

R. S. Rouse.

THE BRITISH SOCIETY OF RHEOLOGY

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NOT TO BE REMOVED
FROM
FILE.

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THE BRITISH SOCIETY OF RHEOLOGY



Bulletin No. 49

December, 1956

Price to non-members 7s.

Conference and Annual General Meeting at Sheffield.

The Conference held at Stephenson Hall, Sheffield on September 27th and 28th, was attended by about sixty persons, representing a wide range of industries concerned with rolling and extrusion techniques. We were glad to welcome two of our foreign members, Dr. Meskat and Mr. Stromsoe who came to England for this meeting. The Conference paid an afternoon visit to the B.I.S.R.A. Metal Working Laboratories and saw, among other items, a demonstration of continuous casting of steel bar.

At the Annual General Meeting which was held after the Conference dinner, the following officers were re-elected for 1956-57.

President : Professor J. G. Oldroyd.

Hon. Secretary : Mr. N. Wookey.

Hon. Treasurer : Mr. D. W. Jopling.

Hon. Editor : Dr. E. W. J. Mardles.

Mr. C. C. Mill and Dr. J. Vernon were also elected to the Committee.

Accounts for the Year Ending 30th June, 1956

1954-5

£		<i>Income</i>						£	s.	d.
453	Balance on 1st July	..	..	..	..	..	..	520	7	5
251	Subscriptions	..	..	..	..	..	..	207	16	11
17	Sale of Bulletins to non-members	..	..	..	..	..	..	16	8	6
	Credited on returned cheque book	..	..	..	..	..	..		4	0
5	Interest on P.O.S.B.	..	..	..	..	..	..	7	11	8
726								752	8	6

1954-5

£		<i>Expenditure</i>						£	s.	d.
14	Postage	..	..	..	..	..	..	15	10	4
159	Stationery and Printing	..	..	..	..	..	..	118	4	8
21	Committee and Administrative Expenses	..	..	..	..	..	..	28	9	8
12	Subsidy of Meetings	..	..	..	..	..	..	32	3	8
520	Balance on 30th June, 1956	..	..	..	..	..	..	558	0	2
726								752	8	6

A. DE WAELE, *Hon. Auditor*,
4th September, 1956.

D. W. JOPLING, *Hon. Treasurer*,
17th July, 1956.

Future Meetings of the Society.

Rheological Control of Industrial Processes. Details of this meeting at the Institute of Physics, London, on December 7th will be circulated separately.

The Flow of Dispersions. A joint meeting of the Society with the Hull section of the Oil and Colour Chemists' Association has been arranged for Monday evening, January 7th at Hull. Dr. G. F. Eveson, who has been investigating the flow properties of dispersions of small spheres with Prof. Stacey G. Ward, at the University of Birmingham is lecturing.

Rheology of Elastomers. Proposed date—May 30th to 31st.

New Member.

Mr. I. S. Davidson, Barry, Ostlere and Shepherd Ltd., Forth Works, Kirkcaldy, Fife. Interests: Linoleum and paints, extrusion and rotation viscometry.

News of other Societies.

U.S.A. Society of Rheology. Abstracts No. 3369, 3371, 3405, 3422 and 3423 are of papers presented before the Annual Meeting of the Society, November, 1955 in New York City. A large part of the rheology work now in progress deals with polymeric materials. Purely analytical work is being done in the field of theoretical mechanics to describe the general behaviour of viscoelastic response. Diverse fields of interest, such as the flow of synovial fluids in arthritic patients, flow patterns of glacial ice and deformation studies of the earth are under investigation. Considerable interest has been shown in the time dependent bulk modulus of polymeric materials which is being studied under conditions of dynamic loading.

Nederlandse Reologische Vereniging. "The Proposals on Rheological Nomenclature and Definitions," prepared by the Nomenclature Committee are now available in booklet form.

Copies of the English text may be obtained from the Hon. Secretary or Hon. Editor. It is hoped that the proposals may be used as a starting point for a discussion at the next International Rheological Congress, together with the more comprehensive reports, like those of Burgers and Scott Blair and by Leaderman. The Committee has restricted its proposals to the more limited concepts of ideally elastic deformation and uniform flow, while some more general cases are collected together under the heading of viscoelastic behaviour. The problems connected with the superpositions of, for example, elastic behaviour and flow should be investigated experimentally for each special case. The Committee is of the opinion that a definite nomenclature should as yet not be proposed for these more complicated cases. On the other hand in the case of viscoelastic deformation a well-established system of terms exists for the special case of linear behaviour.

The Committee has excluded all controversial matter from its list of terms.

Rheology in the Paint Industry.

The following six lectures given at the Borough Polytechnic on "Rheological Conceptions in the Paint and Related Industries" will be published in "Paint Technology" in due course.

"General Rheology of the Pigment-Medium System." R. F. Bowles, Ph.D., F.R.I.C. (Lorilleux and Bolton Ltd.).

"The Wetting and Dispersing Action of Liquids and Powders." E. J. W. Mardles, D.Sc., F.R.I.C. (R.A.E. College).

"Instrumentation." P. S. Williams, B.Sc., A.R.C.S., A.Inst.P. (I.C.I. Paints Division, Slough).

"Characteristics of Heavily Pigmented Pastes on Putties." G. E. Bessey, M.Sc., F.R.I.C. (The Chalk, Lime and Allied Industries).

"Rheology of Thixotropic Media." A. G. North, B.Sc. (Cray Valley Products, Ltd.).

"Rheology of Bituminous Materials." E. N. Thrower (Road Research Laboratory).

FURTHER SUMMARIES OF PAPERS READ AT THE CONFERENCE AT SHEFFIELD

September 27th and 28th

Milling and Calendering of Plastics.

By E. B. ATKINSON (BX Plastics Ltd.)

Two-roll mills are used in rubber and plastics technology for a variety of purposes e.g. mixing of ingredients (polymer, plasticisers, pigments etc.) removal of volatile solvents (during the manufacture of cellulosic plastic compositions by the "wet" process) pre-curing of phenolic resins and mastication (molecular weight reduction) of natural and synthetic rubbers.

Calenders with two, three or four rolls are used for producing thin rubber or plastic sheet, and also for textile or canvas sheet, floor covering materials etc.

In both machines polymeric materials in a softened condition pass through the region between pairs of rollers which are rotated with adjacent surfaces moving in the same direction. The surface speeds of the rolls may be the same or differ slightly. A "bank" of plastic material is built up at the entrance side of the "nip" and is squeezed steadily through the gap between the rollers as a continuous band or sheet.

