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RECENT PROGRESS IN COTTON RESEARCH AND ITS IMPORTANCE FOR THE COTTON INDUSTRY [1]

by

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1. INTRODUCTION

Recent developments in cotton research will be reviewed from the perspective of the International Institute for Cotton (IIC) which is an inter-governmental organization formed in 1966 to increase the use of cotton in Western Europe and Japan. The member countries of the Institute are the USA, Mexico, Spain, India, Tanzania, Uganda, Greece and Brazil. Other countries have expressed interest in the IIC and may join it before long.

The successful marketing of cotton, as of any fibre, depends on many factors, such as price, profit opportunities at all stages of processing, good design, sales promotion and, of course, quality. Fibre cost and marketing are outside the scope of IIC's activities which are concentrated on market research, promotion and technical research (1). This presentation is restricted to a review of IIC's technical research activities which are aimed at meeting the quality requirements of the consumer.

2. GENERAL

2.1 IIC Market Research

The IIC conducts extensive market research to form a basis for the promotional and technical research activities and the following main facts need stressing.

Cotton is the most widely used of all textile fibres, 57% of the total fibre offtake in the world as a whole, and 42% in Western Europe. The overall consumption of cotton, in millions of bales, is increasing, but only slowly although the total fibre consumption expands at the rate of about 7% a year.

The markets for cotton can be broken down into three sectors; 50% of the fibre sold goes into apparel end-uses, 30% into household uses and 20% for miscellaneous industrial purposes. The latter market is fairly static and cotton still holds a high percentage of the household market but it is in the apparel field that cotton has sustained its largest losses. Although cotton is still very much appreciated for its comfort qualities, such as coolness, absorbency, "breathing properties", etc. it is considered to be deficient in certain maintenance properties. In layman's terms this is expressed as "wrinkles too easily", "needs too much ironing", "too slow to dry", etc. All these ideas can be expressed in the one phrase - lack of adequate easy-care properties, and the solution of this problem forms one of the major objectives of the IIC technical research programme. This same objective is shared by many other organizations including the NCCA, USDA, chemical suppliers, commission finishers, etc. and the IIC programme has been planned to reinforce and complement these existing activities.

2.2 IIC Technical Research

Easy care can be improved by various means, such as fabric construction (for example, knitted fabrics crease less than comparable woven fabrics), but the most effective means is resin finishing. Great progress has been made in this field in the past 25 years but the basic problem remains; how to obtain easy-care properties without undue loss of wear life. It should be emphasized that the basic problem in the finishing of cotton fabrics is not the creation of easy-care properties but is the maintenance of an adequate wear life and strength after the required high levels of easy-care performance have been achieved. Until recently, developments had centred on the synthesis of new and improved chemicals but further substantial progress along these lines now seems unlikely. Instead, attention is being devoted to modifications of the structure of the cotton fibre itself. Accordingly the first IIC-sponsored projects were concentrated on a study of fibre structure. Other areas of easy-care finishing were gradually added to the IIC programme, and it also includes a few projects in areas not related to easy care.

The IIC does not have a research laboratory of its own and its research programme is carried out under sponsorship or co-operative agreement in existing research organizations. At this time (May 1970), 22 projects are conducted in 20 research institutes, Universities and private companies in the United Kingdom, France, Belgium, the Netherlands, Western Germany, Switzerland, Sweden, Czechoslovakia and Japan. Additional contracts are under discussion in Spain, Western Germany, the United Kingdom, and the Netherlands.

Recent findings in the IIC-sponsored projects will be reported briefly, and developments in cotton research not sponsored by the IIC will also be mentioned. Since easy-care finishing is the most important problem for cotton, it will be reviewed first, starting with findings on fibre structure.

3. COTTON FIBRE STRUCTURE AND EFFORTS AT MODIFICATION

A clear and productive model for the structure of the cotton fibre is emerging from recent work in Europe and the USA. The current view is that the fibre is composed of almost entirely crystalline fibrils, the surfaces of which are the sites for chemical reactions, such as dyeing, and crosslinking. In the outer or primary wall, the fibrils form an open network but in the secondary wall, which forms 95% of the fibre, the fibrils are mostly parallel and follow a spiral path. At intervals the direction of the spiral reverses at places called "reversal points".

