

THE
BRITISH SOCIETY
OF RHEOLOGY

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RHEOLOGY IN THE PRINTING INDUSTRY—III

by E. W. J. Mardles

The art and science of printing consist essentially in laying a film of ink evenly on a surface to give a clear image of acceptable appearance and this has to be done economically and rapidly in mass production to give good print and quality. As the excellence of a watercolour is to a great extent dependent on the kind of paper, choice of pigments and their mixing, and the mode of application by the artist to give freshness and charm while displaying the special qualities of the materials including colour, so the printer too is aware that different effects are obtainable by a choice of variables in the ink-paper-press combination. Harmony of the three must be ensured, and in this a knowledge of the rheology of inks, paper and roller compositions, etc., makes a big contribution.

The choice of materials and press setting, etc., to give the best quality printing is subjective to a high degree, as opinions vary regarding the final production.

There is no universal ink for any printing process that excludes every failure; inks must be selected individually and adapted in accord with the paper and equipment. The ink plays a special role inasmuch as any defects become visible and recognisable through the print but it does not mean that the ink is the cause of failure, a faulty setting or imperfectly shaped or spongy rollers may be the cause. It is not clearly known which physical properties of ink and paper are predominant for ease and quality of printing as the rapid process of ink transfer involves the little-understood mechanisms of film splitting with cavitation and stringing, and entry of ink into cavities and capillaries under high pressure. The rheology of the thin film (less than 20 microns thick) of high surface area, between rollers, and roller or forme and substrate is probably not the same as for the bulk ink. The ink film, as with lubricants, comes under the influence of surface forces when adhesion and wettability play an important part. Deviations from hydrodynamic reasoning for thin films became apparent when Tower, 1883, "accidentally" found that although a pressure of 625 lb./sq. in. was maintained, two surfaces immersed in oil were completely and continuously separated by an oil film. Sir William Hardy considered the limit of surface effects resulting in boundary lubrication as distinct from hydrodynamic extended to film thicknesses up to 0.01 mm. Hardy used the diachysis hypothesis which supposes that polarisation is transmitted from molecule to molecule

with a decrement. This hypothesis was first put forward by Sutherland in 1881, and also by Reynolds in a communication to the British Association in the same year. The concept of a bound surface film has been used by scientists in the Soviet bloc to explain much in ink rheology and to be a deciding factor in ink transference and ink film splitting. Bikerman's roughness concept that "the immobile boundary layer is less likely to be due to oriented molecules than to oil which instead of moving in a truly laminar manner meanders between surface elevations forming eddies and vortices in the roughness of the surface" has been criticised partly because of the gaps and contradictions in the experimental evidence. Sometimes a set of data may appear to support or disprove a theory, there being so many unknown controlling factors in the problem. Roess considered that surface phenomena involved are so hopelessly complex that a direct approach is practically impossible. Extensive investigations in Russia and the West on the special properties of thin films and their rheology are now in progress, new and ingenious techniques being employed.

The practical study of ink transference is being made with a variety of instruments simulating press conditions, while the laboratory testing of inks and papers and their printability qualities is done by means of miniature presses (print testers), in which variations in speed, pressure and ink flow can be made. Rupp, 1960, for example, has described in detail a printability tester designed at the Institute of Graphic Tech., Leipzig, and using this device he prepared ink transfer curves between inks and papers at various speeds and pressures. The curves were analysed mathematically: on metal foils the ink was found to split equally. One constant derived from the analysis was considered to be associated with the combined properties of smoothness, softness, and wettability of the paper, while another constant gave the maximum amount of ink penetration at impress. He was also able to measure by the same instrument the speed at which picking of the paper surface began, as well as drying times. Zettlemoyer and colleagues have similarly described transference tests with their own design of printability tester and came to the conclusion that ink transfer results are not in direct relation to the viscosity of the ink, but agree well with tack measurements. The contact of ink with the paper increased with ink film thickness, time of impress and smoothness of the paper. The retention of ink at impression was by adhesion and ink penetration into the surface roughness.