The flow regime in the plastic in the region between the rolls, and the magnitude of the stresses set up in the plastic are of considerable practical interest both to the plastics technologist and the engineer designing such equipment. There have been several theoretical treatments of the problem (^{1, 2, 3}) some of which are based on assumptions of doubtful validity. Except in the case of a high degree of slip (i.e. with heavily lubricated compositions) the flow regime is equivalent to the extrusion of a plastic material through a slot of varying height, and the pressure distribution, roll thrust and shaft torque are determined by the shear stresses set up at the roll surfaces.

The treatment of Gaskell³ is based on these assumptions, but in its original form is not easily applied to Non-Newtonian materials. A similar treatment⁴, based on an empirical power-law relationship between shear stress and velocity gradient has been derived. In this the pressure distribution, total roll thrust and shaft torque may be obtained from expressions which contain the rheological parameters, roll dimensions and speeds from tables of numerically evaluated functions which depend upon the size of the "bank" of plastic in the nip and the exponent of the power law.

REFERENCES

1. ARDICHVILI, V. *Kautschuk*, Vol. 14, 1938, p. 23.
2. ELEY, D. D. *J. Polymer Science* 1, 529, 1946.
3. GASKELL, R. E. *J. app. Mech.*, 17, 334-336, 1950.
4. E. B. ATKINSON and H. A. NANCARROW. *Transactions of the Plastics Institute*, Vol. XIX No. 30, pp. 38-42, October, '51.

Theoretical Aspects of Hot Rolling.

By A. W. MCCRUM (B.I.S.R.A.).

Despite the great importance and widespread application of the hot rolling process, its theory has received very little attention. In general, hot rolling is distinguished from the comparatively well explored field of cold rolling by two factors, the temperature and the nature of the deformation. Within the range of hot-rolling temperatures, the frictional stress between the rolls and stock is known to approach the yield stress of the material in shear, whereas in cold rolling, the coefficient of friction is kept low by lubrication. As a consequence of this and the geometry of the process the deformation is complex and is, in general, three dimensional with appreciable increase in width (spread) occurring.

A rigid theoretical solution of even the simplest problem, a rectangular bar rolled between parallel rolls, is at present unobtainable without making some simplifying assumptions. Past solutions have been mainly empirical and only the analyses of Ekelund,

Orowan and Sims can be said to have a theoretical basis. The theory of Ekelund is complicated and the equations too unwieldy for practical use. The Orowan equations are simpler but the load results are less in agreement with practice than those given by Sims' theory which requires a complex investigation of the yield stress. In practice, these theories are little used at present.

For the calculation of the spread in the rolling of rectangular bars between parallel rollers Ekelund's formula is of reasonable accuracy but is complex. A recent formula by Hill is simple and accurate, but requires the determination of a special parameter in advance.

The practical requirements of a satisfactory theory are (1) the load and torque should be indicated as to whether they are within the capacity of the mill and its drive and (2) the spread must be predicted for bars of different cross sectional shapes and for the final product to have the required tolerance limits.

With the development of continuous rolling mills other factors are of interest ; some method of calculating the exit and entrance speeds is desirable so that the speeds of the stands may be matched and it will be important to know the effect of tensions applied to the front or rear end of the bar on the load, torque and spread, particularly the latter. By rolling with tension, it might be possible to use smaller plant and to improve accuracy.

SUMMARIES OF PAPERS

to be read at the meeting on December 7th

Some Problems in the Industrial Application of Continuous Reading Viscometers.

By A. R. BOYLE.

On an industrial plant viscosity measurements may be divided into three main groups; 1, the arbitrary or "rule of thumb" method, 2, transferring a sample for a laboratory test, 3, continuous measurement on the plant itself.

The last is divided into two sub-groups; accurately calibrated viscosity measurements, and trend measurements on an arbitrary scale.

The advantages of continuous measurement are many, provided that it is reliable. Time lags inherent in sampling testing are removed, and this considerably reduces the possibility of having to re-mix the material.

The first problem which is encountered is nearly always one of the temperature of the material. In many applications where viscosity measurement is required the temperature is high and special problems of construction and fitting arise. There is another, more general, in that variations in temperature arise in nearly all industrial processes. Temperature control to 1 degree C. can cause a 5 per cent error in viscosity. Accurate thermostating is often impossible and some sort of temperature compensation is desirable. This problem is common to all viscometers.

The second problem arises from the large ambient temperature changes which can arise in an industrial plant, particularly if the measurement point is outside. In this case the ambient temperature change may be as high as ± 10 degrees C. from night to day. If the instrument itself is unaffected by temperature changes no problem arises, but, in general, it is necessary to apply some compensation.

Often the material is in a line at high pressure, or in a vessel under vacuum conditions, and some method must be arranged so that the sensitive pick-up can reach the material. Vibration methods have an obvious advantage, but for any other method it is usually necessary to circulate a small amount of the material through a by-pass line, which at one point can be at normal pressure. Combinations of high temperatures and low or high pressures

make a particularly difficult problem for the instrument designer, and this particular problem is met frequently in the manufacture of Alkyd Resins.

Under hazardous conditions, flame-proof or intrinsically safe equipment must be used, and this adds to the difficulty of designing an equipment of an electrical nature. In some processes gas bubbles are generated and in others, such as in the mixing of lube oils, air is introduced to provide good mixing. In these circumstances it is almost impossible to get a reliable indication of the viscosity of the material and the writer knows of no method by which this can be satisfactorily overcome.

The servicing of a viscometer is most important under industrial conditions, and the use of continuous equipment on the plant makes it likely that laboratory check facilities will not be easily obtainable. If it should be necessary to service the instrument and replace components, then the calibration accuracy should remain unaffected.

In many instances the instrument must be able to measure non-Newtonian materials. For the continuous control of one product it may only be necessary to measure continuously under one particular condition of rate of shear while in others it may be necessary to correlate the results from a number of instruments operating at different rates of shear. A particular problem arises because the majority of continuous reading instruments operate under different shear conditions from the laboratory instruments. Practical problems arise when materials which have been regarded as of the same viscosity, show differences on the continuous reading unit. Again, materials which were widely separated on laboratory tests appear to be the same on continuous instruments.

