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THE MANUFACTURE OF MONOAXIALLY STRETCHED FILM TAPES 1/

by

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Hans Domininghaus
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Jute, hemp and sisal are natural products which differ in quality and price. In contrary to these polyolefins as chemical products stand out in constant properties and prices.

The technical advantages of polyolefin flat yarns are:

- high tensile strength and elongation at break
- low specific density
- excellent chemical resistance
- not rotting

Manufacturing processes of flat yarns are:

a) Tubular film process

First a tubular film is extruded. Via a higher adjustable departure tower

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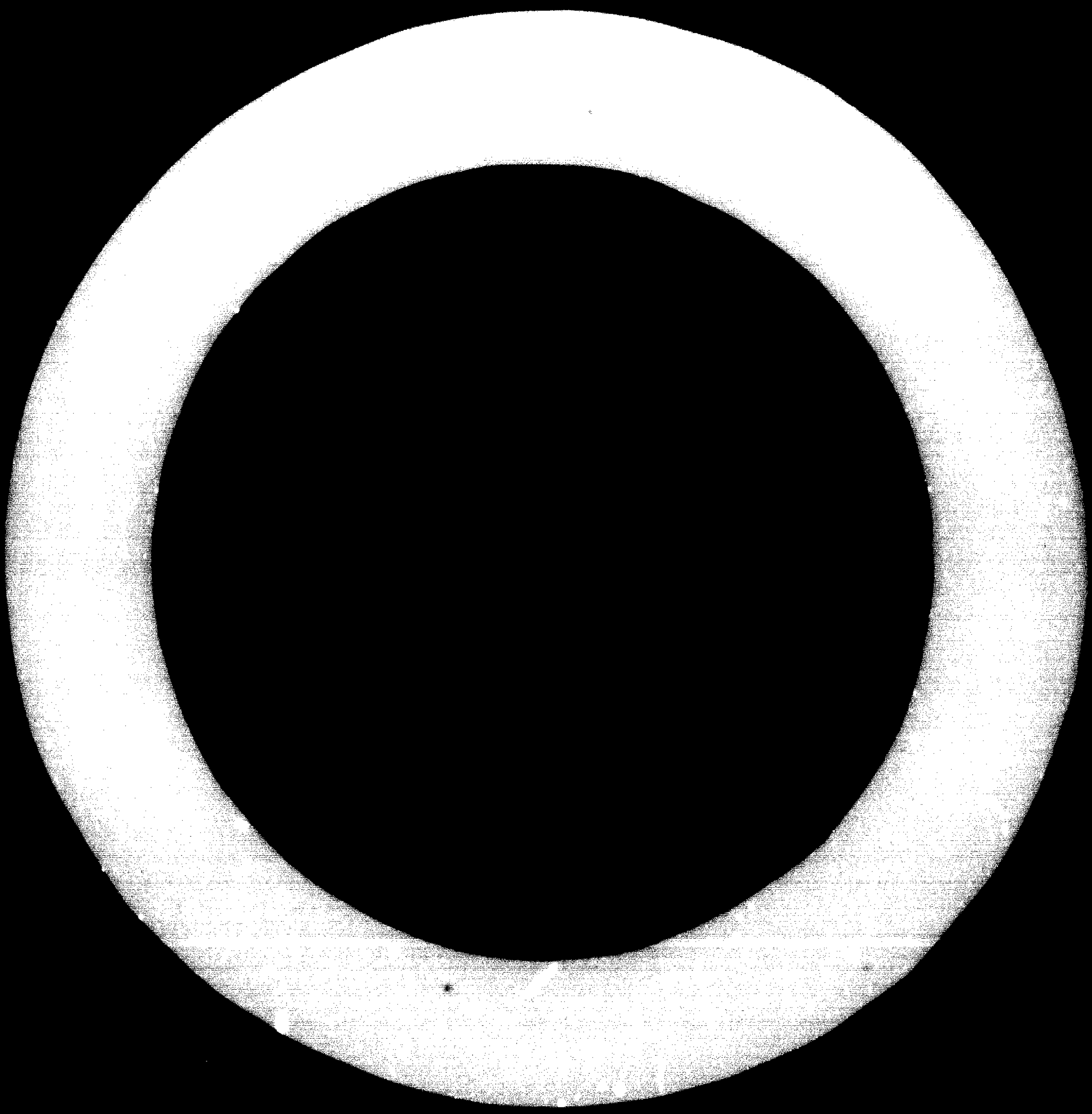


(cooling of film) the film is laid flat and runs over a cutting aggregate. Then follows stretching and fixing of the film to obtain a higher tensile strength. Winding machines are switched behind the stretch aggregates. (For calculation of costs see appendix.)