In the unopened cotton boll, the fibres are more or less circular in cross-section but, when the boll bursts and the fibres are exposed to the air, they dry and collapse to the well-known bean-shaped section. At the Paris laboratories of the Institut Textile de France, Kassenbeck has discovered (3) that this collapse destroys the original uniformity of the structure and produces a "bilateral structure" in which the load sharing of the fibrils is very far from uniform. Such a fibre is obviously weaker than it would be if the structure supported its load evenly.

The variation in the density of packing of the fibrils in different portions of the fibre results in variation in the accessibility of the fibre to swelling agents, easy-care resins, enzymes, etc. All these effects have been demonstrated experimentally and it is believed that they have important consequences in such processes as rotproofing, flameproofing and the easy-care finishing of cotton fabrics. All these implications are being followed up but in the meantime these ideas have been confirmed by the work of Borsten in the IIC sponsored work at the Vezelinstituut TNO in Holland.

Working from a different starting point, Borsten has shown that cotton fibres can be made more uniform by suitable swelling processes, and the elimination of the "bilateral" effect increases the strength of the fibre very considerably. The process also results in the retention of a fairly high elongation so that the total energy needed to break the modified fibre is also increased. This is important as energy to break can be taken as an indication of probable abrasion resistance or durability. A substantial part of all these increases is retained after the usual quantities of easy-care resins have been applied so that the pretreated and resinated fibre is at least as tough as the original unmodified cotton fibre. It should be emphasized that these results have all been obtained with the use of sodium hydroxide as a swelling agent combined with simple mechanical and thermal treatments.

Table I

Energy-to-break (arbitrary units)

of single cotton fibres (Acala 442)

Resin applied	No pre-treatment	Borsten pre-treatment in 24% NaOH	
		without stretch	with 5% stretch
0%	54	158	94
6%	22	60	76
12%	20	29	51

The Borsten studies were initially made on fibres. When fabrics are treated, additional problems arise because yarn twist and the weave structure create restraints to the swelling of individual fibres. To obtain maximum toughness, it is desirable to swell all the fibres uniformly and it is preferable to modify all the fibres partially than to modify fully a fraction of the fibres. A swelling agent is therefore required which will penetrate very rapidly between the fibres and then, and only then, cause swelling to take place. Caustic soda solutions can be used at suitable temperature and concentration and are being tried, but new techniques based on liquid ammonia (see later) offer an alternative and in some ways more attractive approach.

