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SURFACE RHEOLOGY

ANNUAL CONFERENCE OF THE BRITISH SOCIETY OF RHEOLOGY

THE annual conference of the British Society of Rheology was held in the Washington Singer Laboratories of the University College of the South West, Exeter, during September 22-24. Dr. S. Gregg (University College, Exeter) opened the conference with a paper on the effect of adsorption on the strength of brittle solids. After summarizing the general theory of the subject, he described his recent experimental work, assisted by Dr. D. Dollimore and Dr. A. Desai, on the strength of compacted disks of compressed powders, broken *in vacuo* and in controlled atmospheres. Adsorption isotherms were prepared. The density of elastic energy located

between two planes at distance a apart is $\frac{1}{2} \cdot \frac{\sigma^2}{E} \cdot a$,

where σ is the stress and E Young's modulus. Although, in the case of glass at the rupture point the value of $\sigma_{\max}$ is calculated to be 10^{11} dyne cm^{-2} , the experimentally measured value is about one-hundredth of this amount. The discrepancy is attributable to the weakening effect of the adsorption of water molecules on the surfaces of incipient cracks. The reduction in surface energy on exposure to vapour, $(\gamma_{\text{vac.}} - \gamma_{\text{vap.}})$, in relation to the amount

adsorbed per gm. of solid is $\frac{RT}{SM} \int_0^p x \, d \ln p$, where S is

the specific surface, p the pressure of adsorption and M the molecular weight. Graphs relating the breaking strength of disks of compacted calcium carbonate, kaolin and boric acid powders, measured under different states of adsorption and desorption, together with derived graphs relating strength and surface energy, etc., were shown.

When benzene vapour replaced that of water in the experiments the strength of the disks remained practically unchanged, although the vapour had been strongly adsorbed with a consequent fall in surface energy. Dr. Gregg explained this anomaly as being due to the relatively large size of the benzene molecule, the ingress of the vapour into the cracks being prevented. In the discussion the meeting supported this view, and considered explanations of other

anomalies found under conditions of supersaturation, and the partial absence of hysteresis with boric acid during adsorption and desorption.

In a paper on lubrication by films of solid materials, Miss E. Kay spoke on an investigation at the Royal Aircraft Establishment, Farnborough, made jointly with Mrs. E. Bielak and Dr. E. W. J. Mardles, in which a wide variety of fine powders, including metallic stearates, waxes, polytetrafluoroethylene, molybdenum sulphide, graphite, etc., dry and dispersed in liquid media, were examined under different conditions and between various bearing surfaces. Dry lubrication is often preferable both under the condition of a wide temperature-range, such as that with aircraft, -80°C . to beyond 250°C ., and with light mechanisms of precision when oil seepage and creep, even of 'non-spread' oils and with use of 'epilame' barriers, tend to produce dry bearings and alteration in the inertia of fine moving parts. It was found that with a dry lubricant, although a higher coefficient of friction may be obtainable, the coefficient changes but little over a wide temperature-range. A wide scatter of results obtained with powders under some conditions is attributed to the inclusion of moisture or of oil, to failure of the surface to retain the solid lubricant and to physical changes. Considerable attention is required to find the best method of applying solids for different lubricating purposes.

Members of the meeting then discussed the effect of particle size and shape and the relative merits of dry powders and their use in oil and grease dispersions.

A. F. Latham with Dr. K. G. A. Pankhurst (British Leather Manufacturers Research Association, Egham) spoke on surface viscometry—the tanning of protein monolayers. Insoluble monolayers, spread on a water surface, may exist in a variety of states of aggregation ranging from a rigid two-dimensional 'solid' to an almost perfect surface 'gas'. Mr. Latham described the design and use of a rotational viscometer for measuring the viscous drag of these surface films and distinguishing between Newtonian and non-Newtonian flow.

Protein monolayers exhibit a wide variety of surface rheological properties according to the surface pressure. The changes are reversible and, in the case of serum albumen, can be interpreted by change from the α - to β -keratin pattern. The surface viscosity of collagen is much lower than that of serum albumen due to reduced inter-chain linkage; but, when spread on a tanning material such as mimosa tannin, the surface viscosity increases by nearly a thousandfold. Mr. Latham described how use is

made of the rate of formation of cross-linking to investigate tanning reactions. In reply to queries, he spoke on results obtained with a number of substrates and on the technique used for examining various rheological properties of the monolayers.

In a paper on surface films of poly-di-methyl siloxanes on organic liquid substrates, Dr. W. H. Banks (Printing, Packaging and Allied Trades Research Association, Leatherhead) considered the spreading behaviour of a silicone fluid of average molecular weight 2,000, its surface films having the property of suppressing the foaming of oils and the mottling of paints. The special apparatus developed for the study was described, and graphs were shown relating results obtained for film pressure and film area. Hysteresis effects were observed. Lycopodium was used for observing the rate of spreading on a variety of organic liquids, which was found to be in accord with the relation $l \propto \sqrt{t/\eta}$, l being distance moved, t time in sec. and η the viscosity of the substrate. The movement of the surface films caused a gradient in the substrate, a film of thickness 25 Å. being sufficient to cause motion. In the discussion that followed, members considered possible mechanisms of action of silicone fluid films in suppressing foaming, mottling, evaporation and surface turbulence.

