Fiber spinning

Essentially the spinning process can be divided into two classes

- High-speed spinning (long)
- Low-speed spinning (short)

Table 3 - Comparison between low-speed spinning and high-speed spinning

	Unit	Low-speed spinning	High-speed spinning
Spinning	—	continuous	batch
Extrusion temperature	°C	220-260	220-260
Holes/die	number	10000-15000	30-200
Throughput	g/hole	0.1-0.5	>1
Quenching length	m	0.1-1	1-5
Take-off speed	m/minute	<100	300-1000
Stretching speed	m/minute	<400	100-700
Stretching temperature:	°C		
oven heat		100	100
plate		140	—
hot rolls		150	150

Table 3 shows briefly the main differences between the two types of process. Normally, the low-speed spinning process is adopted for the production of cotton and wool system staple fiber, while for the production of continuous filament (CF) or bulk continuous filament (BCF) either the fast or slow spinning process can be used.

Fiber and Non Woven Processing technologies

A brief description is given hereunder of the basic steps of the three processes used respectively for conversion of the granule into staple yarn, continuous filament, bulk continuous filament and spun bonded

PP Staple yarn process technology

The production technology for cotton and wool staple yarns is schematically represented in fig. 21. It includes:

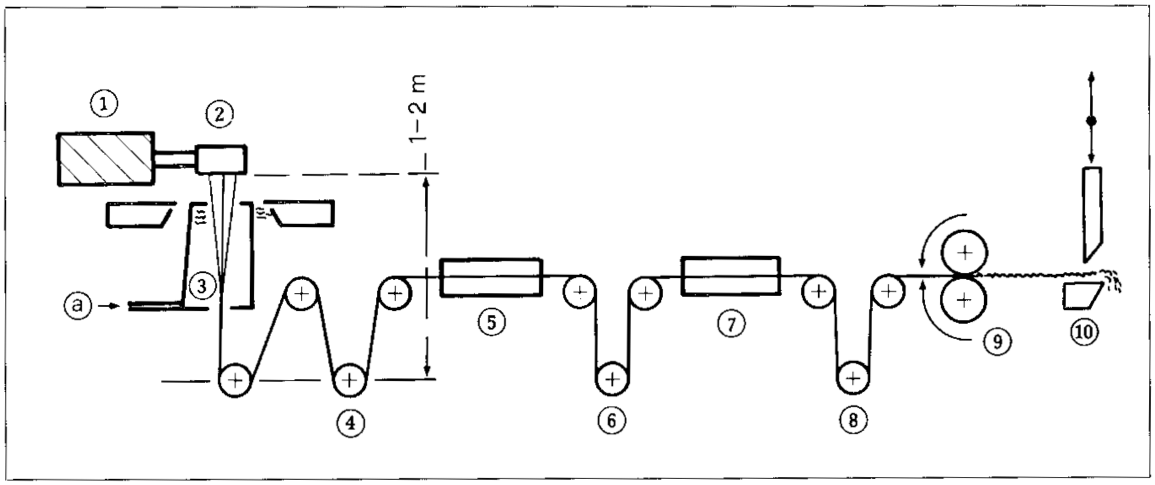

Fig. 21 - Layout of plant for the production of wool or cotton system staple fibre (a = air; 1 = extruder; 2 = filter-pack; 3 = blower box; 4-6 = couples of stretching rolls; 5 = stretching oven; 7 = thermosetting oven; 8 = return rolls; 9 = crimper; 10 = cutting).

Extrusion - The extruder is of the type commonly used for polypropylene, with L/D ratio equal to 30 and compression ratio = 1:3.5.
Metering - One or more geared spinning pumps receive the molten polymer and send it through to the spinning pack. Their purpose is to homogenize the product, feeding the spinning pack in a constant way to prevent fluctuations due to the screw.
Spinning - The spinning pack is comprised of three parts:
1) filter
2) distributor, which distributes the molten polymer uniformly over the die surface
3) die. The die hole diameter varies from 0.5 to 1.5 mm, according to the deniers required, and the length/diameter ratio varies from 5 to 20. Experience shows that the best de-hole profile, as far as the absence of dangerous rheological phenomena is concerned, is the one shown in figure 22

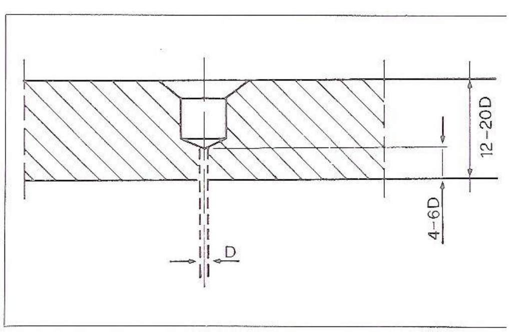

Fig. 22 - Optimum profile of die orifice.