There is a difference of opinion amongst users as to whether it is better to measure viscosity under the actual condition of manufacture, which may be at a very high temperature, or whether it would not be better to sample off continuously and cool to the temperature of the end product. It is difficult to obtain real correlation between these two methods of measurement.

Rheology in the Paint Industry; the use of a Wide Range Thin Film Viscometer.

By C. C. MELL (Blundell Spence and Co. Ltd.).

Paints are rheologically complex fluids whose viscosity coefficients generally rise with decreasing rates of shear and with time of resting after rapid shearing. Their rheological characteristics largely control the practical application properties, e.g., brush pick up, flow, sagging, drag under the brush, etc. The majority of these properties involve the shearing of thin films of the paint at rates of shear of the order of one to many thousand reciprocal seconds. The instrument described has been constructed to produce flow curves on thin films of paint approximately 0.003 in. thick at two rate of shear ranges, 0—15 sec.⁻¹ and 0—3000 sec.⁻¹.

The instrument consists of two plate and cone viscometers. The cone angle is chosen to give a clearance at the periphery of 0.006 in., the apex of the cone being ground off to give a minimum clearance of 0.001 in. at the centre so as to avoid interference due to oversize pigment particles. The plates, which are the lower members, are driven by electronically controlled motors to give maximum speeds of approximately one and 200 r.p.m. giving corresponding rates of shear of 15 and 3000 sec.⁻¹. The motors can be controlled to run at a constant speed or to accelerate at a constant rate from zero to their maximum speed. The accuracy of speed control at any speed up to their maximum of 3000 r.p.m. is plus or minus 4 r.p.m. The speed is independent of mains voltage or frequency, temperature or load up to the stalling torque. The torque on the cone is measured by unsupported strain gauge wires. Four prestressed nickel-chromium wires approximately 0.001 in. in diameter are used, their outer ends anchored to insulating blocks and their inner ends attached to an insulated cylinder concentric with the cone spindle. When a torque is impressed on the cone the tension in, and therefore the resistance of two of the wires is increased, and of the other two decreased. The four wires are arranged in a d.c. Wheatstone bridge network and the out-of-balance voltage

amplified and fed to a chart recorder. Full scale deflection can be obtained with an angular rotation of the cone of less than one fifth of a degree. The circuit is arranged for easy range changing and the maximum shearing stress measured on each range can be varied from 100 to 1250 and 1000 to 12,500 dynes per square centimetre on the low and high rate of shear heads respectively. The chart of the recorder is driven by a synchronous motor. The cycle of operation is initiated by a press button which starts the acceleration of the main drive motor and the chart travel. When the motor has reached its maximum speed an electronic relay stops both motors, a curve of shearing stress against rate of shear is thus automatically drawn. The rate of acceleration of the motor can be varied so that the cycle is completed in from 20 to 120 seconds. If the motor is switched to run at a constant speed, curves of shearing stress against time of shearing will be drawn. The drive to the low rate of shear plate is fitted with a lost motion device to enable the plate to be manually oscillated to break down all structure before a determination is made. This enables a family of curves, after various resting time to be obtained.

Use of the viscometer over a considerable period has shewn that the high rate of shear curves obtained on brushing paints cannot be correlated with the drag under the brush as assessed by a practical decorator. It is evident that the maximum rate of shear obtained, i.e., 3000 sec.⁻¹ is too low. Curves of shearing stress against time of shearing at high rates of shear obtained on paints based on complex media do show a marked fall in viscosity after shearing times of 10 seconds or so, whereas at lower levels of shear, no appreciable reduction of viscosity occurs. It is thought that this may be a factor in the decorator's assessment of feel under the brush.

The curves produced at low rates of shear have been found to correlate fairly well with application properties such as flow and sagging, and in fact with paints of similar solvent content, correlation is extremely good. The instrument has been used to determine the end point in the manufacture of polyamide modified alkyd media (thixotropic alkyds). The rate and amount of structure build up can be accurately assessed. It has been found that the end point can be determined much more precisely than with the conventional turbidity test.

Errata—Bulletin 48, page 8, tenth line from bottom: instead of "(b) Birefringence" read "(b) The phase difference is proportional to thickness, etc."

RHEOLOGY ABSTRACTS

3369. Mechanical Behaviour of Viscoelastic Fibres.

F. AKUTOWICZ. *J. Appl. Phys.*, 1956, 27, 439.

Theoretical discussion.

3370. Cold-Flux Mastics. 2. Rheological Properties of some Bitumen/Oil Systems.

E. R. BALLANTYNE and B. L. REIDY. C.S.I.R.O., Division of Building Research. Report No. 05.3—3: Melbourne, 1955.

Since the consistency of a cold-flux mastic depends largely on the particular bitumen/oil combination used in its formulation, the flow characteristics of a number of bitumen/oil systems have been measured by one or more of the three experimental techniques described in Part I of this report. The bitumen used in most of the systems examined was either a hard gel-type (air blown) or a hard sol-type (vacuum distilled), both from Venezuelan crudes. The oils ranged from 99% aromatic to 100% paraffinic content. Both rate of fluxing and viscosity were a function of the aromatic content. Rate of fluxing was greatly influenced also by the particle size distribution of the bitumen. The gel-type bitumen gave non-newtonian behaviour with all oils tested except those having high aromatic content, whereas the sol-type bitumen gave Newtonian behaviour except with the 100% paraffinic oil. A combination of the gel-type bitumen with a naphthenic oil has suitable flow characteristics for use in cold-flux mastics.

Authors' abstract.

3371. Theory of Deformation of Porous Viscoelastic Anisotropic Solid.

M. A. BIOT. *J. appl. Phys.*, 1956, 27, 459.

Equations are established for the deformation of a viscoelastic porous solid containing a viscous fluid under the most general assumptions of anisotropy. The particular cases of transverse and complete isotropy are discussed.

A.

3372. Calculation of the complex modulus of Linear Viscoelastic Materials from Vibrating Reed Measurements.

D. R. BLAND and E. H. LEE. *J. appl. Phys.*, 1955, 26, 1497.

Two methods of determining the variation of real and complex modulus with frequency from vibrating reed test results are detailed. One is based on measurements of the relative amplitude and phase lag of the motion of the free and driven ends of the reed, the other on amplitude resonance measurements only. The analysis is based on a general linear viscoelastic law, and takes into account the influence of the frequency dependent moduli of the material on the frequency and amplitude of the resonance peaks.

A.