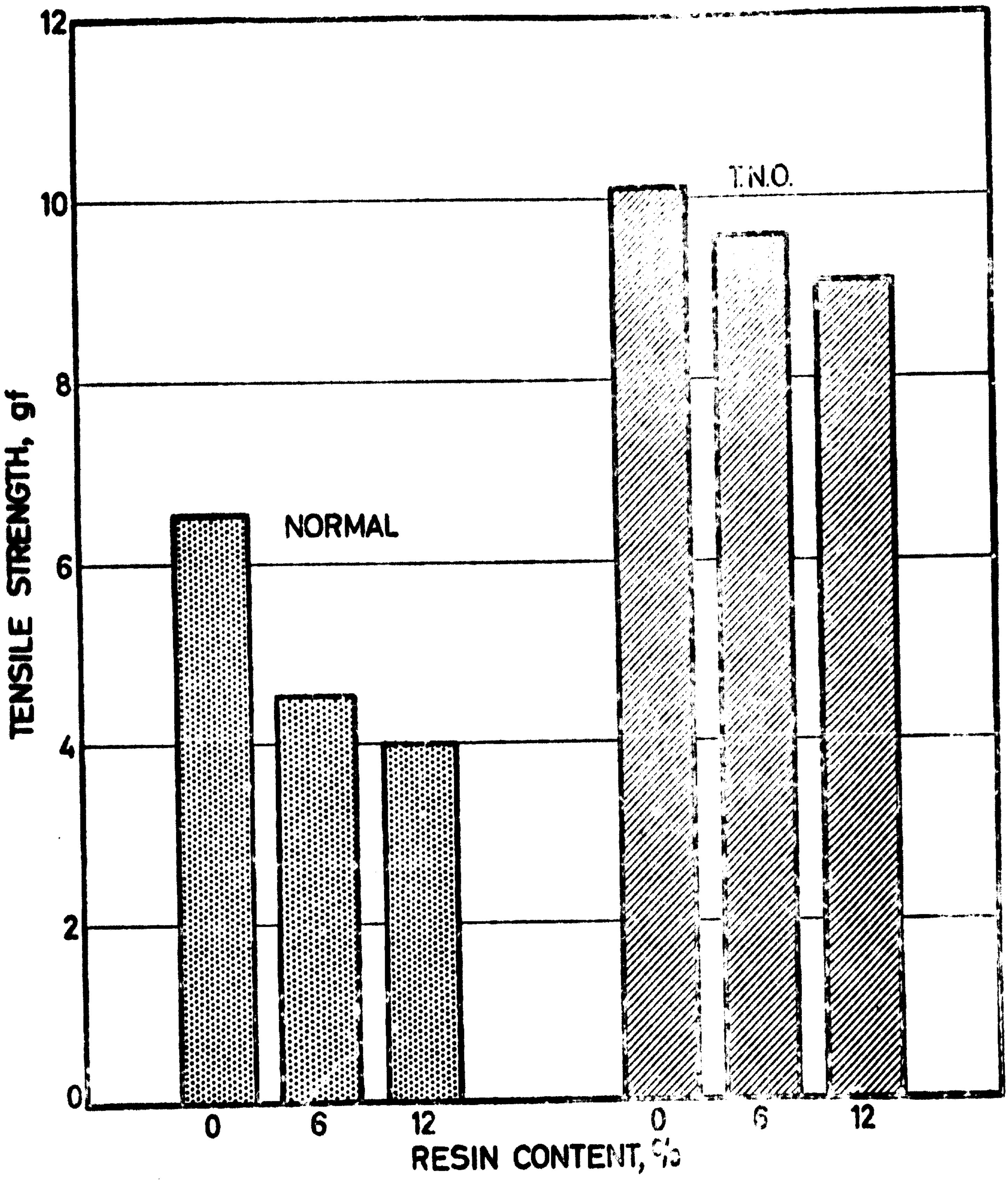

Fig. 1 Dependence of cotton fibre strength on resin content

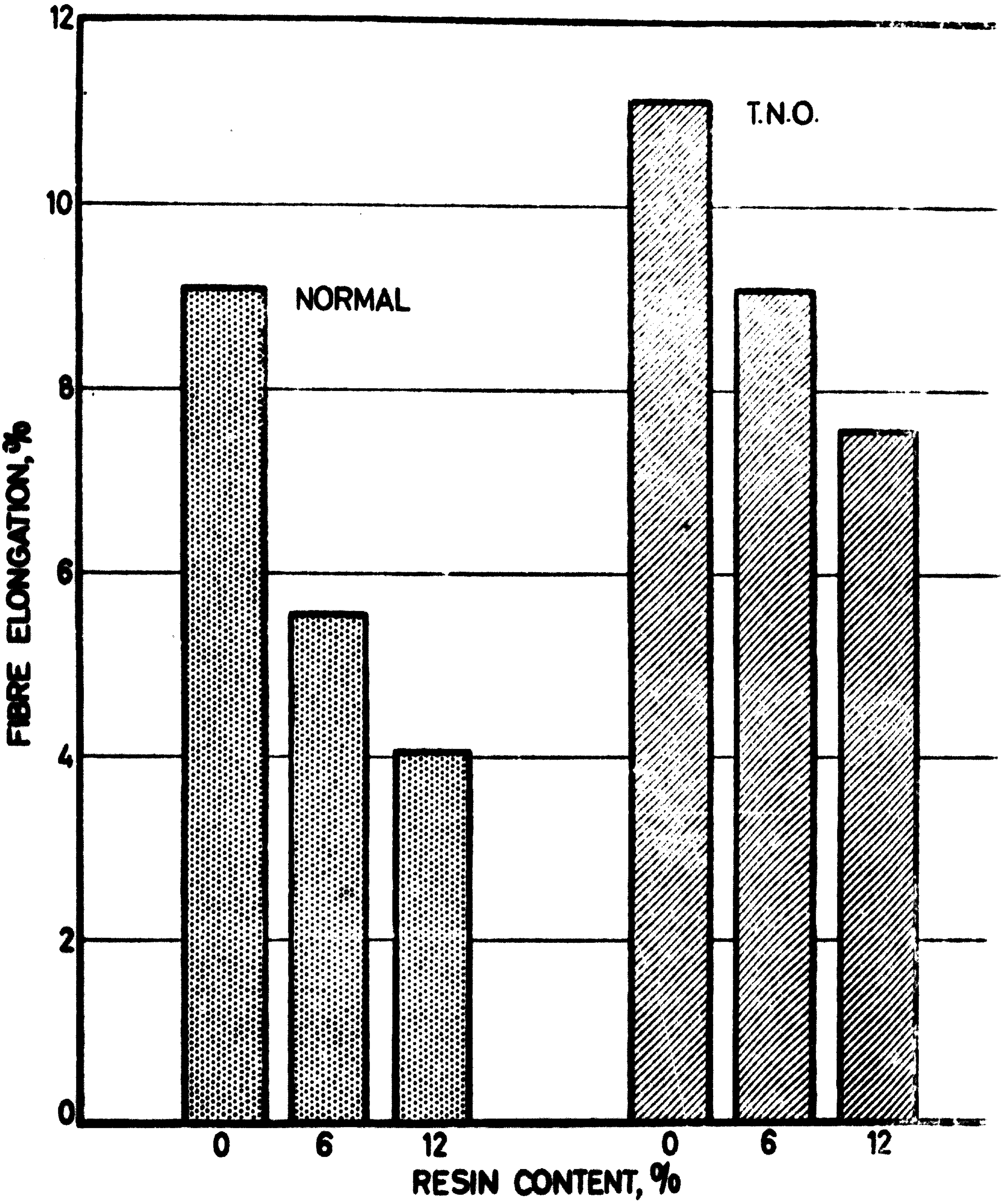

Fig. 2 Dependence of cotton fibre elongation at break on resin content

In addition to the bilateral structure of cotton fibres, another source of their weakness lies in fibre reversals which form places of stress concentration along the fibre. Professor [illegible] at the De Meulemeester Laboratory of the University of Ghent (Belgium) has shown that the strength of a cotton fibre at a reversal point is only about 75 to 80% of its strength between reversal points. Numerous attempts using chemical, physical, enzymatic and irradiation techniques have failed to change this relative reversal strength although the absolute fibre strength can be varied quite considerably. The reasons for the weakness at the reversals are not clear and a number of theories are under discussion. Work on the mechanism of fracture is also being conducted by Dr. Hearle at the University of Manchester who has shown that the form of a break at a reversal point is different from that obtained between reversals. A very fibrillated fibre end is produced when the fibre breaks near a reversal but there is an almost complete lack of fibrillation at a between-reversal break.

4. NEW FINISHING TREATMENTS FOR COTTON

The area is a broad one, and many new processes have recently been described as alternatives to the conventional pad-dry-bake technique. They include the Wet-Fix and moist-cure processes, several variants of which have been introduced in the past few years. They will not be discussed here but two newer aspects of easy-care processing will be mentioned, one of which is being investigated under IIC sponsorship.

4.1 Liquid Ammonia Treatment for Cotton

The effects of treatment with liquid ammonia bear some similarity with conventional mercerization using caustic soda. By liquid ammonia is meant pure ammonia, NH_3, at a temperature below its boiling point of -33°C. Several difficulties had to be overcome before the process could be used industrially, such as working at low temperatures, the explosive nature of the ammonia/air mixture, etc. Once mastered, the new technique shows the advantage of a high speed of reaction, easy removal of the ammonia for recovery, no danger of damage to the cotton during treatment, and no effluent.