In their paper on the rheological properties of dispersions as criteria of the degree of wetting, Dr. E. W. J. Mardles (Farnborough) and Mr. A. de Waele (Gestetner, Ltd.) first pointed out the difficulties of ascertaining the degree of wetting of a solid surface by a liquid using the Young-Dupré equation modified by Harkins. Contact angles at 'equilibrium' may not exist due to the presence of adsorbed liquid films beyond the periphery of the pool, and the spreading of a liquid over a solid surface can be shown to be non-Newtonian. Although there is some correlation between heats of immersion of powders in various liquids and the rheological properties of their dispersions, numerous exceptions occur due possibly to the fact that the wetting of a surface by a liquid continues over a long period of time. Evidence of this is given by a decrease with time in the viscosity of a freshly made dispersion, by the decrease in the coefficient of friction by oil between bearings during several hours of wetting, and by electrical conductivity measurements which, in the case of a dispersion of carbon black in liquid paraffin (British Pharmacopœia), continued to change over a period of twelve months. The authors presented results in graphical form indicating the effect of adding wetting-agents on the rheological properties and conductivity

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of a number of suspensions. Using one powder dispersed in a variety of liquids, or several different powders dispersed singly in the same liquid, the concentration by volume being the same, the rate of aggregation of the particles (indicated by the rheological constants, by the sedimentation-rate and volume, and by conductivity tests) was found to vary considerably, the variations being related to the degree of wetting of the particles by the dispersing media.

The conference included an afternoon visit to the works of the Exeter Brick and Tile Co., Ltd., when Dr. H. H. Macey gave a talk on rheological problems connected with clays and ceramics. At the annual general meeting of the Society, Prof. J. G. Oldroyd was elected president.

E. W. J. MARDLES

THE BRITISH SOCIETY OF RHEOLOGY

Bulletin No. 45

December, 1955

Price to non-members 7s.

EXETER CONFERENCE AND ANNUAL GENERAL MEETING, SEPTEMBER 22-24, 1955

Our congratulations and best wishes go out to our friends and members at Exeter and the west country. The University College of the South West, since the Conference, has become the University of Exeter by Royal Charter. The Washington Singer Laboratories for physics and chemistry, costing nearly £100,000, were opened 1931, the estate having been declared open in 1927 by the Duke of Windsor, then Prince of Wales. The first Chancellor of the University will be Mary, the Duchess of Devonshire, sister of the Marquis of Salisbury, who on retiring from the Presidency offered the robe worn by his grandfather as Chancellor of the University of Oxford to the new University. We look forward to yet another successful conference in the not distant future at the Washington Singer Labs and another happy visit to the ancient City.

At the Annual General Meeting Prof. J. G. Oldroyd was elected President of the Society for 1955-1956, together with the officers and committee listed in this Bulletin.

The Audited accounts and membership for 1954-1955 are as shown.

A discussion arose during the meeting as to how the Bulletin could best serve the interests of the members of the Society. Many useful suggestions were made. The editor will be glad to receive further ideas and comments for consideration in committee.

The following tentative list of subjects for discussion in the new year has been proposed:—

Rheology of Protein Systems	..	..	..	Jan.	1956
Rheological Measurements and Automation	..			Apr.	1956
Extrusion and Rolling Processes	..	..	..	June	1956
Rheology of Textiles	..	..	..	Sept.	1956

Accounts for the Year Ending 30th June, 1955

<i>Receipts</i>							£	s.	d.
Balance on 1st July, 1954	..	..	..	..	..	..	453	1	0
Members Subscriptions	..	..	..	..	..	..	250	14	6
From Sale of Bulletin to non-members	..	..	..	..	..	..	16	15	1
Received in connection with Meetings	..	..	..	..	..	..	9	6	0
Accrued Interest	..	..	..	..	..	..	5	2	6
							734	19	1

<i>Expenditure</i>							£	s.	d.
Postage and Receipt Stamps	..	..	..	..	..	..	14	8	3
Stationery and Printing	..	..	..	..	..	..	158	9	4
Secretarial Help and Committee Expenses	..	..	..	..	..	..	21	5	10
Expenditure in connection with Meetings	..	..	..	..	..	..	20	8	3
Balance on 30th June, 1955	..	..	..	..	..	..	520	7	5
							734	19	1

Excess of Income over Expenditure for 1954-55=£67. 6s. 5d.