3373. Theory of Turbulence.

S. CHANDRASEKHAR. *Phys. Rev.*, 1956, 102, 941.

It is pointed out if there are aspects of the turbulence phenomenon which are truly universal, then they should be capable of being characterized in terms of the two parameters ϵ and ν which denote the constant rate of dissipation of energy per unit mass and the kinematic viscosity respectively.

A.

3374. Effect of Gas Absorption on the Modulus of Rigidity of a Metal Wire.

A. CLAUS. *C.R. Acad. Sci. (Paris)*. 1956, 242, 1578.

By using a dynamic (torsional-pendulum) and a static method of investigation, the author found that the modulus of rigidity of an Ag wire (0.06 mm dia.) decreased as the boiling-point of the ambient gas (He, H₂, A, CO₂) increased. The differences between the results obtained by using the two methods are explained.

A.

3375. A Variability Study of Firmness in Cheese using the Ball Compressor Test.
C. P. COX and M. BARON. *J. Dairy Res.*, 1955, **22**, 386.

Large numbers of sphere-hardness tests on ten Cheddar cheese show that the total deformation under load is more discriminatory than is the proportion of deformation recovered elastically. Most cheese show an increasing firmness (reciprocal of total deformation) from the centre towards the rind, so tests should be done at some definite distance.

A table of 95% confidence intervals shows that the usual process of taking four readings per cheese gave, on this particular population, an error of ± 2.3 units ($\approx 5\%$).

G.W.S.B.

3376. Stress Waves in Solids.

R. M. DAVIES. *Brit. J. appl. Phys.*, 1956, **7**, 203.

Discusses in fairly elementary fashion, the topic of the transmission of transient stress pulses of short duration in solids, together with the associated problem of the measurement of pressures subject to very rapid changes.

A.

3377. The Plastic Flow Law for Polycrystalline Metals.

U. DEHLINGER, J. DIEHL and J. MEISSNER. *Z. Naturforsch.*, 1956, **11a**, 37.

General linear equations are stated for the rate of plastic flow and the stress-strain relationship. Prager's increment theory, assuming isotropic strain-hardening, is substantiated by torsion-tension tests (up to 9% elongation) on annealed aluminium. This is contrasted with the behaviour of α -brass which exhibits strain-hardening anisotropy.

A.

3378. On uniqueness in the Theory of Plasticity.

D. C. DRUCKER. *Quart. Appl. Maths.*, 1956, **14**, 35.

3379. Velocity Discontinuity Instability of a Liquid Jet.

B. DUNNE and B. CASSEN. *J. appl. Phys.*, 1956, **27**, 577.

The instability of a high-speed liquid jet with a velocity which has a transient rise followed by a linear decay with time is studied experimentally and theoretically.

A.

3380. New Formulae for Sedimentation.

J. M. DUNOYER. *J. Chim. Phys.*, 1956, **53**, 352.

Formulae are derived for all kinds of sedimentation of solid particles in a liquid due to gravity, or of the separation of solids and liquids in a centrifuge or an ultracentrifuge, or of the fall of small solid particles in a gaseous atmosphere. Laminar and turbulent flow of spherical particles are studied and expressed in their functional relation to number of grains and to mass of the particles.

A.

3381. Isothermal viscosity—molecular weight dependence for long Polymer Chains.

T. G. FOX and S. LOSHAEK. *J. appl. Phys.*, 1955, **26**, 1080.

3382. Study of Plastic Deformation in Aluminium Crystals by Electron Diffraction and Electron Microscopy.

F. E. FUJITA, D. WATANABE, M. YAMAMOTO and S. OGAWA. *J. Phys. Soc., Japan*, 1956, **11**, 502.

Single crystals of very pure aluminium (99.99%) were plastically deformed and examined by means of electron microscopy and electron diffraction. Surfaces of the deformed crystals produce innumerable slip lines of various slip amounts, and deformation bands.

A.

3383. Experimental verification of Landau's formula for the Determination of the Coefficient of Viscosity of Liquids by the method of Damped Torsional Oscillations of a Disk.

G. A. GAMTSEMLIDZE. *Dokl. Akad. Nauk. U.S.S.R.* 1955, **100**, No. 3, 441.

Model tests with distilled water show that Landau's correction for disk thickness is valid under conditions under which the viscosity of helium II has been determined by several investigators.

A.

3384. Investigations of Clay Types with the help of a Cone Plastometer.

I. M. GOR'KOVA. *Koll. Zh.*, 1946, **18**, (1) 26.

Shearing stress corresponding to force on Rebinder's Cone Plastometer shows characteristic curves when plotted against moisture content for different types of clay.
G.W.S.B.

3385. Intersection Faulting Mechanism theory of Flow and Fracture of Face-centred Cubic Metals.

R. B. GREEN. *Phys. Rev.*, 1956, **102**, 376.

The intersection of any dislocation avalanche with a stationary dislocation having a Burgers vector component normal to the slip plane is shown to produce a close-packed partial plane of vacancies or interstitials in the slip plane, intrinsic or extrinsic faults for (111) slip planes. These faults have high energy in non-close-packed planes, consistent with observed slip plane preference. The mechanism gives improved understanding of recent X-ray results.
A.

3386. Theory of Mechanical Damping due to Dislocations.

A. GRANATO and K. LUCKE. *J. appl. Phys.* 1956, **27**, 583.

A quantitative theory of damping and modulus changes due to dislocations is developed.
A.

3387. Free Slip in Monocrystals.

B. JAOU, *C.R. Acad. Sci. (Paris)*. 1955, **241**, 161.

The first part of the stress-strain curve representing plastic flow of a single crystal, from the initial yield to the point of inflection, is observed to be of the form (stress increment) $\propto \log$ (strain increment). A theoretical justification of this equation is given, based on the increasing destiny of obstacles to flow, arising where slip planes intersect.
J.G.O.

3388. Some Recent Developments in the Mechanical Testing of Materials.

A. JOBBING. *J. Oil and Col. Chem. Assn.*, 1955 **38** (12), 739.

The extension of the laws of classical mechanics to account for the observed behaviour of materials with a consistency intermediate between solid and liquid is discussed. Weissenberg's rheogoniometer provides the means for measuring the different components of stresses and strains in all three directions of space as well as in time. In continuous flow a fall in apparent viscosity with increasing rate of shear may be a purely geometrical effect arising from the presence of an appreciable amount of recoverable strain and the consequent divergence of the main directions of the stress and strain velocity. Author.

