



BRITISH RHEOLOGISTS' CLUB

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Issued for the information
of members of the Club only

CLUB NOTES

Membership.

It is gratifying to record that the membership of the Club continues to increase. The membership now numbers 109. We feel that the Club is serving a useful purpose in co-ordinating the activities of rheologists assisting in the war effort in many different fields.

Notices to Members.

In view of the help which the Club is able to give, the Paper Control authorities have informed us that the Bulletin cannot be published periodically, but that there would be no objection to our sending to members any general informative communication as may be necessary from time to time, provided that the quantity of paper is reduced to the absolute minimum, and to the extent to which we feel such information necessary to the national interests. In order to avoid any possibility of wasting paper on unnecessary abstracts, the Committee wishes to ascertain from members what type of abstract they find of practical value to them in their work. A form relating to the enquiry is enclosed. Any other suggestions as to useful activities or information are welcomed at all times.

Classification of Rheological Properties.

A useful meeting of the Club was held at Birmingham University in January when classification of rheological properties was discussed. A reprint of an account of the discussion published in "Nature" is enclosed. The Committee will welcome comments and suggestions from members. Some further progress has been made since this meeting and it is proposed to present and discuss for a short time an improved table, at the next meeting of the Club. The (American) Society of Rheology is being kept fully informed of these activities.

Next Meeting.

The next meeting will be held at the Imperial College of Science, South Kensington, London, S.W.7, on Saturday, May 16th, at 11 a.m. Dr. J. Needham, F.R.S., will speak on "Studies on Protein Particle Shape by the methods of flow-birefringence and anomalous viscosity". The address will be followed by a discussion. Arrangements are being made for members to lunch together after the meeting, and in the afternoon a visit will be paid to the Laboratories of the Limmer & Trinidad Lake Asphalt Co. Ltd. in Fulham. Details will be circulated in due course.

Anomalous Viscosities.

On the suggestion of a member, the Committee has discussed the confusion that is apt to arise when viscosities are quoted in c.g.s. units but when the experimenter knows that the value of viscosity obtained depends on the range of stress or rate of shear of the instrument used. The Committee would urge members quoting such viscosities always to make it quite clear that the values given depend on the instrument used.

/Discussion

Discussion on Tack.

Several members have expressed an interest in the subject of "tack" and "tacky" materials. These materials are of particular importance in the adhesive, paint and varnish, and printing ink industries. What "tack" is, is not yet precisely defined, but it seems closely connected with "stickiness", "spinnbarkeit" and elastic recoil of viscous liquids, and it appears to be associated with systems containing long-chain polar molecules. Some think that "tack" is not merely a manifestation of viscosity, since it is reported that of two liquids which have the same viscosity as measured in a rotating cylinder viscometer, one can be "tacky" and the other not.

It is felt that an informal discussion would help to clarify ideas on "tack" and how best it may be defined and measured. A full meeting of the Club on the subject would hardly be justified at this stage, but if the members who are most interested get together and exchange views, it may become possible to present a paper at a later full meeting. It would accordingly be appreciated if those interested would get into touch with:

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RHEOLOGY IN INDUSTRY - III

SOME RHEOLOGICAL PROBLEMS IN THE PLASTICS INDUSTRY, (Part II)

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In the first part of this article we traced the usefulness of the science of rheology to the manufacturer of plastic materials. Rheology and rheological methods are equally important to the manufacturer of plastic goods.

Sheet Plastics, moulding powders and films are the raw materials used by him and it is the custom to shape these sheets, foils and powders by means of suitably designed shaping equipment operating under heat and pressure. Under these conditions the plastic materials develop thermoplasticity and can be made to fix together under heat and pressure flux in suitable moulds. The hot mould can be chilled before the plastic material produced by the fluxed powder can be withdrawn. This technique is generally used with those plastics known as "thermoplastics", i.e., those which become plastic when heated, and solidify on cooling. These plastics can be resoftened by reheating.

There are other moulding powders, known as the thermosetting powders, which flux when heated under pressure, but after a certain exposure to such conditions they become hard and infusible. The same types of mould as those used for thermoplastics are used for preparing articles from them. No cooling, however, is required to set the fluxed material. The explanation of this behaviour lies in the chemical change which materials of this type undergo when they flux under heat and pressure. With thermoplastic powders the change on heating is purely a physical one, and is reversible.

Films possess thermoplastic properties similar to the thicker sheets, and articles are fabricated from them in much the same way. The temperatures required are equal to those used for the thicker sheets but the pressures necessary for shaping are of course very much less.

