The Newer Developments in Textile Microscopy*

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EDITOR'S NOTE—The paper was illustrated with a short moving picture showing the technique for various microscopical operations as developed at the M. I. T. Textile Laboratory, and fifty special lantern slides, ten of which were natural color photomicrographs. The latter were shown publicly for the first time.

Microscopial research in textiles, like "All Gaul," may be divided into three parts. There is first, fundamental investigation; second, applied research; and third, pure science. The author's work has been in all three fields and it is proposed to outline briefly the newer trends in each.

Turning to fundamental investigation, it will at once be apparent that one of the major endeavors should be the design of apparatus which shall be suited to the determination of basic data. We must prepare, handle, illuminate and measure textile specimens, and we must also record their microscopic appearance.

Developments in Equipment

There has long been special optical equipment for the chemist, biologist, metallographer, geologist, physician, and even for the detective. There should also be specialized equipment for the textile technologist. The design and application of such instruments is a comparatively recent achievement and one of the results is a microscope of wide range, high precision and low cost.

This provides facilities for the study of fiber, yarn, and fabric longitudinally and in cross section. It is equipped to measure crimp, twist, corkscrew, fabric set, diameters, angles, indices of refraction and areas, as well as to complete determinations of density and fiber analysis. With it, not only fabric surfaces can be studied, but also the most minute details of internal fiber structure. It is arranged to take the usual accessories including polariser and analyser, and will serve admirably for photomicrography.

Much of the existing general equipment could be utilized for mounting and manipulating textile specimens and, so far as possible, this has been done. New devices are being developed to meet peculiar conditions and a great deal of work is still to be accomplished.

Yarns, for example, must be controlled in such a manner that they will remain at all times in the field of the microscope and yet will be movable at will in a direction parallel to their longitudinal axes for inspection and for measurement. In certain cases, they must be under controlled tension and must not be allowed to untwist or to turn at all about a horizontal axis, and yet be free to rotate through a wide angle about a vertical axis. Fabrics must often be constrained to a horizontal or vertical plane, and yet be under a minimum of tension, while remaining free to move within the plane.

Since we are wholly dependent upon the light reflected from, or transmitted by a specimen for the production of the magnified image, proper illumination is vital. Very infrequently in textile work, as a whole, are we dealing with minute entities as in bacteriology, for instance; or with a plane surface as in much medical and botanical work. We have rounded and irregular contours in fiber, yarn, and fabrics, and hence a complex problem must be solved if correct illumination is to be provided.

Cotton, because of its convolutions and surface characteristics is a difficult specimen to study.

Weave structure which involves crossing of certain yarns can only be satisfactorily studied with proper microscopic equipment.

Yarn, obviously, offers many difficulties in ordinary mounts due to its fuzzy surface, uneven diameter, multifilament construction, etc.

Apparatus for direct axial illumination, which is highly efficient for metallographical work, proves quite useless for textiles and other means and modifications must be provided. These may take the form of special illuminants or of optical systems to properly control the path of light from the desired source. Old and sometimes nearly forgotten devices can be resurrected and given a new lease of life.

For purposes of measurement again many existing forms of optical equipment may be utilized. Stage and ocular micrometers, filar micrometers, graduated mechanical stages, analytical stages for determining percentage composition of mixed fiber samples, the rotatable graduated stage, etc., are all examples in point.

To preserve a record of the observation, equipment is available for making precise drawings to scale, and for photographing the specimen. There are inexpensive and compact projectors for laboratory or factory use. These are the most elaborate photomicrographical apparatus, and the simplest arrangement of the camera as

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well. The tendency is toward simplification of such equipment, and surprisingly good results are now obtainable at but a fraction of the former cost.

Detail of structure can be made very apparent as in the case of the cross section of the stem of the flax plant, in the cross sections of ramie fiber, or in the study of surface characteristics of rayons.

