Polyamide 6. The right raw material for ropes: its production and technical characteristics

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Introduction.

After a tremendous growth of the production of rayon during the twenties of the last century it was the scientific work of the German chemist Hermann Staudinger which opened the door to macromolecules and finally the development of new synthetic yarns and fibres. 1931 the first synthetic fibre from polyvinyl chloride was spun. Wallace Hume Carothers invented 1935 polyamide 6.6, called "Nylon". And 1938 polyamide 6 was found, known for a long time as "Perlon".
It was Paul Schlack, scientist in the German company IG Farben who discovered the polymerisation of caprolactam and the production of polyamide 6 in 1938. The first industrial production of Polyamide 6 was running in Landsberg as from 1943. (Remark: the city of Landsberg an der Warthe is today in Poland and called Gorzow. Today this plant belongs to Rhodia.) Polyamide 6 as well as 6.6 became materials of military importance, one in the United States, the other one in Germany. And only after the 2nd world war they both helped to develop today's world.

Let us have a look into the process of making polyamide 6 multifilaments.

The raw material

The raw material for polyamide 6 is ε-caprolactam. There are different ways to make ε-caprolactam. Starting material is cyclohexanon made from cyclohexane or phenol.
ε-caprolactam is a solid crystal product with a melting point of about 70°C.

Polymerisation

The formation of polyamide 6 from caprolactam starts with the opening of the ring structure followed by a polycondensation. This ring opening is initiated by water. Typical temperatures applied are 250 - 260°C and the pressure is up to 10 bars. In a second phase, at lower pressure but in a nitrogen atmosphere, the growth of the molecular chains is continuing. The viscosity is changing from fluid to a honey-like state. This hot polymer melt is then pressed through a kind of spinnerets into a water quench where the polymer is cooled down and gets solid forming a strand. In the granulator these strands are cut into granulates.
During the process there are additives involved in the reaction which regulate the chain length and the needed viscosity can be achieved. Special additives, like manganese are added to the polymer to grant a protection against UV-light and for special applications cupper additives are added to protect the polyamide 6 against thermal degradation. In additional washing and extraction processes the monomers and oligomers are washed away. The granulate is then dried to receive a remaining humidity of 0.1%.

Spinning

The spinning process used for polyamide 6 is the so-called melt spinning process. In this process the polymer is melted under exclusion of air. The used temperature is in the range of 250-270°C which is 30-50 °C higher then the melting temperature of polyamide 6. For a very homogenous melting process the polymer is melted in a extruder. With the help of the extruder and the spinning pump the hot and melted polymer is then transported to the spinnerets. The spinnerets are round metal plates with tiny holes where the melt is pressed through. Each hole is forming one filament. The number of holes in the spinneret is determining the number of filaments.
The spinning speed which is the speed of the filaments after passing the spinneret is an important factor for the quality of the filament. For high tenacity yarns it is in the range of 500 - 1000 m/min. On the lower part of the spinneret the filaments are entering in the quench duct. This is a part of 2-4 meters where the still hot filaments are quenched with air. It is very important to keep the airflow very gentle and stable to avoid the filaments sticking together.

For the next step, the filament bundle has to be treated with a spin finish. The spin finish is an emulsion or a solution of tensides, oils and other additives. This cocktail which is one of the yarn producers last secret, has the important duty to allow the drawing of the yarn and to guarantee the textile processing later at the customers plant. Friction reducing tensides, oils and static inhibitors are the most important ingredients of each spin finish.
The spin finish is applied to the yarn either by so-called kiss rollers or by jet applicators. The typical amount of spin finish on the yarn is 0.7 - 1.0 %.

Drawing

During the drawing process which is nowadays directly linked to the spinning (spin-draw process) the filaments are stretched by a factor 4 - 5. During that process the macromolecules are orienting themselves in the best way. It is this orientation of highest parallelism which gives the needed yarn properties as high tensile strength and tenacity.
This drawing is processed on godets which are hot, rotating cylinders, running with different speeds so the yarn is stretched between the different duos.

After this drawing, the filaments (normally between 140 and 280) are intermingled with a continuous air-jet. This intermingling tangles the filaments together and allows the customer to work with the yarn easily.

The now finished yarn is directly wound on cardboard tubes. The classical size of such a bobbin is about 9.0 kg of yarn. The wind-up speed in the spin-draw process varies from 2000 to 4000 m/min. The fully automatic winders change within seconds from a full to an empty tube to start a new bobbin.

The whole process of spinning polyamide 6 is a continuous, uninterrupted process which runs 24 hours and 7 days a week. Stops are only made for maintenance and to change from one product to an other one.

Main characteristics of polyamide 6.

Polyamide 6 has the following characteristics which are of high importance specially for the rope industry:

- they have a high tenacity of around 78-84 cN/tex
- the modulus of elasticity and flexion is specifically qualified for mountaineering ropes

- the abrasion resistance of polyamide 6 is higher than that of polyamide 6.6 or polyester
- the density is low with 1.14 g/cm^3
- polyamide 6 is taking up about 3.5 - 4.5 % of water only
- product made from polyamide 6 are drying quickly
- polyamide 6 yarns are rotting resistant
- polyamide 6 is good resistant against alkalis
- the dye ability of polyamide 6 is very good
- polyamide 6 is available as spun-dyed yarn

Rhodia Industrial Yarns

Rhodia, a traditional producer of raw material for the polyamide 6.6 chain, is buying the raw material in the free market in the case of polyamide 6. As one of the biggest buyer of caprolactam worldwide, Rhodia is in the position to assure the access of caprolactam for very competitive prices. In Slowakia Rhodia runs two continuous polymerisation lines for polyamide 6. One dedicated to tyre yarns and the other line to yarns for the ropes and nets market. Having two separate polymerisation lines enables Rhodia to have constant and competitive polymer quality for both, tyres and ropes.

The same principle of using specific lines to specific markets and to achieve different customers requirements, is used by Rhodia in the two modern one-step spinning lines for polyamide 6. The total capacity of 35'000 tons makes Rhodia the biggest producer of high-tenacity polyamide 6 yarns in Europe. The Slowakian spinning lines are mainly used for tyres. The state-of-the-art and recently acquired spinning lines of Daugavpils, Latvia, are 100% dedicated to the market of ropes and nets. A highly educated and motivated production team in Latvia is operating these spin-draw lines with 12'000 tons of capacity, which are the latest installations for high-tenacity polyamide 6 yarns in Europe, installed in the nineties.

For the rope market Rhodia is producing different types of yarn with heat-protected and UV-stabilized polymer. Different yarn counts and different physical characteristics are produced to serve all needs of our customers. As a speciality Rhodia is also producing spun-dyed polyamide 6 yarns. They are available in up to 15 different colours. A product with a special water repellent finish is actually under development.

A specialized team of technical people and engineers is dedicated to R&D, customer orientation and marketing activities of the rope market under which the mountaineering ropes have an outstanding interest for Rhodia.