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PET.SYMP. D/6

SILK LIKE FIBRES[1]

Technical Committee of Japan
Chemical Fibre Association
Tokyo Japan

presented by

T. Betsuno

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1. General [illegible]

1.1 Introduction

[illegible] by far the most [illegible] fibre with its [illegible] history dating [illegible] inspiration for [illegible] such as Ja- panese [illegible] as well as European [illegible] all made of silk. [illegible] silk production [illegible] weather and climate [illegible] because of the labor [illegible] silk production reached a [illegible] in more recent years, it has [illegible] output has remained constant at about 3[illegible],000 tons. [illegible] growth in the future is not anticipated. In contrast, demand for silk is increasing year by year, thus making [illegible] valuable. Under these circumstances, many countries are striving to develop silk-like fibres. Recently, rapid [illegible] in high polymer chemistry and in production techniques have brought a variety of [illegible] to the market.

1.2. [illegible] of silk

The superior characteristics of silk are understood to result from a integration of the following properties:

(1) [illegible]

(2) [illegible]

(3) [illegible]

Of these, the handle may concretely be expressed as follows:

(1) High [illegible] and good recovery owing to moderately high bending [illegible]

(2) [illegible] and heavy touch

(3) [illegible] giving feeling as if fibres are caught on the skin surface

(4) Soft and [illegible] drape

(5) [illegible] deform but easily recover the shape when released

(6) [illegible]

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PET. SYMP. D/6

SUMMARY

SILK-LIKE FIBERS [1/]

presented by

T. Betsuno

Technical Committee of Japan Chemical Fibres Association
Tokyo, Japan

We can recommend the traditional rayon filaments which have a long record of performances as silk-like fibers, such as rayon, cupro and acetate. In recent years, however, synthetic fibers have been developed and further silk-like filaments are being used.

Synthetic fibers, which have been produced in Japan for use of silk-like filaments, are nylon, polyester, acrylics and vinylon. In addition, there are a benzoate fiber and a copolymerization fiber of acrylonitril and protein. They are developed especially for the silk-like fiber.

To manufacture silk-like synthetic fibers, we strive to give a particular shape to the fiber, to employ a special spinning and to use special raw material for making fibers.

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id.69-4144

Nylon and polyester, when given modified cross-sections, have silk-like lustre and touch. By employing particular shapes of spinning nozzles, various cross-sections such as triangle, hexagon and hollow can be obtained.

Acrylics, which are mainly produced in the form of staple, have a small production of filament. In Japan, Asahi Chemical Industry Co., Ltd. started producing acrylic filament "Tewlon" in 1968. "Tewlon," which has a silk-like lustre and touch, has a pleasant feeling and is not waxy which is a characteristic of synthetic fibers.

The production of vinylon began with staple, which is produced by wet spinning. However, the development of dry spinning and the partial acetalization of raw material PVA have given the fiber acid dyeable property. These developments have made it possible to produce silk-like vinylon filament. Nihon Vinylon filament, which has even cross-section structure and no skin-core, can be produced in bright colors. Dry spinning, with water used as a solvent, provides the filament silk-like lustre and touch.

Benzoate fiber "A-Tell" is also a silk-like fiber which has been produced by Nippon Rayon Co., Ltd. since 1968. The "A-Tell" is a fiber produced by polymerization of p-oxyethoxybenzoic acid. This fiber has ether and ester linkages in its moleculde, which gives the fiber a silk-like touch.

Production of "Chinon" which is the copolymerization fiber of acrylonitril and protein, has just begun by Toyobo Co., Ltd. in 1969. It is a unique silk-like fiber which has a general property similar to silk. It has better sunlight resistance than silk and also a silk-like lustre and touch.

Microscopic observation of the cross-section of silk shows that two triangular fibroins are covered with sericin. The sericin constitutes 20 – 25 % of the entire silk fiber. The fibroin is said to have triangular cross-section and a layer structure. These give silk its elegant lustre.