At the 5th Intn. Conf. of Pr. Res. Insts., Lehigh University, 1961, several papers were discussed on the influence of inks, papers and press on colour. Various new techniques of examining print quality were described and, although the results were not always in line with those obtained subjectively by "experts," progress was reported in establishing useful scientific tests. Using various laboratory printing devices a large number of observations and some regularities between

them and rheological parameters of both ink and paper were presented in tables and graphs. The authors remarked on the extreme complexity of the problem and danger of over-simplification, and emphasised the need of fundamental researches. With regard to picking tendency it was concluded generally, since the tendency to pick the paper surface is influenced by both tension and dwell conditions, that it is mainly dependent on ink film thickness and vehicle penetration. Mill and Richards, P.A.T.R.A., investigated the misting of litho varnish-based inks but found no definite relation between the misting tendency of inks and their varnish vehicle with rheological parameters, although there was an approximate straight line relation between the Reed inkometer reading and the square root of the viscosities. On the basis of rheogoniometric measurements it could not be said that there was any clear dependence of misting on the elasticity although it appeared that high elasticity values favoured low mist figures.

Considerable attention at the Conference was given to pressure and pressure distribution between rollers affecting ink transfer and control of ink film thickness.

Eisenbach and Wagenbauer read a paper on impression forces and pressure distribution in the cylinder contact area of a sheet-fed offset printing press, giving the optimum conditions for favourable printing results. Mill described an experimental test of a theory of ink distribution stimulated by the occurrence of ink sling in a rotary letterpress machine. He found a reasonable correlation between calculated values and the ink supply (duct setting) with print film thickness, the ink film thickness on one roller in the train and the rate of change of print thickness with time when the ink supply was discontinued.

At the 6th Intn. Conf. of Pr. Res. Insts. at Elsinore, 1962, the subject of functional testing of materials by laboratory instruments was further discussed with special reference to ink transfer. Results obtained at the various research Institutes with miniature presses varied with the different geometries, although in general, similar conclusions regarding the effect of packings, roller speeds and pressures, film thickness of ink, etc., were usually obtained.

However, there were apparent contradictions, and Banks remarked that it was not surprising that various printability machines did not give the same results as it was not known in general how comparative are the hydrodynamic pressures produced during impression. Carlsson and Ginman found that laboratory testing should be done under conditions comparable with those in the actual press; thus, for example, ink transfer to paper decreased markedly at higher speeds, while increased pressure only slightly increased the ink transfer, indicating that at high speeds insufficient wetting of the paper by the ink occurs.

Miss Fetsko, who compared ink transfer on four different print makers at two different pressures and speeds, reported similar transfer in the practical film thickness range but the onset of picking and effect of speed varied with the machine. Printing smoothness, as indicated by low film thickness transfer parameters, generally increased with increasing packing smoothness, printing pressure and dwell time.

The influence of printing conditions on ink immobilisation and film splitting depended on the paper and print machine. The position of the transfer curve peak correlated well with the paper roughness but the height of the peak did not correlate with surface absorbency and the observed trends were complex.

The problem of ink splitting and ink transfer to surfaces involves many considerations, including humidity and temperature, the rheological properties of the materials and their physical and chemical properties, and the setting of the machine, together with subjective judgment of print quality. As there are so many tests required to cover the range of factors, some unknown, specialised methods of analysing the accumulation of results are necessary. Glassman, 1961, who pointed out that no known method could fully explain in numerical fashion why many uncoated papers print smoothly, whereas at similar test values coated papers print with such extreme graininess as to be commercially of very poor quality, has described a "battery of tests" analysis. In this procedure, laboratory workers co-operated with a panel, representing five paper companies, an ink maker and a printer, which made subjective judgments of prints from precise printing conditions on a 4-colour champlain press with three inks of known viscosity and with 14 papers. A total of 126 combinations of paper-ink-press was dealt with using an IBM 610 computer, for equations relating laboratory tests with print quality. Good correlation was claimed by this procedure.