Audited and found correct,

A. DE WAELE

Paid-up Membership as at 30th June, 1955

1953-4						
196	Members	(U.K.)	..	..	..	208
17		(Foreign)	..	..	..	23
19	Subscribers	(U.K.)	..	..	..	5
		(Foreign)	..	..	..	11
232	Total	..	..	..	..	247

Foreign Membership

U.S.A.	..	..	3	Norway	..	..	2
Germany	..	..	4	Sweden	..	..	1
France	..	..	4	Italy	..	..	1
Holland	..	..	4	Belgium	..	..	1
Israel	..	..	2	Japan	..	..	1

W. WOOKEY,

Hon Treasurer,

September, 1955

Surface Viscometry: The Tanning of Protein Monolayers *

A. F. LANHAM and K. G. A. PANKHURST

(British Leather Manufacturers Research Association)

Insoluble monolayers spread at the surface of aqueous solutions may exist in a variety of states of aggregation ranging from a two dimensional "solid" to an almost perfect surface "gas". Fluid films possess characteristic surface viscosities which can be measured by two-dimensional analogues of conventional methods, e.g. surface canal method oscillating disc or vane methods, rotational methods. Both the surface slit and oscillation methods suffer from the disadvantage that the film cannot be maintained at constant pressure throughout the determination, which is a serious drawback since the viscosity of a monolayer is frequently highly dependent on the surface pressure. Furthermore oscillation techniques do not permit the study of films at a constant rate of shear. Both of these shortcomings are avoided with a rotational viscometer analogous to the three-dimensional Couette pattern. In this the surface film is admitted under constant pressure to the annulus between a floating wax-covered platinum ring and a concentric circular waxed mica template also floating on the water surface. The ring is rotated through a torsion wire and the viscous drag imposed by the monolayer is measured by observing the angular displacement between the two ends of the torsion wire. The velocity gradient can be varied either by changing the width of the annular space or by changing the speed of rotation of the ring, and thus any non-Newtonian behaviour can be detected.

Protein monolayers show a wide range of surface rheological properties. Thus serum albumen which at low degrees of compression behaves as a Newtonian fluid, becomes non-Newtonian at surface pressures of about 5 dyn. cm⁻¹ and above, being plastic at 6 dyn. cm⁻¹ and a gel at 10 dyn. cm⁻¹. Collagen, on the other hand, behaves as a Newtonian fluid up to 10 dyn. cm⁻¹, and has a much lower surface viscosity. These observations can be interpreted in terms of the amino acid make-up of the respective proteins. Serum albumen can easily conform to the α and β keratin patterns of Astbury and its molecules are therefore capable of alignment, in which state inter-chain links can be formed. Collagen, however, does not conform to either of these patterns owing to its large content of proline and hydroxy-proline which prevents the completely free rotation of the main polypeptide chains. The monolayer cannot therefore be easily packed into a two-dimensional orderly pattern in which inter cross-linking can occur. Only when compressed to a surface pressure of 15 dyn. cm⁻¹ or so does the surface viscosity rise to more than a few hundredths of a surface poise.

When, however, a collagen film is spread on to a solution of tannins, the surface viscosity is increased over a thousandfold even at surface pressures as low as 3 dyn. cm⁻¹. This increase in viscosity is characteristic of tanning and is interpreted as evidence of the formation of tannin bridges linking the individual polypeptide chains into a highly viscous continuum. Monolayers of synthetic polymers of the nylon type can also be similarly cross-linked by certain tanning agents, and a study of their behaviour towards tannins and synthetic tanning agents has assisted in an understanding of the chemistry of tanning processes.

**Author's abstract of paper read at Exeter Conference, September, 1955.*

New Standard Methods for the Determination of the Viscosity of Liquids in c.g.s. Units

Both the Standard Methods B.S. (British Standard) 188 and I.P. (Institute of Petroleum) 71T for the determination of the viscosity of liquids in c.g.s. units have been revised and completely rewritten. They will be published early in 1956. The revisions were based on new knowledge, apparatus and experience, and aim at increased accuracy and convenience while the scopes of the methods have been considerably extended.

An important change now made is in the basis of calibration. Instead of allowing three liquids (water and two sucrose solutions) to be used in different ranges, the revised standards require all calibrations of viscometers to be based on the value of 1.002 centipoises (1.0038 centistokes) for the absolute viscosity of water at 20.00°C., a value adopted from 1st July, 1953.

Advantage has been taken of this opportunity of revision to introduce the use of precision bore tubing which has now become more generally available. The change should minimize trouble in the selection of tubing and will allow all viscometers of a given range to have approximately the same calibration constant. The reduction in the tolerance on the diameter of the capillary makes the rate of shear of a given liquid more closely reproducible. This constancy of shear rate is of some advantage in specifying the behaviour of liquids of non-Newtonian behaviour which show different viscosities when tested in viscometers of different dimensions and consequently of different shears rate.