Although the fibroin is as fine as about 1 denier, it has high Young's modulus of [illegible] – 1200 kg/mm^2 and high elasticity. In addition, the fibroin is said to have minute crimp properties. The silk deprived of a part or the majority of the sericin through degumming, has voids among its fibres owing to the crimp properties of the fibroin. This combination of properties is believed to account for the warm, flossy, soft yet stiff and resilient handle peculiar to silk.

1.3. Development of silk-like fibres

The admiration of mankind for silk has acted as a challenge. It is no exaggeration to say that many man-made fibres have been developed with the aim of imitating and emulating silk.

Recently, the relationship between the structure and the handle of silk fibres has been clarified as previously described. This, coupled with recent advances in fibre production and processing techniques, has led to the physical and chemical modification of new high polymers, some new silk-like synthetic fibres have also made their appearance.

The silk-like synthetic fibres which have been described up to now in Japan can be generally classified as follows:

(1) Those made from new polymers

Benzoate fibres

"A-Tell" Nippon Rayon Co.

Acrylonitrile-protein copolymer

"Chinon" Toyobo Co.

(2) Those modified from existing fibres

Modified cross-section polyester

"Silpearl" Teijin Ltd.

"Sillook" Toyo Rayon Co.

"Siltine" Toyobo Co.

"Pefeel" Nippon Rayon Co.

Modified cross-section nylon	
"[illegible]"	Teijin Ltd.
"[illegible]"	Toyo Rayon Co.
"[illegible]"	Toyobo Co.
"[illegible]"	Nippon Rayon Co.
"[illegible]"	Kanegafuchi Spinning Co.
[illegible] filaments	
"[illegible]"	Asahi Chemical Industry Co.
Vinyl filaments	
"[illegible]"	Nihon Vinylon Co.

[illegible] output of silk-like synthetic fibres is approximately [illegible] month. This figure is already close to a half of the pro- [illegible] in Japan. Since [illegible] and new construction [illegible] silk-like fibres will continue to develop in [illegible] the fields previously reserved for silk but also on their [illegible]

[illegible] give a brief description of each silk-like [illegible] Japan.

[illegible]

2.1 Introduction

[illegible] silk-like [illegible] nylon by alteration of the [illegible] of manufacture [illegible] nylon [illegible] materials, [illegible] the United [illegible]. [illegible] the silk-like [illegible] modification of [illegible]

[illegible] silk-like [illegible] modification of nylon [illegible] modification [illegible] lustre and [illegible] nylon.

In Japan, [illegible] marketed. The [illegible] and feel are [illegible] bal cross-section [illegible] special [illegible] and [illegible], [illegible] knitted fabrics.

2.2 [illegible]

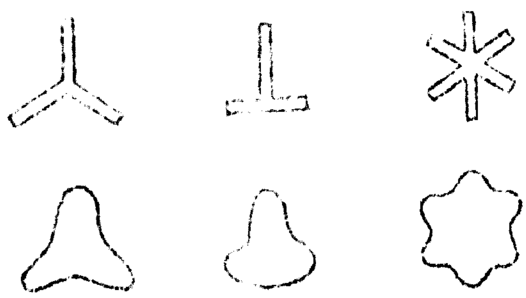
To [illegible] bright [illegible] that the [illegible] modified cross-section yarn [illegible] modified [illegible], a method of using specially [illegible] spinnerets [illegible] cross-section [illegible] summed up as follows:

1. [illegible] cross-section profile [illegible] The [illegible] and the cross-section of the filament is illustrated in Figure 1.

Figure 1 : Shape of spinneret and cross-section of filament

Shape of spinneret

Cross-section of filament



2. [illegible] in melt [illegible] to a circular cross-section, owing to [illegible] the shape of the spinneret [illegible] the change in the cross-section [illegible] of the molten

[illegible]

[illegible] ..., ..., ..., [illegible], etc.