In a report of the 1st Scientific session on the physico-chemical mechanics materials at Kiyev, 1962, a survey of recent trends in the development of instrumentation within the Soviet bloc was given, the main objective being the standardisation of instruments with the aim of simplifying automation processes.

Rehbinder and others spoke on the problem of finding optimum conditions of use for materials, the question of the scientific basis of generalised laws, and also obtaining mechanically optimum parameters using machines capable of dealing with vast quantities of facts. In this way test methods can be established although the scientist may not have a clear understanding of fundamentals involved. The importance of fundamental research on the range and magnitude of surface forces, rates of wetting and of penetration into porous surfaces of liquids and the rheology of their thin films, etc., has been realised for

some time as evidenced by the large number of publications now being made on the subjects.

Banks, P.A.T.R.A., speaking at an Int. Cong. at Budapest, 1962, mentioned some phenomena affecting print impression. The mechanism of ink transfer is different in letterpress from that in gravure, when absorbency has a negligible effect. In the latter process the volatile nature of the ink makes transfer measurements difficult, but the transfer curves in both processes can be related. It had been found that electrostatic charges during printing produced a loss of edge sharpness due to ink filaments, and on plastic foils, especially, the ink shows a tendency to migrate across the surface, limiting the tonal quality in gravure printing.

Kosarovitsky, Moscow, pointed out that the surface micro structure of a paper governs printability as well as ink receptivity and ink rheology. Mass and capillary distribution of ink into the paper are important, as it is known that the same paper can cope with one ink, but not with a similar one in which the ink pigment binder relation is different.

Gati, Hungary, 1963, in a paper on the development of offset and letterpress inks, at the 7th Intn. Conf. of Pr. Res.Insts., Sanderstead, discussed the printability qualities of offset and press inks as determinable by rheological principles.

He considered the rheology of the thin ink film to be different from that of the bulk ink, and this perception gave a new aspect to interpreting the physical phenomenon of ink transfer and of the equations derived from it. Gati quoted experimental evidence that the relaxation time and viscosity of the ink film laid on a surface increased exponentially with proximity to the surface, and the higher viscosity could be detected in films up to 20 microns in thickness. When the ink thickness on the forme does not, or barely exceeds, the thickness of the boundary layer, then little or no ink transfer occurs. With a thicker ink film a quasi-complex layer structure develops between the forme and the paper, sensitive to rate of impression and degree of selective vehicle absorption by the paper.

Ink splitting would occur in the plane where surface forces were at a minimum, depending on the relative thicknesses of the boundary ink layers on forme and paper. The merit of Gati's paper is that it directs attention to the special rheology of liquid films and the manner in which it affects ink transfer. The problem of the range of surface forces was discussed by the Faraday Society, 1954, when Overbeek reviewed the situation; it would seem that liquids do not form orientated chains extending beyond 1000 Å but adequate data are still lacking.

The writer has found that the wetting rate and rate of spread of liquids over and between flat polished surfaces is highly complex and

specific to the kind of liquid, and when the film thickness falls below 20 microns spreading is usually filiform, while cavities form in the film, there being a resistance to further increases in the specific area (cm^2/cc). The rate of spread of the broken film is much less than that deduced by hydrodynamic equations (Stefan, Reynolds, Taylor and others), and there is evidence of elastic properties which increase with time of standing.

With a fuller knowledge of the fundamentals of wettability and adhesion, rates of wetting and capillary movement, and in general progress in surface physics and chemistry, especially as applied to colloidal dispersions and their stability, there can be expected a collateral progress in the rheology of inks, paper, adhesives, etc., and in the way the physical properties affect print quality and smoothness of printing.