3389. Internal Friction (Viscosity) and Sedimentation Volume of Polydispersed Kaolin Suspensions in Electrolyte Solutions.

G. G. KANDILAROV. *Koll. Zh.*, 1956, **18**, (3), 293.

A Bulgarian study of the properties of two types of kaolin (Gee and Shering, and Senova) with progressive additions of HCl , H_3PO_4 , AlCl_3 , Ca(OH)_2 , NaOH , etc. The curves for both kaolins appear to follow the usual well-known patterns, but their positions on the graphs are different.
G.W.S.B.

3390. Viscosity Variations of Soda-lime glass within the working temperature due to substitution of lime by Magnesia.

S. R. KHANNA. *Trans. Indian ceram. Soc.*, 1954, **13**, 154.

The problem was studied using 3 series of colourless alkali-MgO glasses covering a field of commercial composition: in series 1, CaO was replaced by MgO in 1% steps; in series 2, CaO was replaced by MgO in amounts molecularly equivalent to the CaO removed; in series 3, MgO was replaced by CaO in amounts molecularly equivalent to the MgO removed. The composition of series 1 was (%): SiO_2 , 74; (CaO , MgO), 10; Na_2O , 16; series 2 (parts): SiO_2 , 74; (CaO , MgO), 10; Na_2O , 16. The melts were made in 6-in. sillimanite crucibles in a gas-fired furnace at $1,400^\circ$ - $1,450^\circ$ C. The viscosity

of selected glasses in the 3 series within the annealing temperature range was determined by fibre extensions. Densities were determined by Preston's density comparator. Viscosity measurements from 900°-1,250° C. were made on five samples from each of series 1 and 2. The determinations were carried out in a rotating Pt cylinder apparatus. Results are tabulated and shown graphically. Series 1 and 2, replacing CaO by MgO in the lower temperature range, caused a decrease in viscosity until 5% replacement had been made; further addition of MgO had no appreciable effect in series 2, whereas there was a definite increase in viscosity in series 1. At higher temperatures the viscosity increased in the whole composition range tested within the normal working range. In both series 1 and 2 the densities of the glasses decreased when MgO was added. A.

3391. An Electron Diffraction study on the Plastic Deformation of Aluminium Single Crystals.

K. KIMOTO. *J. Phys. Soc. Japan*, 1956, **11**, 485.

The deformation was studied by means of Kikuchi lines of electron diffraction using a new technique, the large-angle convergent beam method. By this method the irradiated area on the specimen surface can be reduced to $5 \times 20 \mu^2$, and thus laminar regions and deformation bands can be studied separately. For 99.99% aluminium it was found that in laminar regions the distortion is so small that Kikuchi lines are produced even at 10% elongation, and that in deformation bands it is large enough to extinguish Kikuchi lines. For 99.55% aluminium, at any place in the crystal the distortion is so large that Kikuchi lines become diffuse at about 3% elongation and are extinguished at about 7% elongation. It was confirmed in all cases that no rotation occurs in the slip plane. The interior of elongated crystals was studied after removal of the surface layer by electropolishing. Irrespective of the purity of crystals, no recognizable difference was found in the surface layer and in the interior. The order of dislocation density was estimated through Kikuchi line experiment. The results obtained for 99.99% aluminium are 10^6 lines/cm², 10^7 lines/cm², and 10^8 lines/cm² for well annealed crystals, for laminar regions of 10% elongated crystals, and for deformation bands of % elongated crystals, respectively. A.

3392. Apparatus for the Measurement of Time of Impact.

P. L. KIRBY. *Brit. J. appl. Phys.*, 1956, **7**, 227.

Apparatus is described whereby the time of impact of a freely falling sphere on a horizontal surface is measured electrically without direct connection to the sphere. The time of impact of an 8 mm steel sphere on a solid Pyrex glass slab is $18 \mu s$ at room temperature and is the same within $\pm 10\%$ at 700° C. Over this range of temperatures the absorption of fractional impact energy increases considerably and rebound is zero at about 1000° C. A.

3393. Viscosity of preparations of starch in water and alkaline solutions.

M. I. KNYAGINICHEV and T. M. SHCHINNIKOVA. *Koll. Zh.*, 1956, **18** (1), 38.

Lists viscosities of starches from eleven different varieties of potato in water and in 1N. NaOH solution. G.W.S.B.

3394. The velocity of dislocations.

J. S. KOEHLER. *J. Phys. Soc. Japan*, 1955, **10**, 669.

The theory of Mott and of Fisher, Hart and Pry for the production of slip bands is considered. This theory suggests that the kinetic energy of dislocations maintains glide on a slip band; it also asserts that the process is stopped by the back stress resulting from dislocation loops previously generated at the Frank-Read source. Experimental observations giving the damping experienced by a dislocation and giving the velocity of glide are used to show that the potential energy of a dislocation is in general more than an hundred times the kinetic energy. Present evidence indicates that the rate of glide decreases by a factor of about fifty during the production of a single slip band in aluminium. Present data also indicates that twinning requires rapid dislocations whereas slip seems to demand slow dislocations. A way of reconciling these observations is suggested. A.

3395. Analysis of the generalized distortion tensor.

E. KRÖNER. *Z. Naturforsch.*, 1956, **11**, 95.

A continuation of earlier work on the vector analysis of the distortion tensor arising in the theory of elasticity and plasticity. A.

3396. Stress-strain relations in snow under uniaxial compression.

J. K. LANDAUER. *J. appl. Phys.*, 1955, **26**, 1493.

Two types of tests were performed on the uniaxial compression of snow; experiments at constant strain rate and at constant load. The strain rate can be represented as the product of functions of density, stress, temperature, and time. For densities between $\gamma \cong 0.3 \text{ g/cm}^3$ and $\gamma \cong 0.6 \text{ g/cm}^3$ the strain rate is proportional to $(\gamma_{\text{ice}} \gamma) / \gamma$ to the fourth power. The strain rate varies linearly with stress for low stresses ($2 < \sigma < 100 \text{ g/cm}^2$) but increases to an approximately cubic relationship at higher stresses ($1 < \sigma < 5 \text{ kg/cm}^2$). An activation energy of about 14000 cal/mole can be derived from the temperature dependence. In the constant load tests the strain is proportional to the time to a power of about 0.8. The effect of snow type is small, being less than the relatively large experimental scatter encountered. A.