2. [illegible]

[illegible] ...ly [illegible] ...ks [illegible] a

silk [illegible] and [illegible]
to [illegible]
cross [illegible]
pro [illegible]
by [illegible]

3. [illegible]

3.1. [illegible]

[illegible]
te [illegible]
cross [illegible]

[illegible]
tion [illegible]
tient

T[illegible]

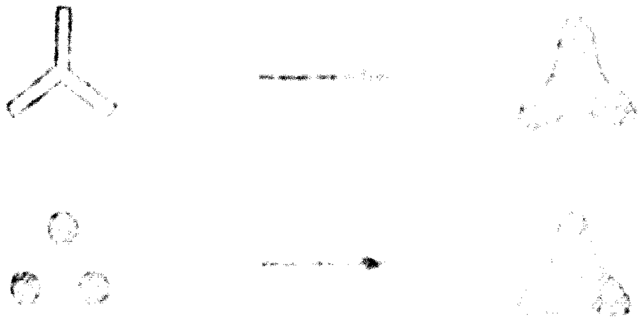
(1) [illegible]
(2) [illegible]
(3) [illegible]
(4) [illegible]
(5) [illegible]
(6) [illegible]
(7) [illegible]

Through [illegible]

(1) [illegible]
(2) [illegible]
(3) [illegible]
(4) [illegible]
(5) [illegible]
are [illegible]
(6) Friction [illegible] between fibres decreases.

3.2. Manufacturing process

For better [illegible], the raw material for polyester silky yarn should be bright polymer. For modifying cross section to the proper shape, [illegible] of [illegible] uniformity is used. In the manufacture of [illegible] cross-section yarn, a method [illegible] cross-section.



[illegible]

[illegible] multi-[illegible]

[illegible] marke-[illegible]

Table 1 shows the properties of modified cross-section yarn and hollow yarn versus ordinary circular yarn.

Table 1 Properties of Modified Cross-section Yarn

[illegible]

Cross-section shape / Properties	Circular	Modified hollow cross section	Modified cross section
Cross-section			
Denier	2[illegible] – [illegible]	[illegible] – 100	30 – [illegible]
Tensile strength, g/d	[illegible]	4.0 – 6.0	1.[illegible] – [illegible]
Elongation, %	[illegible] – 40	25 – 30	25 – [illegible]
Hollowness ratio, %	–	10 – 20	–
Young's modulus, kg/mm2	1000 – 1[illegible]00	1000 – 1800	1000 – 1[illegible]
Elastic recovery, at 1% stretch, %	100	100	100
at 3% stretch	[illegible] – 100	95 – 100	95 – 100
Friction coefficient, 100 cm/sec	[illegible] – 0.3	0.[illegible] – 0.3	0.2 – [illegible]
Friction coefficient, 300 cm/sec	0.2 – 0.[illegible]	[illegible].2 – 0.4	0.2 – 0.[illegible]

[illegible] Hollow Yarns

[illegible]

slightly pale in density.

Utilizing such [illegible] visual density through modification of cross-section, [illegible] possible to give [illegible] two tone effect. Especially with [illegible] [illegible] [illegible] [illegible] [illegible] of [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] application [illegible] [illegible]

3.[illegible] [illegible]

[illegible] [illegible] [illegible] [illegible] production [illegible] [illegible], it is the most important material [illegible] [illegible] [illegible] a variety [illegible] [illegible] likely to [illegible] developed in the [illegible].

4. [illegible]

4.1. [illegible]

[illegible] [illegible] developed for production of filament, [illegible] [illegible] [illegible] [illegible] world [illegible] [illegible] [illegible]

[illegible] [illegible] in Japan [illegible] [illegible] [illegible], [illegible] [illegible] the [illegible] [illegible] [illegible] in [illegible] [illegible] ment. [illegible] [illegible] [illegible] some [illegible] [illegible].