Two organizations have so far tackled the ammonia process and brought it to an industrial stage. They are J. & P. Coats Limited, the British sewing thread manufacturers, and the Norwegian Institute for Textile Research. The ammonia treatment is suitable only for cellulosic fibres and confers major benefits on cotton and linen only.

J. & P. Coats announced their ammonia process (4, 5), called "Prograde", during 1969; it had been applied commercially for over two years previously. The present pilot plant has a production of around 7000 kg of sewing thread per week. The process increases the strength of the thread, the amount depending on yarn twist and on the number of plies. An increase in strength of 40% is typical and, with two-ply yarn, 80% or more can be achieved. This is equivalent to over 5 g/denier. The producer can thus use the process either to make a stronger thread or to keep the same strength and use a lower grade of cotton. At present only sewing threads are treated in quantity by the Prograde process but there are many outlets possible for cotton yarns of increased strength, especially in the industrial sector. One potentially large market lies in the replacement of the more expensive mercerized cotton knitting yarns by ammonia-treated yarns, and IIC is co-operating with Coats in studying the knitting performance of these yarns. The first results are very encouraging; the Prograde yarn knits at least as well as conventionally mercerized yarn and the fabrics have equivalent lustre and handle. It is worth emphasizing that the costs of the Prograde treatment are about one half of those for conventional yarn mercerization.

The Norwegian Institute for Textile Research has been granted patents (6) for the liquid-ammonia treatment of fabrics and a pilot plant is being installed in Norway. The treated fabrics do not shrink during laundering and an improvement is observed in the smoothness of the fabric surface after washing. This latter advantage is not to be confused with crease resistance but it does mean that good easy-care properties can be obtained more easily, that is, with less resin and therefore with a better wear life than that of resin-treated fabrics without ammonia treatment. Additional smaller advantages of the ammonia treatment are very soft handle, possibility of making stretch fabrics easily, better resistance to soiling, and less seam slippage.

4.2 Solvent Finishing of Cotton Fabrics

Crease-resist resins are normally applied from a water solution but the Shirley Institute has investigated, in co-operation with IIC, the use of solutions or emulsions in solvents, such as the chlorinated hydrocarbons used for drycleaning. A more favourable distribution of the resin within the fibre was hoped for and hence a better balance of strength and easy-care properties. No such gains were realized in practice but, in the course of the work, a new method for curing resins was discovered.

In the new curing technique, the fabric is padded through an aqueous solution in the normal way and then cured in a chamber filled with vapour of a boiling solvent. The vapour acts as an efficient heat-transfer and moisture-removal agent and the resin is cured within a few minutes. Fabric properties have been obtained as good as in the best conventional resin treatments, namely, in moist-cure crosslinking.

We anticipate two major applications for the solvent vapour process. When a finisher has to use continuous methods of curing to obtain the required production, the solvent vapour cure can replace the high temperature baking process with a resultant improvement in fabric properties. Alternatively, where a finisher is using a batch process (e.g. a moist-cure system) then the batching delay of 12-18 hours can be replaced by a continuous vapour cure. In this case, equivalent fabric properties will be obtained and the advantage will lie in terms of productivity.

5. SPINNING AND FABRIC MAKING

Several new developments are taking place in the spinning field which offer opportunities for cotton. IIC is not directly involved in these spinning developments but is studying the finishing of fabrics made from the new yarns. We believe that far too little attention has been paid to the problems and opportunities in these areas and that the success of OE spinning for example will depend on the progress which is made in finishing methods for these fabrics.

