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Physical phenomena and chemical reactions: the production of a conveyor belt

Technological development is always associated with exact sciences such as chemistry and physics, thanks to which it is possible to understand the processes taking place in the world around us. These two disciplines interpenetrate each other, and in fact in many cases it is difficult to determine precisely where the first ends and the other begins. The deeper the understanding of the phenomena and laws governing chemistry becomes, the closer it comes to new achievements of the world of physics. Only the implementation of knowledge from both fields allows the continuous improvement of products used in belt transport.

Key words: *conveyor transport, conveyor belt, rubber*

1. INTRODUCTION

Belt transport, due to its simple operation, extremely high efficiency of load transfer and flexibility of working parameters, is widely used in numerous sectors of the economy such as: mining, coke, metallurgy, power sector, as well as in the chemical industry and the branches of construction and agriculture. With increasing importance of belt conveyors as the main elements of transport systems, the requirements for durability, safety of use and energy consumption are increasing. With the development of new technologies, materials engineering and computer techniques, improvements are constantly introduced in order to improve the service and to increase the reliability and efficiency of those transport systems.

2. BELT AS A COMPONENT OF THE CONVEYOR

The conveyor belt constitutes the main supporting element of the belt conveyor. The process of its production is a multi-stage task using a specialized machinery park which includes such devices, like looms, mixers, rolling mills, calenders or vulcanizing presses. Currently, technical progress related to the improvement of belts is focused on transferring ever greater loads and overcoming even more extreme operating conditions, such as the high temperature of the transferred material or chemically aggressive working environment of the conveyor. Such material requirements can be satisfied by a group of polymer-textile composites with specially selected properties, and first of all, appropriately composed rubber mixtures, together with compounds from the group of polyesters and polyamides that make up a conveyor belt. Fiber-reinforced composites dominate the market for their best mechanical and strength properties, with a minimal weight. maintained.

The basic and overriding functions of a conveyor belt are supporting and moving the material along the conveyor route, as well as transmitting the highest possible tensile force that occurs during the start-up and the set operation of a conveyor. The component directly responsible for the above tasks is a textile-rubber core, which transfers longitudinal and transverse loads and gives the entire belt a sufficient stiffness value necessary to support the material handled.

The core is covered with rubber covers at the top and bottom, and on the side with rims. Additionally, in order to protect it against punctures and cuts, a protective spacer may be used which also increases the transverse stiffness of the belt and protects against overheating. The core is the crucial component of the tape which determines its quality and durability. Aware of this fact, the Conveyor Belt Factory introduced a system in its production line that controls the process of packaging belts in a calender, which enables a contactless and continuous recording, control and archiving of the most important parameters of the calendering process, thus facilitating process control. The installed measuring system, by using the interference phenomenon, allows for high accuracy of the results and eliminating the possibility of committing a human error, which could have occurred with the previously used contact measurement – viz. manual [1, 2]. Currently, textile and steel cores are most often used. The structure of mining conveyor belts is shown in Figure 1.

Depending on the place of use, certain physical and mechanical parameters and appropriate properties are expected from a conveyor belt. In addition to the tensile strength mentioned above, these are: a low modulus of elasticity, impact resistance, resistance to cutting and puncture, abrasion resistance, self-cleaning properties, oil resistance, antistatic properties, low rolling resistance and many others. Considering very difficult conditions of operation the belt usually has to cope with, such as an ubiquitous effect of often undesirable friction, large temperature fluctuations reaching in extreme cases –60°C or +40°C, high humidity or aggressive wear of the material handled, rubber technologists and designers of belt conveyors will face a real challenge. The satisfaction of all the requirements for conveyor belts entails that during the production process there should be the close cooperation and exchange of knowledge between experts in the field of textile industry, chemical technologists and scientific and research units [3].

