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RECENT DEVELOPMENTS IN PRINTING[1)]

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1) The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO.

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CONTENTS

Recent developments in machinery and chemicals [illegible] make the mass-production of good quality prints of [illegible] larger than [illegible]. [illegible] of [illegible] and [illegible] the use of printing, to introduce pattern and colour, to increase in importance.

Such a technically possible and economically desirable trend can only be successfully realised, however, if due attention is given to standards of design and the marketing of the printed fabric. In export markets premium prices will be obtained for prints with customer appeal, but mediocre prints with poor colour sense may be saleable only below production cost levels. The fashion trade inevitably exaggerates the differences between high and low demand for colour and style, and gives printers the extra problems of seasonal demand. With this [illegible]ing, that printing requires judgement and courage of a higher order than most occupations, we can return to the technical developments.

It is possible to consider separately the mechanical, impression, operations and the chemical, colouration, aspects of printing.

1. IMPRESSION

1.1. Engraved roller printing. In the world as a whole this must still be the most used technique, although satisfactory statistics are difficult to obtain. In Europe, however, more fabric is now printed by screen techniques.

The essential principle of roller printing survived unchanged since Bell's patent of 1783. Improvements in detail have been made, especially in mechanising of pattern-register adjustment, but attempts to overcome the fundamental limitations of the method may prove to have been left until it was too late.

The limitations of the standard type of machine are:

(a) the pressure required to transfer colour paste from the engraving to the fabric leads to non-uniformity across the fabric width, because the pressure is applied at the ends of the roller mandrel, and limits the fabric width that can be satisfactorily printed.

(b) the pressure forces colour paste through the fabric structure, reducing the effective colour depth, unless a very shallow engraving can be used.

(c) the pressure of subsequent printing rollers "crushes" the freshly-printed areas and removes a film of colour which contaminates the following colour.

(d) the use of doctor blades requires considerable skill and, even so, owing to the engraved roller, print faults associated with doctoring cannot be avoided.

(e) pattern-changes are time consuming because of the weight and complexity of the colour application system.

One recently developed type of machine reduces the printing pressure required by providing an arrangement of individual pressure cylinders that increases the contact time between the fabric and each engraved roller. These machines may also be used without mandrels, to reduce pattern changing time.

The use of shallow-engravings and print-paste of low viscosity also makes it possible to print with less pressure, and experimental work on the gravure printing of paper has shewn that an electrostatic charge applied to the pressure cylinder can be applied to induce an opposite charge on the paste and bring about complete emptying of the engraving. It seems unlikely however that enough reduction in pressure can be achieved to change the situation radically.

The one clear-cut advantage of engraved roller printing is the sharpness of mark that can be obtained with very fine patterns consisting of lines, small objects or two-tone effects.

1.2. Screen Printing. In Europe and the U.S.A., hand-screen-printing is now only used for the production of short lengths of high-fashion prints, because substantial quantities can be obtained at lower cost by using automatic machines. Where labour costs are not a limiting factor, however, and a low capital cost and geographically wide-spread development is desired, screen printing by hand has many advantages. The screens are cheap to produce, by comparison with engraved rollers and rotary screens, and experience of design and of the use of dyes and pigments can be acquired by many people, among whom some will be found to have natural ability.

By comparison with engraved roller printing, screen printing produces strong, "bloomy", colours and encourages innovation in design. The mechanisation of this technique was first achieved in the period 1950-1960 and large numbers of the various "flat-bed" machines were installed and found to be competitive with roller printing under European conditions of short runs per design. This system was essentially intermittent, however, because the printing occurs while the fabric (on its conveyor belt) was stationary. The maximum speed attainable was 1000 metres per hour for a 1 metre pattern repeat. Well-designed machines give very precise prints and are especially suitable for wide fabrics and large repeat patterns, for example table-cloths, but the machines are quite complex and must be well maintained. By about 1970 it was clear that this development, the mechanisation of a hand-operation, was comparable with the mechanisation of hand-block-printing by Perrotine in 1834, which also had a substantial but only short-lived success. In both cases, truly continuous, rotary, processes were developed later, and proved to be more successful than intermittent techniques. Since 1973 the number of flat-bed machines purchased has fallen significantly, but sales of rotary-screen machines have been maintained at about 200 per year.

