Viscose Rayon: A Legendary Development in the Manmade Textile

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ABSTRACT

Cotton is the best suitable fiber for apparel purpose, especially in tropical region where comfort stands at first priority. Developing countries are the major producers for the cotton. However, the blooming population has created scarcity of the available agricultural land in this region. Thus, it becomes indeed difficult to satisfy increased demand of cotton. This has geared up the research direction in finding its option from manmade fibers. Replacement option must not be thought off only in terms of quantity but also quality. Synthetic origin based materials (Nylon Polyester etc.) although undergone modifications via various processes (texturising/short staple spinning) are not able to offer comfort similar to natural cellulosic cotton. This has directed researchers to develop man made yarn obtained from viscose solution of natural regenerated cellulose. Thereby, it was nomenclatured as regenerated cellulose initially and later on as viscose rayon. Fabric obtained out of this yarn has exhibited good simulation with natural cotton fiber fabric, especially in comfort associated characteristics. However, viscose rayon yarn lags behind from cotton in service properties and technical properties. It's physico-mechanical properties need to be of high degree of regularity to meet the stringent demands of market and meets the demands of consumers for attractive products. So, many changes in terms of technology, material, etc. have been undergone in the manufacturing process for getting the most preferred cotton replacement. The article represents brief summary of the growth and development of this legendary fiber/filament yarn.

Key Words: Viscose rayon, Cellulose, Physico-mechanical properties, Spinning, Comfort

Brief History of Development

Rayon is the generic term used for fiber (and the resulting yarn and fabric) manufactured of regenerated cellulose. Its historical development started by an "artificial silk" theory. As natural silk was incredibly tedious to produce and therefore, was more expensive, chemists sought to synthesize their own silk which was given the name "artificial silk." English naturalist Robert Hooke has theorized "Artificial Silk" first in 1664. He suggested that artificial filaments might be spun from a substance similar to that which silkworms secrete to make silk. This was often tried by various scientists in the ensuing years but not succeeded. Finally George Audemars, the Frenchman was able to make a thread by dipping a needle into a viscous solution of mulberry bark pulp and gummy rubber in 1855. While interesting from a scientific standpoint, this process was hardly viable economically - it was very slow, and required a great deal of skill and precision [1-3].

The first commercial synthetic fiber was produced by Hilaire de Bernigaud, Count of Chardonnay (1839-1924) after 29 years of research, was patented in 1884, and manufactured by him in 1889. This cellulose-based fabric known as Chardonnay silk was pretty but very flammable; it was removed from the market. Soon after, the English chemist Charles Frederick Cross and his collaborators Edward John Bevan and Clayton Beadle discovered the viscose process in 1891 [1, 3]. Courtaulds Fibers produced the first commercial viscose rayon in 1905; the first in the United States was in 1910 by the American Viscose Company. Initially rayon was called "Artificial Silk", and many other names.

In 1924, a committee formed by the U.S. Department of Commerce and various commercial associations decided upon the name "rayon" for "Artificial Silk". It was called "rayon" for one of two reasons: either because of its brightness and similarities in structure with cotton (sun = ray, on = cotton). The name Viscose was derived from the word "viscous" which means sticky spinning solution out of which "Rayon" was manufactured. Thus the innovative cellulosic derivative has taken the present name of "Viscose rayon" [1-5].

Categorization of Viscose rayon

Unlike most manmade fibers, rayon is not synthetic as it is made from wood pulp, naturally-occurring, cellulose based raw material. So, viscose rayon is not defined as synthetic base polymer but as natural base polymer [figure 1]. Therefore, viscose rayon's properties are more similar to those of natural fibers made of cellulose, such as cotton or linen, than those of petroleum-based synthetic fibers such as nylon or polyester [5, 6].