The Standard Methods give the general principles of accurate viscometry and the specific requirements for several types of viscometers in general use in this country. Their design and dimensions are shown in figures and tables and reference has been made to other types of viscometers which are accurate and generally acceptable.

The sets of viscometers described are suitable for the methods and have been designed to provide a nearly equal overlap between viscometers with adjacent constants of 1 and 3 times a power of 10, namely 0.003, 0.01, 0.03, 0.1, 0.3, 1, 3 and 10.

Miniature viscometers, for use when the test sample is available only in limited quantities, and reverse flow viscometers for opaque liquids have been included. All viscometers may be used over a wide range of temperature. With the listed I.P. thermometers the temperature range is from -65°F. to 212°F.

All test viscometers for use with oils are calibrated by means of secondary calibrating liquids of accurately-known viscosity referred to the viscosity of the primary standard, freshly distilled water at 20.00°C. These secondary calibrating liquids are usually stable oils selected to cover the desired viscosity range.

Master (or calibrating viscometers) are described, together with the procedure for their use, in a separate appendix. These viscometers are required for basic calibration purposes and are used for determining the viscosity of secondary calibrating liquids. They are so designed that the effect due to surface tension differences and the quantity B/t is negligibly small (less than 0.1 per cent) in relation to the term Ct of equation (1).

$$v = Ct - B/t \dots\dots\dots 1$$

where v is the kinematic viscosity, C the constant of the viscometer, B the coefficient of kinetic energy of efflux and t the flow time in seconds.

Considerable attention has been given to the problem caused by the difficulty of experimentally determining the coefficient of kinetic energy B . Complaints of the cost in time of measurement and the unreliability of experimentally determined values of B when different kinds of oils are involved have led to a consideration of the means, where possible, of avoiding the use of B . Approximate values of B for several viscometers, obtained by calculation from their dimensions together with the method of calculation, have been given in an appendix.

Values of minimum flow times and the method of calculating these minima, when the term B/t of equation (1) is not greater than 0.1 per cent of the flow time are also given.

Some approximate minimum flow times, when the shortened equation (2) derived from equation 1, namely,

$$v = Ct \dots\dots\dots 2$$

may be used are as follows:—

<i>Viscometer C constant (cS. sec⁻¹)</i>	<i>Minimum flow time (sec.)</i>
0.1 and over	200
Below 0.1 to 0.03	300
0.03 to 0.01	500
0.01 to 0.003	900

MORNING SESSION 9.45 a.m.

Introductory Remarks by Chairman,
Mr. A. G. Ward

Mr. E. J. Ambrose (Chester Beatty Research Inst.)
"The Formation of Structures in
Protein Solutions."

Dr. A. Wassermann (University College, London)
"Viscosimetric Investigation into the Influence
of pH and Ionic Strength on Molecular Shape
of a Structural Muscle Protein."

**BUFFET LUNCH—12.30 p.m.
AT INSTITUTE OF PHYSICS**

AFTERNOON SESSION 2.0 p.m.

Mr. D. W. Jopling (Kodak Ltd.)

"Some Rubber-Like and Relaxation Properties
of Gelatin."

Dr. J. Brooks and Mr. H. P. Hale
(Low Temp. Research Station)

"Mechanical Properties of the Ovomucin Gel
of the Egg."

To be sent before January 12th, 1956, to
Hon. Secretary, 52 Tavistock Road,
Edgware, Middlesex.

I shall be present at the Symposium on
"RHEOLOGY OF PROTEINS"
and would like to book

Morning Coffee6d.

Buffet Lunch7/6d.

Tea2/-

10/-

I enclose remittance for/.....

Signed.....

British Standard 1733 : 1955. Flow Cups and their methods of use

B.S. Standard 188 was first published in 1923 with the object of furthering the expression of viscosity in c.g.s. units rather than in the readings of any arbitrarily selected standard instrument. To meet current technical needs, however, a separate British Standard, B.S. 1733 has been prepared which describes selected flow cups intended for the rapid control testing in the manufacture of paints and varnishes and other industrial liquids. Many different cups have been described in literature consisting essentially of a

THE BRITISH SOCIETY OF RHEOLOGY

Hon. Secretary : Mr. N. Wookey
52 Tavistock Road, Edgware, Middx,

RHEOLOGY OF PROTEINS

A Symposium will be held at the Institute of
Physics, 47 Belgrave Square, London, S.W.1,
on Friday, January 20th, 1956.

Some appropriate minimum and maximum values which the viscosity equation (η) assumes from equation 1, namely.

$v = Ct \dots \dots \dots 2$		
may be used are as follows :—		
<i>Viscometer C constant (cS. sec⁻¹)</i>	<i>Minimum flow time (sec.)</i>	
Below 0.1	0.1 and over	200
0.1 to 0.03		300
0.03 to 0.01		500
0.01 to 0.003		900

Minimum flow times vary with the design of the viscometer and accurate values may be calculated by the method given.