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Quenching - This is generally made up of a column whose purpose is to convey the cooling *air* for the yarn (extrudate), without causing its damage (bulging, sticking). It is composed of two parts:
1) blower box or air distributor (fig. 23), which should be designed in such a way as not to distribute the air onto the extrudate in a violent way. Generally, a good "box" will distribute $3m^3$/minute of air without giving rise to damage
2) air conveyer pipe. This is situated immediately after the blower box and collects the air from the latter together with the extrudate of the die. Its length must be such as to allow a complete cooling.
Finish - The finishing operation, that is immersion of the fiber in a concentrated antistatic, slip, cohesion etc. solution becomes necessary in order to impart to the fibers the properties indispensable to their processing on the textile machines.
Hot stretching - The stretching operation is essential for conferring precise physico-mechanical properties. The stretching operation takes place between two groups of rolls rotating at different speeds. Between the two rolls there is a heating element (oven, plate, etc.) which confers the thermal energy required to overcome the AE due to the passing of the molecules to a higher state of potential energy (oriented state).
Crimping - This is a thermal-mechanical treatment that imparts to the fiber a characteristic undulation highly important parameters, which give respectively the number of undulations and their intensity.

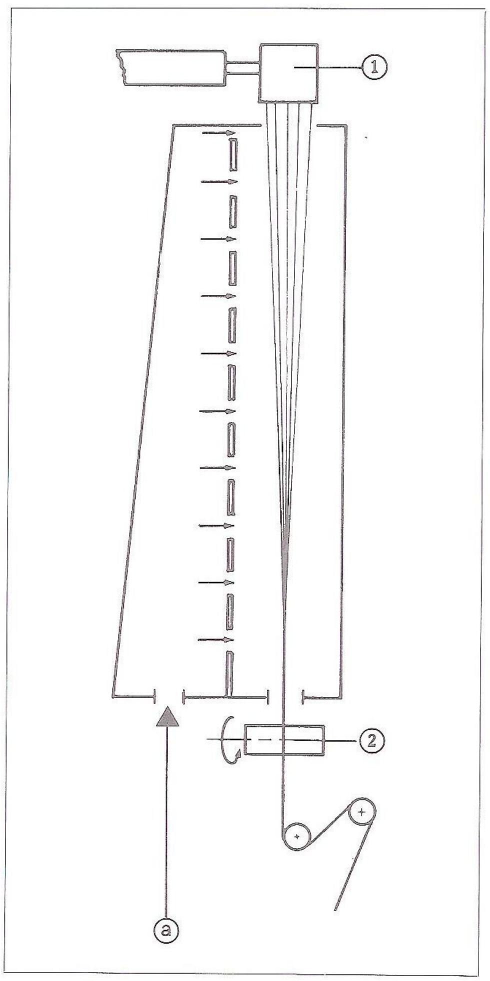

Fig. 23 - Blower box or air distributor (a = air; 1 = extrusion head; 2 = finishing roll).

Thermosetting - Thermosetting is a treatment in hot air or steam, which removes internal stresses and relaxes the fiber. By this the fiber is heat stabilized and its denier is increased.
Cutting - Accordingly as to whether the system is cotton type or wool type, the length of the cut is adjusted at a minimum of 20 mm to a maximum of 120 mm.
Packaging - Normally, the cut staple is pressed in or in smaller sized ballots, ready for shipment.

b. CF PP = Continuous filament process technology(fig. 24)

The first six steps (extrusion, metering, spinning, quenching, finish and hot stretching) are the same as for staple yarn, but the crimping, thermosetting and cutting operations are left out. The hot stretching operation can be done in continuous with the previous step or batchwise. Usually, batch stretching is necessary when spinning speeds are very high.
The packaging step always consists of winding the stretched yarn onto reels or cops.