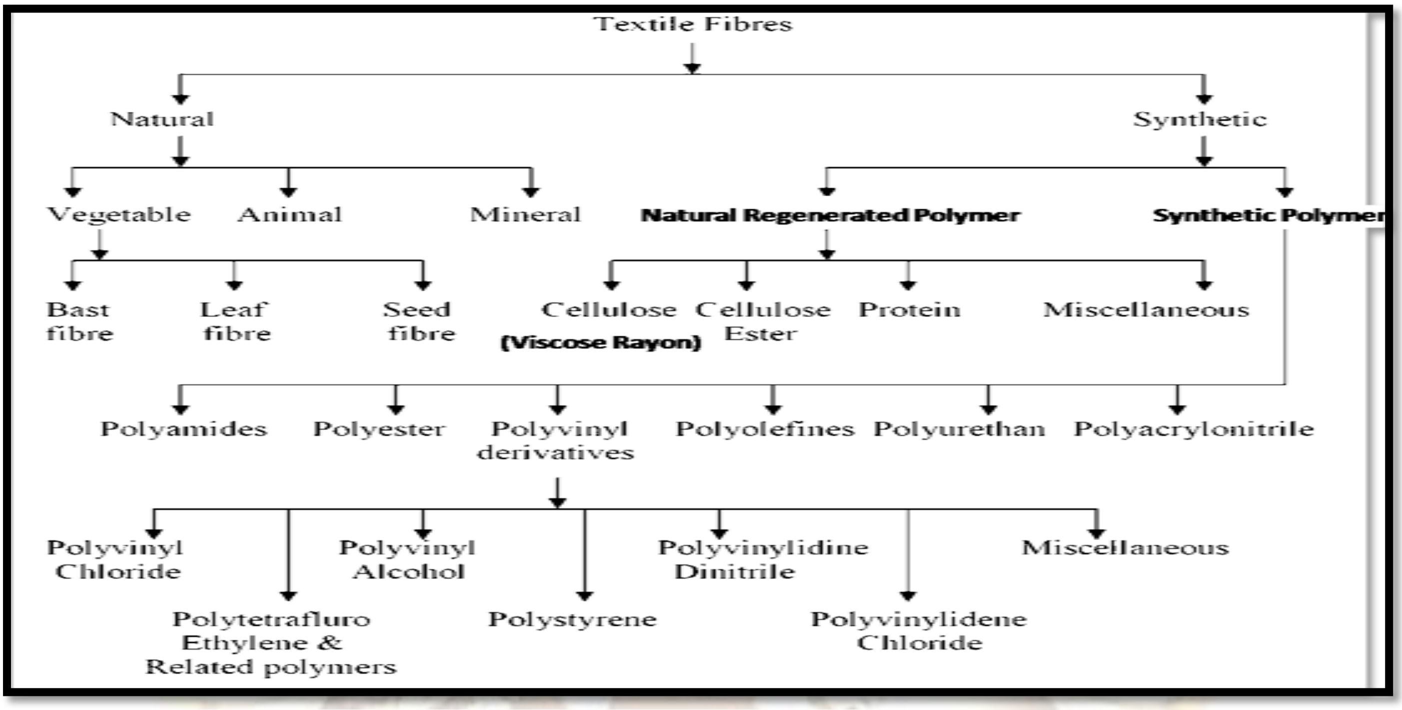

Figure: 1 Classification of Textile fibres **[*Goswami et al.*]**

Manufacturing of Viscose Rayon

Manufacturing process is shown diagrammatically in figure 2. Pulp (usually from pine, spruce, or hemlock trees) is dissolved in caustic soda and after steeping for a specified period of time it is shredded and allowed to age. Ageing contributes to viscosity of viscose. The longer the ageing time the less viscosity it will have. The aged pulp is then treated with carbon disulfide to form an orange-coloured cellulose xanthate, which is dissolved in caustic soda of a lower concentration. This is the starting stage of viscose formation. During the process an acetate dope is added to alkali cellulose which is necessary for the yarn lustre. Purified cellulose is chemically converted into a soluble compound. A solution of this