4.2. [illegible]

[illegible] [illegible] acrylic filament is [illegible] the same as that for acrylic staple, [illegible] [illegible] [illegible] in Japan [illegible] [illegible] process. At present, however, most [illegible] [illegible] propylene and ammonia [illegible] [illegible]

4.3. [illegible]

Acrylic [illegible] [illegible] processes are the dry-spinning process and the wet-spinning process

The [illegible] shown in figure 2

[illegible]

4.4. Types, Characteristics and Properties

Types of acrylic [illegible] produced in Japan range from [illegible] to [illegible] generally used for woven fabrics and [illegible]

[illegible]

(1) [illegible], but has no [illegible]

[illegible]

(2) [illegible]

[illegible]

(3) [illegible]

(4) [illegible]

[illegible] described [illegible]

Table [illegible]

Tensile [illegible]	[illegible]
Tensile [illegible]	[illegible]
Young's [illegible]	[illegible]
Specific [illegible]	[illegible]
Official [illegible]	[illegible]

4.5. [illegible]

Silk [illegible], but is little used for knitting [illegible].

[illegible] filaments afford a combination of lightness [illegible] in-
[illegible] filo-
[illegible]

[illegible], [illegible] grade
[illegible]

[illegible] conditions
[illegible]

[illegible] and to
[illegible]
[illegible] entirely
[illegible].

Advantag[illegible] over the [illegible] process in the manu[illegible]

(1) [illegible]

(2) [illegible]

(3) [illegible]

(4) [illegible]

[illegible], a method [illegible]

[illegible]

[illegible] from [illegible]

[illegible]

[illegible] PVP [illegible]

colo[illegible]

[illegible]

Figure [illegible] vinyl [illegible]

Figure 3 Flow Sheet for the Manufacture of Vinylon Filament by Dry Spinning Method

PVA

[illegible]

[illegible] are available. The

[illegible]

[illegible] loped

[illegible].

Advantages of vinylon filaments are:

(1) Owing to the [illegible] cross-section of the fibres, without skin and core [illegible], the [illegible] is extremely bright.

(2) The [illegible] with water as solvent makes fibre surface [illegible] similar to that of silk.

(3) [illegible] dye [illegible]

(4) [illegible] than other synthetic fibres: for [illegible] electrostatic charge is [illegible]

Properties of vinylon filament fibres are shown in Table 3.

Table 3 [illegible]

Item		[illegible] improved type	[illegible] improved type
Tensile strength (g/d)	dry	3.0 - 5.0	[illegible]
	wet	[illegible]	[illegible]
[illegible] strength [illegible]		70 - [illegible]	[illegible]
[illegible]		4.5 - 7.0	[illegible]
Knot [illegible]		[illegible]	1.4 - [illegible]
Tensile [illegible]	dry	17 - [illegible]	17 - [illegible]
	wet	17 - [illegible]	[illegible]
Elastic [illegible]		[illegible]	[illegible]
Young's [illegible]		60 - 90	[illegible]
Softening [illegible]		11[illegible] - 118	[illegible]
Softening [illegible]		210 - 230	
Specific gravity		1.26 - 1.30	
Moisture [illegible]	[illegible]	5.0	
(%)	([illegible] condition) 20°C, [illegible]	3.5 - 4.5	
	20°C, [illegible]	1.2 - 1.8	1.0 - 1.3
	[illegible]°C, [illegible]	10.0 - [illegible]	9.0 - 1[illegible].0

5.5. Applications

Viny[illegible] accepted in the field of high grade apparel owing to [illegible], silk-like luster and handling.

(1) High [illegible]

Fabrics [illegible] or mixed with silk, wool and oth[illegible] high grade silk fabrics such as [illegible], "obi", small pieces for "[illegible]

(2) [illegible]

Fabrics [illegible] or mixed with silk are used for women's [illegible], [illegible], [illegible] by "habutae", satin georgette, [illegible]

(3) [illegible]

Appl[illegible] for women's suit cloth, men's polo sweater, [illegible], etc. using [illegible] vinylon filaments of el[illegible]

(4) Tricot

With [illegible] moisture absorbency, tricot fabrics of [illegible] are used in the field of underwear including [illegible], [illegible] etc.