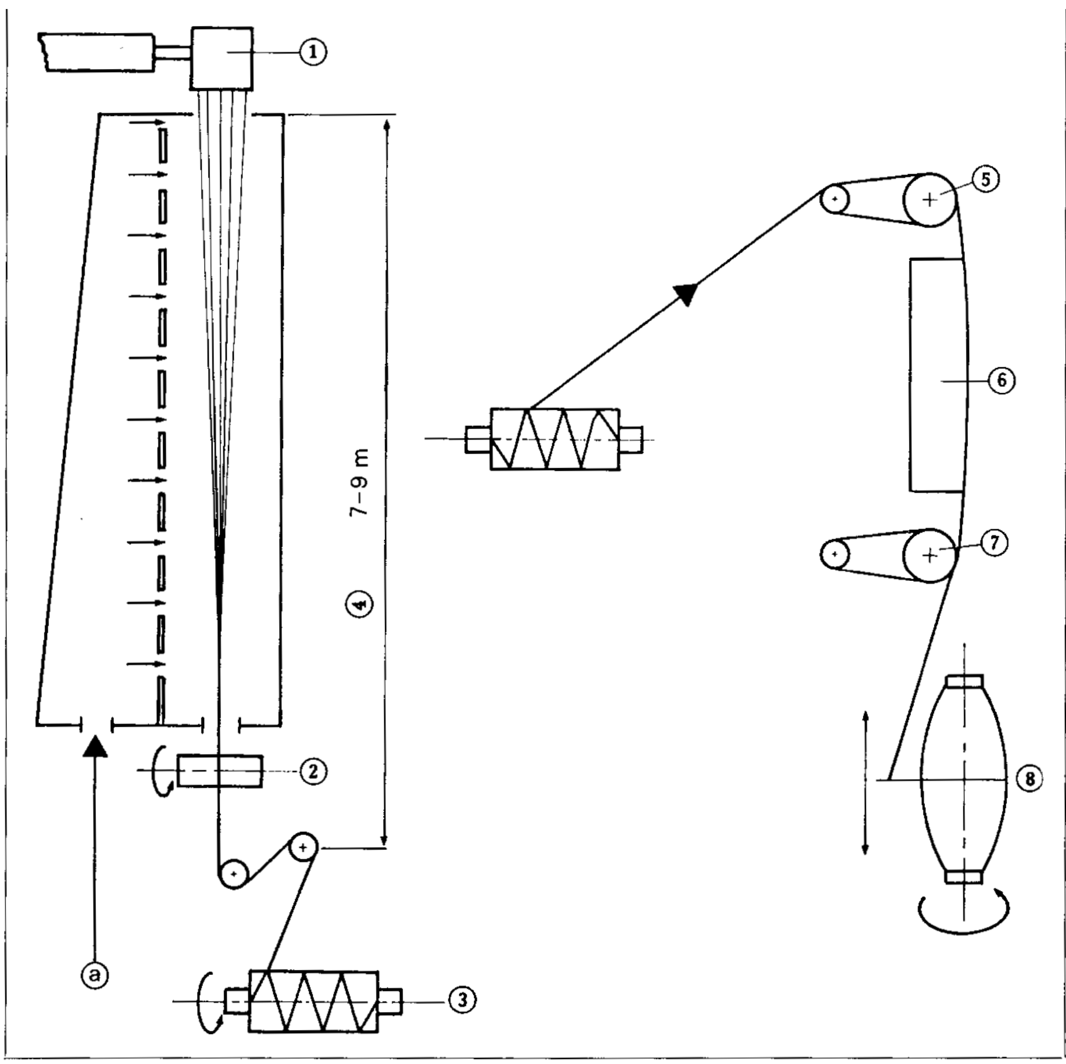

Fig. 24 - Production layout for continuous filament (CF), twisted (a = cooling air; 1 = extrusion head; 2 = finishing roll; 3 = non-stretched reel; 4 = spinning height; 5 = slow rolls; 6 = stretching plate; 7 = fast rolls; 8 = takeup reel for stretched-twisted yarn).

c. BCF PP = Bulk continuous filament process technology (fig. 25)

The first six steps are the same as for CF. After stretching, and prior to being wound onto reels, the filament is subjected to a bulking operation by means of steam.