/Probably

Probably the latest method for the mass production of articles from thermoplastics is the injection process. Here the plastic moulding powder is automatically fed through a continuously heated chamber; being freed through the chamber by means of a piston which is hydraulically operated, and which develops a pressure on the material as high in some cases as 20 tons per square inch. During its passage through this heating chamber the material slowly fluxes and the conditions are so arranged that near the exit (a cylindrical orifice) of the chamber, the material is practically "fluid". This orifice is automatically brought near a cooled mould into which the "fluid" plastic is squirted. The mould is kept closed until the plastic has solidified by cooling when the mould is opened and the article so produced removed.

The rheologist in the factories devoted to plastic goods manufacture has therefore to be able to assess (amongst other things) the thermoplastic properties of

- (a) Thermoplastic sheets, tubes, rods and foils.
- (b) Thermoplastic moulding powders.
- (c) Thermosetting moulding powders.

For thermoplastic sheets, rods and tubes, the shearing stress may be as small as that used for hand modelling. It may, on the other hand, be as high as two tons per square inch, e.g., when the material is compressed in steel moulds under hydraulic pressure. For thermoplastic moulding powders shearing stresses corresponding to 20 tons per square inch pressure have been noted (the injection process) and for the other compression moulding processes, pressures up to 2 tons per square inch are not uncommon. Pressures of one ton per square inch are not unusual when moulding thermosetting powders and sometimes pressures up to 2 tons per square inch are used.

With certain shaping processes in which the plastic sheet is bent carefully to a desired shape the rate of bending and therefore the rate of shear is very low. With the injection process on the other hand, it is not unusual for a fairly large charge of hot plastic to be squirted through a narrow cylindrical orifice into the mould in a matter of a few seconds, the driving pressure being of the order of 20 tons per square inch. Clearly the rate of shear here is very high indeed.

With the thermosetting powders another difficulty is encountered from the rheological point of view. Although the material fluxes under the action of heat and pressure it also tends to harden as flow proceeds owing to the chemical action which takes place under these conditions.

Thus no simple rheological study of the flow properties of thermosetting materials is possible. It is true that empirical flow tests have been worked out for these materials but it is not possible to get a simple analysis of the flow curves for the reasons mentioned above. Two of these empirical flow tests are described below.

(a) B.S.S. Cup Flow Test. The time required for a standard cup mould to close when loaded with the test sample and subjected to a pressure of 10 tons is measured. The mould is kept at a predetermined temperature during the test. If the test material fluxes only slowly under these conditions the press will close slowly, while a rapidly fluxing powder will allow the mould to close at a correspondingly increased rate. This test has proved extremely useful to the plastics industry.

(b) Rossi-Peake Flow Test. In this test a cylindrical pellet of the material is forced along a capillary tube formed in a split steel mould. The flow along the tube during a standard /time

time under prescribed conditions of pressure and temperature is taken as a measure of the flow properties of the material.

Here again the flow is affected by the rate at which the material hardens under heat and pressure and Peakes has given some interesting curves to illustrate the effect of this hardening due to chemical change.

The curves show that with increased temperature the flow increases to a maximum, corresponding to a temperature beyond which the rate of hardening due to polymerisation or chemical condensation increases so rapidly that it completely neutralises any tendency for the fluidity to increase.

The A.S.T.M. method of test for thermoplastics was referred to in the Abstracts circulated with the B.R.C. Bulletin No.1, (Abstract No.11). In this method, the flow under pressure of a pellet of the heated plastic along a heated cylindrical orifice is measured. The apparatus used is the Rossi-Peake Flow Tester, and pressures up to 2 tons per square inch are used.

The information obtained by this test is somewhat empirical in character and so far it is difficult to obtain any useful comparison of different basic materials by means of it.

Other methods have been used for the estimation of the rheological properties of these thermoplastics. These are the Cup-flow test previously mentioned - this test gives the flow properties in purely arbitrary units - and the parallel plate plastometer. This last mentioned apparatus was used extensively by Houwink and other workers and many references to its use can be seen in the literature. It is possible to derive the fundamental flow characteristics by means of this machine and on this account it is proving an extremely useful tool to these research workers studying the molecular structure of plastics. (See Abstract B.R.C. 71, October 1941). Modern work shows quite clearly that the thermoplastic properties of plastic depend on the molecular structure of the materials.