Rotary(cylindrical) screens must be rigid enough to be mechanically mounted and driven, flexible enough to ride over fabric sewings and selvedges, and durable enough to withstand accidental mishandling; they must also provide a uniform, dense pattern of fine openings for passage of colour through the screen. The most widely used solution is to build a perforated nickel cylinder by electro-deposition [illegible] thickness of 0.08 mm. Aluminium end-rings [illegible] cemented [illegible] the cylinder. The design can be built-in to the screen (galvano-plastic) or can be transferred to plain screens using a light-sensitive lacquer. In the latter case lacquer stripping and re-use of the screen is possible. These screens are now readily available all round the world.

Such screens must be carefully handled to achieve the expected 100,000 metre life. An alternative type of screen with greater robustness is made from woven wire mesh, with a tubular nylon sleeve shrunk onto the cylinder. At present the seams on such screens limit the pattern selection for smooth surface fabrics. Progress in the production of robust and fine screens can be expected.

Rotary screen printing is usually effected on conveyor belts, significantly shorter than those required for flat-bed printing, and speeds of 75 metres/minute are commonly attained. The hot-air drying machines must therefore be of high efficiency. Squeegees inside the rotary screen may be of the electro-magnetically held rod type or of the flexible blade (usually stainless-steel) type. Very wide fabrics, and carpets up to 5 metres wide, are more readily printed with the former type of squeegee, the diameter chosen being greater when more colour is required. Print paste is pumped in to the screens as required using automatic level controllers. Pattern changing can be achieved in about three minutes per screen because of the low weights and simple drive couplings used.

<u>1.5. Transfer Printing.</u> With the large growth in production of polyester fibre and of weft-knitted polyester fabrics in recent years, the concept of transferring a pattern produced with heat-volatile disperse dyes has become more interesting. Paper has a smooth surface, and uniform thickness, and can be printed at high speed and with greater accuracy than textile fabrics. Print faults can be cut out and the printed paper transported around the world. As and when required, the design is then transferred by bringing the fabric and paper together and heating to 200°C for 15-30 seconds. Transfer calendars for this purpose are now widely available. Alternatively, garments may be "printed" in hot-presses. The dye sublimes on to the polyester and diffuses into the fibre. Satisfactory wash and light fastness are obtained without washing-off treatment, so that water consumption and pollution problems are almost eliminated and overall costs can be competitive with direct printing on to the fabric. The technique has been of special interest to knitters with no printing facilities and to paper printers. The paper has been printed by gravure and flexographic methods but recently rotary screen printing has also been used. A textile printer can therefore achieve complete flexibility with a rotary screen machine choosing either to print on to paper and transfer when fabric orders are obtained, or to print directly on to the fabric.

Blends of cotton and polyester may be transfer printed if the proportion of polyester is high. Below 80% polyester the colours obtained are weak and staining of the cotton may make the result unsatisfactory.

Woollen garments have been transfer printed using a wet-transfer technique and reactive dyes, but a wash-off is required. Cotton can also be transfer printed with reactive dyes but again the necessity for a washing-off stage and therefor a re-drying stage makes it unlikely that it will ever be a profitable approach.

11. COLOURATION

11. 1. Dyes for Cotton. There have been no recent developments of interest to printers in the use of vat or azoic colourants and because of the complications and cost of the application methods, these dyes are used much less than they were.

Reactive dyes are, conversely, of much increased importance. Developments fall into two categories; the availability of more satisfactory dyes and changing fixation methods.

Dyestuff manufacturers have investigated a wide variety of chemically different reactive systems and many have been made available commercially but, for cotton printing, none have shown properties clearly superior to the original chlorotriazine and vinylsulphone types. What has been clearly demonstrated (1) is that for given fixation conditions a balance must be maintained of reactivity, substantivity and diffusion properties. A clear advantage has also been shown (2) in the case of those dye molecules with two separate reactive centres, which leads to an increase in fixation efficiency from a typical 75-80% up to 90%. Reduction of the substantivity, by chromophore selection or by alkylation of the imino bridge group, then makes the removal of the small amount of hydrolysed dye at the washing-off stage relatively simple. This has removed the major hazard of printing with reactive dyes.

