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Current Inorganic Fibers for Tires: Steel

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Synopsis

An outline covering the evolution of the more popular tire-reinforcing materials from 1960 to 1970 is presented. Technical and economic factors pro/con steel tire cord for that period are reviewed. Using the past period as a base, the present and future prospects for steel tire cord are analyzed. Comments on the present properties of steel tire cord in relationship to tire requirements are given. In addition, desirable and expected product improvements are covered with special emphasis on achievable product development.

EVOLUTION OF THE TIRE-REINFORCING MATERIAL MARKETS

Europe

As we notice from Figure 1, rayon and steel were the most popular tire-reinforcing materials in Europe during the sixties. With regard to steel, its popularity was mainly due to the success of the highly qualified Michelin steel-belted radial tires.

Indeed, until 1967 at least 85% of the total steel tire cord used in tires was consumed by Michelin. The most important obstacles restraining other European tire manufacturers from switching their tire production to steel radials were: the Michelin patents, which were very difficult to circumvent; adhesion problems, which obliged tire manufacturers to delay their investment programs for steel belted radials.

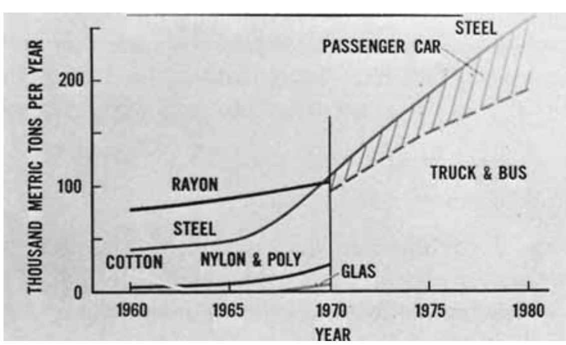

Fig. 1. Tire cord usage in Europe.

Owing to the expiration of the Michelin patents in 1967 and the improved quality of steel tire cord (which solved to a large extent the adhesion problems), a genuine explosion of steel tire cord consumption occurred in Europe.

In 1970, the market share of steel was estimated at 35% in the passenger tire sector and 54% in the truck and bus tire sector, and is expected to increase by 1980 to 51% for the passenger tire sector and 75% for the truck and bus tire sector.

Nylon and polyester have not made large inroads into the European tire cord market as yet, and the use of glass fiber is negligible.

U.S.A.

The evolution during the sixties of the U.S.A. tire-reinforcing market differs in many respects from the European market. The growth rate of nylon, polyester, and, during the last three years, of glass fiber has been quite remarkable, all to the detriment of rayon (Fig. 2).

Although steel has been consumed during the entire decade, it did not leave the experimental stage. Some reasons were adhesion problems resulting in tire failure; lack of interest by the tire manufacturers in investing in radial tire equipment; lack of promotion of the steel radial tire in the U.S.A.; and absence of a domestic supplier of steel tire cord.

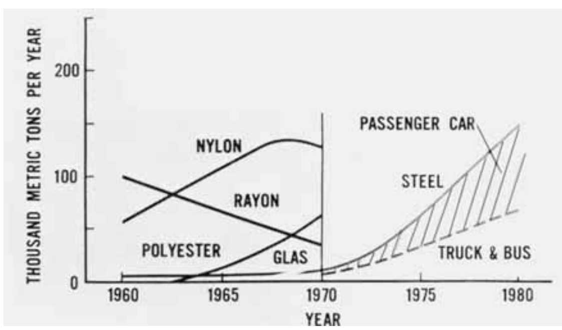

Fig. 2. Tire cord usage in United States.

Somewhat recently, this situation has changed, and steel is expected to become the leading tire-reinforcing material by 1980 with an estimated penetration of 50% in passenger tire sector and 32% in truck and bus tire sector.

Japan

The Japanese tire-reinforcing market reflects the considerable growth rate of the Japanese tire sector during the last decade (Fig. 3).