RHEOLOGY ABSTRACTS

Note: The Club assumes no responsibility for the opinions expressed by abstractors; these are given in square brackets.

89. Soil classification and its bearing on soil stabilization. A.H.D. Markwick. J.Inst.Petroleum, 27, p.313, 1941. Soil classification tests commonly used, and some of which have been standardized by the American Society for Testing Materials (A.S.T.M. D 424 - 39) are described. The significance of the liquid limit (moisture content limit at which soil will just begin to flow), plastic limit (minimum moisture content at which a thread of soil can be rolled down without breaking until it is 1/8" diameter) and other measurements are discussed with regard to the "stabilization" of soils for road and runway construction. E.W.J.M.

90. Use of bitumen in soil stabilization. E. Gardener, J.Inst.Petroleum, 27, p.329, 1941. The load-bearing capacity (or ability of a surface to support a load without permanent displacement) of soils of different grading and water content is discussed. It was found by means of a cone penetrometer that all soils exhibit an optimum water content in this respect. The author concludes that a satisfactory "stabilizer" should show no tendency to wet the soil particles and so displace the water film. E.W.J.M.

91. Action of alkalis on starches. G.B. Jambuserwala. J.Text.Inst. 32, T 201, 1941. Viscosity measurements, noting times of falls of a ball, were made by means of a H⁸pppler viscometer using 1% starch paste at 30°C. Samples of 100 g. each of dried corn, sago, wheat and farina with 200 ml. of sodium hydroxide, potassium hydroxide, trisodium phosphate and sodium carbonate solutions of concentrations up to 10%, care being taken to avoid turning the starch into a gummy mass. The alkalis were found to modify the starches in accordance with their hydroxylion concentration. The relation between alkali concentrations and viscosities of starch pastes was almost linear; a sharper fall in viscosity was observed with caustic soda modifications. E.W.J.M.

92. The Tackmeter, and instrument for analyzing and measuring tack. H. Green. Ind. & Eng. Chem., Anal.Edn., 13, p.632, 1941. The "finger tap-out test" for "tack" is described, in which the finger is pressed into a film of ink and then drawn away suddenly in order to get an idea of the "pull-resistance". It is claimed that the Tackmeter is in effect a mechanical finger which places this test on a numerical basis. Possible causes of "pull-resistance" or tack are discussed; it is considered that the main factor operating is viscosity, with possibly yield value and surface tension. The instrument is described and results of experiments are tabulated from which an empirical equation is derived connecting viscosity with ink film thickness, pulling weight, time of break and radius of "finger". From this equation it appears that tack is as much a function of the instrument that measures it as it is of the ink itself. For this reason its measurement is of no particular value and it is more convenient to use "relative tack", which is the tack of the ink divided by the tack of a standard substance such as stable mineral oil. For normal printing speeds, yield value and surface tension are negligible and the equation for relative tack reduces to the ratio of the viscosities of ink and standard. It is claimed that the range of the largest "finger" used on the instrument is from 1 poise to over 3×10^7 poises, on film thicknesses from 5 to 1250 microns.

(In the instrument as used, the ink film is not actually broken and the resistance offered at the beginning of the determination is mostly due to the flow of ink underneath the "finger" under external air pressure as the "finger" is raised. The lines of flow of the ink under these conditions must be complicated and variable, but the initial resistance must be due mainly to the restricted flow between "finger" and base plate - a pure viscosity effect. It is therefore not surprising to find that "relative tack" reduces to a ratio of viscosities. The instrument itself is a crude form of viscometer. The author has missed the main characteristic of "tack". "Tack" is a stickiness of thin films of certain materials. When the finger is pulled away from a tacky surface a resistance is felt even for slow rates of separation. The cessation of this resistance is gradual, not abrupt. "Tack" seems invariably to be associated with some degree of "spinnbarkeit" and it appears to occur only with liquids consisting of long-chain polar molecules. It is quite possible to get a liquid of medium viscosity (e.g., litho varnish) which is much more tacky than one of higher viscosity as measured by a viscometer (e.g., mineral oil).

It is difficult to see the point of publishing this paper. The tackmeter gives no information which would not be given more reliably by a properly designed viscometer; the author's attempts to prove that tack is merely a manifestation of the effect of viscosity are unsound and he ignores the possibility that work may be done in orientating long-chain molecules - i.e., that tack is a phenomenon characteristic of a certain type of molecule which can only be adequately explained on a molecular basis.

V.G.W.H.