5.6. Processing [illegible]

(1) Weaving [illegible]

Vinylo[illegible] higher moisture absorbency than other synthetic [illegible], [illegible] significant change in yield stress by humidity, [illegible] control of tension, temperature and humidity [illegible].

(2) Dyeing

Almost all dyestuffs commonly used may be used. Of them acid dyes in particular [illegible] suited.

Other [illegible] are disperse dyes and metal complex dyes which [illegible] depending on applications and required color [illegible].

Temperature dependency of dyeing affinity is great. Except acids dyes and a part of disperse dyes, abrupt dye absorption occurs in dyeing [illegible] of 80 – 90° C.

5.7. Future Development

Along with the advance in processing techniques, the recently [illegible] elasticity-improved type, conjugated yarn and modified cross-section yarn, which are expected to be developed in the future, nylon filament can be expected to make a further progress as fibres for apparel use.

6. BENZOATE FIBRES

6.1. Introduction

Benzoate fibre is a new synthetic fibre developed and brought into production under the tradename of "A-tell", by Nippon Rayon Co. in May, 196[illegible]. The benzoate fibre is made from phenol and ethylene oxide. In its molecule ether bonds and ester bonds are regularly arranged. This type of synthetic fibre is unique in the world today and is manufactured by purely Japanese techniques. It is a new fibre [illegible] closely resembling the silk and has [illegible]-over strength and easy care properties not found with [illegible]

6.2. Raw Material and Manufacturing Process

The starting material for benzoate is phenol which is made in large volume at a low cost by petrochemistry. Reaction of carbon dioxide and phenol [illegible] yields para [illegible] benzoic acid. Then ethylene oxide is [illegible] to react to [illegible] benzoic acid which is then esterified by methanol to produce monomer. This monomer undergoes poly-condensation under suitable conditions. It is then extruded by melt-spinning and is further [illegible] to produce filaments.

CH_2 — CH_2 \ O /

CO_2

HO [illegible] HO — COOH → HO — CH_2 — CH_2 — O — COOH

CH_3OH

→ HO — CH_2 — CH_2 — O — $COOCH_3$ → Polycondensation

→ Melt spinning → Hot drawing → Filament

6.2. Types

Benzo[illegible] [illegible] variety of types by combining [illegible] [illegible], cross-sectional shape and lustre.

(1) [illegible] high shrink

(2) [illegible] sections

(3) [illegible]

Filam[illegible] [illegible] follows:

303/[illegible] [illegible] fil,

[illegible] fil, 36 fil, 48 fil

36 fil [illegible]

6.3.[illegible]

(1) Ch[illegible] [illegible] fibre versus silk.

[illegible] fibre possesses out-

[illegible] its specific gravity

standing [illegible] [illegible] silk

is clo[illegible] [illegible], as this

(1.3[illegible] [illegible] absorbency)

fibre [illegible]

of [illegible]

Its [illegible] higher

[illegible] desirable for

[illegible] In addition,

[illegible] it does not cause

[illegible] with

fib[illegible] [illegible] highly as a fibre.

its [illegible]

Table 4 Characteristics of Benzoate Fiber versus Silk Fiber

		Benzoate Fiber	Silk
Specific gravity		1.34	1.33 - 1.45
Equilibrium moisture regain (%)		0.4	9
Tensile strength (g/d)	dry	4.0 - 5.3	3.0 - [illegible]
	wet	4.0 - 5.3	[illegible] - [illegible]
Tensile elongation (%)	dry	15 - 30	15 - [illegible]
	wet	15 - 30	27 - 33
Elastic recovery at 3% stretch (%)		95 - 100	-
Young's modulus (kg/mm^2)		700 - 900	650 - 1,200
Melting point (°C)		Approx. 225	-

(2) Weathering and Sunlight Resistance

Benzoate fiber is so resistant to weathering and sunlight that unlike silk it will never suffer yellowing or degradation. It is also highly durable under outdoor exposure.