3397. On the question of "Limiting Viscosity" in solutions which contain Different kinds of molecules.

G. LANGHAMMER and M. RICHTER. *Naturwissenschaften*, 1956, **43**, 125.

On the assumption that at low concentrations the specific viscosities are additive, it is shown that the "limiting viscosity" of a mixture of two polymers varies linearly with the mixture ratio. This conclusion is not fulfilled in a mixture of polyvinylpyrrolidone and polyvinyl alcohol (mol. wts. about 28,000) in water. A.

3398. Influence of Moisture on Modifications of the Structural-Mechanical Properties of Gelatine in Process of Drying.

L. A. LEPILKINA, *Koll. Zh.*, 1956, **18**, (3) 302.

An apparatus is described for obtaining stress-strain curves for gelatine and these are given for various temperatures and moisture contents. Stress build-up and elastic recovery curves are also given for a series of stresses at fixed temperature and moisture. Results are discussed in the light of a few electron-micrographs. G.W.S.B.

3399. Viscous Flow and the constitution of liquid Boron Trioxide.

J. D. MACKENZIE. *J. Chem. Phys.*, 1956, **24**, 925.

By assuming that the principle units of flow are B_2O_3 , excellent agreement is obtained between the free energy of activation (ΔF^*) for flow evaluated from recent viscosity data, and that evaluated from the relationship $\Delta E_v / \Delta F^* = 2.45$, where $\Delta E_v = \Delta H_v$, (the latent heat of vaporization), $-RT$. A discussion on the compatibility with experiment of other views on the constitution of liquid B_2O_3 is given. A.

3400. Viscous Flow in Melts of "Rigid Anisotropic" Molecules.

AL-MAHDI, A. A. K. and A. R. UBBELOHDE. *Trans. Far. Soc.*, 1955, **51**, 361.

3401. Rheology of Synthetic Latex v. Flow Behaviour of Low-Temperature G.R.—S. Latex.

S. H. MARON and SHIU MING FOK. *J. Coll. Sci.*, 1955, **10**, 482 and 494.

Rubber-volume fractions up to 0.60 were studied over shear stresses from 50 to 800 dynes per sq. cm. between 20° and 50°C . The latex was Newtonian below a volume fraction of 0.25 and non-Newtonian above this concentration.

Unlike latices studied previously the dependence of flow on shear stress could not be represented by the exponential equation nor could the dependence on volume-fraction be represented by the log-equation used. The flow behaviour could, however, be represented by a two-parameter modified Eilers equation, one parameter being a function of temperature and the other of shear stress. When interpreted, the values

obtained indicate that the close packing of the non-uniform spheres in the latex is primarily tetragonal changing to rhombohedral packing as the shear stress increases. The deviation of the latex from Newtonian behaviour is independent of temperature and dependent only on shear stress and concentration. D.J.K.

3402. Investigations of the entire Rheological Curves and Formulae for the Calculation of Effective Viscosities of Structured liquids; with a Molecular-Kinetic Interpretation of the Participating Units.

N. V. MIKHAILOV and A. M. LIKHTGEIM. *Koll. Zh.*, 1955, **17** (5), 364.

A mathematical treatment of the Ostwald type of flow-curve, including a "Laminarast." Diagrams show nature of molecular exchanges in flow processes. A few data for bitumens are given, but evidence for the Laminarast is scanty. G.W.S.B.

3403. Surface phenomena on extended aluminium single crystals and their dependence on the velocity of extension.

H. MÜLLER and G. LEIBFRIED. *Z. Phys.*, 1955, **142**, 87.

Single crystals of Al of controlled orientation were extended at room temperature at strain rates from 10^{-6} to over 10^2 , and the slip line structure examined by optical and electron microscopy. The slip line density increased to double as the strain rate was raised between these limits. The breadth of the lines decreases rapidly up to 10^{-3} /sec, then more slowly. The length of the slip lines decreases slowly up to a strain rate of 10^2 /sec. and then rapidly. Investigation of clustering showed that the most common spacing was always about 1.5μ , which may be regarded as the range of the stress field of a work-hardened plane. The density of striations and kink bands increases with velocity. At liquid-air temperature the glide bands are shorter, denser and narrower, and kink bands are ten times more dense. The results are discussed in terms of a theoretical model of the state of the interior of the crystal, and it is deduced that at high strain rates dislocations move at a speed of at least 20 metres/sec. A.

3404. On the Dependence of the Initial Deformation of Face Centred Cubic Metals on the Applied Stress.

G. MÜLLER. *Ann. Phys. (Leipzig)*, 1956, **17**, 141.

Extension-time curves were obtained for helical coils of silver and gold wire and, in the plastic region, were found to conform to the law: $\gamma = \gamma_0 + CT^\alpha + \Delta\gamma_{sp}$ where γ = the angle of shear, γ_0 the elastic part, T the time, $\Delta\gamma_{sp}$ a spontaneous torsion and C and α are constants. The best values of C and α were found in each case and then the line was extrapolated to determine the purely elastic strain at zero time (γ_0). The difference between this and the measured strain was the spontaneous initial strain ($\Delta\gamma_{sp}$). The spontaneous strain increased markedly with the applied shear stress and a comparison of the results with data published for aluminium and copper showed that a general relationship exists for face centred cubic metals. A.

3405. Viscometric Analysis of Dispersions at small Shear Stresses

R. R. MYERS, J. C. MILLER and A. C. ZETTLEMOYER. *J. appl. Phys.*, 1956, **27**, 468.

The flow behaviour of certain dispersions at small shear stresses has been studied in a rotational viscometer. Criteria which were used in analysing the dispersions are the relative viscosity and its temperature dependence, the ratio of viscosities at infinite and zero shear, sedimentation rates, and the existence of a critical volume concentration for the occurrence of non-Newtonian behaviour. A.

3406. Elastico-Viscous Characteristics of Macaroni and Pastry Doughs.

B. A. NIKOLAEV and L. S. BEGANSKAYA. *Koll. Zh.*, 1956, **18**, (1) 67.

Tabulates viscosities, elastic moduli, relaxation times, coefficients of plasticity and elasticity (all obtained under standardized conditions) for doughs and glutens worked in varying degrees. G.W.S.B.

3407. The Lowering of Fracture-stress due to Surface Adsorption.

N. J. PETCH. *Phil. Mag.*, 1956, **1**, 331.

Gibbs' adsorption equation and the Griffith and dislocation theories of fracture are used to calculate this lowering. The possibility that such adsorption caused the embrittlement of iron by hydrogen is discussed and is shown to be in good agreement with measured fracture stresses. A.