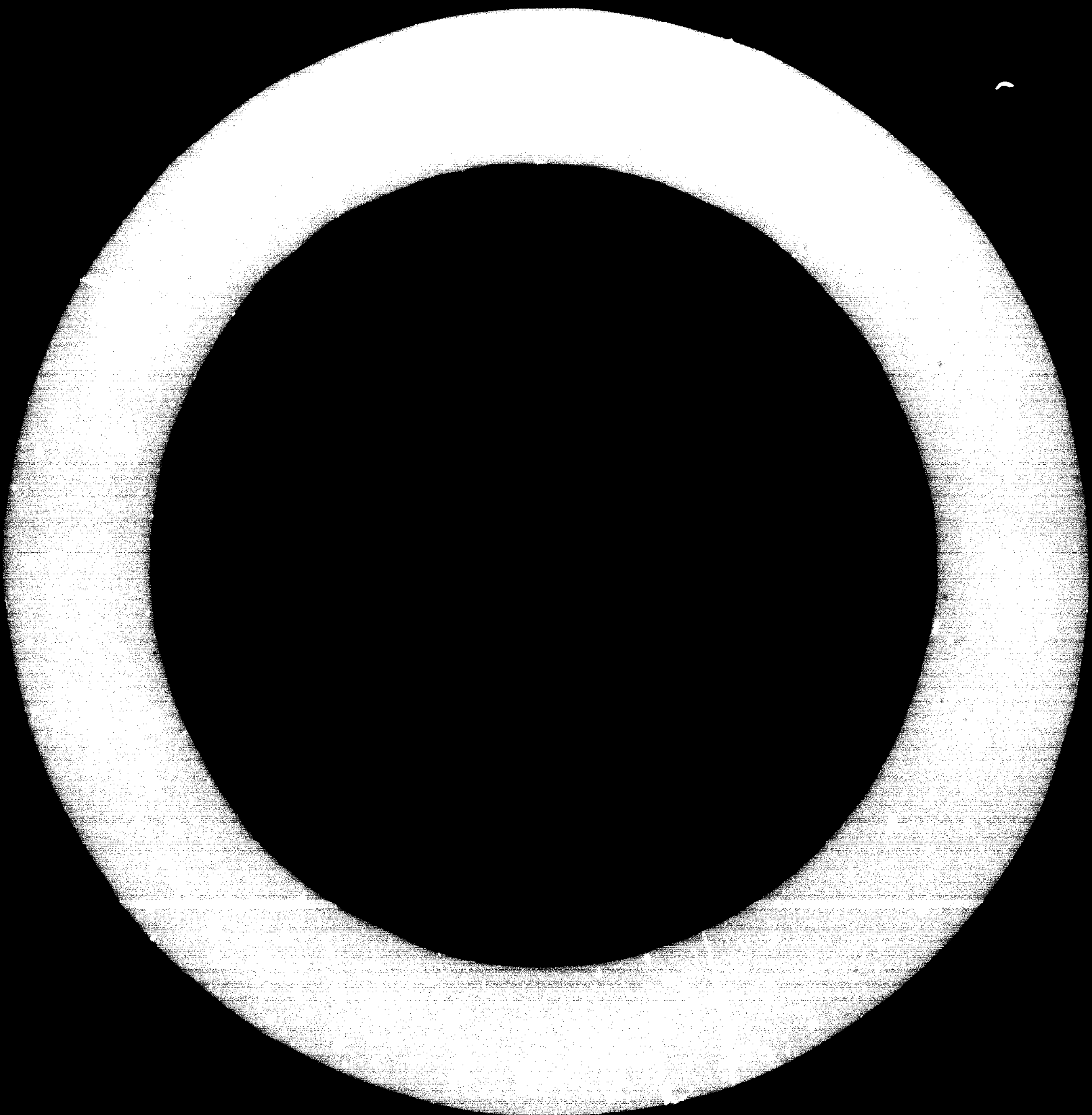
b) Cast film process

Via a breadth slit jet extruder a cast film is produced. With this process the film is cooled through dipping in a water bath.

