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SIGNIFICANCE OF FELT ROUGHNESS IN WET PRESSING

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Introduction

SEVERAL widely recognised operational problems in papermaking have been attributed to the felt structure. All of these result from phenomena occurring at the macroscopic level, e.g. shadow and yarn-marking.(1) However, phenomena occurring at the microscopic level, i.e. at the scale of the individual fibres of the felt and paper, have received less attention.

Recent experimental studies(2, 3) on press felts show that their surface properties strongly affect water removal in wet pressing. Two mechanisms have been proposed to account for these effects: rewetting, and load uniformity. While a first approach to a quantitative discussion of the effect of felt properties on rewetting has been made,(3) account of the structural influence on load uniformity has hitherto been considered only from a qualitative standpoint.(2, 4) In this brief note we present some findings of a more quantitative study(5) to investigate the latter problem. In this study we have evaluated felt roughness and assessed its effect on water removal.

Microscopic characterisation of press felts

(a) *Uncompressed and compressed structures* Detailed examinations of uncompressed felt surfaces were made in a scanning electron microscope. As an example, Fig. 1 shows two of the felts investigated. The woollen felt (Fig. 1(a)) appears to have a random structure consisting of partially entangled fibres in a fairly dense network. In contrast a batt-on-mesh felt (Fig. 1(b)), after prolonged commercial operation, shows flattened surface fibres; in some areas these have compacted into dense masses, creating a very irregular structure.

Compressed felts were examined in a Chapman Smoothness Tester(6) in which the sample is pressed against a glass prism at pressures comparable to

Under the chairmanship of Dr J. D. Peel

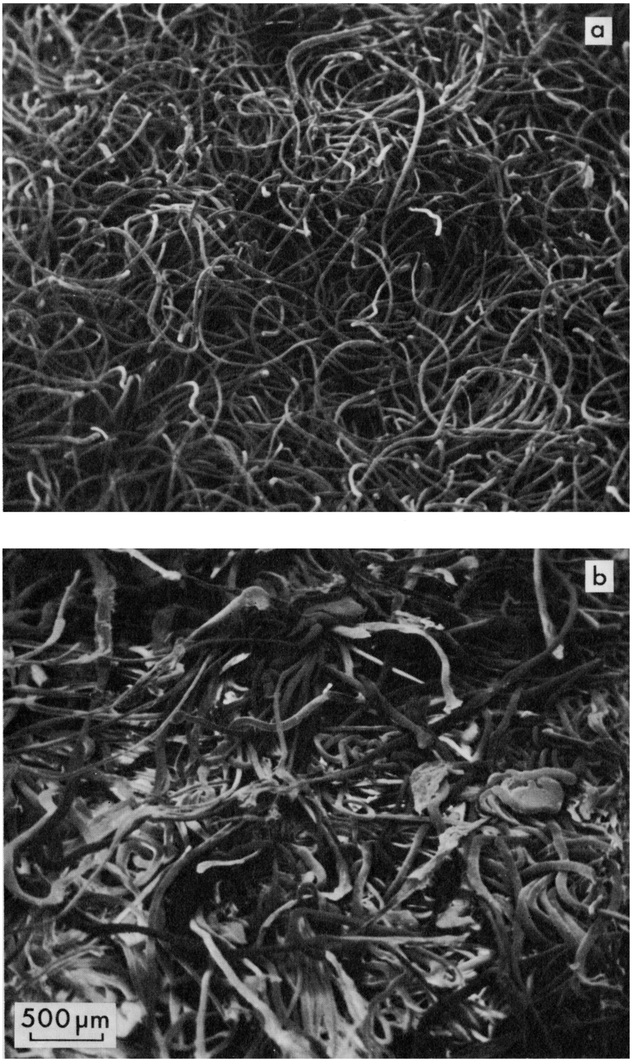

Fig. 1—Scanning electron micrographs of (a) unused woollen and (b) commercially used batt-on-mesh felt. Note the bundles of twisted fibres evident in (b) corresponding to needled batt fibres which during extensive use have been stretched and pulled out of the underlying structure and have become horizontally aligned with the felt surface. In the new felt these fibres were more or less vertically oriented

normal machine loads. This enables measurement of the percentage area of surface in optical contact (*F*), and can also be used for direct observation of the corresponding contact pattern produced by the compressed surface.

Between loads of 0·69–6·9 MPa (100–1 000 psi) the felts examined[5] gave *F*-values of only 6 to 15 per cent. The contact areas in all cases were independent of pressure, indicating that the felts maintain essentially rigid structures in this load range. It appears, therefore, that in a press nip, felt surfaces do not provide high sheet contact, and contact does not increase significantly with higher loading.