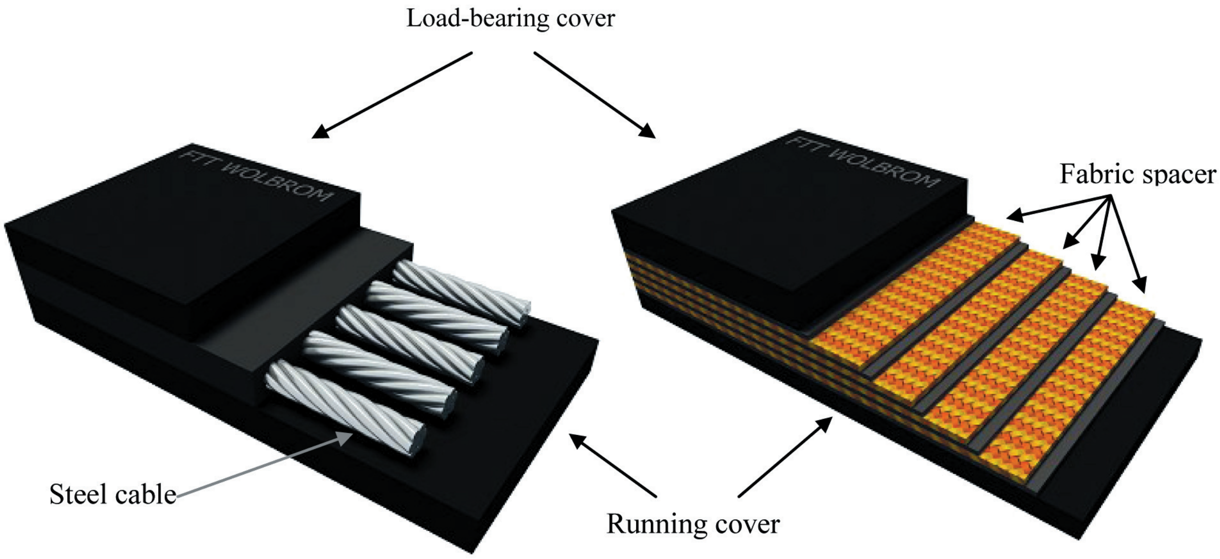

Fig. 1. Conveyor belt with steel cords and fabric-rubber conveyor belt

3. BELT COMPONENTS – MANUFACTURE

The mechanical strength of the core in the case of fabric-rubber tapes is ensured by appropriately selected fabric spacers. The physical and chemical properties of the fibers that make up the fabric and the rubber covering it complement each other, creating a composite with features that are the resultant of the strengths of both the components. The most popular type of reinforcement of conveyor belts are fabric spacers using polyamide and polyester yarns in various configurations. The fabric consists of a system of longitudinal threads called warp and transverse fibers called weft, the simplest example of which is shown in Figure 2. Polyester-polyamide fabrics – in order to increase their adhesion to rubber – should be covered with an appropriate impregnant that activates the fiber surfaces and constitutes a transition layer, appropriate for adhesion of rubber mixtures. At the same time, the fabric leaving a loom has a load of stresses accumulated in the processes that create it – from yarn twisting through weaving with maintaining an appropriate warp tension. Those stresses must be removed from the fabric prior to the core construction phase of the belt so that they do not adversely affect belt properties like elongation under load with subsequent dimensional stability. Both of the above problems are solved in one combined process of impregnation and thermal stabilization. FTT Wolbrom, taking into consideration a continuous improvement of its products and the repeatability of the process, launched a modern technological line, where during one pass the fabric is saturated with a solution increasing adhesion to rubber, the excess solution is removed, and then, with appropriate tension, the fabric is thermally stabilized. The semi-finished product – which is the result of the above process – is ready for use in further stages of the conveyor belt production process, and due to an automated station for the preparation of the impregnating solution and continuous control of the parameters of the impregnation and stabilization process, we are sure of the highest quality at every meter of the fabric [4, 5].

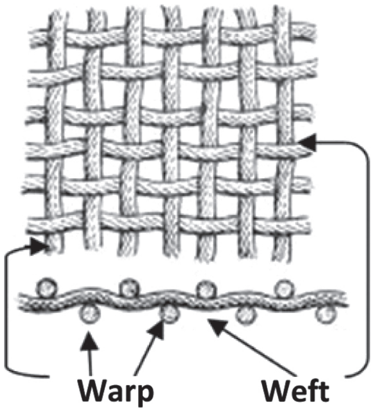

Fig. 2. A fabric with a plain weave

Rubber is a complex system consisting of many different compounds. The basic components of rubber mixtures are synthetic and natural caoutchoucs, and their selection determines the basis of the physical and mechanical properties of the finished rubber products. From the technological point of view, the most important rubbers used in production are diene caoutchoucs, i.e. those containing unsaturated bonds in their structure. They include: polybutadiene, acrylonitrile-butadiene caoutchoucs and chloroprene caoutchouc, whose chemical structure s shown in Figure 3b. They rank among a group of elastomers, i.e. polymeric materials, characterized by the ability to almost immediately return almost immediately to their original form after considerable deformation at ambient temperature.