The steady contribution of basic research, standardisation of physical and chemical tests and ad hoc experimental work at printing research Institutes such as P.A.T.R.A., and in industrial scientific research laboratories, during the past 25 years has been recognised as the main cause of progress in the printing industry, which now is becoming a branch of applied engineering. However, future progress will depend not so much on the designing of complex, automated and costly machines as on the training of personnel in scientific principles and in craftsmanship, so as to obtain from the equipment and materials available the optimum printing quality, despite economic and social pressures just to get by.

Editor of Bulletin

For business reasons Mr. P. E. Knapp has found it necessary to relinquish the office of Editor of the Bulletin. Members of the Society must be grateful to Mr. Knapp for his efforts in enlarging the scope of the Bulletin, and will regret that he has been unable to complete his term of office.

The Committee has co-opted Dr. D. W. Hadley to be responsible for editing the Bulletin, and all communications should be sent to Dr. Hadley at:

J. J. Thomson Physical Laboratory,
Whiteknights Park,
Reading, Berks.

EXPLORATORY COMMITTEE ON RHEOLOGICAL RESEARCH

The Executive Committee, at its meeting on July 15th, received, and accepted in principle, the Final Report of its Exploratory Committee (Chairman, Dr. A. S. Lodge).

The Report is too lengthy to be reproduced here in full, but the relevant parts of Section A (Chairman's Report) are given below.

It is anticipated that further statements on Rheological Research will be made during the Annual Conference at Exeter in September.

Chairman's Report

The Exploratory Committee has met three times and has considered all the points raised in the Resolution passed by the A.G.M. on 26th September, 1963.

The following members of the Exploratory Committee (in alphabetical order) attended one or more meetings: Mr. R. J. Cole, Dr. M. F. Culpin, Prof. R. W. Douglas, Mr. A. Graham, Dr. J. Harris, Mr. A. T. J. Hayward, Mr. A. Horsley, Mr. G. K. Jones, Dr. A. Jobling, Mr. R. A. Lammiman, Dr. A. S. Lodge, Mr. C. C. Mill, Mr. D. R. Reid, Mr. J. E. Roberts, Dr. G. W. Scott-Blair, Dr. G. H. Tattersall, Dr. J. H. C. Vernon, Dr. W. C. Wake, Mr. B. Warburton, Dr. I. M. Ward, Mr. R. W. Whorlow.

The Exploratory Committee makes the following recommendations:

1. The British Society of Rheology should endeavour to arrange for the publication at appropriate intervals of a classified survey of rheological research in progress in the United Kingdom.*

* A first survey of this kind is being prepared by N.E.L. (E. Kilbride) in collaboration with the British Society of Rheology.

2. The British Society of Rheology should set up a Permanent Research Committee whose responsibilities should include the following:
 - (a) To review periodically the state of rheological knowledge in order to ascertain the more important gaps and to recommend research topics thought most likely to prove fruitful.
 - (b) To take such action as may seem appropriate in order to promote greater contact between industry and rheologists.
 - (c) To publish in the journals of learned Societies suitable notices of the formation and activities of the Research Committee.
3. The British Society of Rheology should endeavour to promote greater contact with other societies having interests in rheology, if possible by representation on the appropriate committees. In particular, closer liaison with the American Society of Rheology is recommended.
4. The setting up of a central laboratory for rheological research is not recommended at the present time.
5. The Exploratory Committee views with satisfaction the part that Government Research Institutes play in rheological research, and offers no recommendation for action in this respect. No recommendation is offered in relation to the Resolution Appendix items (iii) and (v) (which refer to universities and technical colleges and to locations for specific projects).

The above recommendations were agreed by majority votes of the Exploratory Committee.

RHEOLOGY ABSTRACTS AND YOUR SUBSCRIPTION

Members will be pleased to learn that the Officers of the Society have negotiated new and more favourable terms with Pergamon Press for the publication, on behalf of the Society, of Rheology Abstracts. In future the Society will gain financially from the commercial success of the Journal and as a direct result it has been found possible, contrary to earlier expectations, to recommend to the A.G.M. that the subscription be maintained at the present figure of £1 for at least another year, in spite of the various new activities being undertaken. However, in order to maintain the level of this publication it is essential that more members join our voluntary panel of Abstractors.