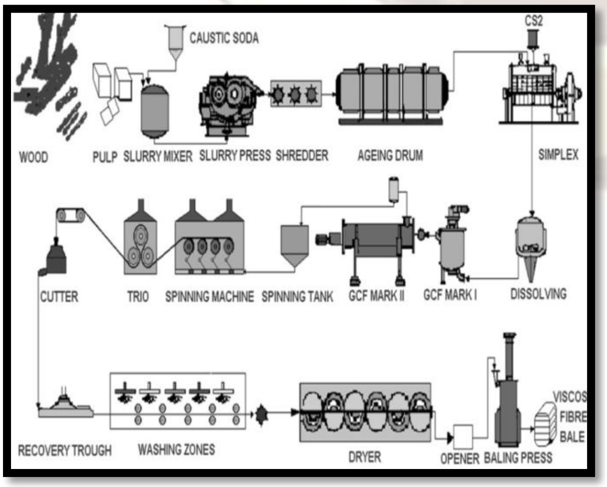

Figure 2: Manufacturing process ***[Birla Cellulosic TRADC]***

compound is passed through the spinneret to form soft filaments that are then converted or “regenerated” into almost pure cellulose. Because of the reconversion of the soluble compound to cellulose, rayon is referred to as a regenerated cellulose fiber [6, 7]. The final chemical structure of viscose rayon is shown below [figure 3].

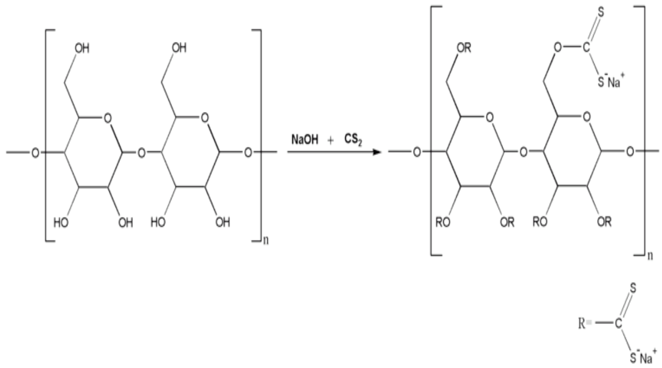

Figure 3: Cellulose is treated with alkali and carbon disulfide to yield Viscose Rayon ***[Wikipedia, 2008]***.

Chemical reactions those undergo during the manufacturing process are summarised in brief henceforth [figure 4]. There are several types of rayon fibers in commercial used today. They are named according to the process by which the cellulose is converted to the soluble form and then regenerated. The most popularly used Rayon fibers are as follows:

1. Regular Rayon
2. High wet Modulus (HWM)
3. Tyre cord Rayon
4. Cuprammonium Rayon
5. Polynosic Rayon

(1) $C_6H_9O_4OH + NaOH \rightarrow C_6H_9O_4ONa+H_2O$
(Cellulose is converted to alkali cellulose during Steeping.)
(2) $C_6H_9O_4ONa + CS_2 \rightarrow C_6H_9O_4OCSSNa+Na_2CS_3$
(Carbon disulphide reacts with alkali cellulose. Sodium cellulose xanthate & sodium trithiocarbamate is produced during Xanthation.)
(3) $C_6H_9O_4OCSSNa + NaOH \rightarrow$ Viscose Solution
(Viscose solution is formed during dissolution.)
(4) $C_6H_9O_4OCSSNa + H_2O \rightarrow C_6H_9O_4OH+CS_2+NaOH$
(Sodium cellulose xanthate is decomposed to get cellulose during Ripening.)
(5) $C_6H_9O_4OCSSNa + H_2SO_4 \rightarrow C_6H_9O_4OH+CS_2+Na_2SO_4$
(Recovery of cellulose from cellulose xanthate by acid decomposition during spinning.)

Figure 4: Chemical reactions took place during manufacturing of Viscose Rayon

Factors which are to be considered for engineering the properties of different rayons are: degree of polymerization (DP), where higher the DP, higher will be the strength of fiber, low acid concentration spinning dope to slow down the rate of coagulation, use of modifiers along with zinc which will increase the gel state length during spinning, so high stretch can be given through orientation of polymer chains to improve physical properties, high spinning stretch is given to increase the orientation of polymer chains, zinc free dope. [8]

They all are wet spun yarns produced by semi continuous process. Wet spun refers that the filaments emerging from the spinneret pass directly into chemical baths for solidifying or regeneration. All of the early viscose production involved batch processing. In more recent times, processes have been modified to allow some semi-continuous production [6, 7].

