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Rheometer Strain and Strain-Rate Errors

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D.W. Giles and M.M. Denn

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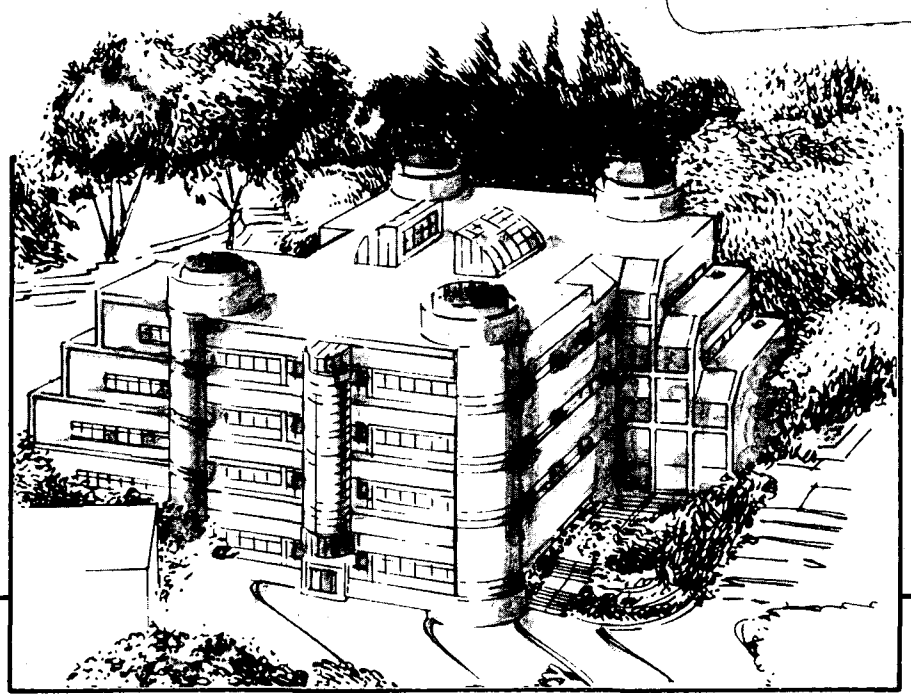

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RHEOMETER STRAIN AND STRAIN-RATE ERRORS

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ABSTRACT

We have found systematic errors which can affect measured rheological properties in the instrumentation of two commercial rheometers. Users of commercial instrumentation should establish the extent to which these and similar errors may exist in their systems.

INTRODUCTION

We have found systematic errors in the operation of two commercial rheometers, the Rheometrics Mechanical Spectrometer Model 705M (*RMS*) and the Rheometrics Stress Rheometer Model 8600 (*RSR*). The errors appear to be inherent in the designs, though we do not know the extent to which such errors exist in other examples of these models or in similar rheometers produced by the same or other manufacturers. Users of commercial instrumentation should establish the extent to which these and similar errors may exist in their systems.

MECHANICAL SPECTROMETER

The error in the RMS is in the steady strain-rate drive system, which has an oscillatory component superimposed on the steady component. The oscillations are illustrated in Figs. 1a and 1b at strain rates of 0.001 and 0.01 s^{-1}, respectively, for a polydimethylsiloxane test fluid (code 040890) at 23°C. The measurements were carried out in the cone-and-plate geometry with 25mm platens and a 0.1 rad cone angle, using the 100 gm-cm transducer. The oscillation amplitude is about twelve percent of the mean

