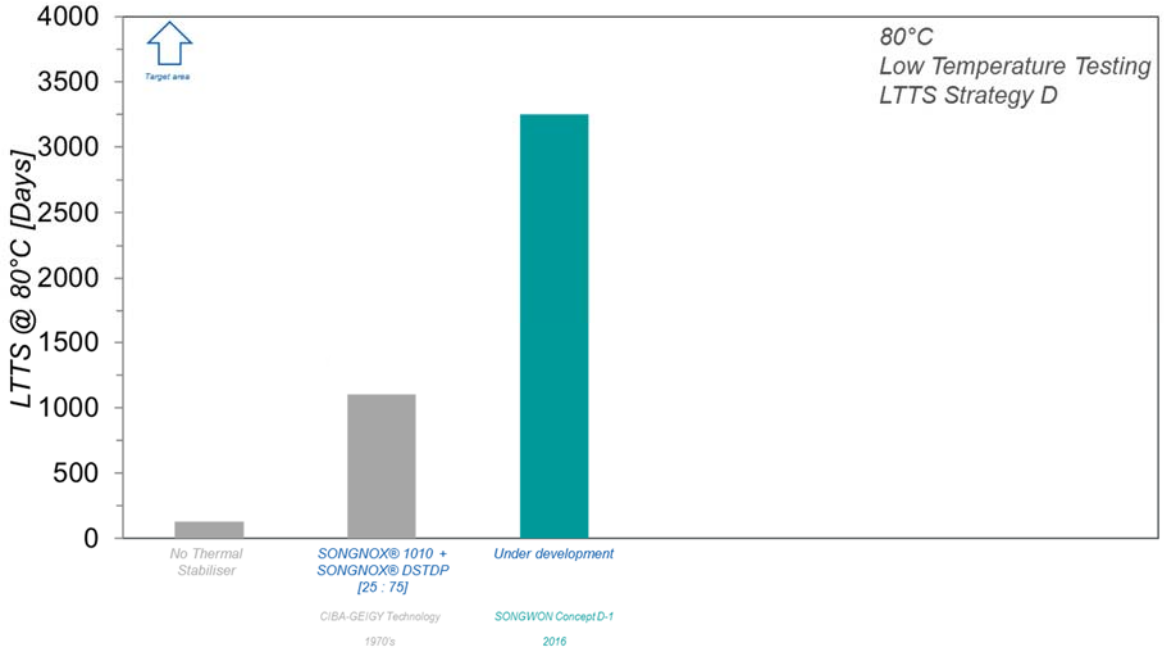

Figure 2: Maximum LTTS achievable with new LTTS strategy
Substrate: PP homopolymer
Sample: 1 mm compression molded plaques
Exposure: 80°C in air
Stabilization: 5000 ppm Ca-stearate + 1000 ppm AO-28 + *1000 ppm thermal stabilizer as indicated*
Pigmentation: unpigmented

Conclusions

Numerous LTTS requirements can be covered by either SONGNOX® 1010 alone or by a combination of SONGNOX® 1010 + SONGNOX® DSTDP. Significantly improved solutions have in the meantime been developed for demanding applications and work is ongoing.

For more information and advice, please contact techservice@songwon.com.