Pollution during manufacturing

Polluting effects of carbon disulfide, zinc and other by-products of the viscose rayon production process has limited production volume in 1996 [8]. One way to comply with sulphur emission standards is to install a wet sulphuric acid process unit which recovers sulphur compounds to sulphuric acid or use the Lyocell process which uses N-Methylmorpholine N-oxide as solvent [3-4].

Although rayon is made from wood pulp, a relatively inexpensive and renewable resource, processing requires high water and energy consumption, and has contributed to higher cost. Not only had that but also produced added air and water pollution [4], here zinc may cause skin cancer also, which affects the human life. Modernization of manufacturing plants and processes thereby mainly targeted towards the reduction in the product cost as well as pollution, which also added zinc free technology to reduce pollution due to zinc. Domestic spinning-finishing equipment for production of fibres and yarns has been improved in recent years to create highly efficient, unified equipment and to ensure the required sanitary-hygienic conditions [9].

Properties

Viscose Rayon has a silk-like aesthetic with superb drape and feel and retains its rich brilliant colors. Its cellulosic base contributes many properties similar to those of cotton or other natural cellulosic fibers. Rayon is moisture absorbent (more than cotton), breathable, comfortable to wear, and easily dyed in vivid colors. It does not build up static electricity, nor will it pill unless the fabric is made from short, low-twist yarns.

Rayon is comfortable, soft to the skin, and has moderate dry strength and abrasion resistance. Like other cellulosic fibers, it is not resilient, which means that it will wrinkle. Rayon withstands ironing temperatures slightly less than those of cotton. It may be attacked by silverfish and termites, but generally resists insect damage. It will mildew, but that generally is not a problem.

One of rayon's strengths is its versatility and ability to blend easily with many fibers—sometimes to reduce cost, other times for lusture, softness, or absorbency and resulting comfort.

Rayon has moderate resistance to acids and alkalis and generally the fiber itself is not damaged by bleaches; however, dyes used in the fabric may experience colour change. As a cellulosic fiber, rayon will burn, but flame retardant finishes can be applied.

Thus rayon's properties are more similar to those of natural cellulosic fibers, such as cotton as shown in table 1[4, 5].

Applications of Viscose

For a considerable time after viscose rayon was discovered in 1891, it was produced only on a small scale and was used mostly for decorative purposes, such as for imitation flowers or for small ornaments on dresses. Later on, it either replaced or was used with mercerized cotton yarns for embroidery purposes and for stockings. It was also used for domestic articles such as ties, children's coats, hoods, tablecloths, socks, shoes, and ornamental bags (Woodhouse, 1926).

Today, viscose rayon has found versatility especially in apparel, value addition applications, domestic items etc. due to its similarity with cotton and some places superiority on cotton [table 1]. Even high tenacity rayon has found application in industrial textiles. Few end uses are listed below along with summarized photographic images given in figure 5 [3, 10].

Table 1: Comparison of Cotton and different Rayon Fibers [8]

	REGULAR VISCOSE	POLYNOSIC RAYON	High wet Modulus (HWM)	COTTON
Tenacity (gpd)				
Dry	**2.5 – 3**	**3.2 – 4**	**4 – 5**	**3 – 5**
Wet	**1.4 – 2**	**2.6 – 3.2**	**2 – 3**	**3.3 – 5.5**
Wet Strength (gpd)				
(with 5% NaOH)	**1 – 1.3**	**2.2 – 2.7**	**2.5**	**2.7 – 3.3**
Wet modulus (gpd)				
(with 5%NaOH)	**2.3 – 2**	**4 – 4.5**	**6–9.5**	**N.A.**
Breaking Elong. (%)				
Dry	**16 – 24**	**7 – 12**	**15–23**	**6 – 10**
Wet	**21 – 29**	**8 – 14**	**24–28**	**7 – 11**
Initial Wet Modulus (gpd)	**26**	**12**	**12**	**13**
Degree of Polymerisation	**250-300**	**450-500**	**500**	**1500-3000**
Recovery from stretch (at 2%)	**85% Poor**	**95% Good**	**95% Good**	**98% Good**
Cross section	**Serrated**	**Round**	**N.A.**	**Bean Shaped**
Moisture regain (%)	**11 – 14**	**11 – 14**	**11–14**	**6 – 8**
Density(gm/cc)	**1.5**			**1.52**
Diameter	**15, 20,25 micron**			