It can be shown from Poiseuille's law and the Hagenbach-Couette correction for kinetic energy of efflux that

$$\text{Constant } C = \pi \frac{d^4}{128} \frac{hg}{LV} \text{ and } B = \frac{mV}{8\pi L}$$

where d is the capillary diameter

h the mean head of liquid

L the corrected length of capillary (which may be taken as the length plus three times the diameter)

V the volume of liquid

m the "constant," to which small positive values up to 1.5 have been assigned.

If m is taken as unity and the viscosity unit is the centistokes then :—

$$B = 3.98 \, V/L \dots\dots\dots 3$$

from which it is possible to calculate values of B.

To calculate minimum flow times the following equation may be used.

$$t_{\min} = 63 \sqrt{\frac{V}{LC}} \dots\dots\dots 4$$

The percentage error, x, due to omitting the kinetic energy correction is given by

$$x = 100B/Ct^2 = \frac{398V}{Ct^2 L} \text{ (since } B = 3.98 \, V/L \text{)}$$

where the symbols have the same meaning as before, therefore

$$t = 20 \sqrt{\frac{V}{xLC}}$$

from which equation 4 is derived when x=0.1 per cent.

Timer—the accuracy required in timing is obtainable by means of a jewelled lever stop watch or electrical timing device graduated in divisions of 0.2 sec. or less and accurate to within 0.07 per cent when tested over a period of not less than 15 minutes. With a minimum timing period of 200 seconds the over-all timing errors are within an acceptable limit.

The methods of checking thermometers and of the selection, cleaning and calibrating a viscometer and of expressing the results have been rewritten in the light of recent experience and practice.

In B.S. 188 the method of use for the falling sphere viscometer has been revised. Although the precision normally obtainable is not much better than ± 0.5 per cent it provides for the examination of transparent liquids of high viscosity (above 15,000 centistokes).

British Standard 1733 : 1955. Flow Cups and their methods of use

B.S. Standard 188 was first published in 1923 with the object of furthering the expression of viscosity in c.g.s. units rather than in the readings of any arbitrarily selected standard instrument. To meet current technical needs, however, a separate British Standard, B.S. 1733 has been prepared which describes selected flow cups intended for the rapid control testing in the manufacture of paints and varnishes and other industrial liquids. Many different cups have been described in literature consisting essentially of a

container provided with an orifice which controls the rate of efflux of the liquid, but there has been little general standardization by prescribing dimensional tolerances of such cups. In consequence, wide variations have been experienced in flow times measured on cups purporting to be identical.

The British Standard was accordingly prepared and first published in 1951. It is now revised, under the authority of the Chemical Divisional Council, in the light of practical experience gained in its use over the past four years.

The Ford "cup viscometer", having a conical base centrally drilled with an orifice has been adopted by many industries for works' use in Great Britain and four flow cups (Type B in the standard) having the essential dimensions given on the original blueprint of the Ford Motor Co., Dagenham in 1925 are described.

For more accurate measurements in the laboratory, especially with materials which give an uncertain end-point, the procedure in which the time of efflux of a definite volume of liquid is measured is recognized as being preferable. This procedure is described in A.S.T.M. (American Society for Testing Materials) D.333-40, "Standard Methods of Testing Nitrocellulose Clear Lacquers and Lacquer Enamels", and differs from that normally employed with the "Ford cup", in which the end of the timed period is indicated by the breaking of the efflux stream into drops. The A.S.T.M. type cup (Type A in the standard) is therefore included. The flat design of its base enables precise manufacturing control to be more readily exercised over the length of the orifice.

It is recognized that it is difficult to manufacture flow cups economically to narrow dimensional tolerances and that it is unlikely that many users are provided with the measuring instruments required for gauging cups accurately. The original tolerance on the orifice diameter of the Type A cups of ± 0.0001 in. has been relaxed to ± 0.0005 in. the same as for Type B cups.

The specification gives the materials of construction and apparatus required. It states how the cups are to be marked and their method of use, their care and checking against wear and damage and how the results are to be expressed. A note of warning is given to the effect that it is considered that "cup viscometers" of this type should properly be called "flow cups" and that, although standardized, they should be issued with a recommendation against their use as viscometers. The cups have a useful function to perform if it is understood that the flow time is subject to surface and inertia effects, and that there is no effectual temperature control. The variation of flow time in a given set of conditions may be as much as ± 10 percent for normal-flowing liquids with a flow time in the region of 30 seconds.

