Chapter 17. Continuum Mechanics

- Three -Dimensional stress and strain

· Mechanical properties : deformation under loading behavoir

· Deformation : geometrical shape, the way of load application .

History (sample preparation)

Rate of application load(frequency, time)

· stress existing at any point in a material -three arbitrary coordinate directions

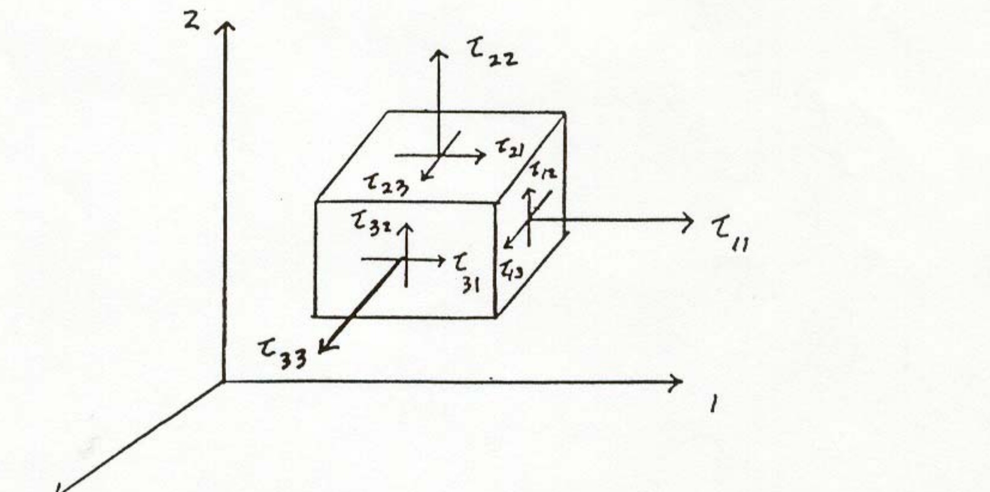


Fig. Stress components acting on an element of material.

· First subscript : direction of normal to the plane on which the stress acts

· Second subscript : the direction of force itself (stress)

· Three normal stresses - τ_{11}, τ_{22}, τ_{33}

· Six shear stresses - τ_{12}, τ_{13}, τ_{21}, τ_{23}, τ_{31}, τ_{32}

· stress tensor - These nine quantities, necessary for specifying the state of stress at a point completely, are the components of the stress tensor

$$\tau = \begin{vmatrix} \tau_{11} & \tau_{12} & \tau_{13} \\ \tau_{21} & \tau_{22} & \tau_{23} \\ \tau_{31} & \tau_{32} & \tau_{33} \end{vmatrix}$$

· The goal of continuum mechanics - to develop general constitutive relations (between the stress and rate of strain) and use them for predicting material response in the widest variety of situations.

· For equilibrium viscometric flows of incompressible fluids (assumption)

- There are two independent differences of the normal stresses in shear flows.

$\sigma_1 = \tau_{11} - \tau_{22}$ (first normal stress differences)

$\sigma_2 = \tau_{22} - \tau_{33}$ (second normal stress differences)

· Fluid moves along one coordinate direction only and its velocity varies only in one other coordinate direction :

1 direction - the direction of fluid velocity

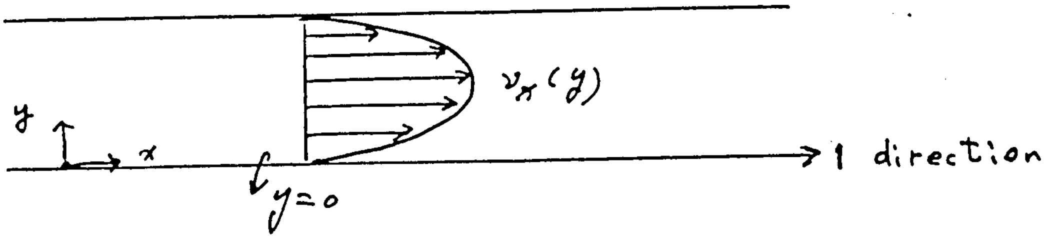
2 direction - the direction of velocity variation

3 direction - the remaining neutral direction

· For polymeric fluids :

$|-\sigma_1| > |+\sigma_2|$

· the first normal stress difference is practically always negative and numerically much larger than the second normal stress difference - polymeric fluids exhibit an <u>extra tension</u> aling the streamlines, (that is, in the 1 direction), in addition to the shear stresses.