From the chemical point of view, caoutchoucs are macromolecular compounds with long chains made up of periodically repeating blocks containing unsaturated bonds. It is the structure of those repeating blocks – monomers which determines the basic chemical properties of the final product, viz. the cover of the conveyor belt. Depending on the conditions of use and requirements for the products, the appropriate type of caoutchoucs is used, for example, products resistant to oils and gasoline contain acrylonitrile or chloroprene butadiene caoutchouc, while materials with increased strength properties include styrene-butadiene caoutchoucs. For example, natural cis rubber – polyisoprene and chloroprene caoutchoucs have the following structure (Fig. 3).

An appropriate caoutchouc is only the basis for a rubber mixture; only due to mixing it with a group of additives will the ready rubber meet all the requirements set for it. In order to obtain the expected material, some compounds must be added to improve the properties and processing capacity, e.g. carbon black, vulcanizing substances, plasticizers, anti-aging agents, vulcanizing activators, accelerators and many others. An appropriate qualitative and quantitative composition, as well as a properly selected technological regime, will allow one to obtain a mixture with the parameters expected [6–8].

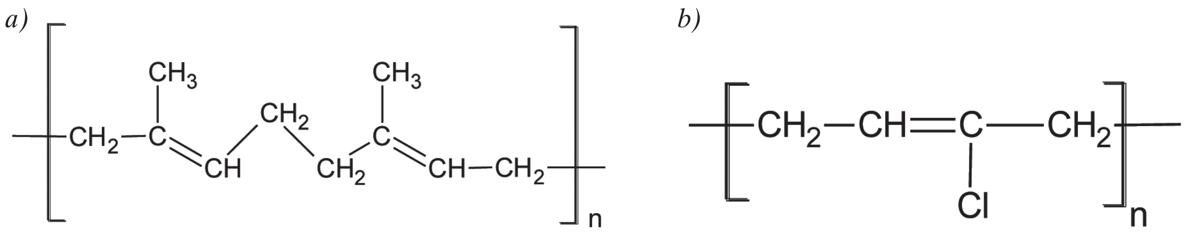

Fig. 3. Structure of rubber monomers: a) natural cis-polyisoprene caoutchouc; b) synthetic chloroprene caoutchoucs

FTT Wolbrom, by investing in the development and meeting the market requirements, purchased a modern laboratory mixer, shown in Figure 4, which is an excellent tool for conducting the process of designing and modifying rubber compounds – since it significantly facilitates and accelerates it, which is in compliance with the newly launched compound production line. The use of a laboratory mixer allows a micro-scale representation of the process of mixing individual components of the mixture, and then setting the appropriate parameters for the production mixer, thus ensuring an optimal dispersion of supplementary ingredients in the caoutchouc matrix, simultaneously bearing in mind the economic aspects of the device's operation.

Fig. 4. Laboratory mixer

The most important and simultaneously last stage of conveyor belt production is its vulcanization. It seems to be an uncomplicated process which in simple terms consists in heating up a raw rubber mixture under an appropriate pressure for a certain period of time. The abovesaid description only defines the conditions of the appropriate course of chemical reactions taking place in the previously prepared rubber mixture. Multiple bonds –C = C– present in the chains of the caoutchoucs used in conjunction with sulphur added to the mixture will enable – due to a chemical reaction – a transformation of one-dimensional molecules into a three-dimensional lattice, as shown in Figure 5. Depending on the type of three-dimensional caoutchoucs used, sulphur, which is a cross-linking agent, can be replaced by another compound, e.g. organic peroxides or diazo compounds containing a free group –N = N – in their structure. Cross-linking itself is subject to the same laws as all chemical reactions. The subsequent properties of the vulcanizate will depend on the level of dispersion of the cross-linker complex and its supporting catalysts, as well as its quantitative ratio to the amount of free bonds. 1.5–3.5% sulphur vulcanized rubber has a similar flexibility as the starting polymer. During the vulcanization process, particles of the fillers and other additives used are enclosed in the resulting structure, improving such properties as abrasion or resistance to high temperatures. Thanks to the application of proven recipes, a modern line for preparing compounds and vulcanization presses that allow controlling all process parameters, obtained is a rubber product that meets even the most demanding requirements of customers from around the world [9].

The production process of fabric-rubber conveyor belts includes several unit processes presented in the diagram above which are schematically presented in this article. As the oldest manufacturer of rubber products in Poland, we have both the staff and know-how to guarantee the full control and repeatability of the production stages, thanks to which the product offered is of the highest quality [10].