Symposium on Methods for Expressing the Viscosity-Temperature Relation for Oils

Members of our Society have been invited to contribute to a symposium on the above subject, to be held at Dallas, U.S.A., during the week of February 6th, 1956. For some time past there has been continued criticism of the ASTM D.567, (I.P. 73) method for calculating Viscosity Index, the VTI being an empirical number indicating the effect of change of temperature on the viscosity of oil. A low viscosity index signifies a relatively large change of viscosity with temperature. As a result of the Larsen and Schwaderer presentation on VTI at the Fourth World Petroleum Congress a resolution was passed that the subject be submitted to competent Scientific Institutes for study. The programme is confined to oils of Newtonian flow and the following methods will be discussed:— 1 Larsen and Schwaderer; 2 ASTM Viscosity Temperature Chart Slope; 3 Ramser; 4 Hardiman and Nissan and 5 Blott and Verver.

The Institution of Mechanical Engineers—Conference on Properties of Materials at High Rates of Strain, in London, March, 1957

The Council, I.M.E., will be interested to receive papers from our members. Information can be obtained from the Secretary, Brian G. Robbins, 1 Birdcage Walk, Westminster, S.W.1.

The materials under consideration at the Conference will include only those used in the manufacture of mechanical engineering structures or elements and will exclude fluids. The Conference will largely take the form of the presentation and discussion of a series of papers, and arrangements will be made to issue copies of these in advance. It is expected that the papers will be grouped under six main subject headings as follows:—

- | | |
|---------------------------------------|-----------------------|
| (a) Metal Physics. | (d) Metal Working. |
| (b) Experimental Techniques. | (e) Non-metals. |
| (c) Impulse Loading and Stress-Waves. | (f) Basic Properties. |

The Council is ready to consider the publication of manuscripts submitted in connection with the proposed Conference. So as to allow sufficient time for the refereeing of manuscripts, the latest date for submission to the Secretary will be 30th September, 1956, but authors should notify the Secretary as early as possible of their intention to submit a paper, and finished manuscripts should be submitted without delay.

RHEOLOGY ABSTRACTS

3203. Elastico-viscous properties of thixotropic structures in aqueous suspensions of bentonite clays.

L. A. ABDURAGIMOVA, P. A. REBINDER AND N. N. SERB-SERBINA. *Kolloidnyi Zh.* 1955, **17**, (3) 184.

In the "gel" state, these suspensions have viscosities $\sim 10^7$ – 10^8 P., some 10^8 times greater than in "sol" state. The shear modulus is constant over a wide range of stresses.
G.W.S.B.

3204. Determination of principal stresses in an isotropic material under conditions of plane strain.

Y. V. G. ACHARYA AND L. S. SRINATH. *Appl. sci. Res.* 1954, **A5**, 45.

Starting from basic considerations, equations have been developed for the determination of principal stresses in an isotropic material, under the action of a two dimensional stress system. It has been shown that the slip lines, in the case of a plastic state of stress, and the shear stress pattern and the isoclinics in the case of an elastic state, together with the boundary conditions, provided enough data for solving any specific problems.

The method is, perhaps, not applicable in a case where plastic and elastic states of stress coexist.

From Author's Abstract.

3205. On the theory of two-dimensional extension of synthetic rubbers.

G. M. BARTENEV. *Kolloidnyi Zh.*, 1955, **17** (1) 18.

Claims that Treloar's equation does not fit data for deformations >10 – 20 per cent and proposes an alternative which fits better. Ordinary elasticity theory is adequate for small extensions
G.W.S.B.

3206. Pressure effects of relaxation and bulk viscosity in gas motion.

L. J. F. BROER. *Appl. sci. Res.* 1954, **A5**, 55.

A comparative study is made of the pressure effect of relaxation and bulk viscosity in stationary flow. It is shown that both stagnation pressure defects (Kantrowitz effect) and pressure distribution in small nozzles in principle constitute methods for distinguishing between the two theories. A discussion of the experimental data on carbon dioxide shows that in this case only the relaxation interpretation is possible.
Author

3207. Transmission of stress through a thick slab supported by a yielding foundation.

J. E. CAMPBELL AND H. S. HEAPS. *Can. J. of Techn.*, 1955, **33**, 324.

The problem arises in connection with foundation design. Formulae and graphs are given for the stresses and displacements in a finitely thick elastic slab of infinite lateral extent supported by a perfectly discontinuous elastic medium and subject to a load which varies in one direction only. The results are dependent upon the foundation modulus k .
E.W.J.M.

3208. Creep and stress relaxation in wood during bending.

P. U. A. GROSSMAN AND R. S. T. KINGSTON. *Australian J. Appl. Sci.* 1954, **5**, 403.

The present paper discusses the influence of deviations from the principle of superposition on the relation between creep and stress relaxation in a viscoelastic body.

Pairs of small matched wooden beams were tested in bending, one of each pair at constant load, the other at constant deformation. Results for creep and relaxation are

compared to determine whether the relations derived for a linear viscoelastic body can be applied to wood. The irrecoverable component of deformation appears to be non-linearly related to stress in dry wood. The departure from linearity is small in dry normal wood, although more pronounced when compression wood is present. Non-linearity in green wood seems to be of different origin from that in dry wood. Both microscopic and macroscopic compression failures gradually develop in wood maintained at constant high deformation.