The main characteristic is the predominant position of only one reinforcing material. During the early sixties it was rayon; since 1965, nylon has taken over the leading position.

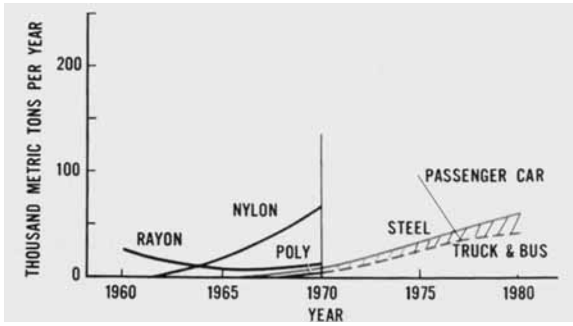

Fig. 3. Tire cord usage in Japan.

Only a few years ago, steel made its appearance at an industrial scale, and it is most likely to become the tire-reinforcing material of the later seventies. Steel penetration by 1980 is estimated at 38% in passenger tires and 56% in truck and bus tires. Even though we did not mention the off-the-road tire sector when commenting above on the tire-reinforcing markets, the breakthrough of steel in this sector may soon be expected.

The really bright future for steel as a reinforcing material for tires is attributed to the superior characteristics of steel tire cord. In the second part of this presentation, we will deal with the steel tire cord assets which will make those bright prospects come true.

FUTURE DEVELOPMENTS AND IMPROVEMENTS IN STEEL TIRE CORD PROPERTIES

Since you are sufficiently familiar with steel tire cord properties, we will confine ourselves to discussion of the improvements and new developments which can be anticipated in the years to come.

Tensile Strength

Of all the fibers used for tire reinforcement, steel tire cord has the highest tensile strength/volume ratio. Since tensile strength is obtained by a cold-drawing process, it can be adapted to the requirements of each specific application. However, this does not imply that there is no tensile strength limit for a given grade of steel quality. In fact, if the degree of cold drawing becomes too high, tensile strength will continue to increase slightly, but the material will become so brittle it will lose all the dynamic properties.

It is our experience that the limit of a high tensile strength combined with excellent fatigue properties is obtained by the manufacturing techniques presently used. However, for particular applications, there will always be a demand for higher tensile strengths, e.g., for the carcass reinforcement of heavy tires (off-the-road tires, etc.).

By applying special manufacturing techniques, it will soon become possible to reach tensile strengths exceeding by 20% and more the present tensile strengths and still maintain the present fatigue resistance.

Fatigue Resistance

The fatigue resistance of the present steel tire cord generation is approximately one third of its tensile strength. Considering the tensile strength of steel reaches such high values, it is quite obvious that steel tire cord, under certain alternating stress, will not be affected by any fatigue phenomena, whereas other fibers under that same stress, only statically applied, already lead to fractures.

Typical fatigue phenomena rarely occur in a well-developed steel cord tire. In certain cases, steel tire cord composed of heavier filaments is used in order to reduce costs and/or to obtain a higher compression resistance. The bending stress occurring in the wire's surface increases by increasing wire diameter for the same curvature radius. Fatigue resistance increase of steel tire cord will enable us to use thicker filaments in specific cases even though it may not be really needed.

Fretting Fatigue

If no fatigue phenomena show up in well-developed tires, even after a long operating time, another phenomenon, also occurring with textile fibers, can and does occur. This is called fretting fatigue. Under dynamic stress, the cord fibers or filaments continuously come into contact with each other. These repeated contacts cause scarfs on the surface of the fibers or filaments, leading to fracture of the fiber after a relatively long period. These fractures give rise to a cascade effect; the unimpaired fibers will fracture sooner than usual because they are now put under a heavier stress and thus subjected to higher fretting.

Of course, steel tire cord filaments are less subject to this phenomenon than textile fibers, because their diameters are considerably larger and the scarfs which may occur on the surface are less important compared to the overall wire cross section.