3408. The Elastic Behaviour of Isotropic Solids.

C. V. RAMAN and K. S. VISWANATHAN. *Proc. Indian Acad. Sci.*, 1955, **42**, 1.

The notions regarding stresses and strains adopted in the classical theory of elasticity are critically examined. The neglect of rotations in the analysis of strain and of torques in the analysis of stress characteristic of that theory is shown to be unjustifiable. A reformulation of the stress-strain relationships taking account of these factors leads to the result that an isotropic solid has *three* independent elastic constants and not *two* as hitherto supposed. Two of these three constants determine the velocities of propagation respectively of longitudinal and transverse waves in the solid. The latter does not make its appearance in any observations involving only homogeneous strains nor does it appear in the formulae for the bulk modulus, Young's modulus and Poisson's ratio obtained in the present paper. A.

3409. Solution of some Problems in the Exact Theory of Visco-Elasticity.

R. S. RIVLIN. *J. Rational Mechanics and Analysis*, 1956, **5**, 179.

Deals with rectilinear laminar flow, torsional flow between two parallel discs and helical flow in the annular region between two coaxial cylinders. R.R.

3410. Stress relaxation in Incompressible Elastic Materials at Constant Deformation.

R. S. RIVLIN. *Quart. appl. Maths.*, 1956, **14**, 83.

A theoretical treatment of the finite deformation of incompressible isotropic elastic materials which behave as ideal elastic materials when subjected to sudden deformations but exhibit relaxation when deformed for long periods. Many of the results of the theory of finite deformations of ideal elastic materials are found to apply with slight modification. R.R.

3411. On the Question of the Determination of Intrinsic Viscosity of Dilute Solutions of High Polymers.

E. S. ROSKIN, *Koll. Zh.*, 1956, **18** (3) 369.

Applies to solutions of polyacrylonitrile in dimethyl formamide the formula $(\eta) = (\alpha(\eta)_2 - (\eta)_1)/(\alpha - 1)$ where $(\eta)_1$ and $(\eta)_2$ are reduced viscosities at two concentrations and α is the ratio of the concentrations. The results are said to be in substantial agreement with the Huggins' formula:

$$\eta_{sp}/C = (\eta) + K_1(\eta)^2C + K_2(\eta)^3C^2.$$

G.W.S.B.

3412. Investigations of Hydrosols of Hydrated Aluminium Oxides: Influence of Sodium Chloride and of Ethyl Alcohol on the Thixotropic Setting of Sols.

P. V. RUIMFSKII, *Koll. Zh.*, 1956, **18** (3) 332.

Author gives triangular diagrams for concentrations of (e.g.) C_2H_5OH , H_2O and Al_2O_3 , marking off portions in which thixotropic setting occurs. The hydrosols were prepared by Crum's method (see M. Aschenbrenner, *Z. Phys. Chem.*, 1927, **127**, 415).

G.W.S.B.

3413. A Study on the Significance of the Ductility Test for Bitumen.

R. N. J. SAAL. *J. appl. Chem.*, 1955, **5** (12), 663.

An analysis of the primary factors governing the ductility of bitumens, as determined by the well-known test, is given. Two phenomena are distinguished: (1) brittle fracture (ductility 0.1 cm); (2) thread formation (ductility greater than 1 cm). Brittle fracture occurs if the stiffness of the bitumen at 10 sec. is higher than $10^7 N/sq.m$; this limiting

value has been deduced both theoretically and experimentally. Thread formation occurs at lower stiffnesses. For bitumens of medium penetration index (P.I. between -2 and $+2$), thread formation must be considered as being largely due to a rise in temperature in the thread formed, resulting from the large amount of energy introduced during stretching. For bitumens with P.I. greater than 2 the ductility behaviour must be attributed partly to the said rise in temperature, but mainly to thixotropy due to breakdown of the structure during stretching. Newtonian-type bitumens having P.I. less than -2 and ductilities, under normal conditions of either 0 or more than 100 may also show intermediate values if the energy of stretch is increased by appropriate means. The significance of the ductility test is doubtful and tests adapted to practical conditions should be preferred. D.J.K.

3414. An Experimental Study on the change in Young's Modulus of Quenched Carbon Steel due to wetting by liquids.

M. SATO. *J. Sci. Res. Inst. (Tokyo)*, 1955, **49**, 1.

The change in Young's modulus of a quenched carbon steel due to wetting by several liquids is studied experimentally, showing that the modulus is lowered by one group of liquids, while the reverse is the case with another group. A.

3415. Analogue Study of Columns of Variable Section in the Elastoplastic State with the help of Electrical Resistance Models.

R. SCANLAN. *C.R.Acad. Sci. (Paris)*, 1956, **242**, 1123.

Critical loads for buckling can be predicted satisfactorily by setting up a certain electrical network. The resistances in the electrical analogue are related to the constants of the cross-section at a series of positions along the column and to the appropriate slopes of the stress-strain curve, corresponding to local stresses which are beyond the elastic limit. Possible modes of buckling are found by making adjustments to the resistances in an iterative process which is found to converge. J.G.O.

3416. On the Viscosity and Elasticity of Paper Pulp (massy).

G. F. SHAIUROV. *Koll. Zh.*, 1955, **17** (5), 397.

Mixtures of paper fibre in water at concentrations of 0.6–1.2% paper were sheared in a concentric cylinder viscometer. The flow curves showed a marked Laminarast (the best experimental evidence your abstractor has yet seen). Stresses 0–6 dynes/cm²: γ 0–20 sec.⁻¹: temp. 19.2–19.6° C.

Instantaneous elastic deformations are proportional to stresses. Slow fore-and after-effects were also measured. Author proposes a model of the type Kelvin-Maxwell (in series). Relaxation curves are consistent with this hypothesis. G.W.S.B.

3417. Rheological Properties of Printing Colours.

B. N. SHAKHKEL'DYAN. *Koll. Zh.*, 1956, **18** (1), 111.

Measures viscosities over a wide range of shear rates: 10^{-1} – 10^{-6} sec.⁻¹. Gives curves of specific viscosity against concentration in relation to chemical composition, also consistency curves of shear-rate against stress. G.W.S.B.