· The extra tension arises from the stretching(다시 random 상태로 돌아가려고 하는 힘 -> elasticity effect) and alignment of the polymer molecules along the streamlines - polymer molecules act as small 'rubber bonds' wanting to snap back (Weissonberg's effect)

· The second normal stress difference is quite small - in a shear flow the fluid exhibits a small extra tension in the 3 direction.

(Ref. R.B.Bird et al,. Dynamics of Polymeric Liquid, Chapter 2, Vol 1)

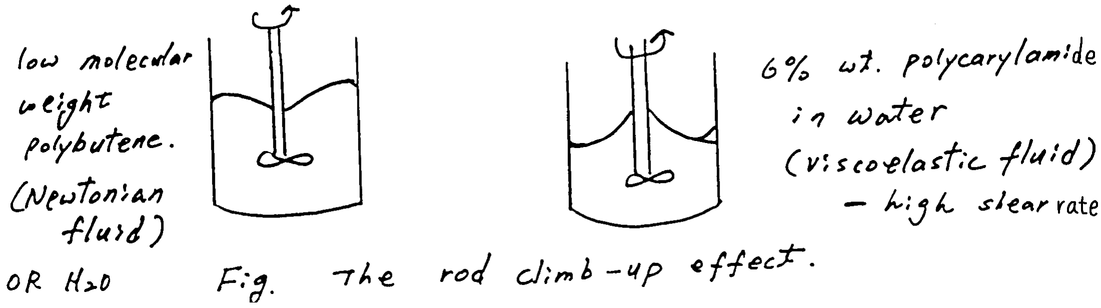
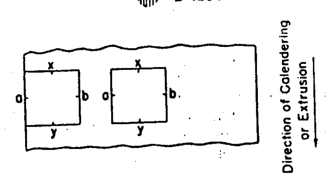


Fig. The rod climb-up effect.



Points *a*, *b* and *x*, *y* are reference marks at midpoint of test specimen edges.

FIG. 1 Method of Cutting Test Specimens from Sample

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Standard Test Method for

FLOW RATES OF THERMOPLASTICS BY EXTRUSION PLASTOMETER[1]

This standard is issued under the fixed designation D 1238; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This method covers measurement of the rate of extrusion of molten resins through a die of a specified length and diameter under prescribed conditions of temperature, load, and piston position in the barrel as the timed measurement is being made.

1.2 The values stated in SI units are to be regarded as the standard.

2. Applicable Document

2.1 *ASTM Standard:*

D618 Methods of Conditioning Plastics and Electrical Insulating Materials for Testing[2]

3. Significance and Use

3.1 This method is particularly useful for quality control tests on thermoplastics.

3.2 Procedure A is a manual cutoff operation based on time used for materials having flow rates that fall between 0.15 and 50 g/10 min. Procedure B is an automatically timed flow rate measurement used for materials having flow rates from 0.50 to 300 g/10 min. By both procedures, the piston position is generally the same during the timed measurement: the piston foot, at the extremes, is between about 51 and 20 mm (2.0 and 0.8 in.) above the die during the course of measurement. Comparable flow rates have been obtained by these procedures in interlaboratory round-robin measurements of polyethylene and polypropylene.

NOTE 1—Polymers having flow rates less than 0.15 or greater than 300 g/10 min may be tested by the procedures in this method; however, precision data have not been developed.

3.3 This method serves to indicate the uniformity of the flow rate of the polymer as made by an individual process and, in this case, may be indicative of uniformity of other properties. However, uniformity of flow rate among various polymers as made by various processes does not, in the absence of other tests, indicate uniformity of other properties.

3.4 The flow rate obtained with the extrusion plastometer is not a fundamental polymer property. It is an empirically defined parameter critically influenced by the physical properties and molecular structure of the polymer and the conditions of measurement. The rheological characteristics of polymer melts depend on a number of variables. Since the values of these variables occurring in this test may differ substantially from those in large-scale processes, test results may not correlate directly with processing behavior.