The processes differ from each other by the film thickness obtained.

Applications: Carpet backing, packaging (sacks), binder, twines, tarpaulins, upholstery-material, camping articles.

For use in the textile field fibrillated flat yarn has been developed. This is produced by mechanical splitting of the flat yarn. Thus the yarn obtains a textile character.



The Manufacture of Monoaxially Stretched Film Tapes

1. General survey

Jute, hemp and sisal are being undercut in price by synthetic products. Stretched polyolefin film tapes are beginning to close in on these natural fibres in their customary markets.

The manufacture and fabrication of monoaxially stretched film tapes represents a new development in plastics technology. Within a short space of time, efficient processes were developed which soon formed the basis for large scale production units. The importance of this material for a wide range of applications in the textile industry cannot yet be foreseen because development is still in progress and new techniques are constantly being worked out. It is estimated that at the present moment there are 500 film tape production units in the world.

Monoaxially stretched film tapes are narrow tapes made by a slitting process from tubular film or flat film, which are stretched under heat to many times their original length. During this operation the thread-like molecules of the thermoplastic material are oriented in the direction of stretching. The distance between the chains is thereby decreased and this leads to an increase in the secondary valency forces and thus to a pronounced increase in tensile strength, depending upon the degree of stretching. Although a number of thermoplastics are suitable for this purpose, the two polyolefins - high density polyethylene and polypropylene - soon attained position of greatest importance because of their special properties. Film tapes (also called flat yarn) are distinguished by the following:

- high tensile strength and elongation at break
- low specific gravity

- excellent chemical resistance
- negligible water absorption

Fabrics made from these film types have the following advantages:

- rectangular cross-section and thin gauge of the tapes enable light-weight fabrics for covering large areas to be made
- fabrics made from film tapes, though permeable to air, are water repellent - coated they are rendered water impermeable
- no flavour or odour is imparted to products packed in bags or sacks made from these fabrics.

Film tapes have the following advantages over monofilaments with round or oval cross-section as regards their manufacture properties and uses:[1])

- film tapes can be more easily extruded as cast or blown film than an identical quantity of monofilaments, since the denier uniformity is adjustable by controlling the width of the die gap
- film tapes have a bigger surface area than monofilaments of the same cross-section and this leads to more uniform heat diffusion and orientation of the film tapes and thus at the same stretch ratio to greater strength
- film tapes made from polypropylene tend to fibrillate at high stretch ratios. This imparts the character of raffia or sisal to the tape, and opens up new fields of application, such as ropes, hawsers, binder and packaging twine.
- stretched film tapes, when wound up, can be woven
- film tape which has been fibrillated can be

twisted and then used directly as binder twine
or rope strands
- carpet backing can be made from weaving tape
or twisted cord

Some of the possible applications are shown in fig. 1.

Fig. : Examples of applications of monoaxially stretched film tapes

a	carpet backing	c	hawsers
b	sack fabric	d	binder twine

2. Economic importance of film tapes

2.1. Woven film tape

In assessing the sales potential for high density polyethylene and polypropylene, raw material manufacturers are first of all guided by the consumption of jute fabrics. This is slightly just below 2.5 million tonnes at the present moment half of which is used in the production of jute sacks. Consumption is estimated as follows:-

USSR	400 million
USA	250 million
South and east Africa	140 million
Britain	75 million
W. Germany	40 million
Italy	20 million

The remainder is used by other industrial and agricultural countries. In the competition between jute and polyolefins, the latter benefit from the fact that sacks made from these materials have twice the drop strength and weigh only one-fifth of a jute sack of identical size. In comparing prices in force at the present time, the advantage of a sack made from film tape is that the price of polyolefins is stable with a tendency to fall, whereas the price of jute is stable with a tendency to rise.