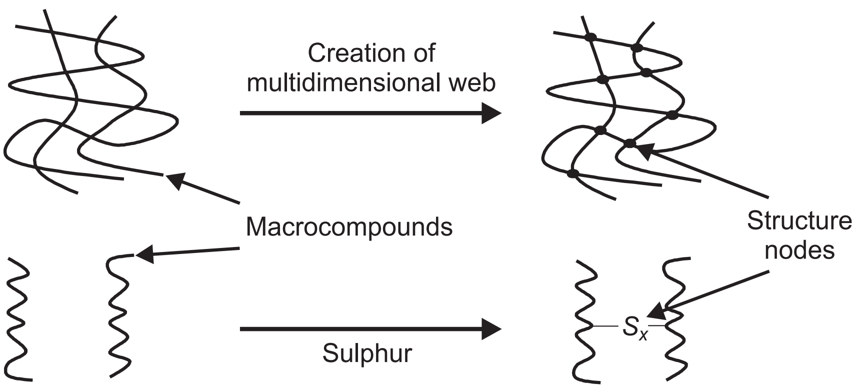

Fig. 5. Simplified course of the vulcanization process

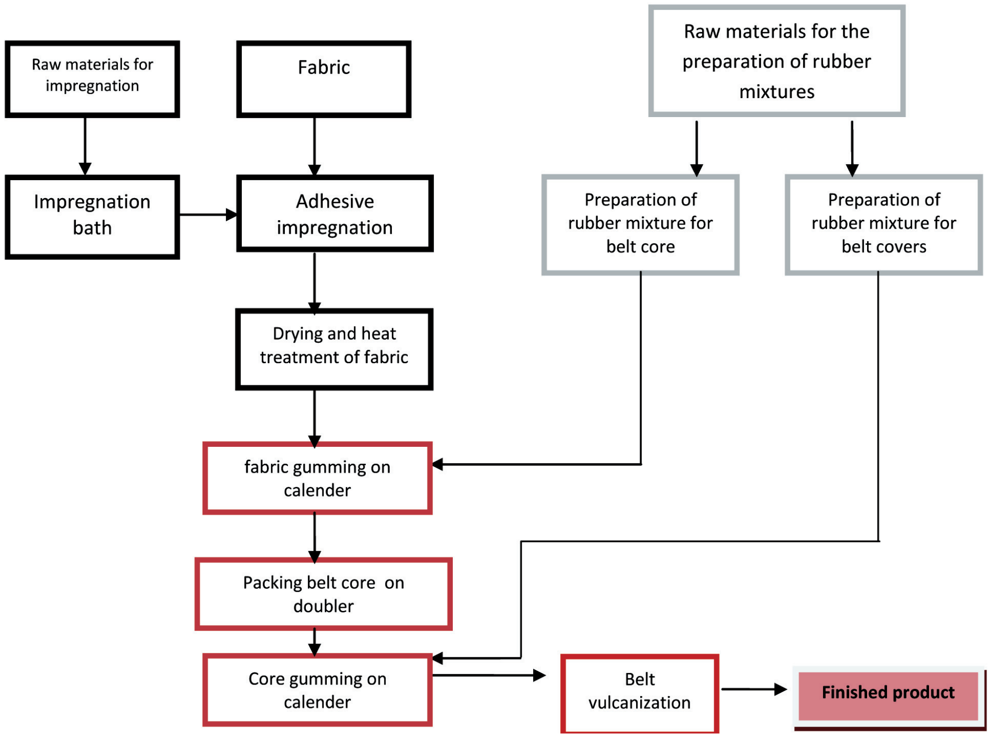

Fig. 6. A simplified diagram of the production process of a conveyor belt with a textile core

4. SUMMARY

To sum up, it should be stated that the chemical reactions occurring, for example, in the vulcanization of a raw rubber mixture, are intertwined with physical phenomena such as mixing in a mixer or calendaring. The application of exact sciences, led by chemistry, physics and mathematics, provides both theoretical and experimental resources for the improvement of products and manufacturing processes in all branches of industry. Our products, especially conveyor belts, are also exposed to physical and chemical phenomena during operation. Most of them are desirable and but for their presence our products can fulfil their functions and meet the requirements such as resistance to high peak temperatures up to 280°C or fabrics with a strength of up to 700 N/mm. The remaining destructive portion, which causes accelerated destruction, is kept to a minimum. The goal that always guides our actions is to utilize the known physical phenomena and chemical processes in such a way that we can confidently say that both chemistry and physics are our allies.

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