3418. The stability of viscous flow between rotating cylinders.

H. STEINMAN. *Quart. appl. Maths.*, 1956, **14**, 27.

3419. Brittle Fracture and Yielding.

A. N. STOK. *Phil. Mag.*, 1955, **46**, 968.

The stresses round a piled-up group of dislocations may either initiate a crack or operate a Frank-Read source by pulling it from its locking impurities; the latter is related to the propagation of a Lüders band. This interpretation leads to results in accord with experiment. The model gives a sharp transition from brittle to ductile behaviour as the temperature is increased. E.M.

3420. Deformation of thin Copper Crystals.

H. SUZUKI, S. IKEDA and S. TAKEUCHI. *J. Phys. Soc. (Japan)*, 1956, **11**, 382.

Stress/strain curves of many copper crystals having various radii from 0.06 to 1 mm were measured. The range of easy glide increases considerably when the radius of crystal decreases. In the case of suitably oriented crystals the range of easy glide reaches 50% in shear, when the radius of crystal decreases less than 0.1 mm. The extrapolation of the range of easy glide to the infinitesimal radius gives a value between 40 and 80% in shear irrespective of the initial crystal orientation. The hardening rate in the easy glide region considerably decreases with the decreasing crystal radius. Meanwhile, the critical shear stress, the stress required for the transition from the easy glide to the rapid hardening region, and the hardening rate in the rapid hardening region reveal only slight dependence on the crystal radii, i.e. the former two slightly increase and the last slightly decreases with decreasing crystal radii. These results are discussed qualitatively by introducing a concept "mean free path of dislocations" in a crystal. A.

3421. The Physical Meaning of Indentation and Scratch Hardness.

D. TABOR. *Brit. J. appl. Phys.*, 1956, **7**, 159.

A study of the plastic deformation of metals by hard indenters shows that the indentation hardness is essentially a measure of the plastic yield stress of the metal. With pyramidal (and conical) indenters the hardness, because of geometric similarity, is independent of the size of the indentation. With spherical indenters this is not so, the hardness increasing with size of indentation. From the increase in hardness with load, a semi-quantitative estimate may be made of the work-hardening characteristics of the metal. In the scratching and indentation of brittle solids such as minerals it is shown that the high hydrostatic pressures developed around the deformed region are often sufficient to inhibit brittle fracture. Under these conditions the deformation is primarily plastic. For this reason there is fairly good correlation between indentation and scratch hardness since both are essentially a measure of the plastic and not the brittle properties of the solid. From this approach it is possible to provide a physical basis for Mohs' scratch-hardness scale and to show that, excluding diamond, there is a reasonable "equality of intervals" between each number on the scale. A.

3422. Fracture in the Extrusion of Amorphous Polymers through Capillaries.

J. P. TORDELLA. *J. appl. Phys.*, 1956, **27**, 454.

In the extrusion of an amorphous, un-cross-linked polymer through a capillary, there is a critical stress at and beyond which the emerging stream becomes irregular in shape. This effect appears to originate in the approach to the capillary rather than within the capillary. Tearing or fracture of the molten polymer appears to occur in this region. A.

3423. Hypo-elastic Shear.

C. TRUESDELL. *J. appl. Phys.*, 1956, **27**, 441.

Hypo-elasticity is a smooth, simple theory of elastic response based on time rates. For small strains it agrees with the classical linear theory of elasticity. The determination of stress-strain relations for large deformation is a mathematical problem. For bodies which soften, a theoretical prediction of "hypo-elastic yield" is obtained. A.

3424. On the Flow of Two Immiscible Layers of Visco-plastic Liquids in a Circular Tube.

N. V. TYABIN and criticism by A. KH. MIRZADZHANZADE and A. A. MIRZOYAN, *Koll. Zh.*, 1956, **18** (3), 379, 382.

T. criticises an earlier paper of M. and M. (ibid 1955 **17** (4) 299) concerning the profiles of alternate elastic and plastic zones in a two-phase rheologically complex system flowing through a pipe. M. and M. counter-criticise and T. replies. The debate continues. G.W.S.B.

3425. A Method of Measuring the Mechanical Parameters of Rubber at Sonic and Ultrasonic Frequencies.

V. V. TYUTEKIN. *Akust. Zh.*, 1955, 1, 356.

The paper describes a method for determining the mechanical parameters over a continuous frequency band. The elastic modulus and loss coefficient can be measured for shear strains over a frequency range 4-50 kc/s. A.

3426. Some reflections on the performance of the ball compressor in Cheese Testing.

W. G. WEARMOUTH. *Dairy Inds.*, 1955. 20, 726.

The number of tests needed adequately to specify the hardness of cheese by means of a sphere hardness tester depends mainly on the homogeneity of the population tested.

G.W.S.B.

3427. A New Triaxial Stress Testing Machine for Determining Plastic Stress-Strain Relations.

H. A. B. WISEMAN and J. MARIN. *Proc. A.S.T.M. Amer.*, 1954, 54, 1365.

This paper describes a new machine for testing metals under triaxial stresses. The stresses applied consist of two equal compressive principal stresses with the third principal stress either tension or compression. These triaxial stresses are produced by subjecting a cylindrical specimen to radial hydraulic pressure and axial tension or compression. Triaxial plastic stress-strain tests serve to check further the validity of plasticity theories used to predict plastic stress-strain relations under combined stresses. This paper also describes a preliminary investigation dealing with plastic stress-strain relations for an aluminium alloy 14S-T6 subjected to the triaxial state of stress described. A.

3428. The Viscoelastic Properties of Network Structure. 1. General Formalism.

M. YAMAMOTO. *J. Phys. Soc. (Japan)*, 1956, 11, 413.

Many kinds of amorphous high-polymer substances show non-ideal rheological behaviour even in "static" observations. In this paper, the general stress-strain-time relation and energy of dissipation of these systems are treated by adopting the modified rubber-like network model in which the junctions connecting the polymer chains break up and reform continually. The probability of the breakage of the junction (i.e. the breakage of the chain) per unit time is not a constant, but a function of both the number of segments which construct the chain and the end-to-end distance of the chain. It is assumed that the velocities of deformation of the system and of the change of the situation of network structure are very much slower than those of the micro-Brownian movements of polymer segments. The statistical mechanical considerations of equilibrium states may be used to derive the stress-strain-time (S-S-T) relation at each "instance" of macroscopic observations. From the general expression of S-S-T relation it is pointed out that, in the case of small deformation, the S-S-T relation is essentially similar to that of the phenomenological generalized Maxwell model, and the reciprocal of the probability of chain-breakage corresponds to the relaxation time of each Maxwell element A.