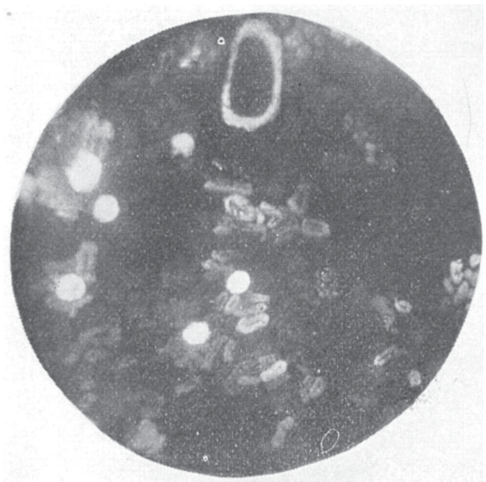

Fig. 1 First Photomicrograph of Miscellaneous Fibers Sectioned by the Schwarz Slide Method.—Note the opportunity for fiber identification

Development of Technique

Proceeding concurrently with the development of apparatus, we must have a similar development and adaption of technique. Too often the attempt has been made to transfer approved methods from some other field bodily to textile research. Perhaps a most striking illustration is concerned with the preparation of cross sections of textiles. The complicated and time consuming technique in common use for biological, botanical, and histological specimens, when adopted blindly for textiles required apparatus costing several hundred dollars, and occupied several days. By study of the requirements of much of the textile work, the expense has been cut to little more than one dollar and the time to a few minutes. A razor blade, a length of strong, fine wire, and the special metal slide designed by the author are all that are needed. In some cases a piece of cork, a sewing machine needle, a length of strong silk yarn and the razor answer the purpose. Something of the possibilities of the method may be judged from the accompanying photomicrograph of the first section of fibers prepared by a student in the laboratory. Note the chance for fiber identification.

The older technique may sometimes be required, but the new methods represent, for the major portion of such work, a most important saving in time, labor, and expense. Even the more complex apparatus has been modernized and the evidence of precise workmanship is quite apparent in the newest microtome.

Not only in the preparation and handling of specimens, but in their illumination, modern developments in technique contribute much. In the latter part of the last century, Rheinberg devised and described a modification of dark field illumination which, long forgotten or neglected, has finally found an important place in textile research with the microscope. Wratten filters are employed in thin glass disks so that each carries a central circular spot of one color and is surrounded by a colorless, transparent annular ring. A supplementary set of disks carry clear central spots, and colored annular rings. When two of these filters are combined properly in the substage of the microscope, arranged as if for ordinary dark field work, the specimen and background appear in contrasting colors. Thus, a plain white cotton fiber illuminated by the dark field method, appears as white against a black background, while when the differential illumination is employed, the fibers may appear yellow against green, or red against blue, or any desired combination.

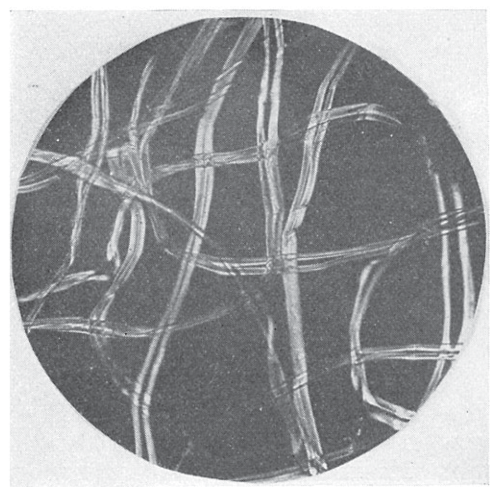

Fig. 2 Raw Silk Fibers as Viewed by Polarized Light. The Colors are rendered in Monochrome

Not only can much of the surface detail be rendered more distinct, but many of the advantages of a stained specimen are obtained without the necessity for staining. It must also be remembered that, once stained, the color of the specimen is usually determined permanently. By the above scheme of lighting, this and many other difficulties can be obviated.

A special disk divided into quarters, alternate sectors being red and blue, provides means for producing two colors in the specimen. Flax, for example, may be illuminated thus to show the cross markings as brilliant red against a blue fiber—the whole upon a dark field.

Special arrangement of the substage diaphragm will also bring out structural detail such as wool fiber scales, by a form of oblique lighting devised by Manby of Leeds University.

Possibilities for quantitative work employing regular accessory equipment should be better understood. A good camera lucida provides a splendid means not only for making a record of the observation, but for micrometry as well. For such things as measurement of area, filament density, disk coefficient, filament count, crimp, etc., it provides a simple, convenient and precise means of quantitative analysis.