Author's Summary

3209. On the question of the rheological properties of glycerine.

A. KOROTKOVA AND D. SANDOMIRSKIĬ. *Kolloidnyi Zh.* 1955, 17, (3) 264.

Authors unexpectedly confirm findings of Dumanski and Khailenko that glycerine is non-Newtonian under certain conditions. (See Abstr. 2944).

G.W.S.B.

3210. On the rheological properties of hydrogenated greases and solidified oils.

V. G. LEBEDEV AND G. V. VINOGRADOV. *Kolloidnyi Zh.*, 1955, 17 (1) 38.

Show effect of temperature on comparatively straight lines plotting log shear-rate vs. log stress; also other very complex strain/stress curves.

G.W.S.B.

3211. On the law of visco-plastic flow proposed by Shvedov. (Report).

S. M. LEVI. *Kolloidnyi Zh.*, 1955, 17 (2) 158.

3212. Observations on the radial flow of water between fixed parallel plates.

J. H. MCGINN. *Appl. sci. Res.* 1955, A5, 255.

Dye filament techniques were employed to investigate streamline configurations for both converging and diverging radial flow. Inherent characteristic of diverging flow are the boundary layer separation phenomena and the formation of axially symmetric vortex sheets. In contrast, converging flow retained a laminar character up to the highest rate of flow attainable.

From Authors' Abstract.

2313. The structure and properties of paper.

A. W. MCKENZIE AND H. G. HIGGINS. *Australian J. App. Sci.*, 1955, 6, 208.

Eucalypt a-cellulose fibres were acetylated to various degrees up to 30 per cent hydroxyl group substitution and made into paper sheets in both water and acetone. The stress-strain curves of the papers in tension were determined and the dependence of tenacity and extensibility. Young's modulus, and rupture energy, and of sheet thickness on the degree of substitution were used to assess the relative contributions to the inter-fibre adhesion of fibre swelling, and its consequent effects, and of hydrogen bonding between the hydroxyl groups in the solvated shells of adjacent fibres.

In general, the mechanical properties of the water sheets do not vary greatly below 9 per cent substitution; above this they decline sharply as the hydrogen-bonding capacity of the fibre surfaces is reduced, until in the vicinity of 20 per cent substitution the strength of the sheet depends only on small frictional effects. The corresponding properties of the acetone sheets rise as conditions become more favourable for surface swelling during the sheet-making process, with consequent enhanced possibilities for molecular entanglement in the highly solvated surface regions of the fibre. The strength of the highly acetylated acetone sheets is of the order of ten times that of the unacetylated water sheets, which can be attributed to the cellulose acetate phase formed between the fibres on drying.

The rheological properties were found to vary with the extent of mechanical conditioning during the drying of the paper, but this did not affect the conclusions.

The mechanical effects on the paper of swelling the fibres in pyridine and in pyridine and ethanol were also studied.

Author's Summary.

3214. On the flow and consistency of structured liquids. (Discussion).

N. V. MIKHAILOV. *Kolloidnyi Zh.*, 1955, **17** (1) 68.

Appears to have obtained, from bitumen, experimental evidence for Ostwald's proposed "Laminarast"—also other types of flow-curve. G.W.S.B.

3215. Structural-mechanical properties of dispersed and high-molecular systems.

N. V. MIKHAILOV AND P. A. REBINDER. *Kolloidnyi Zh.*, 1955, **17** (2) 107.

A mainly theoretical discussion on classical lines.

G.W.S.B.

3216. Elastico-plastic properties of oil-bitumens.

N. V. KIKHAĬLOV. *Kolloidnyi Zh.*, 1955, **17**, (3) 242.

Elastic and plastic behaviour explained in terms of formation and destruction of intermolecular linkages. G.W.S.B.

3217. A capillary viscometer of the Zeitfuchs Cross-Arm type for routine testing of small quantities of liquids.

H. DE MIRANDA. *Chem. Weekbl.* 1954, **50**, 741.

The above-mentioned viscometer is slightly altered for the purpose of adapting it to routine testing of small amounts of liquids with viscosities, slightly deviating from water viscosity. Only 0.5 ml. of liquid is used. P.G.M.

3218. A historical survey of the theory of elasticity.

J. NOVIŃSKI. *Rozprawy Inżynierskie*, **3**, (1) 1955, 59. (In Polish; English Abstract).

The history of the mechanics of deformable bodies is considered in three stages: Galileo to Navier, Navier up to the creation of the theory of plasticity, and from then onwards to the present day. A number of suggestions are made as to the problems best suited to further studies in Poland to-day. P.F.

3219. The theory of the limiting load sustained by plates and its experimental investigation. (I).

W. OLSZAK AND A. SAWCZUK. *Rozprawy Inżynierskie*, **3**, (2), 1955, 180. (In Polish; French Abstract).

The theory of fracture of loaded plates is reviewed and the author's experimental results are given. Theory and experiment are compared in a number of special cases. P.F.