93. General law of friction for liquids and its application to the calculation of the resistance to motion of disperse systems under isothermal and non-isothermal conditions".

A. Skryabin. Koll.J.U.S.S.R. V, p.363, 1939. Using the Maxwell equation relating viscosity (η) to shear modulus (μ) and relaxation time (t_r) viz.: $t_r = \eta/\mu$, the author proceeds to re-write a number of well-known rheological equations (Bingham, Buckingham-Reiner, etc.) in terms of relaxation times. The Buckingham-Reiner equation is taken as a special case for very small relaxation times, of the generalised equation:-

$$\frac{1}{\mu} = \frac{\pi R^4}{8L\eta} \left(P - \frac{4}{3}p + \frac{p^4}{3p^3} \right) e^{-t/t_r} \quad \text{where the symbols have the usual significance.}$$

Temperature coefficients are also studied.

There is nothing highly original in this, but the reviewing of a well-known equation from a new angle is sometimes suggestive and helpful. G.W.S.B.

94. Beitrag zur Frage der Verweildauer der Milch in Durchflusshelsshaltern. W. Sell. Milchwirtschaftl. Forsch. 21, p.42, 1941. A hydrodynamic study of the flow of milk through Pasteurisers.

The treatment for streamline flow is given in extenso though the author realises that flow in pasteurisers is turbulent.

95. Chocolate coating. Factors affecting viscosity and coverage value of chocolate coating for ice cream products.

J.H. Erb. Ice Cream Trade J. 37, p.18, 1941. A study of the viscosity of chocolate used for coating ice-cream bars is made with a MacMichael viscometer. The effects of lecithin are investigated with special reference to spreading. The Freundlich "bob test" is used, in which a metal "bob" is lowered into the chocolate and then withdrawn, the amount retained after draining being measured. The undesirable effect of increased moisture in enhancing the retention of the film of chocolate can be counteracted by the addition of lecithin.

96. Consistency test for lubricating greases. H. Levin and C.J. Schlagel. Ind. Eng. Chem. Anal. Edn. 13, p.295, 1941. A penetrometer is described based on the A.S.T.M. method. B.R.R.A.

97. Plasticity of phenol-formaldehyde resins and moulding powders. L.M. Debing and S.H. Silberkraus. Ind. Eng. Chem. 33, p.972, 1941. A brief description of the principal methods used in America for determining the plasticity of phenolic moulding powders is presented. Typical one-stage and two-stage resins are compounded with and without various standard fillers to illustrate the inadequacy of any one method to classify these materials properly as to plasticity. The factors to be considered are discussed on the basis of experimental data presented. The complexities of this problem are such that empirical test methods appear to be the only practical methods available. Standardization of one method would be desirable but no one test method appears to be adequate. B.R.R.A.

98. Stress-strain characteristics of plastic clay masses. R. Russell, Jr. and C.F. Hanks, J.R. J. Amer. Ceram. Soc., 25, p.16, 1942. An apparatus is described for reproducing stress-strain data and it is concluded from investigation of the stress-strain characteristics of plastic clay masses that the plastic character depends on several physical properties, and cannot be completely evaluated by any single parameter. The shape of stress-strain curves depends on the clay mixtures and it is thus possible to distinguish between different compositions on the basis of their mechanical behaviour alone. "Moisture equivalent", i.e., the moisture content necessary for an arbitrarily selected equilibrium stress (5 lb. per sq. in.) is a satisfactory parameter for the comparison of the plastic properties of clays and similar body/compositions.

compositions. Bodies of different non-plastic content cannot be compared by "moisture equivalent" data. Variations in moisture content have a pronounced effect on the equilibrium stress value and in the plastic behaviour; ageing has a pronounced effect on the plastic properties of ceramic bodies and clays. Ageing of china clays or kaolins and bodies lowers the moisture equivalents and an opposite effect is noted for ball clays; the ball clay of highest organic content was most affected by ageing. Ageing of ball clays and bodies resulted in a progressive change at least up to one week, whereas china clays were unaffected after ageing four hours. Cyclic loading indicates that a clay body is essentially non-elastic after being stressed to its yield point. An increase in the strain rate shows a marked effect on the stress-strain results and increases the equilibrium stress. For the evaluation of various materials or mixtures plasticity should be determined under standardized conditions. Workability depends on ageing, the use of electrolytes and organic agents, vacuum treatment and variation in water content. For a clay body of determined plasticity, the workability is said to improve in direct relationship to a decrease in moisture equivalent (increased softness) caused by the effects of special treatment and processing. B.R.R.A.