In assessing the economic possibilities of sacks made from weaving film tapes, it should not be forgotten that in very many agricultural areas the use of paper sacks is on the increase. These have the advantage that they can easily be constructed with a valve, and in this form are widely used for the packaging of fish meal, animal feeding stuffs and sometimes also for mill produce, e.g. flour etc. On the other hand many considerations favour the use of film tape sacks for the packaging of hops. Non-slip, raschel, knitted film tape sacks have in the meantime been developed for use as potato sacks; because of their more open work structure these require much less material than woven cloth. Woven tape sacks will become popular especially in those fields where decisive advantages are to be gained, as in those countries with high wool and viscose production. The use of jute sacks invariably causes contamination of the contents from loose fibres.

Other important uses of woven film tapes include coastline protection against erosion, sandbags, so-called fabric shuttering in the laying of siphon pipelines and the production of coated tarpaulins for agricultural use and for building site protection during the winter months.

2.2. Binder twine and hawsers

The characteristic property of stretched polypropylene film tape to fibrillate at high stretch ratios, which is promoted by torsional stress, makes it the ideal material for use as binder twine for harvesting. Depending on the amount of twisting, e.g. at 50 beats/m, yarns are obtained with breaking length of up to 50 km. During fibrillation, fine fibrilles are formed, giving the twine increased surface roughness.

Twisted polypropylene strands can be made into hawsers by braiding or beating, on conventional equipment.

2.3. Covering and upholstery materials

Since it is possible to impart a textile character to weaving tapes - mainly those made of polypropylene - by fibrillating, numerous possibilities are opened up in the field of needeloom felt manufacture, in the production of carpets for outdoor use and mixed-fibre furniture upholstery materials. Although initially it seemed that the use for tufted carpets would predominate, there has recently been a increasing trend towards needleloom carpets. Apart from their easy-care properties, their felt character is also an advantage.

Carpets for outdoor use are going to be very important in future. The demand for artificial lawns comes mainly from athletes, football teams and others, who cannot use their grounds during bad weather. These outdoor carpets are useful not only for playing fields but also in swimming pools, terraces, front gardens, playgrounds and in camping. They are not completely resistant but if suitably stabilized can withstand exposure to sunlight for many years.

If fibrillated fibres are blended with natural or other synthetic fibres there is an excellent opportunity of strengthening fabrics. Besides the usual patterns special effects can be achieved by controlled shrinkage, which produces crinkling.

3. Production of monoaxially stretched film tapes

Film tapes are made from extruded film. The continuous method starts out from granules, then passes through the various production stages and finishes with the winding up of the tape. In the discontinuous method of production the blown or cast film is first prepared and stored in roll-form. Stretching, heat setting and winding up of the finished weaving tapes takes place in a second operation. Here it may be mentioned that special effect fabrics can also be made by starting out from extruded multi-layer film. Furthermore, so-called profiled film can be produced for making textile fibres.

3.1. Manufacture of film

The film used for making film tapes is produced in the form of tubular film by means of an annular die, or as cast film by means of sheeting die. These methods apply equally to the production of film tapes from both high density polyethylene and polypropylene. Single screw extruders with screw lengths of 20-25D are suitable for both methods. One can use the so-called short compression screws as well as the three-zone screws. The compression ratio should be about 3:1. The metering zone should be cut rather deeper than is used for conventional polyolefin screws. This applies particularly to screws with a metering zone longer than 6D. In screws which have been cut too shallow there is a risk of overheating the melt due to too great an amount of frictional heat being produced. This, in turn, cause a deterioration in the stretching characteristics of the films. The flight depth of the metering zone of a 60 mm extruder is about 4 mm, that of a 90 mm extruder about 5 mm. With optimum screw design it is possible to maintain the correct melt temperature, even at high throughputs, without cooling.

3.1.1. Tubular films

Films of thicknesses 30-100 µm are best made by blowing. A typical production line for tubular film is shown schematically in fig. 2.

Processing temperatures suitable for both types of polyolefins are as follows:

Extruder:	160-170°C in the feed zone
	220-230°C in the metering zone
Blowing head	215-225°C

A screen of 1800 - 2000 mesh/cm^2 is selected as the finest member of the screen-pack mounted between the plasticisation cylinder and the blowing head.