3.5 The flow rate of a material may be measured under any of the conditions listed for it in 7.2. Additional characterization of a material can be obtained if more than one condition is used. In case two conditions are employed, a Flow Rate Ratio (FRR) may be obtained by dividing the flow rate at one condition by the flow rate at the other condition.

4. Apparatus

4.1 *Plastometer:*

4.1.1 The apparatus shall be a dead-weight piston plastometer consisting of a thermostatically controlled heated steel cylinder with a die

[1] This method is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D 20.30 on Thermal Properties.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

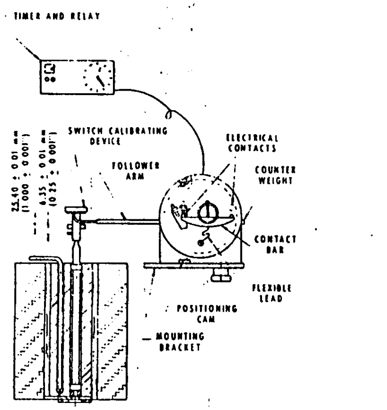

FIG. 3 Extrusion Plastometer with Automatic Timer-Actuating Switch and Timer

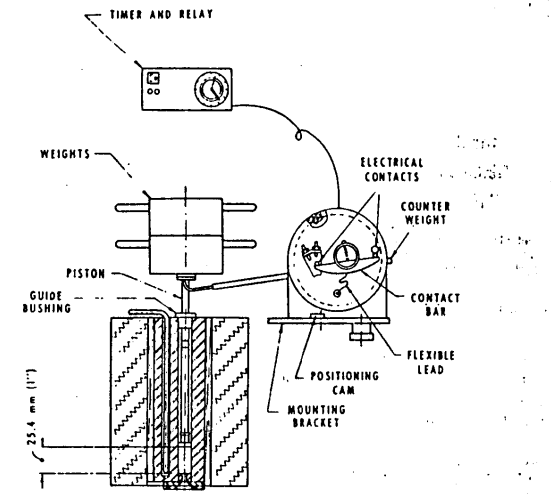

FIG. 4 Extrusion Plastometer with Automatic Timer-Actuating Switch, Switch Calibrating Device, and Timer