Photographs of the corresponding optical contact patterns of compressed woollen and batt-on-mesh felts are shown in Figs. 2(a) and (b) respectively. These patterns appear consistent with the uncompressed structures (Figs. 1(a) and (b)). The pattern of the woollen felt for instance shows that the load is distributed along finer and shorter fibre lengths compared with the much coarser and larger fibres of the batt-on-mesh felt. In addition, this used batt-on-mesh felt shows several dense spots, which probably correspond to the embedded debris or compacted fibre ends evident in the uncompressed structure (Fig. 1 (b)). Although these felts have similar *F*-values, comparison of their contact patterns (Fig. 2) clearly shows that the woollen structure provides a more uniform load distribution.

(b) *Felt-paper interface* To gain more insight into the scale of importance of the felt structures in relation to compaction of a paper web, an experimental technique was developed to allow examination of the actual micro-nips formed between felt and paper fibres. This technique consisted of pressing wet handsheets of a refiner groundwood against various felt surfaces at 3·4 MPa (500 psi), in a press heated to 125° C. Under these conditions impressions of actual contacts made between felt and paper fibres are preserved in the handsheet. The felt impressions were examined in a scanning electron microscope and values of *F*, the percentage of felt/paper fibre contacts, were estimated from low magnification micrographs (see Fig. 3(a)). Under these conditions values of *F* were found to vary from 25 to 33 per cent for a variety of commercial felt structures.

Relevance of experimental F*-values to commercial press nips*

THE present studies demonstrate that felt surface fibres can deeply impress and permanently deform fibres in the sheet. Similar evidence has been suggested in photomicrographs of cross-sections of felt/paper combinations under simulated nip conditions.[2] To a lesser extent evidence of felt fibre impressions has also been revealed on various grades of paper sampled from a commercial machine.[7]

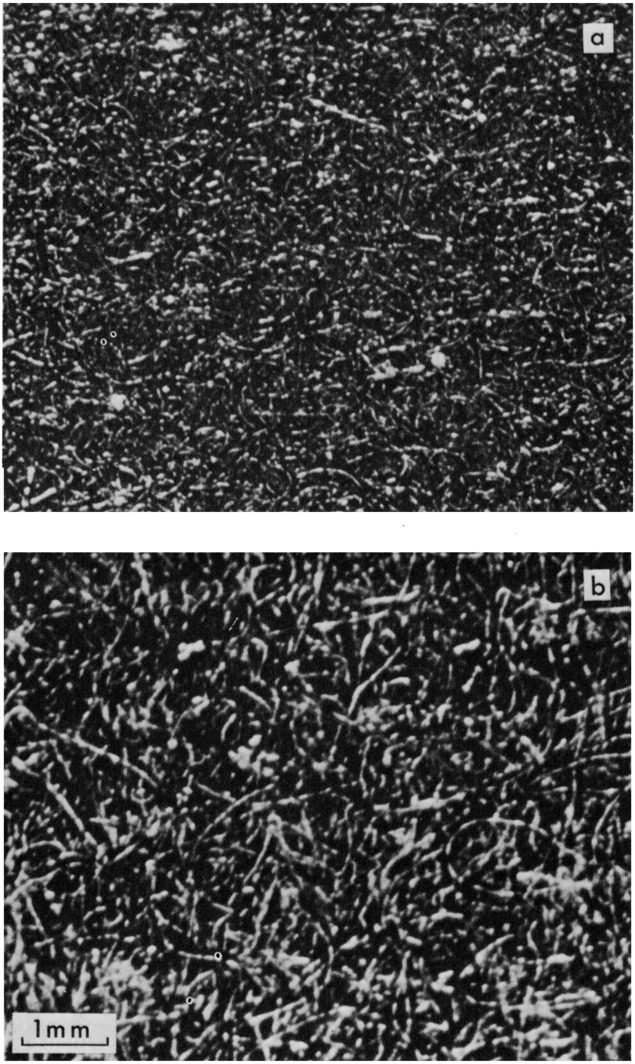

Fig. 2—Optical contact patterns of (a) woollen and (b) batt-on-mesh felts, produced at 2·9 MPa (430 psi) in a Chapman Smoothness Tester. Light regions correspond to areas in optical contact. Note that although these felts have similar *F*-values they produce markedly different load distributions. The more uniform pattern of the woollen felt indicates that its structure provides a more even load distribution