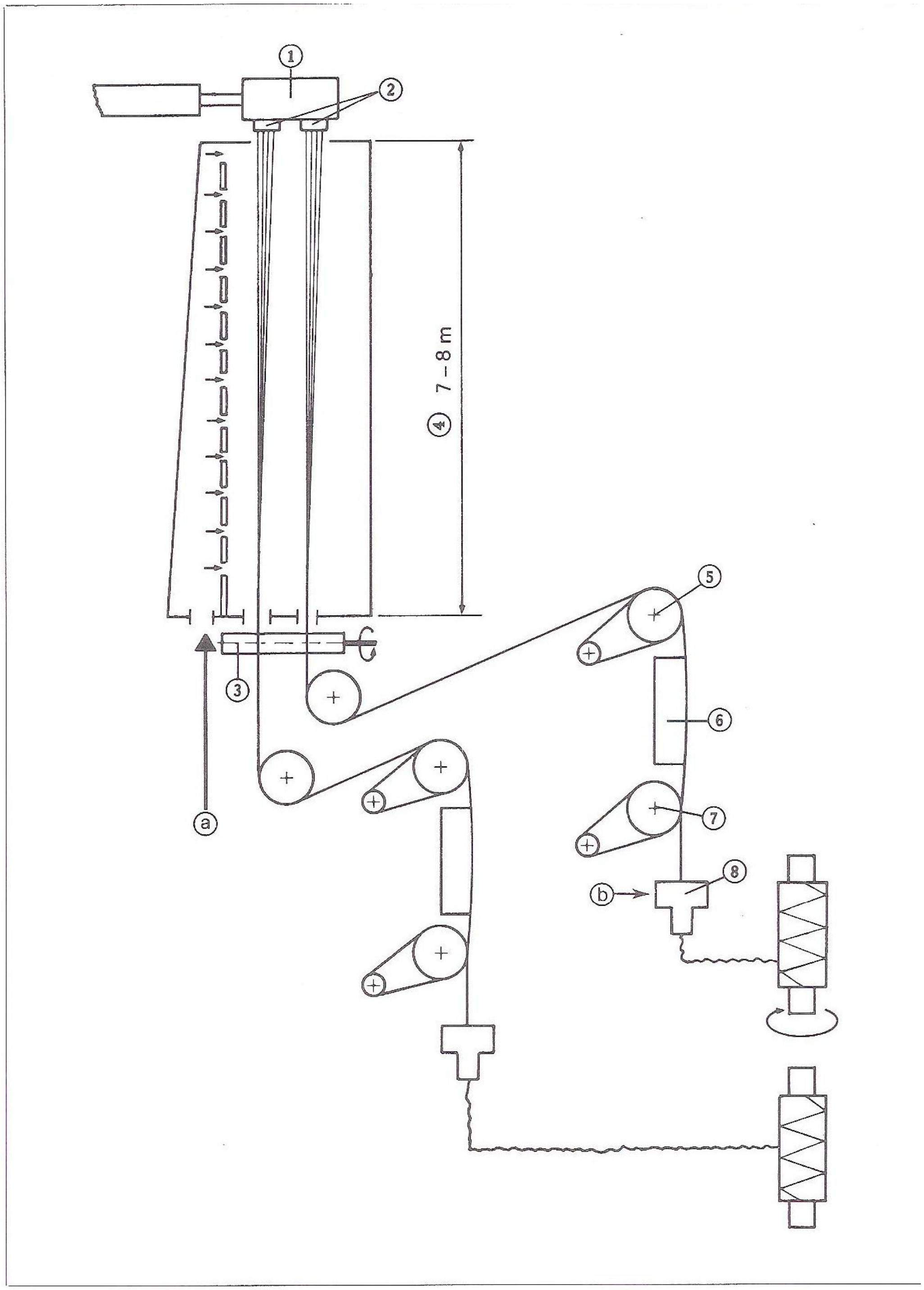

Fig. 25 - Production layout for bulk continuous filament (BCF) (a = cooling air; 1 = extrusion head; 2 = dies fed by volumeric pumps; 3 = finishing roll; 4 = spinning height; 5 = slow rolls; 6 = stretching plate; 7 = fast rolls; 8 = bulker-interlacer; b = hot air-steam).

d. PP Spun bonded process technology (fig. 26)

In the first four steps, the process is similar to the three processes previously discussed. After quenching, the filament is stretched and pulled towards the nap forming system at a speed from 300 to 500 times higher than its extrusion speed.