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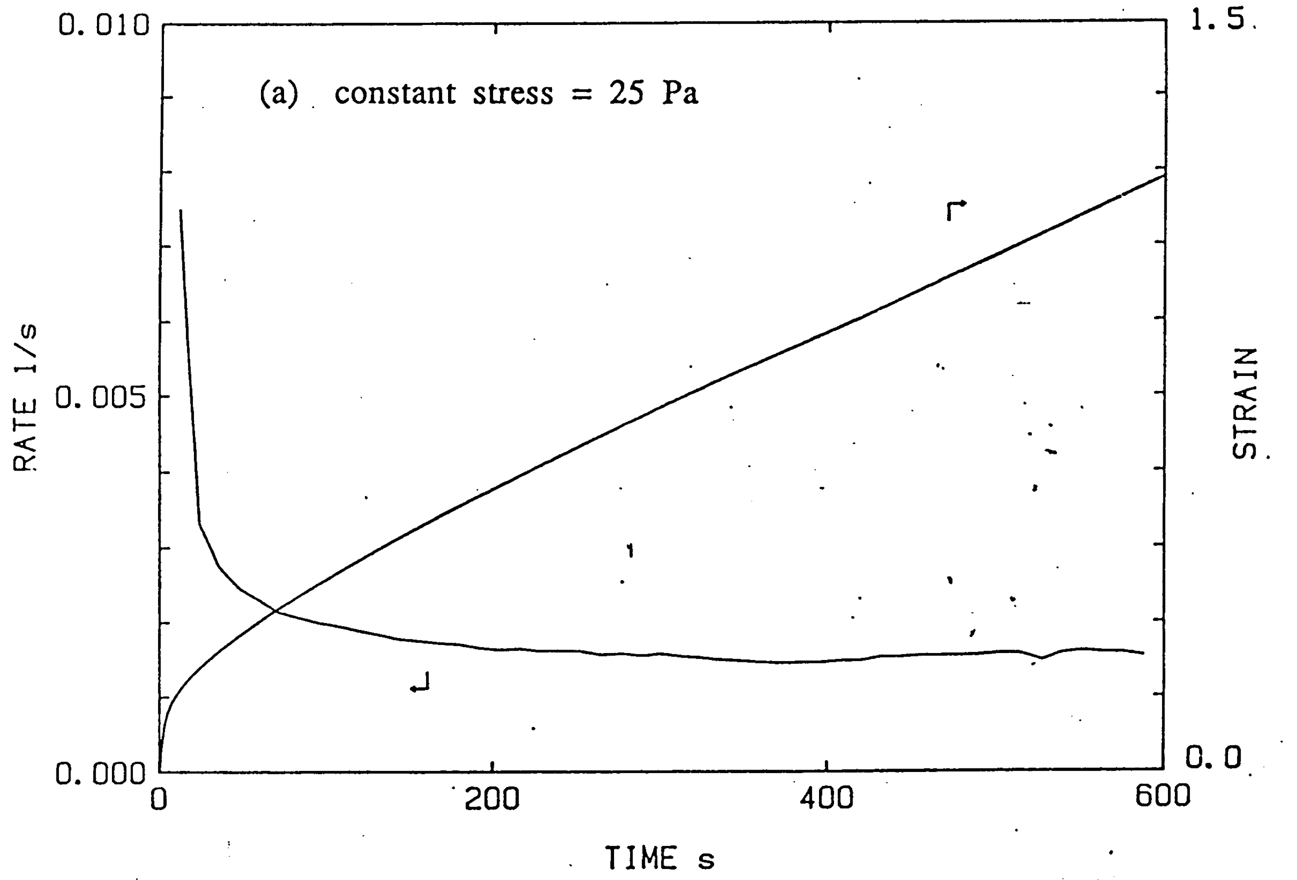