The distance between the top edge of the blowing head and the nip rolls should not exceed 5 to 10 times the tube diameter in order to avoid creasing.

The film bubble is best flattened by cloth covered wooden boards. The angle enclosed by these boards should not exceed 18°. The blow ratio of films which are to be subsequently stretched is 1:1 to 1:1.5. Ordinary films tolerate a blow ratio of up to 1:6.

In high density polyethylene the freeze line is clearly recognisable. It should be up freeze line height and the temperature of the film bubble at the nip rollers (under given machine conditions) can be controlled by the intensity of the cooling air. The volume of cooling air and its constancy of flow are of special importance for the stretching characteristics of the extruded film. The film temperature near the nip rollers should be about 50-60°C so that a wrinkle-free film is achieved when the bubble is collapsed and flattened. At these temperatures there is no risk of blocking.

3.1.2. Cast film

Cast film production is preferred to tubular film extrusion if weaving tape with final thicknesses of 30-40 µm is required. Polyolefins can be processed into cast film either by the chill-roll method or by the water bath method. If chill-roll cooling is employed, it is advisable to use an efficient airknife. There is no risk of water being carried along by the film when cooled in a water bath.

Cast film production units usually operate at higher temperatures than tubular film lines.

Extruder	180°C in the feed zone
	140-150°C in the metering zone
Sheeting die	240-250°C

The choice of screens for the screen pack is the same as in the case of blown tubular film. Ordinary sheeting dies are suitable and it is advisable to fit a restricter bar.

A die gap width of about 0.6-0.7 mm has proved suitable for making film 80-130 μm thick.

When chill rolls are used, the hot film should be drawn off in the same direction as that in which the die lips are facing. It should not be drawn off over a die lip edge.

The vertical distance between die lips and the top edge of the chill rolls is 10-13 mm. The air knife should blow onto the film about 20 mm behind the line of contact with the chill rolls. To produce good quality film it is essential to determine accurately the best position of the air knife.

The temperature of the first chill roll is adjusted to the film thickness required, the efficiency of the air knife and the surface finish of the roll. This temperature is in the region of 50-90°C, the higher value applying to chill rolls handling thick film. The recommended temperature of the second chill roll is in the region of 20-30°C.

If the water bath method of cooling is used the vertical distance between the die lips and water surface should be

2-3 cm. The temperature of the water should be kept constant as near as possible between 50-60°C. As bubbles can be eliminated by passing the yarn over rollers fitted just above the surface of the water.

Films made by the chill roll technique show the following differences compared with tubular film, due to the nature of the process:

- greater fibrillation tendency
- better stretchability (especially at sheet thicknesses of 70-150 μm. This reduces the possibility of undrawn regions occurring in the final weaving tape
- the output of cast film plants is higher than that of tubular film plant of equal size, if films thicker than 100 μm are produced.

3.2. Drawing of film and film strip

There are two basic methods of making film strips:

a. the films are slit into strips before stretching, and these are drawn in circulating air ovens, hot water baths or by contact heating (heated metal sheets). The length of the stretching path is about 2-3 cm.

b. the complete roll of film is stretched longitudinally before slitting. The stretching path is short and is between heated rolls.

(Full details for the drawing of film and film strips are obtainable from Farbwerke Hoechst AG, Germany, or from the Managing Editor - Polymer Journal.)

3.3. New Developments

Rarely has a newly developed process become so quickly established in the plastics and allied industries as the production of stretched film weaving tape. This has given rise to strong competition and has made it necessary to improve the profitability of the equipment used.

One way of increasing plant output would be to increase the film width. Godet rolls supported at both ends, with roll widths of up to 1200 mm have been developed. This type of equipment is being successfully used for the production of weaving tapes for sacks, rope strands and tapes for ropes (1).

The width of Godet rolls is however frequently limited to 600 or 800 mm for ease of operation. Here the output is limited by the cooling efficiency of the haul-off unit. For this reason, haul-off equipment with two independent cooling systems has been developed, each of the cooling systems dealing with one lot of cast film. The melt is passed from the extruder with high plasticating capacity to two sheeting dies. After the films have left the chill rolls they are both slit together passing through the machine in a double layer, as in the tubular film method.