(3) Chemical Resistance

Benzoate fiber is impervious to virtually all inorganic and organic chemicals. It shows high resistance to strong acids such as sulfuric acids and nitric acids. It is unaffected by a strong alkali such as caustic soda. Also it is impervious to bleaching agents such as sodium hypochlorite, hydrogen peroxide and hydrosulfides. Of organic solvents, phenol-based solvents dissolve the benzoate fiber, but the majority of organic solvents do not dissolve it unless by heating. The organic solvents which dissolve the benzoate fiber are m-cresol and o-chlorophenol.

(4) Elasticity and Elastic Recovery

Elasticity [illegible] recovery are the important factors which determine [illegible] Nylon is the fibre having by far the best [illegible] recovery [illegible] nylon, [illegible] fibr has an [illegible] that of [illegible] [illegible] repea- ted [illegible] sta[illegible] excellent wear[illegible] qualities [illegible]

(5) [illegible]

[illegible] and elastic [illegible] silk. C[illegible] resistance, s[illegible] and [illegible] silk fa- brics [illegible] provide almost the same [illegible].

(6) [illegible]

[illegible] and a soft[illegible] of synthe- tic [illegible]. This fibre does [illegible]. Polyester requ[illegible] heat set, but [illegible] tempera- ture. [illegible] qualities

(7) [illegible]

[illegible] than that of poly[illegible] dyes are used. An [illegible], at which temp[illegible] stable. Moreover, [illegible] is [illegible] at 1[illegible]°C.

6.4. Application

Owing to the [illegible] of the Kanebo [illegible] fiber almost similar to that of silk, [illegible] fabrics of 100 [illegible] fiber or mixed with silk, to [illegible] high grade [illegible].

[illegible] as follows:

[illegible]

Suit [illegible], [illegible], coats, sweaters, polo shirts

[illegible], [illegible], men's socks, umbrella cloth

6.5. [illegible]

[illegible] characteristics of silk with [illegible] of synthetic fibers not found with silk, it will [illegible] application, not only in the fields where silk is used, [illegible] the highest quality synthetic [illegible]

7. [illegible]

7.1. [illegible]

[illegible] fiber) has [illegible] 10 [illegible] study by [illegible]. This fiber [illegible] to [illegible] silk very [illegible] polyester [illegible] difference [illegible] silk-like [illegible]

7.2. Properties

The [illegible] in the range from [illegible] denier through [illegible] denier [illegible]. In general, [illegible] fibers [illegible] of two [illegible] both constituents [illegible] fiber, [illegible] no definite separation [illegible] structure [illegible].

As shown in [illegible] of the [illegible] fiber [illegible] resemble [illegible] to those of silk [illegible]

[illegible] properties, [illegible] fiber exhibits excellent fiber pro- [illegible] providing a substantial [illegible].

[illegible]

	[illegible] fiber	Silk
[illegible]	[illegible]	[illegible].0 - 4.0
[illegible]	[illegible]	2.1 - 2.[illegible]
[illegible]	[illegible]	15 - 25
[illegible]	[illegible]	27 - 33
[illegible]	[illegible]	2.[illegible]
[illegible]	[illegible]	650 - 1200
[illegible]	[illegible] - 5	9
[illegible]	1.[illegible]	1.33 - 1.4[illegible]
[illegible]	[illegible]	0 - 1

(1) [illegible]

[illegible] silk.

(2) [illegible]

[illegible] modulus is very similar to [illegible] for special purpose.

(3) [illegible]

It[illegible] than that of silk.

[illegible] good crease recovery of the fabrics.

(4) [illegible]

[illegible] defects of silk, but [illegible] sunlight, and is the best of all synthetic [illegible].