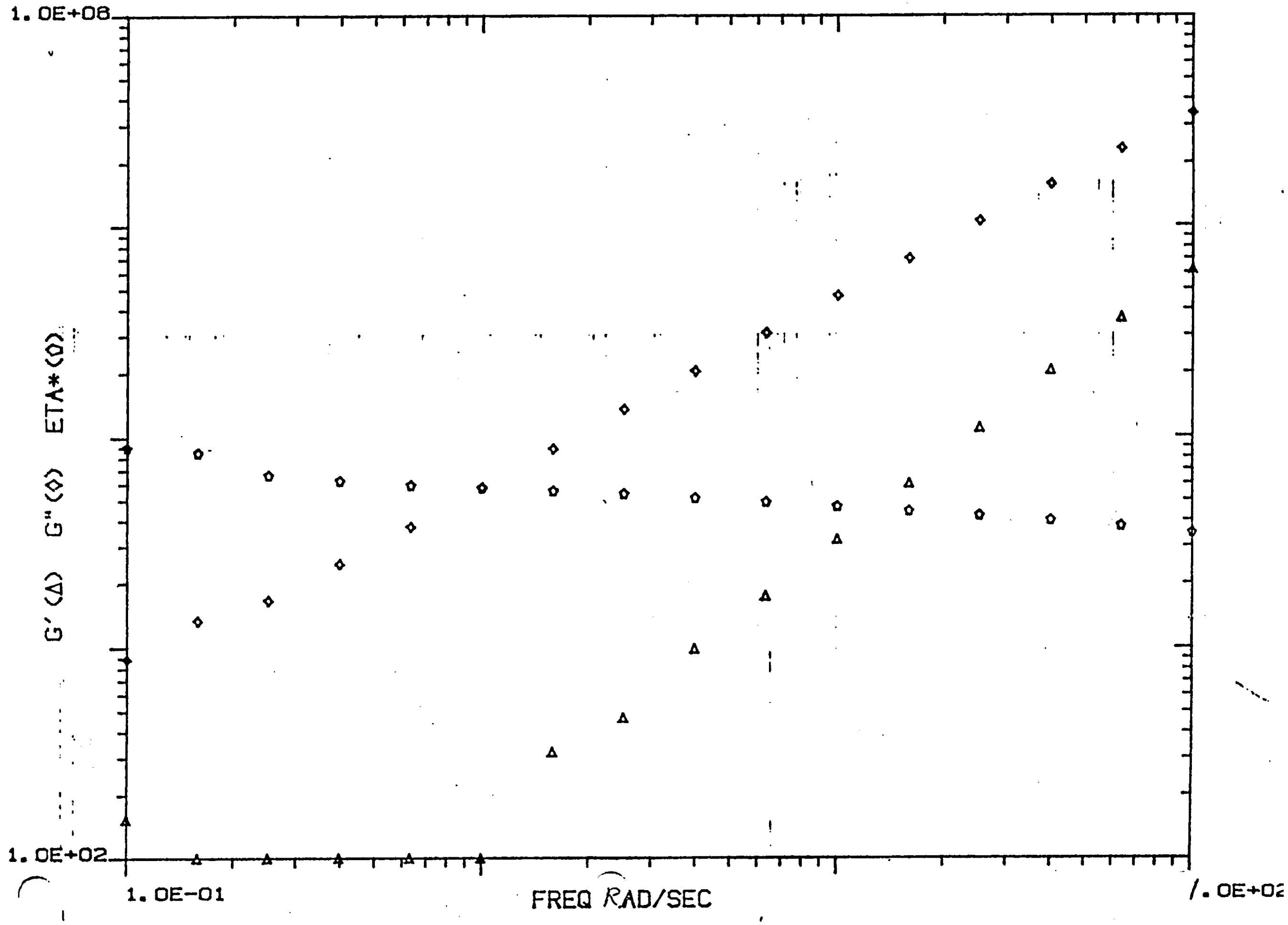
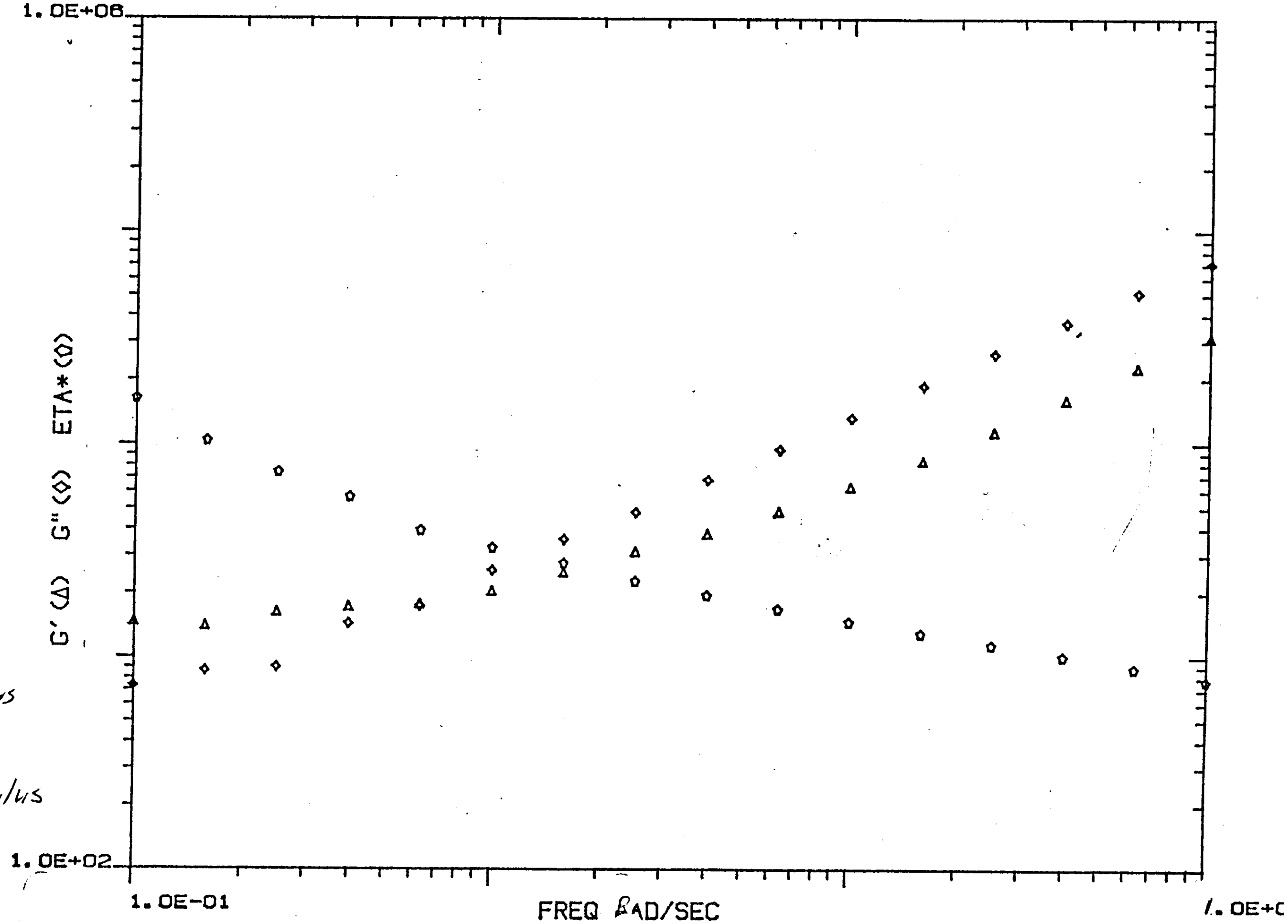