3.3.1. Stretching with arrested shrinkage

In short-time drawing stretching takes place without neck-in, i.e. the initial width of the unstretched film remains unchanged.

Conventional stretching increases the fibrillation tendency, particularly in the case of polypropylene. This causes the material to acquire a sisal-like character, which is undesirable if the weaving tapes are to be used for carpet backing or for making fabrics intended for covering large areas. If transverse shrinkage is arrested, the film is stretched solely at the expense of the thickness and the transverse strength is increased. At film widths of 600 mm the shrinkage amounts to only about 8%.

3.3.2. Fibrillating of film tapes

Continued development in the field of film tapes has been directed not only to increasing output. The arrested shrinkage stretching technique has already resulted in a planned influencing of the film tape properties, in this case by reducing the fibrillation tendency.

The wide variety of possible applications has also made it necessary to impart a more textile-like character to weaving tapes and woven fabrics. The extent of fibrillous structure obtainable when polypropylene tapes are fibrillated is not, however, sufficient for this purpose.

There are various ways of imparting a fibrous character of film tape cut from film or extruded through individual dies. This can be achieved by mechanical after-treatment such as slitting, abrading, twisting or needling. The last named is the method most commonly employed.

A porcupine roller is arranged either without a counter roller, as shown in fig. 2. A higher or lower stretch rate than in the production of ordinary film tapes is used. For this reason it is usual to start from tubular film which is slit, stretched, heat set if necessary and finally fibrillated.

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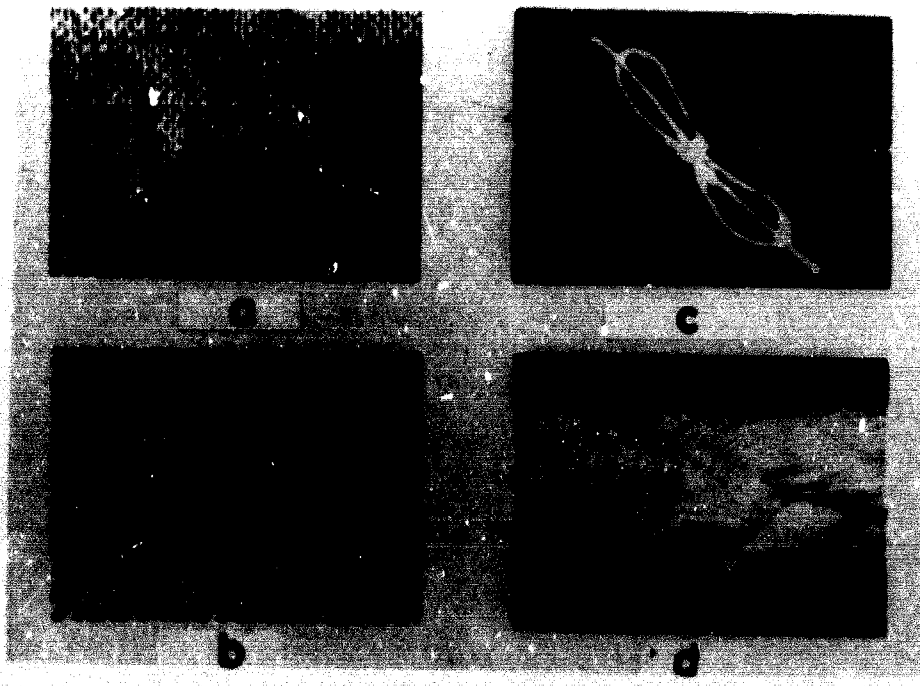
Figure 1