Most printers no longer use the original steam fixation at 100°C for 5-10 minutes, preferring the more economical H.T. steaming at 150°C for 30-60 seconds or a two-stage method. The latter may be either padding in alkali and electrolyte followed by flash-ageing for 15-45 seconds at 110-125°C or passage through a boiling alkali and electrolyte bath, immediately followed by the washing-off. This wet-fixation approach has the attractions of low capital cost, because the steamer is not required and easier washing-off. Pad and cold-batching, usually with sodium silicate, is also used.

Cotton and polyester blends may be printed with selected mixtures of reactive and disperse dyes and H.T. steamed at 160-180°C, but satisfactory washing-off is not at all easy to achieve. A novel alternative approach (3) uses selected disperse dyes in a solvent-water mixture that carries some of the disperse dye into the cotton fibre, to be trapped therein after removal of the solvent in the H.T. polyester fixation and wash-off stages. This development seems not to have been a commercial success, however. Because of the difficulties of printing these blends with dyes, the use of pigments has been stimulated.

II.2. Pigment Prints

Improvements in the pigments and polymer binding systems available are illustrated by the acceptance on the British market of pigment printed polyester-cotton sheets. Ten years earlier the handle and washability could not have been obtained.

Pigment prints also have the advantages of high light-fastness of selected pigments and, above all, the economy of eliminating the washing and drying stages. Developments in this area have been well surveyed (4). The overall improvements have been achieved by many small developments and attention to detail rather than any dramatic discoveries.

Most pigments are printed from oil-on-water emulsions which may consist of 80% white spirit. Because of the increasing pressures to reduce the pollution of our atmosphere and rivers, and the rapid increase in petroleum prices, attention has been directed to alternative means of obtaining the required print-paste viscosity. It is now increasingly the practice to replace part or all of the white spirit with synthetic polymers which give high viscosity at low solids content and form relatively soft films. These polymers invariably contain carboxyl groups which on neutralisation with ammonia, give a highly ionised polymer with extended chains and therefore the high viscosity. Such polymers may be used together with the same polymeric binders used with emulsion thickenings and suitable softening agents. Alternatively, complex co-polymers may be used which combine, in the same molecules, thickening and binding properties (5). It is interesting to note that this is a revival of a practice at least fifty years old, of using natural polymers such as albumen, from blood or egg-whites, as both thickener and binder for metal powder prints.

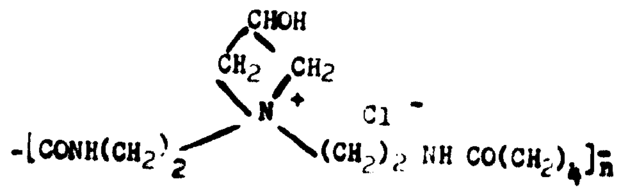
II.3. Polymer systems for printing dyes.

Although pigment printing systems have been much improved, the use of pigments has obvious limitations, especially of wet abrasion resistance and delustred appearance. If dyes could be used in such a way that no washing-off was required after the fixation stage, they would be more attractive than pigments. A major reason for the success of transfer printing is the elimination of the washing-off and re-drying stages, together with the brightness in appearance of disperse dyes after diffusion into the fibres.

Research at UMIST during the last two years has shown that such an approach can be practicable. We have achieved 97% fixation of selected reactive dyes on cotton, measured by extraction of unfixed dye in boiling urea/detergent solution. Fastness to the ISO 3 wash test and to the more critical cold water bleeding test are perfectly satisfactory at the 4-5 grey scale level.

The method recommended is to make an emulsion of water in white spirit, containing only [illegible] to [illegible]% white spirit, reactive dye, sodium bicarbonate, a water-soluble polymer and an emulsified acrylate polymer. Water-in-oil emulsions have been unpopular for use with pigments because of difficulties in washing the printing equipment. With a water soluble dye and water-soluble polymer present we find washing gives no difficulties.