i) strain rate vs time

ii) strain vs time for Vectra only (Liquid Crystalline Polymer) poly(ethylene terephthalate)(PET)



* VECTRA Only -(5) ; Strain = 5 %



G' = storage modulus

G" = loss modulus

ETA POISE	N1 DYNE/SQ CM	TORQUE GM CM	NORMAL GRAMS	STRESS DYNE/SQ CM	RATE
4.143E+03	4.422E+02	1.728E-01	1.107E+00	4.143E+01	1.000E-02

FET Only, strain rate= 20%, Feb. 9. 1991 ✓

RATE SWEEP

G' DYNE/SQ CM	G" DYNE/SQ CM	ETA* POISE	STRAIN %	TORQUE	RATE RAD/SEC
1.533E+02	8.856E+02	8.988E+03	2.004E+01	7.511E-01	1.000E-01
1.569E+01	1.342E+03	8.466E+03	2.003E+01	1.121E+00	1.585E-01
0.000E+00	1.664E+03	6.625E+03	2.003E+01	1.394E+00	2.512E-01
0.000E+00	2.477E+03	6.223E+03	2.003E+01	2.070E+00	3.981E-01
5.592E+01	3.738E+03	5.925E+03	2.003E+01	3.124E+00	6.310E-01
3.309E+01	5.753E+03	5.753E+03	2.011E+01	4.825E+00	1.000E+00
3.203E+02	8.789E+03	5.549E+03	2.004E+01	7.350E+00	1.585E+00
4.654E+02	1.348E+04	5.369E+03	2.003E+01	1.127E+01	2.512E+00
9.874E+02	2.034E+04	5.115E+03	2.003E+01	1.701E+01	3.981E+00
1.743E+03	3.079E+04	4.887E+03	2.001E+01	2.574E+01	6.310E+00
3.241E+03	4.636E+04	4.647E+03	1.999E+01	3.874E+01	1.000E+01
5.988E+03	6.985E+04	4.424E+03	1.992E+01	5.826E+01	1.585E+01
1.103E+04	1.050E+05	4.201E+03	1.975E+01	8.692E+01	2.512E+01
2.045E+04	1.573E+05	3.985E+03	1.933E+01	1.279E+02	3.981E+01
3.624E+04	2.329E+05	3.735E+03	1.841E+01	1.810E+02	6.310E+01
6.163E+04	3.404E+05	3.460E+03	1.670E+01	2.410E+02	1.000E+02

RATE SWEEP
LAST RATE [1.000E+02]
POINTS PER DECADE[5] 3
READINGS PER RATE[2] 1
AUTO SWEEP [Y]

TIME BEFORE MEASURE [5.000E-01]
MEASURE TIME [5.000E-01]

G' = Storage modulus
G" = Loss modulus
η^* = complex viscosity