99. Working-range flow properties of thermoplastics. F.E. Wiley. Ind.Eng.Chem., 33, p.1377, 1941. A test to measure the working range flow of thermoplastics is described and data obtained by this test are presented. For most plastics the data are valid when the rate of flow at 1cm. elongation is not less than 0.01cm. or more than 0.25cm. per sec. If a wide temperature spread is to be investigated, the stress may be varied in such a manner that the rate of flow falls within these limits. Most satisfactory results are obtained at a stress between 90 and 100gms. per sq.cm. B.R.R.A.

100. Reversible aggregations of colloidal particles, I. Centrifugal experiments on thixotropic iron oxide sols. W.Heller. J.Phys.Chem., 45, p.1203, 1941. By centrifuging iron oxide sols containing NaCl it is shown that the first stage in the formation of the gel is the building up of reversible aggregates. The rate of formation of these aggregates increases with the concentration of NaCl. The gel which is separated by centrifugation shows a more marked degree of thixotropy than the original suspension except at the highest speeds, when the gel-sol transformation can no longer be made to occur. The most highly concentrated thixotropic gel maintained an elastic reaction of $1.6 \cdot 10^{-4}$ dynes/cm². The theory is advanced that the aggregates originally formed subsequently adhere to form a network structure. Evidence of this structure is provided by optical observations.

[A valuable piece of research on a difficult subject] L.R.G.T.

101. A Stress-strain curve for the atomic lattice of mild steel, and the physical significance of the yield point of a metal. S.L. Smith & W.A. Wood. Proc.Roy.Soc.A179, p.450, 1942. For mild steel, X-ray measurements of the lattice spacing in a crystal plane perpendicular to the direction of extension showed that this decreased reversibly and proportionately to the load up to the yield point. At this point there was a sudden increase in the spacing, accompanied by a reduction in intensity of reflection, pointing to a release of strain by crystal fragmentation. On release of the load there was a residual expansion of the lattice, indicating internal strain. The effects are discussed in terms of the polycrystalline structure of the metal. L.R.G.T.

102. New method of determining the viscosity of viscous liquids at increasing temperatures. K. Gühde. Chem.Fabrik., 13, 1, p.9, 1940; Papierfabrikant, 39, (31/32), Auszüge, 74, 1941. /The

The amylograph devised at the Institut für Mehlphysik, Duisburg, for measuring the viscosity of starch products at increasing temperatures has been adapted for use over a smaller range of viscosities by substituting a balance for a spring system. The resulting apparatus is called a Viscosigraph. The apparatus can also be used for measuring the effect of mechanical and chemical influences on viscosity. The applications of the apparatus to the effect of temperature on the viscosity of photogravure inks, glues and polish emulsions, the effect of working on the machine on the coagulation point of latex mixes and the determination of the degrees of ripening of viscose are discussed.

The Amylograph is a self recording rotation viscometer. It is electrically heated, the temperature being controlled by a platinum wire contact mercury thermometer. The platinum wire is mechanically raised so that the rise in temperature is linear with time.

It was devised for measuring the liquification of flour-water suspension due to amylase activity. This is important in the manufacture of rye bread. V.G.W.H.

103. "Instruments" (Editorial) 15, p.34, 1942. The recording viscometers are described. (1) A recording viscometer and specific gravity meter, by the Petroleum Instrument Corporation, for use with fluids. A cylindrical metal rotor is kept rotating at constant speed in a cage containing six stationary blades, shearing the liquid between its surface and the vanes. The instrument works from 100 V. A.C. supply. (2) A recording viscometer, by the Brabender Corporation, Rochelle Park, N.J., suitable for materials of a "viscous or light plastic nature..... or whose thixotropic effect is important". The material is placed in a bucket and the resistance on a paddle wheel caused to rotate in it is continuously recorded by means of a spring. It operates at six different speeds from 30 - 300 r.p.m. G.W.S.B.

104. Viscosity of Glass. S.R. Scholes. Modern Glass Practice, Industrial Publications Inc., Chicago, 1941. Viscosity is discussed on pp.119 - 123 and is regarded as the most important property as far as manufacture is concerned. L.A.S.

105. Soil Mechanics. D.P. Krynine. McGraw Hill Book Co., New York and London, 1941. Plasticity and Consistency are discussed on pp.27 - 48. L.A.S.