Figure 5: Applications of Viscose yarn

- **Yarns:** Neither build up static electricity, nor will it pill unless the yarn is made from short staple with low-twist thus preferred for sewing thread, Easily dyed in vivid colours so, used as embroidery thread, chenille, cord, novelty yarn.
- **Apparel:** Rayon as a cloth is soft and comfortable. It drapes well, which is one of the reasons it is so desirable as an apparel fabric. Thus it is popularly used for making blouses, dresses, saris, jackets, lingerie, linings, millinery (hats), slacks, sport shirts, sportswear, suits, ties, work clothes.
- **Fabrics:** Rayon is the most absorbent of all cellulose fibers, even more so than cotton and linen (table 1). Because of this, rayon absorbs perspiration and allows it to evaporate away from the skin, making it an excellent summer fabric. Its high absorbency applies equally to dyes, allowing beautiful, deep, rich colours. Thus it is preferred for crepe, gabardine, suiting, lace, outer wear fabrics and linings for fur coats.
- **Domestic Textiles:** Fabrics made out of viscose rayon has silk-like aesthetic with superb drape and feel so, used for bedspreads, blankets, curtains, draperies, sheets, slip covers, tablecloths, and upholstery.
- **Industrial Textiles:** high-tenacity rayon is used as reinforcement to mechanical rubber goods (tires, conveyor belts, and hoses), applications within the aerospace, agricultural and textile industries, braided cord, tapes. It is also used for medical surgery products, non-woven products, tire cord etc.
- **Other:** Rayon is a major feedstock in the production of carbon fiber.

Limitations of Viscose Rayon

Although viscose rayon has many preferable qualities, it offers many restrictions during its processing. Moderate dry strength, pill resistance and abrasion resistance along with poor wet strength limits its processability. Although the structure of the rayon fiber is smooth, inelastic filaments like glass rods, these make it slippery in nature, difficult to handle during manufacturing until sized or highly twisted. Apart from this it is highly cohesive to entangle with shuttle eye or needle. All together add to its processing problems. Its higher lustrousness also enables it to use directly as apparels. [3-4, 11-12] Various attempts are made to overcome these limitations earlier also. Cut staple spinning of continuous filament yarns by ring spinning technique either as 100% viscose yarn or in blend is the best utilized option for the same. Though these yarns overcome limitations mentioned above, needs to follow longer route of production. Longer production process not only adds to time delay but also product cost [13].

Another option is texturising. It transforms flat round slippery structure into crimpy or loopy structure with well bound constituents [6, 14-15]. It modifies glass rod like structure of continuous filament yarn to preferable bulkier and fuller appearance similar to ring spun yarn but without cutting them into staple fibres. The irregular surface caused due to formation of crimp/curl/ loops during texturising reduces its lusture. Bound constituents add to the stability, prevent stickiness, reduces slipping tendency due to increased grip. Apart from that this exercise is carried out in one step immediately after wet spinning. Thus texturising of viscose rayon can help in overcoming majority of its draw backs at economical and quicker way.

However non thermoplastic nature of viscose rayon and its poor wet strength are the major hurdles in its course of texturising. Ivanova et al. [11, 12] have tried to produce bulk yarn of viscose rayon by due modifications in manufacturing process. But it has not found success due to poor stability of the structure attained lost during weaving as well multistep production sequence. Altogether have made this product non favourable as well as costly.

Research is still going on in overcoming the limitations of this legendary cellulosic base filament yarn. This can further add to its acceptance in various applications.

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