Examples of applications of monoaxially stretched film tapes



a - carpet backing

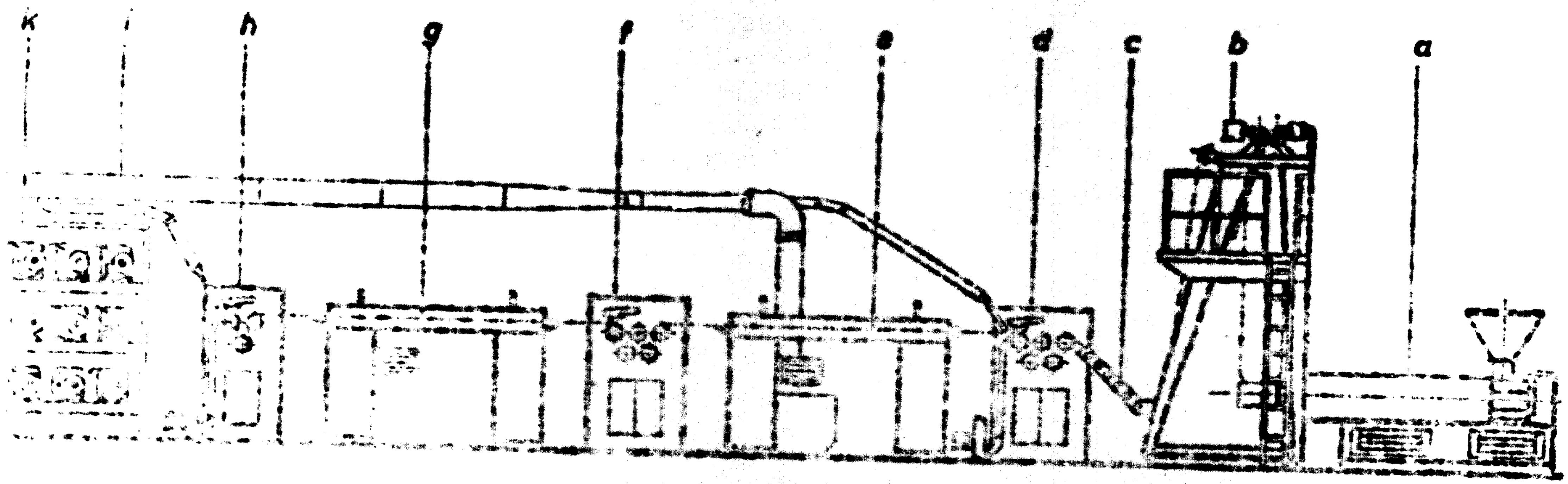
b - sack fabric

c - hawsers

d - binder twine

Fig. 2 Diagram of a tubular film production line for the manufacture of long-path drawn weaving tape

a extruder with film blowing head
b film haul-off with lay-flat and nip roll device
c anti wrinkle stretcher bar and slitting equipment
d stretching unit I
e hot air tunnel I (stretching)
f. stretching unit II
g. hot air tunnel II
h. stretching unit III
i. waste tape extraction system
k. spooling stands