5.1 Open-End Spinning

The "open-end" (OE) spinning system has been developed on cotton and is used mostly with this fibre. The spinning package is not rotated to insert twist but only turned slowly to wind the spun yarn. A break is introduced in the strand of fibres and this "open end" is rotated rapidly to introduce twist. By this means, spinning speed can be increased and larger packages of yarn produced than is possible in ring spinning. Several types of OE spinning have been explored but it is the rotor or turbine type, perfected in Czechoslovakia, which has gained commercial acceptance. The BD-200 frame is manufactured in Czechoslovakia and also under licence in Italy and Japan. The largest installations are at Courtaulds in England and at Daiwa in Japan, and there are ambitious plans to increase OE capacity at Daiwa and in other Japanese firms.

Because of power cost, smaller turbines are preferable, and this fact puts a practical limit on fibre length. For medium-to-coarse counts, OE spinning is suitable at present for fibres up to approximately 40 mm so that cotton has an advantage. Turbines are being built for longer fibres also, but they are suitable only for very coarse counts. The OE spinning speed is approximately 2.5 times that of ring spinning and spinning costs are lower; the advantage of cost is greater for coarser counts. The finest OE yarns produced commercially at present are 20 tex.

OE cotton yarns are more bulky, more even, have a higher abrasion resistance and fewer weak places and knots than comparable ring yarns; they are also 5 to 25% weaker but, because of the comparative freedom from weak places, they process at least as well as ring yarns. The properties of fabrics produced from OE yarns are not well known. In general the fabrics are more uniform, have better cover, are somewhat weaker and may have a harsher handle than fabrics made from comparable ring yarns.

A major project comparing the properties of OE with ring spun fabric has just been completed by the Czech Institute for Cotton Research in conjunction with IIC. The variables studied included fabric construction and the effects of mercerizing, Microstretching and resin finishing. The results of this work are being evaluated but other finishing work on OE fabrics has yielded some interesting data. Some loss in fabric strength always results from the application of easy-care resins but the loss of strength of fabric made from OE cotton yarns seems to be markedly less than the equivalent strength loss on ring spun fabrics for an equal increase in easy-care properties. The relationship is presented schematically in Fig. 3.

The two solid lines represent present findings. The untreated OE fabric is somewhat less strong than a comparable conventional fabric but there is no difference in strength in the resin-treated fabrics. It has been found that the strength of untreated OE fabrics can be increased by such treatments as Microstretching and mercerization. If, as is hoped, the slower loss of strength applies for all OE fabrics, then the dotted line of Fig. 3 can be achieved in the future and strong easy-care OE fabrics can be produced.

The above findings apply to tensile strength only. The abrasion resistance and durability of the two types of fabric will also be investigated with the hope that the higher abrasion resistance of OE yarns will be reflected in the performance of the fabric.

In addition to the work on woven fabrics, the IIC is also undertaking work on the knitting of OE yarns. The performance in knitting and the properties of the resultant fabrics will be examined.

5.2 Twistless Yarns and Fabrics

Twistless spinning has been developed at the Vezelinstituut TNO in the Netherlands and can best be applied to cotton and flax. The spinning technique and fabric properties have been described by Selling (7, 8). The roving is wetted while entering the spinning frame and is impregnated with starch; the yarn is wound without twist. A high spinning speed of 125 m/min is used and speeds up to 300 m/min are considered possible, compared with some 12 m/min for ring spinning and 30 m/min for open-end spinning. After drying, the yarn is strong enough to be woven or knitted. The fabric is desized and its strength is then due solely to inter-yarn friction at intersections. The fabric is smoother and more lustrous than a conventional one, and it also has better cover and absorbency. It has excellent resistance to laundering. Potential uses are many, including shirtings, sheetings, tentings, dress fabrics.

A pilot-plant frame is now being built and will be in production in Holland during 1970. A more detailed study will then be made of twistless fabrics and especially of their finishing for easy care.

From previous comments on the advantages of uniform swelling of the fibres in a fabric, the possibilities from twistless fabrics are clear. Each fibre in such a fabric is far less restricted in its swelling than a fibre in a fabric made from conventionally twisted yarns. For this reason we expect that good easy-care properties and abrasion resistance should be obtainable on twistless fabrics.