3220. The technique of photoelastic investigations of plane states of stress.

J. T. PINDER. *Rozprawy Inżynierskie*, **3**, (1), 1955, 110. (In Polish; English Abstract).

Methods and problems in photoelasticity are surveyed, some treated in detail, i.e. techniques of model manufacture, skin and machining effects, methods of measurement etc. Basic equipment for a photoelastic laboratory is described, with special reference to apparatus designed by the author, in which optical creep is suppressed by a compensating device. P.F.

3221. Some problems in soil mechanics.

W. POGÁNY. *Rozprawy Inżynierskie*, **3**, (1), 1955, 35. (In Polish; English Abstract).

The problems of stress-distribution under a foundation and that of soil-pressure against a wall are discussed. A short historical account of the development of work in these branches of investigation is given. P.F.

3222. The structure and properties of paper.

L. SANTER, H. G. HIGGINS AND J. W. P. NICHOLLS. *Australian J. Appl. Sci.*, 1955, **6**, 197.

A description is given of an instrument designed for recording automatically stress-strain, relaxation, and creep curves of paper strips in tension. Load is measured by the

extension of a spring attached to a lever beam, to the other end of which the specimen is connected. Electrical contacts, adjacent to the beam, operate reversible synchronous motors, which control the extension of the spring or of the specimen, so as to maintain the beam in a state of balance. A feature of the rheometer is its capacity to record consecutive stress-strain and creep curves on a given specimen. Examples are given of the use of the instrument, and applications in the field of paper research and testing are briefly discussed.
 Author's Summary.

3223. On a new model for the dynamical behaviour of inelastic materials with hereditary characteristics.

Y. SAWARAGI AND H. TOKUMARU. *Proc. 2nd Jap. Nat. Congress of App. Mech.*, 1955, p. 33.

The model consists of three sets of "bodies" connected in series: (a) a spring with a displacement-dependent elastic modulus, (b) a chain of Voigt bodies and (c) a chain of Bingham solids. Amplitude dependence of dynamical characteristics and hysteresis phenomena can be reproduced with the model. The wide applicability of the model is shown by considering the principal characteristics of the component systems. P.F.

3224. On the fundamental equation of the dynamical behaviour of non-linear visco-elastic bodies.

Y. SAWARAGI AND H. TOKUMARU. *Mem. Fac. Eng., Kyoto Univ.*, **16**, (2) 1954, 100.

Generalized equations of creep and stress-relaxation are derived from models consisting of dissipative and frictionless assemblies of rheological bodies. Hookean elasticity, Newtonian viscosity, linear visco-elasticity, hysteresis etc. are shown to be special cases of the behaviour represented by the equations. P.F.

3225. On the theory of the visco-elasticity of matter.

A. SENTIS. *Comptes Rendus*. 1955, **241** 729.

The vector-displacement $\bar{D}$ is a function of time. The vector $\bar{D} + \tau(\delta\bar{D}/\delta t)$ can be used to indicate elasticity differences, internal friction, flow, etc. E.W.J.M.

3226. Viscous properties of hydrocarbon grease.

V. V. SINITSYN AND G. V. VINOGRADOV. *Kolloidnyi Zh.* 1955, **17**, (3) 255.

Greases show marked wall-effects in a capillary viscometer. It is not clear whether this is a true sigma-effect. G.W.S.B.

3227. The rheological properties of dispersed systems.

M. P. VOLAROVITCH. *Rozprawy Inżynierskie*, **3**, (1), 1955, 5. (In Polish; English abstract).

The definition of rheology and its scope are discussed, with special reference to industrially important dispersed systems. An account is given of the development of rheology in Russia prior to the Revolution, and the work of Soviet rheologists on dispersed systems is reviewed. A phenomenological theory of visco-plastic flow of dispersed systems, based on the Shvedov-Hencky-Iliushin equations is presented, and applied to flow through circular, annular and flat tubes, to flow under gravity, rotational motion in a narrow space between two coaxial cylindrical surfaces, rotation of a shaft in a bearing, etc. The experimental methods and the instruments used are described, and the advantages of instruments in which the dispersed systems remain during the test in a state of homogeneous shear are emphasized. The molecular and colloidal interpretations of results obtained on the flow of a number of materials are given, and the practical uses of the theory are illustrated by examples. 105 references. P.F.

3228. Melt viscosities of dimethylpolysiloxanes.

E. L. WARRICK, W. A. PICCOLI AND F. O. STARK, *J. of Amer. Chem. Soc.*, 1955, **77**, 5017.

Measurements of the viscosity of high molecular weight materials were made from the rate of fall of $\frac{1}{16}$ in. diameter steel balls in 1 in. diameter tubes. The results are discussed in relation to molecular weight determinations. E.W.J.M.

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