YOU can help your fellow rheologists and also improve the finances of the Society by offering to supply abstracts from any of the journals listed below or from any other journal containing rheological papers.

The Society owes a great deal to past and present Abstractors. Please help share the load. Do not leave it to the other fellow. If you have access to any of these journals write today to the Honorary Editor:

R. W. Whorlow,
Physics Department,
Battersea College of Technology,
London, S.W.11.

The following are some of the journals not at present being abstracted.

J. Chem. Phys.	Engineer
J. Colloid Sci.	Engineering
Chem. Rev.	Rubber Chem. Tech.
Ind. Engng. Chem. Fund.	J. Soil Soc.
Phys. Fluids.	Proc. Soil Sci. Soc. Amer.
Faserforschung.	Soil Sci.

In addition to the above most Russian journals are not abstracted, either in the original or in translation.

First Conference on Steel Works Lubrication

What is believed to be the first ever conference on lubrication in iron and steelworks has been arranged by the Lubrication and Wear Group of the Institution of Mechanical Engineers.

Among aspects to be presented in some 25 papers, including contributions from Germany and the U.S.A., are: lubrication in rolling and extrusion, roll surface and gear tooth damage, pitting and scuffing of gears, sealing of bearings, maintenance, filtration, aerosol lubrication, bearing failures and lubrication requirements of ancillary plant.

The meeting, during which delegates will visit local steelworks, will be from 27th-29th October in the Welsh College of Advanced Technology, Cardiff.

Registration forms (closing date 6th October) are available from:

Conference Section,

The Institution of Mechanical Engineers,

1 Birdcage Walk,
London, S.W.1.

A Materials Science Club

One outcome of the working party on materials science and technology set up by the Institution of Chemical Engineers in 1962 has been the formation of a Materials Science Club. The Club is not connected with any other body, but is composed only of members (as individuals, rather than as representatives of firms or societies) who are actively engaged in research, teaching and development work in the materials field.

The aim of the Club is to hold meetings at which research and education in materials science and technology will be discussed in an informal atmosphere. Meetings will be held not more than three times a year, possibly in conjunction with a dinner.

A conference is to be held at Banbury on 2nd-4th October, at which there will be a discourse on "The Strength of Materials" by Dr. F. J. P. Clarke (A.E.R.E.), and sessions on:

- (i) collaboration in teaching and research between universities and industrial laboratories;
- (ii) university materials courses;
- (iii) the appreciation of materials science and technology in schools.

Further information concerning the Club is obtainable from the Honorary Secretary:

Dr. P. E. Evans,
Department of Metallurgy,
Faculty of Technology,
Sackville Street,
Manchester.

Discussion on Sugar Cane Crushing

The Applied Mechanics Group of the Institution of Mechanical Engineers is to hold a discussion on "The Mechanics of Sugar Cane Crushing" at the Institution, 1 Birdcage Walk, London, S.W.1, on Friday, 23rd October, 1964. The meeting will begin at 6.0 p.m., the opening speaker being Professor Mansergh Shaw of the University of Queensland, Australia.

It was at the University of Queensland that the first closely controlled laboratory experiments on sugar cane crushing began in 1951, and a mathematical theory has now been derived, which agrees with experimental results and also applies to full-scale factory operations.

Professor R. C. L. Bosworth

The death has occurred of R. C. L. Bosworth, Professor of Physical Chemistry at the University of New South Wales, and a Past-President of the New South Wales Branch of the British Society of Rheology.

UNIVERSITY OF GLASGOW

Department of Electrical Engineering

Research on the Viscoelastic Properties of Polymers

Applications are invited from suitably qualified graduates in Physical Chemistry, Physics or Engineering for Junior Research Studentships or for Senior Research Fellowships available in the Department of Electrical Engineering. Applications will be considered from those due to graduate in 1964.