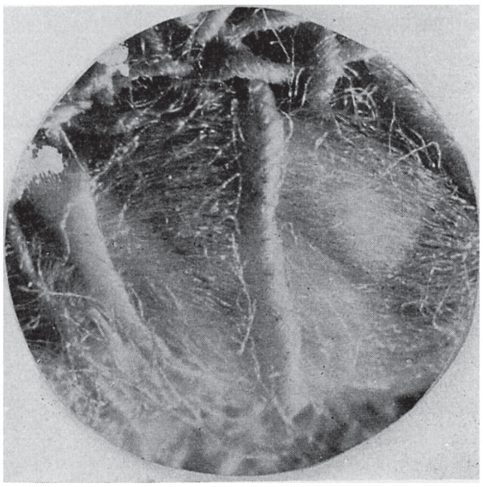

Fig. 3 Portion of Slub Yarn. Photographed through the Stereoscopic Binocular Microscope

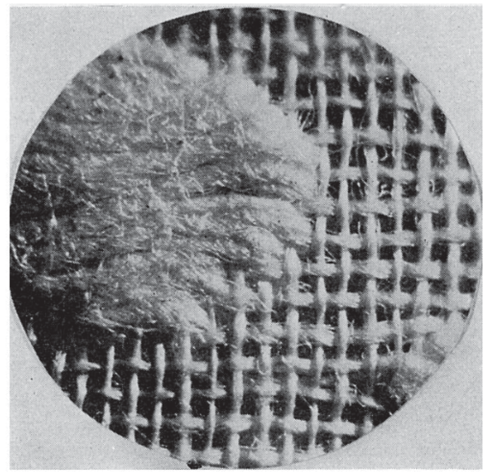

Fig. 4 Swivel Dot. Photomicrograph through the Stereoscopic Binocular Microscope

Use of Data

Too often masses of data are accumulated without a proper realization of relative precisions, utility and importance. No data can be of any real value unless they are interpreted intelligently. Tabulated values mean little when it comes to an understanding of what they really show. Charts, diagrams and plots should be more widely used. But to be useful they must be wisely drawn. Any two sets of data may be plotted against each other, but it does not follow because a fairly smooth curve is obtained that the phenomena represented are related. One might conceivably plot the average weekly rainfall over a year for Kansas City, Mo., against the weekly death rate from automobile accidents in Boston and obtain a curve. No one, in his senses, however would maintain that there was a relationship between them. It has been said that figures don't lie, but that liars do figure. A similar statement could well apply to the plotting of data.

Statistical methods involving the use of frequency curves, probable errors, goodness of fit, skewness, correlation, etc., have been in use for years in social-logical and scientific work in many fields other than textiles. It is only lately coming to the fore in textile work. The utter inadequacy of many of the sampling methods used, and the sheer foolishness of relying upon only a few determinations, on which to base comparisons is rapidly being recognized. There is a constantly increasing number of articles appearing in the literature—notably the "Journal of the Textile Institute," which deal with statistics as applied to the field of textile research, and progress in devising methods for handling this treatment of data is rapid.

Mathematics is a powerful tool and the application of its higher forms involving calculus, trigonometry, analytic geometry, nomography, etc., is demanding better and better trained technicians. The representation of data by means of plotted curves allows anyone who will to visualize certain trends and tendencies. But such curves are not always entirely convenient to use, and in many cases it becomes necessary to determine the mathematical law which exists. This involves fitting an equation to the curve, which may have to be rectified by substitution or by replotting on logarithmic or semi-logarithmic paper, or by still other means. For example, certain data were assembled by Herzog and the author which showed something of the relationship between the so-called "disk" coefficient for rayon filaments and the ratio of maximum to minimum dimension of the filament cross section. (The disk coefficient is the quotient of the cross sectional area of the filament to the area of the circumscribed circle and has an important bearing on depth of shade in dyeing, lustre, and covering power of the rayon.) Treatment of the curve—which obviously cannot be approximated by a straight line—yields a relation:

$$R = \frac{0.9}{K}$$

where—R = Ratio of long to short axes
K = Disk coefficient

This seems good evidence that the general law is probably $R = \frac{1}{K}$ a simple reciprocal relationship, which can also be written $R\,K = 1$.