The water-soluble polymer is a reactive polyamide, containing cationic charges, which is already widely used for increasing the wet-strength of paper and for setting wool (6). The structure of the polymer, shown below, is such that self-cross-linking and reaction with cellulose or polyacrylic acid groups occurs during drying and steaming to give a clear film that adheres well to the fibres and is resistant to washing at the boil. Chemical reaction with the dye is also possible, but physical-chemical association is a more probable explanation of the increased fixation.



It seems reasonable to expect that different polymers can be found that will be equally or more effective.

One of the major problems is that many reactive dyes show a colour change when heated under alkaline conditions that is reversed by washing or by neutralisation. If the fabric is given a chemical cross-linking finish it is a simple matter to make an addition of acetic acid to neutralise the residual alkali in the printed areas. The long term solution will be to make dyes suitable for this application method.

II.4. Print-paste thickeners.

The natural products traditionally used as thickening agents, especially the starches and alginates, are becoming too costly or will be in short supply. Cellulose ethers are widely used as substitutes for alginates in reactive dye pastes, but completely synthetic polymers containing carboxyl groups can also be used. These latter may be derived from maleic anhydride (7) or from methacrylic acid.

Russian workers have shown that bentonite, a natural clay, can replace up to 40% of thickening agent in many applications, with advantages in cost and ease of removal.

In the particular case of polyester-cotton blends, where H.T. steaming can make removal of some thickening agents difficult it has been shown that non-ionic dispersing agents can improve thickener removal and accelerate fixation. The use of emulsions and of thickeners not intended to be removed by washing has been discussed above.

There is improved understanding of the way in which the viscosity of different thickeners changes under shearing stress, but still too little knowledge of what rheological properties are ideal for practical printing. This is mainly due to difficulties in measuring almost instantaneous changes in viscosity. However, for the control of reproducibility of print-paste viscosity, perfectly satisfactory instruments are now available. That designed and sold by the Shirley Institute is one of the most suitable.

II.5. Steamers.

For maximum flexibility printers are increasingly using modern festoon steamers which can be used at temperatures from 100° to 200°c, with saturated or super-heated steam or even dry air. The festoons can be formed without touching the printed face of the fabric, and entrance and exit should be from below. When saturation of the steam is required it is well worth having provision for cooling of the steam during circulation. In this way the heat generated by exothermic reactions on the fibre can be removed without the wasteful use of excess steam.

Festoon steamers also have the advantage of being suitable for knitted fabrics of all types. They are displacing pressure steamers for prints on polyester, and may be properly described as universal steamers. The fixation of pigment prints can be more safely and satisfactorily achieved in H.T. steam than in hot air.

Washing after steaming is still often carried out in continuous rope soapers but perforated drum washers are now available, suitable for knitted fabrics, in which large volumes of wash water are drawn through the fabric to produce efficient washing.

II.6. Discharge and Resist Styles

Because modern screen printing techniques can be used to achieve good quality blotch prints with accurate pattern fitting, it has become less common to print the more expensive discharge and resist styles. A wide range of resist effects can however be obtained with reactive dyes. Combinations of reactive and azoic dyes have been used very effectively in the production of African-style prints (8). The wet-fixation method is recommended for reactive dyes printed on to naphtholated cotton because removal of the naphthol is facilitated.

SUMMARY

Engraved roller printing has fundamental limitations that are unlikely to be overcome. Hand screen printing must be considered for low capital cost developments. Flat-bed screen machines are likely to be useful only in limited circumstances. Rotary screen machines have been proved to be technically and economically the "best-buy" for most purposes. Screens with improved resistance to mis-handling should be available this year.

Transfer printing is important for polyester but unlikely to be used for cotton.

Reactive dyes for cotton prints are now more easily washed-off because the fixation of selected dyes has been increased to 90%. Wet-fixation and H.T. steaming methods are recommended. The use of pigments on polyester-cotton blends avoids many difficulties. The quality of pigment prints has improved and it is now possible to eliminate the use of white spirit emulsion where necessary.

The use of selected polymers in a water-in-oil emulsion makes it practicable to print reactive dyes, dry and steam, to obtain wash-fast prints without the normal washing-off and re-drying.

The replacement of natural thickening agents by synthetic polymers is increasingly practised, and "universal" festoon steamers give maximum flexibility of handling all fibres and all fabric types.

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