Nevertheless, it is important to decrease this fretting fatigue or to avoid it in case of tires that have to be retreaded several times. Experiments revealed that fretting fatigue in steel tire cord can largely be avoided by using the "open cord" concept. Based on this concept, the cords are manufactured in such a way that the strands tend to deviate from each other in a radial direction. Consequently, a more or less complete rubber penetration is possible when calendaring. This rubber penetration not only provides a larger surface for cord penetration, but it also tends to prevent any contact between two adjacent strands.

It is clear that the tire manufacturer can make a useful contribution toward the pursuit of this objective by supplying rubber compounds and/or by using manufacturing techniques favoring the penetration of the cord.

We believe that the application of this "open cord" type will be a valuable contribution, since it can result in a tire reinforcement that will lose none of the original characteristics, even after several retreadings.

Adhesion

Adhesion to rubber is an extremely important property for any tire reinforcement material. Originally, steel tire cord was at a disadvantage vis-a-vis textile fibers, because it has a high modulus and a relatively small surface in contact with rubber, due to the somewhat thick filaments.

This disadvantage was solved by using a brass coating that adheres directly to rubber without the use of adhesive dips. For the future, we do not believe brass coatings will be superseded by other coatings assuming rubber compounds remain approximately the same.

Regarding steel tire cord, better control of the alloy elements in the coating and especially a transition to considerably thinner coatings are a prospect for the near future. This will not only increase the average adhesion capacity, but also increase the adhesion uniformity.

Cord Constructions

There is a clear tendency toward narrowing the wire diameter range. The steel tire cord diameter range formerly varied between 0.15 and 0.38 mm; it now tends to vary between 0.175 and 0.25 mm.

The cord constructions to be used in the future cannot be easily forecast, especially for the American market. Based on the evolution in Europe, we do not expect any spectacular changes. For technical and economic reasons, we believe it is not justified to maintain the present wide range of available cord constructions. This must, of course, be done in conjunction with the tire manufacturers bearing in mind the various programs and specific application.

Because of their low cost and excellent properties, strand constructions will be used wherever possible ($3 \times 1, 4 \times 1, 5 \times 1, 2 + 7$). A potentially standard cord construction for truck tires is 7×4.

In Europe, opinions also differ on the use of a spiral wrap. The advantages of this spiral wrap are not in doubt; however, the cost is higher. We believe that spiral-wrapped steel tire cord will remain popular and likely increase in market percentage. Manufacturing methods must be improved to reduce the price differential between wrapped and nonwrapped. We are well on the way in this direction within the framework of our improved technology.

High-Elongation Cord

The small elongation of steel tire cord under tension load is one of its many valuable properties. Whereas the normal steel tire cord quality has an elongation at fracture of approximately 2%, steel cord quality with elongation of 5% to 20% and more can be obtained by means of the combination of a short lay length and special manufacturing techniques.

High-elongation cords can be used for certain applications in which a gradual decrease of stress between low-modulus rubber and high-modulus steel tire cord is the objective. As these cords are relatively expensive, they should only be used in cases where an optimal use of their special properties is required. We do see an increased use of high elongation cord within this context.

Woven Cord

A newcomer in the wide range of steel tire cord products is woven cord. For a long while we have felt that there was a latent need for steel cord fabric. More specifically, the need becomes urgent in those cases where customers still hesitated to switch to steel tire cord as presently supplied owing to lack of creel space, insufficient cord consumption, and capital outlay.

Recently, we developed our operational steel tire cord fabric, which we intend to supply in the desired cord constructions and width thereby putting a creel decision on another basis.

CONCLUSIONS

The steel tire cord generation of the seventies will have a higher tensile strength for specific end uses, have increased fatigue resistance, eliminate fretting fatigue through the increased application of the "open cord" concept, and have a higher adhesion to rubber value.

We are constantly striving to modernize our manufacturing techniques to enable us to continue looking with confidence toward the future success of steel cord as a reinforcement material for tires, as shown by the foregoing curves.