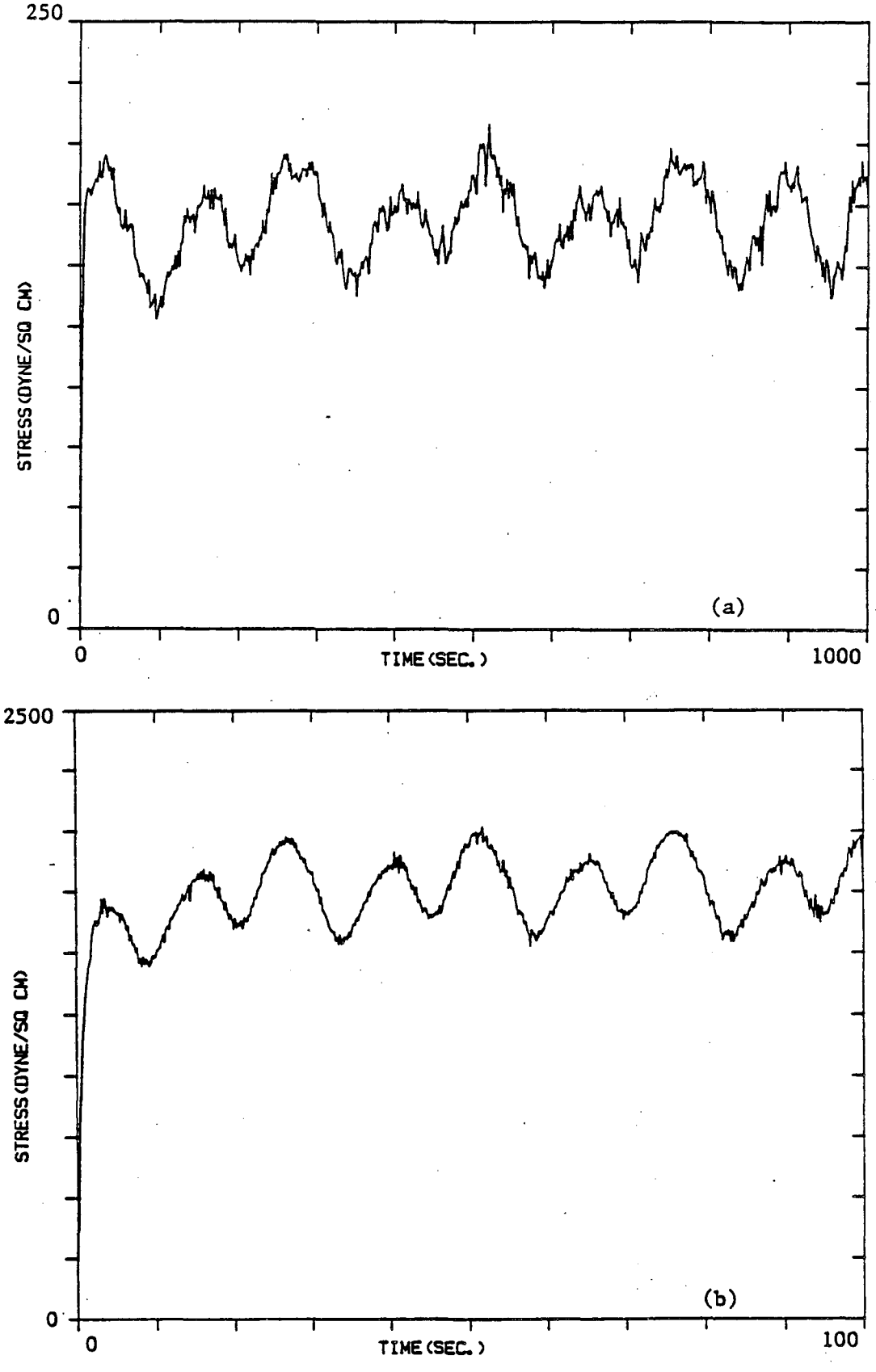

Figure 1. RMS measurement of stress vs time for PDMS at (a) 0.001 s^{-1} and (b) 0.01 s^{-1}. Note the changes in the time and stress axes.

stress in each case, and the stress is proportional to strain rate. The time axes are scaled by strain rate; the full scale is 1,000 s in Fig. 1a and 100 s in Fig. 1b, so the total strain is the same. The two experimental traces nearly superimpose on these axes, demonstrating that the error is in the rotational displacement, with a frequency proportional to the strain rate. It should be noted that the period of the oscillation is very small relative to the period of rotation of the platen.

An error of this magnitude will probably have little effect on the measured steady-state rheological properties of flexible-chain polymers, where the linear region can be quite large and oscillations of this type will average to zero. The effect on the measured properties of highly nonlinear materials, such as thermotropic liquid crystalline polymers, cannot be established without independent shear measurements that are truly steady. We do note that we have obtained overlap of RMS and RSR steady shear data for a fully-nematic liquid crystalline copolymer of 80% p-hydroxybenzoic acid and 20% poly(ethylene terephthalate) to within the apparent precisions of the two instruments as discussed here [1].

STRESS RHEOMETER

We have discussed the error in the strain measurement of the RSR in detail elsewhere [2]. A single, linear conversion is used at low rates to interpret the output of two independent strain sensors, each of which operates over a different angular range. This causes a position-dependent strain error which can be of order five percent. A position-dependent calibration can be developed.

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