Modern passenger car tires are equipped with steel belts, which are placed above the carcass of the tire and beneath the tread compound. Cap-ply or belt-ply reinforcements are used to position the steel belts and to restrict tire growth during driving caused by centrifugal forces on the steel belts. Polyamide 6.6 tire cords can be used here in the majority of passenger car tires.

In recent years, cap-ply reinforcements have become stiffer, applied in ultra-high-performance tires. Hybrid cords consisting of polyamide 6.6 yarns and aramid yarns have been designed for this application: polyamide components enable the required expansion during tire manufacturing; the aramid components provide the required high stiffness for extreme driving conditions. However, these stiff cap-ply reinforcements contribute to elevated rolling noise – externally and internally¹.

Reduction of rolling noise is increasing in importance for modern cars and especially for cars with electronic drive. Therefore, development of passenger car tires is focused not only on the reduction of rolling resistance, but also on reduction of rolling noise.

The former demand can be met by developing lighter tires with the application of improved raw materials. In the cap-ply (tread area), this can be achieved through material reduction of rubber and cap-ply reinforcement. Less rubber, however, means less damping, which means contribution of cap-ply reinforcement in noise reduction becomes more significant.

Cap-ply reinforcements based on polyamide 6.6 cords can provide reduced rolling noise in a wide range of tires as they are less stiff than aramid-based hybrid reinforcements. However, what can be done if the tire has to be designed for more demanding driving at elevated tire temperatures?

A suitable cap-ply reinforcement should have the same advantageous characteristics of polyamide 6.6 reinforcements and be able to keep or even improve its dimensional stability throughout all driving conditions of the tire.

For this requirement, Stanylenka – polyamide 4.6-based – cap-ply tire yarns should be considered. Stanylenka yarn properties are similar to those of polyamide 6.6 yarn when tensile properties are compared at room temperatures. They provide a moderate initial modulus, necessary for the tire vulcanization process, and good tenacity increase at higher elongations (Figure 1).

Stanylenka yarn has been proven to provide reliable adhesion to rubber and good fatigue resistance when used as a reinforcement material in mechanical rubber goods. The advantages of the material over polyamide 6.6 yarns become clear when the yarn properties at elevated temperatures are compared. The Stanylenka yarn has a high level of tenacity; it decays less at elevated temperatures. This becomes evident when tensile properties of technical polyamide 6.6 and 4.6 yarns are compared at 20°C and at 150°C (Figure 1).

The determination of creep elongation at a given force reveals another benefit of polyamide...
4.6 yarns (Figure 2). Compared with polyamide 6.6 at 20°C, the creep elongation is 10% less, and under hot conditions, 23% less.

Another advantage of dimensional stability can be observed under dynamic test conditions. The storage modulus of polyamide 4.6 decays less at increasing temperatures, i.e. only 24% decay of polyamide 4.6, but 38% decay of polyamide 6.6, for temperatures ranging from 50°C to 150°C (Figure 3).

For good tire performance, cap-ply reinforcements have to be pretreated prior to tire manufacturing. This means twisting the yarns into cords and coating with an adhesion promoter. Today, coatings of resorcinol-formaldehyde resin and latex are applied. During these manufacturing steps, the cords are adjusted by hot stretching in order to provide the required modulus and contraction ability, i.e. hot air shrinkage. The latter is necessary to attach the steel belts to the carcass firmly while the tire is vulcanized. In addition, contraction or self-tensioning ability is required during driving, when heat is generated in the tire. This results in softening of the thermoplastic reinforcement on the one hand. On the other hand, cap-ply reinforcement should provide repeatable contraction ability that counteracts the softening and centrifugal forces. For polyamide 6.6-based cap-plies this works sufficiently, but there is room for improvement. Figures 4 and 5 show the results of the stress relaxation test. Dipped tire cords based on polyamide 6.6 and 4.6 were initially pre-tensioned (56mN/tex) – simulating the tire lift after vulcanization. Then the cords were fixed and subjected to heating and cooling cycles – simulating the heat generation cycle during driving and the cooling phase during parking. Tensions resulting from this treatment were recorded at the end of a second heating and cooling cycle (Figure 4).

The diagram in Figure 5 shows for polyamide 6.6 cord during the heating cycle, a tension decay, while polyamide 4.6 exceeds the initial pre-tension. After cooling, the polyamide 4.6 cord is still close to initial pre-tension whereas polyamide 6.6 cord decays even further. This strength of polyamide 4.6 cords is already relied upon in elastic transmission belts. Here, this self-tensioning of polyamide 4.6 enables these belts to be driven without extra tensioners.

The aforementioned comparisons show that Stanylenka polyamide 4.6 yarns/cords clearly offer better dimensional stability. As a cap-ply reinforcement, the steel belt would be kept under tension as it shows less creep relaxation. During driving, the cap-ply immediately aids in restricting the tire diameter increase caused by centrifugal forces. At elevated tire temperature, this will be maintained. For tires reinforced with Stanylenka cap-ply reinforcement, this means enhanced driving performance and simultaneously good rolling noise properties.

PHP Fibers is one of the leading suppliers of high-performance yarns in the automobile sector. The company’s high-quality industrial polyamide and polyester filament yarns, produced at its manufacturing locations in Europe, the USA and China, are used in a variety of areas such as airbags, safety belts, reinforcements in tire design, or even in transmission belts and hoses. The portfolio also includes special types for other challenging technical areas of application such as roofing and sealing membranes, or textile construction. The brand names Diolen (PET), Enka Nylon (PA 6.6), Enkolon (PA 6) and Stanylenka (PA 4.6) are known worldwide. tire

References

1) Molecule to the Road: Integration to system level characterization, Jonathan Darab, National Tire Research Center, Tire Technology Expo 2015