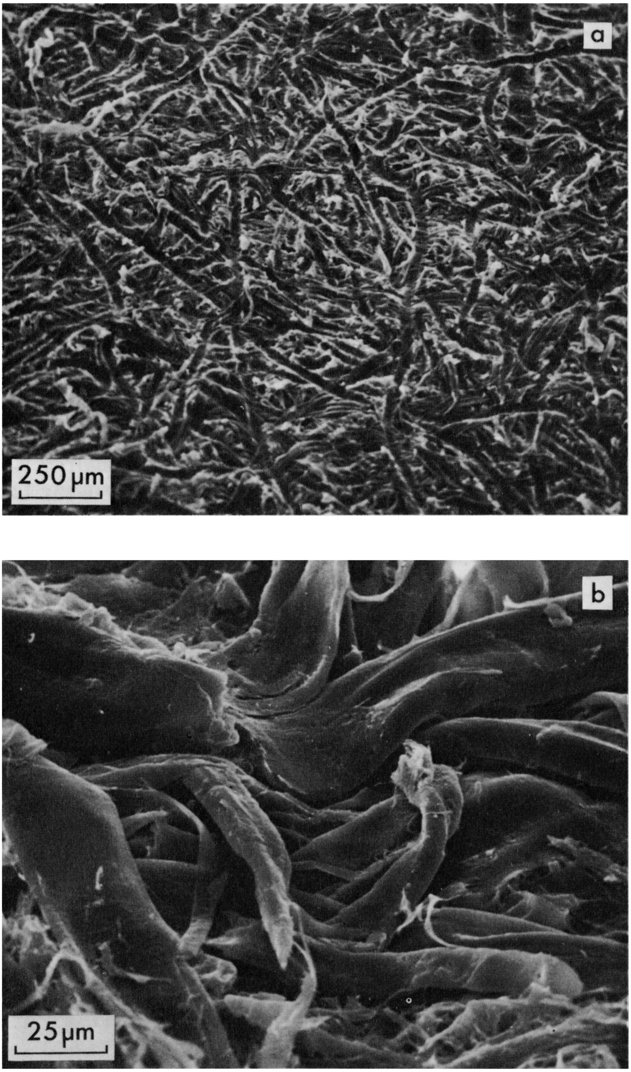

Fig. 3—Structural impression of a batt-on-mesh felt produced on a hot-pressed (125° C at 3·4 MPa) refiner groundwood handsheet

(a) Low magnification: showing the relative proportion of actual contact area (F = 33 per cent), i.e., load-bearing fibres

(b) High magnification of an area to right of centre of (a); fibres have undergone plastic deformation as a result of the intense pressure transmitted in a micro-contacting area

Under the conditions of the replication technique, impressions of actual contacts made between felt and paper fibres are preserved, and the conformability of the fibres is probably greater than it would be in a machine nip. In contrast, in the Chapman technique, the felts were pressed against a smooth rigid solid, which may be assumed to be equivalent to a sheet of non-conformable fibres. Therefore, these techniques cover the maximum range of variation likely to be encountered in practice, so that under normal papermaking conditions real values of contact will fall within these extremes.

Influence of felt structure on F*-value*

A COMPARISON of the contact patterns of various commercial(5) felts shows that it is very difficult to derive any definite relationships between F-values and felt structures. However, the batt-on-mesh felt, with relatively coarser fibres than the woollen felt, has slightly higher F-values, which may result from the extensive wear of the felt. Fig. 1(b) shows that wear has flattened the fibres and filled the surface structure, providing greater contact. If this is true, then higher F-values typical of fine denier felts can be simulated with coarser felts after prolonged wear. From a practical viewpoint this conclusion is highly significant because the use of finer felts is limited by their inferior permeability, greater tendency to become plugged and filled, and greater rewetting propensity.(8) Thus, an appropriate pre-conditioning of commercial felts could raise their F-values. As discussed below, higher F-values may give substantial improvements in dryness after pressing.

Relationship between F *and water removal*

IT is evident from these microscopic studies that at the scale of papermaking fibres, papermakers' felts are very rough. The pressure exerted by felt on paper in the nip is therefore far from uniform; it can vary from very high values at one point to near zero a few tens of micrometres away (see Fig. 3(b)). Clearly, such uneven pressing will lead to uneven water removal. It has now been shown that the water removal given by a rough felt is not only uneven but also inefficient.(5) Calculations indicate that, under similar conditions, pressing with a typical commercial felt will yield paper whose dryness is lower by 5–10 percentage points than it would be if an ideally smooth felt could be used. These calculations have been made with the aid of a mathematical model of the felt/paper interface based on photomicrographs of cross-sections.

Conclusion

OPTICAL examination of the surfaces of several commercial press felts reveals that uneven and irregular load distribution occurs at the felt/paper interface. The true area of contact between a felt and either a solid or a conformable surface is only a small proportion of the total area. Improved water removal might be achieved if a felt could be produced which would distribute the load more uniformly over the surface of the paper.

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