An interesting feature of twistless spinning is the possibility of combining other wet processing, such as mercerizing or dyeing, with the spinning.

5.3 Knitting

A phenomenal growth of knitting, both warp and weft, has been observed in the past several years in Europe, especially in Britain. Some forecasters anticipate that the European apparel market in the late 1970s will be as much as 2/3 knitting and only 1/3 weaving.

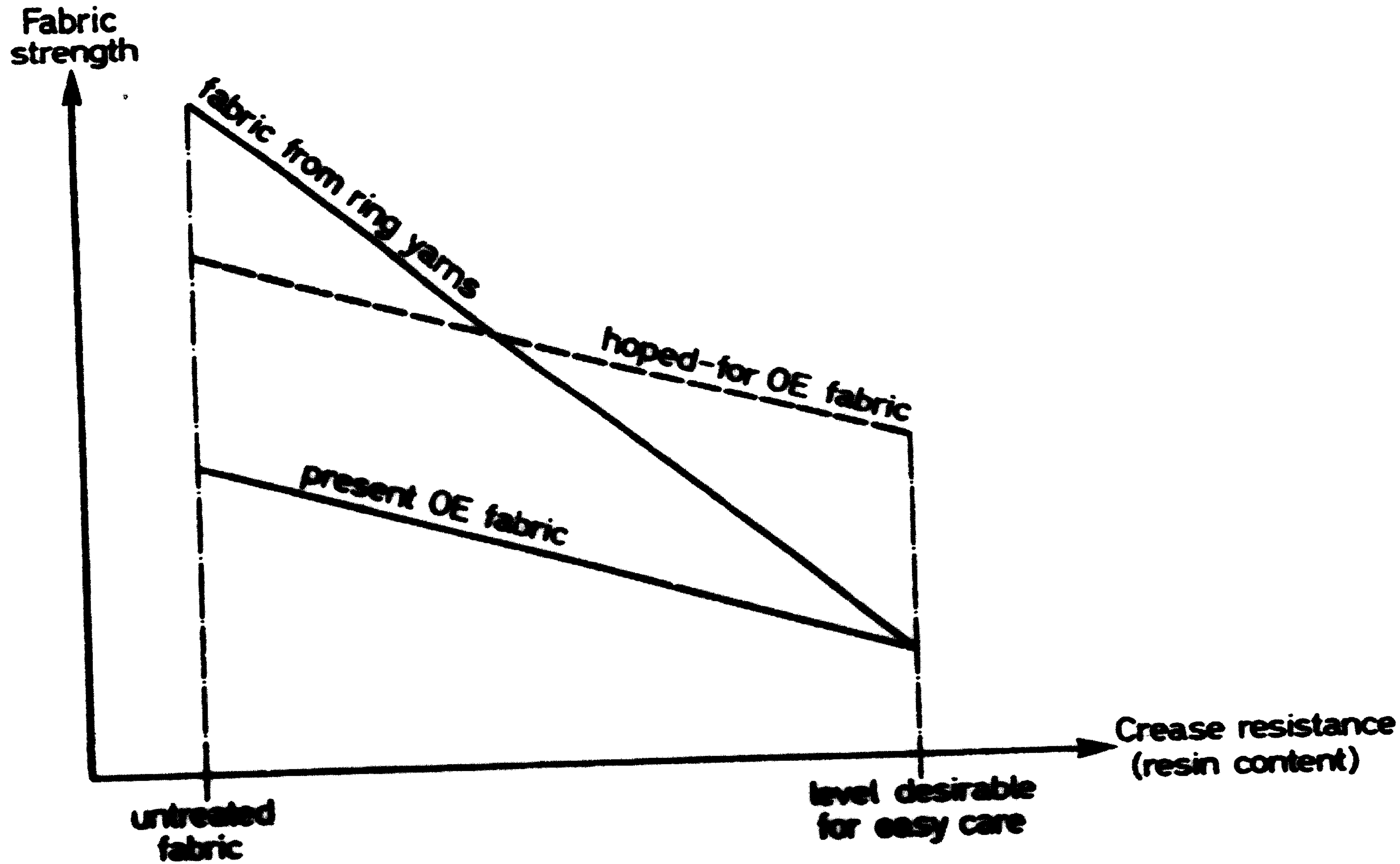

Fig. 3 Dependence of cotton fabric strength on resin content

There are many reasons for this growth; higher production speeds, greater fabric widths, little or no yarn preparation and the inherently better easy-care properties of knitted fabrics. Almost all of this growth has been with synthetic fibres and in certain end-uses, these will always be dominant. However, there are very considerable growth opportunities for cotton in many areas.