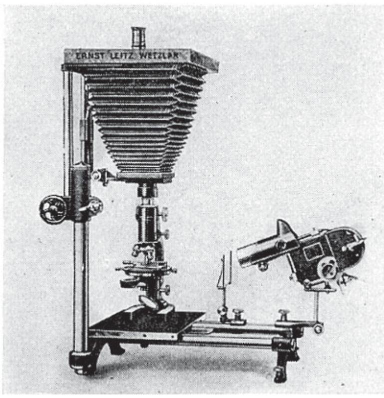

Fig. 5 Photomicrographic Apparatus (E. Leitz) Admirably suited for Textile Photomicrography

This expression could easily be represented in a nomographic chart of two scales, so that when one quantity was known, the other could be read without calculation. In far too many cases have data, which should have been presented as a curve, been but imperfectly and inaccurately handled by means of an approximated straight line.

Applied Research

Passing now to applied research, it would be superfluous to multiply examples of the benefit of scientific research in solving everyday problems of manufacture. That the application might be both practical and efficient, it was necessary to have an instrument of wide range ascending from very low powers of magnification,

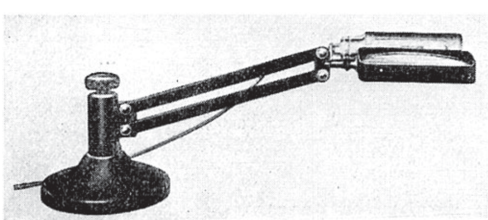

Fig. 6 Bausch and Lomb—Improved Self-illuminated Magnifier

which would be rugged enough and simple enough to be used by comparatively poorly trained technicians for routine work in production. Two instruments have been adapted to fill these requirements. One is a pocket microscope with a range of from 7 to 250 diameters, and the other is a stereoscopic binocular microscope of somewhat lower maximum range. Mills are accepting these with considerable satisfaction and it is hoped that their intelligent use may go far toward answering those three most troublesome questions—"What happened?"—"How did it happen?"—and "What can be done about it?"

If, however, a mill should rest content with this they would have failed to realize the real possibilities. The questions "How can we progress?"—and "How can we make a better product at a lower cost?"—are also subject, in large measure, to solution by the aid of the newer microscopical devices as they become available.

And finally the much misunderstood and often scoffed at "pure science." Someone has defined it as "investigation which is of no consequence to anyone." This definition needs only a slight amendment to be correct. He should have said that pure science was "investigational endeavor in this field which *may not now* be of consequence to anyone." Later possibilities are still to be guessed. One would be hardy indeed, in the face

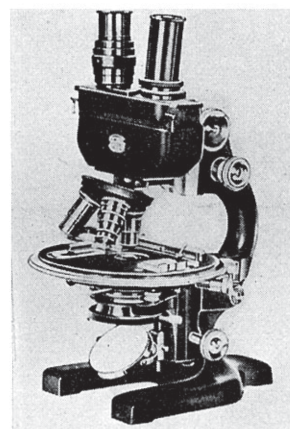

Fig. 7 Spencer—Research Microscope

of the miracles of modern science, which sprang from work of no immediate importance when it was undertaken, to deny the importance of pure science in any field.

As applied to textile microscopy, there are several lines of endeavor which may lead to vastly important results, but which, as yet, seem economically of little value.

There is the application of the x-ray to the analysis of fibers in their ultimate structure. Stereoscopic photomicrography has been tremendously simplified in its application to textiles and bids fair to be of great value.

Recent development of studies in radiation may lead to work in textiles with the fluorescence microscope—

and with the ultra-microscope which has quartz lenses and uses ultra-violet light as illumination.

The photoelectric cell—once a scientific curiosity—a product of pure science, if you will—is forming the basis of several important optical devices for textile testing, among which may be mentioned the Hardy Color Analyser and the Barker Yarn Levelness Recorder.

Still another scheme is the possible study of stress and strain relationships in single rayon and silk filaments by the photoelastic method with the aid of polarized light. Incidentally the importance of work with this medium is scarcely realized, and only fragmentary work has yet been done. The design and construction of a polarizing microscope which would be suited to quantitative work with textiles has been accomplished and future developments should mature rapidly. The instrument may also offer a rather simple means for fiber identification and differentiation.

In this connection, direct color photography is coming into its own as a means of recording data for future study and for comparison with earlier and later work.

Textile research, as a whole, is still in its infancy, and, if this be true, then textile microscopy is but hardly born. Just now it needs the care of trained technicians, but some day it will stand alone, and find for itself a valuable place in every branch of the textile industry.