It is proposed to apply a range of novel electrical measuring techniques to a study of molten polymers and of polymer solutions. Remuneration for Studentships will be equivalent to a D.S.I.R. Award; that for Fellowships will be equivalent to the salary of an appropriate University post, according to qualifications and experience.

Applications (2 copies) with the names of two referees should be sent within 14 days, to Professor John Lamb, Department of Electrical Engineering, The University of Glasgow, Glasgow, W.2, from whom further particulars may be obtained.

New Members

NAME AND ADDRESS	INTERESTS
J. Batchelor, 28 Mansfield Road, Ilford.	Polymers, suspensions.
G. V. Carrette, B. R. Vickers and Sons Ltd., 5 Grosvenor Road, Hyde Park, Leeds 6.	Oils, emulsions.
D. Chung-Hsun Cheng, Warren Spring Laboratory, Stevenage.	Suspensions, viscometry.
F. N. Cogswell, 43 Homestead Court, Welwyn Garden City, Herts.	Extrusion of polymers.
D. W. Hadley, 1 Lakeside, Earley, Reading, Berks.	Polymers.
D. J. Highgate, 12 Norfolk Road, Thornton Heath, Surrey.	Suspensions, rotation viscometry.
G. B. Hodgetts, CIBA (A.R.L.) Ltd., Duxford, Cambridge.	Measurement, adhesion.
H. G. Jerrard, Dept. of Physics, University of Southampton.	Rotation viscometry, biorheology.
W. T. McLoughlin, Technical Div., Small and Parkes Ltd., Hendham Vale, Manchester 9.	Friction.

NAME AND ADDRESS	INTERESTS
J. W. Sellars, "Pantiles," 6 Hazell Way, Stoke Poges.	Education.
M. A. Voyce, Bristol Royal Hospital for Sick Children, St. Michael's Hill, Bristol 2.	Biorheology.
E. A. Watson, British Paints Ltd., Portland Road, Newcastle-upon-Tyne.	Paints, rotation viscometry.
I. M. Whate, 11 Glenhouse Road, Eltham, London S.E.9.	Polymers, viscometry.
V. Wright, Rheumatism Research Unit, School of Medicine, Leeds 2.	Connective tissue and joint stiffness.
W. E. Young, National Adhesives Ltd., Ajax Avenue, Slough.	General.
B. C. Brown, I.C.I.A.N.Z., Central Research Laboratories, Ascot Vale, Victoria, Australia.	Polymer melt rheology.
E. J. Dook, I.C.I.A.N.Z., Central Research Labs., Ascot Vale, Victoria, Australia.	Viscoelasticity of polymers.
N. E. Hartmann, 97 Napier Street, Essendon, Victoria, Australia.	Plastics, elastomers.
L. J. Jones, 30 Union Street, Nth. Williamstown, Melbourne, Australia.	Plastics, elastomers.
M. J. Jordan, 13 Gabriel Avenue, Chadstone S.E.10, Melbourne, Australia.	Elastomers.
B. M. Peryer, 13 Westerfield Drive, Nth. Clayton, Victoria, Australia.	Paints.
P. D. Stewart, 101 Marshall Road, Airport West, Victoria, Australia.	Structure of solids.
D. Cannegieter, Pieter Schoen & Zn., N.V., Oostzyde, Zaandam, Holland.	Paints.
J. Heijboer, Central Laboratory. T.N.O., Julianalaan, 132, Delft, Holland.	Polymers, polymer melts.
R. L. Ballman, Research Dept, Plastics Div., Monsanto Co., Springfield, Mass., U.S.A.	Polymer melts, capillary viscometry.
F. A. Collins, B. F. Goodrich Chem. Co., P.O. Box 122, Avon Lake, Ohio 44012, U.S.A.	Melts, suspensions.