Cotton is well established in weft knitting, for example, in men's underwear, and various possibilities exist of additional large-scale applications, such as knitted terry towelling, fine-gauge interlock, ladies dresses, and several others. Stabilization and resin finishing treatments are now available to eliminate shrinkage in laundering; they are expected to greatly increase cotton's share of the weft-knitting market.

In warp knitting, cotton is excluded from the existing fine-gauge field except for possible use as laid-in yarn in the new weft-insertion machines such as Liba's Schussomat and Karl Mayer's KE-?MS. Greater possibilities exist in medium and coarse-gauge Raschel constructions.

The IIC product development programme is being rapidly expanded; the potentialities of OE, Prograde and twistless yarns are being examined on a wide range of medium and coarse gauge knitting machines. Certain of the resulting fabrics will require chemical finishing or some other process to eliminate shrinkage during laundering and "bagging" during wear. Some of these fabrics are attracting commercial interest.

6. TESTING

The IIC has sponsored two projects in the field of testing, both of them of interest mainly to cotton spinners.

6.1 Fineness and Maturity of Cotton Fibres

Fineness and maturity are two important characteristics of the cotton fibre which are rarely tested separately because the tests are slow.

The air-flow Micronaire test, which has found wide commercial acceptance, gives a value which is a combination of fineness and maturity. Higher Micronaire values are obtained with coarser and with more mature cottons. If a mill uses cotton which is constantly of about the same fineness, then the Micronaire value indicates maturity, and this is the way in which the test is interpreted in most mills in the USA. In Europe, where cottons with different fineness are processed, it is necessary to know from experience what Micronaire value represents a mature cotton for any particular variety; for example, a 3.6 Micronaire reading would indicate an immature American but a mature Egyptian cotton.

Air-flow instruments are rapid and convenient to use, and therefore an air-flow tester is being developed at the Shirley Institute in collaboration with IIC which will give simultaneously two readings, one for fineness, the other for maturity. The work is based on that by Hertel and by the Institut Textile de France (9). The basic work is complete and the instrument will now give accurate values of fineness and maturity.

6.2 Electronic Counting of Neps and Trash

Neps arise mostly at the card and are controlled either by simple observation of the web at the running card or by taking web samples and counting the neps or rating the appearance of the sample. These methods are becoming obsolete as high-production cards gain wider acceptance. It is not possible to observe the web or to collect web samples above a speed corresponding to a card production of 20 kg/hr or so. On the other hand, the control of neps is becoming more important because a large amount of material can be spoiled rapidly if a high-production card is badly adjusted and produces excessive neppiness.

Electronic counting of neps has been studied first by Barella (10,11) and then at the Institute of Textile Technology in Reutlingen (Western Germany) under sponsorship of the U.S. Department of Agriculture. The IIC has continued the work at Reutlingen to build a prototype Sliver Nep Tester which would discriminate between neps and trash. Sliver is passed through the instrument and an optical method is used to count neps and trash particles separately and to classify each of them by size. The numbers appear in four classes for neps and three classes for trash.

7. FINAL REMARKS

This paper is a progress report on the research work being carried out on cotton and is of necessity incomplete. Those developments were stressed which are considered to be of greatest importance for the future of cotton. The main problem is clearly that of strength and durability of cotton fabrics which had been given an easy-care finish. Recent progress is promising and offers real hope of producing cotton fabrics which match the easy-care properties of synthetic fibres and blends while retaining the comfort and wear life of untreated cotton.

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