(5) Appeal to the senses

The characteristics of the [illegible] fibre which appeal to the [illegible] including handle and lustre, show a very close resemblance [illegible] silk. More specifically, it makes fabrics with soft feeling, [illegible] drape, [illegible] lustre, [illegible] slipperiness, [illegible] feeling, and metallic [illegible] with normal [illegible] fibres.

(6) Drape

Drape is said to have important connection with feel of fabrics. The [illegible] beautiful drape and softness most similar to those of silk.

(7) Lustre

Lustre [illegible] resemblance to that of silk, and this [illegible] out by functional test

7.3. Weavability

(1) Weaving and Twist Yarn

[illegible] of [illegible] fibre yarn is far higher than that of silk. [illegible] no problem [illegible] weavability. Its friction coefficient [illegible] lower than that of other synthetic fibres. [illegible] at yarn [illegible] minimum [illegible] like [illegible]. Silk [illegible] to give [illegible]. Also the [illegible] twist [illegible] of the [illegible] fibre can make woven [illegible] with the same handle as that of silk and this is one of the [illegible] of this fibre.

(2) Warp Sizing

The [illegible] fibre is a copolymer of protein and acrylonitrile. [illegible] terials essentially show high adhesion to various sizing [illegible]. As a result, the [illegible] fiber permits far easier sizing than other synthetic fibres.

Excellent weavability can be given with just a little size pick-up. This is also one of the important advantages of this fiber.

7.4. Processibility

(1) Scouring

The AnP fibre does not require intensive scouring which is required for natural fibres such as wool and cotton containing plenty of impurities. As with other synthetic fibres scouring of the AnP fibre need only be to the extent of removing the oil on fibres or removing the size picked up in the weaving step. Since water soluble sizes like PVA are used with the AnP fiber, desizing and scouring may be done simultaneously.

(2) Creping

Hard twist yarn of the AnP fiber provides smaller untwist torque than the hard twist yarn of silk , but it can be satisfactorily creped by the use of mechanical supplementary means or softening agents in bath.

(3) Dyeing

Since the AnP fiber is a copolymer of protein and acrylonitrile, it combines the advantages of natural fibres and synthetic fibres. It is the fiber having properties of protein which shows affinity to anionic dyes, direct dyes and chrome dyes and those of polyacrylonitrile which show affinity to cationic dyes and disperse dyes. Therefore it is dyeable with any type of dyestuffs.
Table 6 shows the affinity of the AnP fiber to various dyestuffs compared with silk. As shown, the AnP fibres exhibits affinity to various kinds of dyestuffs, but the dyestuffs principally used in practice are acids dyes.

Table 6 Affinity to various dyestuffs and fastness.

Dyes / Affinity and Fastness		Acid dyes	Metal Complex dyes 1:2	Chrome dyes	Direct dyes	Cationic dyes	Disperse dyes
Affinity							
Build-up							
Fastness to sunlight	AnP fiber						
	Silk						
Fastness to washing	AnP fiber						
	Silk						
Fastness to rubbing	AnP fiber						
	Silk						

Good   Rather poor   Poor

In its dyeability with acid dyes AnP fibre resembles silk but is unlike other silklike fibres and this is one of the important advantages of this fibre. Other dyes are also applicable depending on use. For example, cationic dyes are used where bright hue or fluorescent color is required and chrome dyes are used for black color, and disperse dyes for light colors.

In dyeing, high temperature dyeing or carrier dyeing is not required. Dyeing at 95 – 100°C under normal pressure can develop sufficiently dark color. Dye absorption curves by temperatures are mild, which implies difficulty of causing uneven dyeing.

Comparison in color development characteristics and stimulus purity between [illegible] fibre and silk shows that the [illegible] fiber is not at all inferior [illegible].

[illegible] that of silk. The [illegible] better [illegible] better fastness [illegible], their [illegible] and wet rubbing [illegible] dyestuffs is [illegible]

[illegible]

[illegible] silk is now used. Even [illegible] in the fields of textured yarn and knitted [illegible] penetrated deeply into the [illegible] development, it will be [illegible] into unique products of great beauty.

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