The bundle of filaments is then dispersed by various procedures and collected in layer form onto a continuous belt prior to the bonding operation, which can be:

— mechanical
— chemical
— thermal

In this way, non-woven fabrics are produced, which possess the best mechanical properties when compared with the non-woven fabrics obtained through the “dry route” (short fibers undulated by combs, the cohesion of which is imparted through the mechanical-chemical route), or with those obtained through the “wet route” (nap formation with short fibers in an aqueous vehicle: procedure of the paper-mill type)

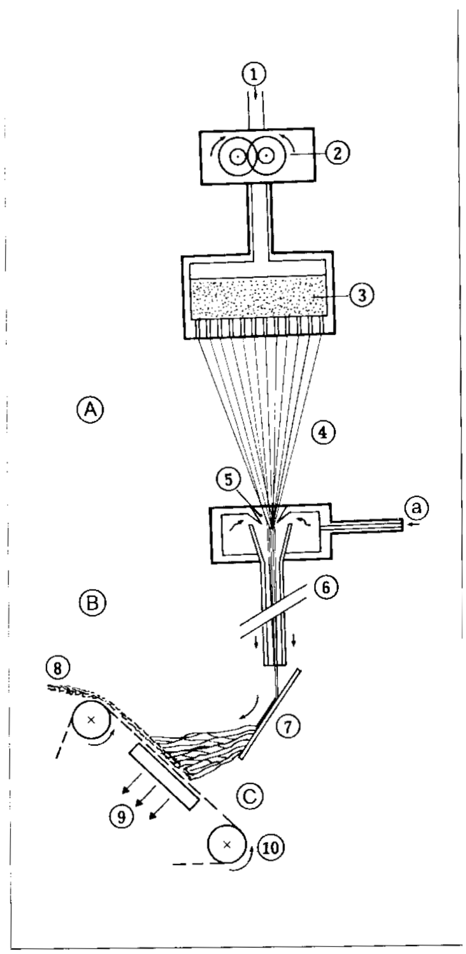

Fig. 26 - Layout for spun-bonded production (A = spinning B = stretching; C = nap formation; 1 = molten polymer 2 = volumetric titration pump; 3 = die block; 4 = filaments; 5 = stretching nozzle; a = air; 6 = stretching pipe 7 = deflector; 8 = web; 9 = suction; 10 = receiver mat)

Polypropylene MF grades for spinning processes

Tables 4 and 5 give the typical grades marketed on for various processes and applications.

Average M.F.R. (230°C/2.16 kg)	Denier count of fibre obtainable dtex	Stretch ratio	Physico-mechanical properties of yarn	Processing characteristics	Applications
12	⩾5	Medium	Medium-tough Resilient	High process heat stability. Suitable for fibres and continuous multi-filaments (CF and BCF) with medium-high deniers even with oil-vapour heated equipment.	Wool-system fibres: carpets, moquettes, blankets, etc. Bulked and unbalked continuous filaments: ropes, weaves, tufting, woven belts, etc.
12	⩾3.5	Medium-high	Tough	The special degradation undergone during the spinning process allows the use of very high stretch ratios (⩾4:1).	Cotton staple fibre with medium-low deniers. High tenacity continuous filament obtained with the fast-spinning process.
18	⩾3.5	Medium-high	Medium-tough	The narrow molecular weight distribution and high flow make it suitable for the processing of bulk continuous multifilaments (BCF) and spun bonded.	Bulked continuous filaments with high spinning speeds. Non-woven fabrics with low gram weights.
18	⩾2.5	Medium-high	Tough Resilient	Batch fibres with medium-low deniers and high mechanical properties.	Cotton system fibre: underwear with high gas-fading resistance, furnishing fabrics, non-woven fabrics, medical-sanitary fabrics, etc.

Average M.F.R. (230°C/2.16 kg)	Denier count of fibre obtainable dtex	Stretch ratio	Physico-mechanical properties of yarn	Processing characteristics	Applications
12	⩾5	Medium	Medium-tough Resilient	High process stability and constant flow during extrusion. Suitable for fibres and continuous multifilaments (CF and BCF) with medium-high deniers even with oil-vapour heated equipment.	Wool-system fibres: carpets, moquettes, blankets, etc. Bulked and unbulked continuous filaments: ropes, weaves, tufting, woven belts, etc.
18	⩾2.5	Medium-high	Tough Resilient	Discontinuous fibres and continuous multifilaments (CF and BCF) with medium-low deniers and high tenacity and mechanical properties.	Cotton-system fibres: clothing, furnishing, non-woven fabrics, medical-sanitary fabrics, etc. Bulked and unbulked continuous filaments: special heavy-duty fabrics, clothing, spun bonded, etc.
25	⩾1.5	High	Highly tough Resilient	The narrow molecular weight distribution and high flow make it suitable for the processing - at high spinning speeds - of fibres and continuous multifilaments (CF and BCF) having a high tenacity	Very low denier fibre for underwear and hygienic clothing, non-woven fabrics, spun bonded with very low gram weights, etc. Bulked and unbulked continuous fila-