2. stretch work

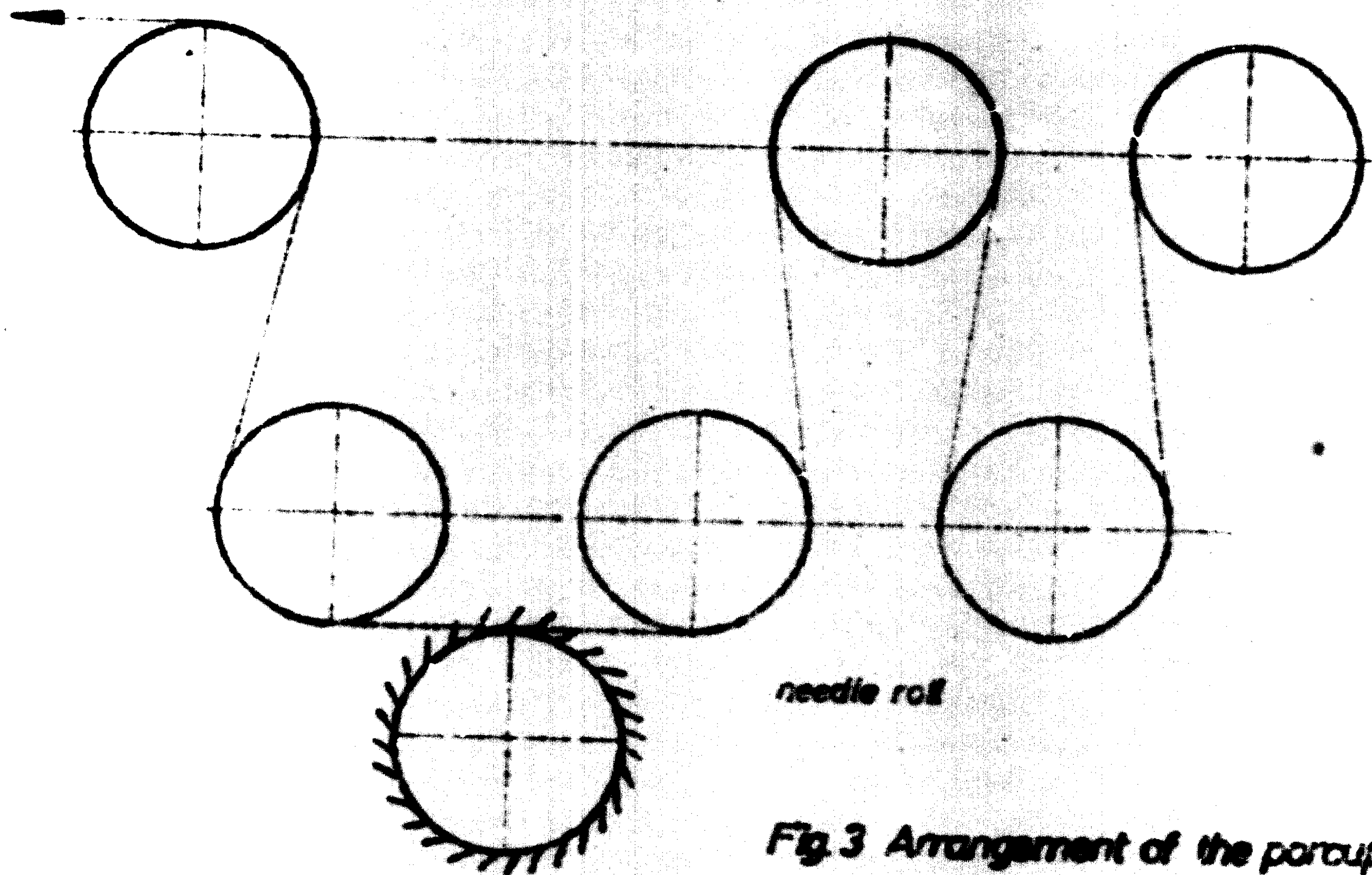


Fig. 3 Arrangement of the porcupine roller without counter roll (sketch by courtesy of Barmag. Remscheid-Lennep)

Rentability calculation of a flatyarn-plant

This calculation deals with data which are only valid for the Federal Republic of Germany.

A confirmation of the data by a manufacturer has not yet been given.

Machine costs:

Conventional stretching

	Dollar
9o. tubular film extruder with 425 slot die pulling-off tower, adjustable in height up to 800 mm	31 25o,-
layflat unit	12 5oo,-
cooling apparatus	12 5oo,-
1. stretching apparatus with a godet-width 8oo mm	8 438,-
drawing plant with hot air tunnel	6 25o,-
2. Stretching apparatus with a godet-width 8oo m	12 5oo,-
heat-setting unit with hot air tunnel	6 25o,-
1o6 winding heads (bandom at 25o)	57 813,-
suction device, control panel, different appliances	9 375,-
	156 876,-
Installation and construction work ca. 2 % of the investment costs	3 137,-
	160 013,-

The plant for 8 den 9oo, 3,6 mm whist of the flatyarn.

It is a 3-shift-production.

22 h x 28o days = 616o h x 7o kg/h (2o - 25 μ film):

431 t / year

Fixed costs

	Dollar
transcription of 5 years	32 oo3,-
calcul. interest 9.5. % of the half capital	7 6o1,-
building 1.o9/m^2 ca. 1oo m^2 x 12 month	1 3o8,-
firm costs/year	4o 912,-

Variable costs

Labour costs:

1 skilled worker 24 h x 28o days = 67oo h	
1/2 unskilled worker 3.98 x 67oo h	26 666,-

Demand for energy:

181,5 kW 22 h x 28o days x o.o3	33 541
Working expenses at 3 shifts 5 % from machine costs	8 oo1,-
plant matter	1 o94,-
	11o 214,-

Fixed and variable costs:

plant cost for 1 kg yarn	o,26

Material cost:

1oo kg HOSTALEN GF	o,5o
+ 2 % Waste	o,51

Production cost:	o,77
Market price:	1,o6

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