Chapter 7
Rotational and Sliding Surface Rheometers

7.1 INTRODUCTION

There are two basic types of instrument for measuring shear properties: capillary and slit rheometers in which the flow is generated by a pressure drop; and drag flow rheometers in which one bounding wall moves relative to a second, stationary wall. Pressure-driven rheometers are described in Chapter 8, and the present chapter deals with drag flow instruments.

In order to generate results that are subject to interpretation in terms of well-defined material functions, it is desirable that the flow generated by the rheometer be as close as possible to simple shear flow. This can be accomplished with a minimum of mechanical complexity by the use of either rotational or rectilinear motion of a solid surface. Drag flow rheometers based on rectilinear motion are referred to here as “sliding surface rheometers.” Both sliding plate and sliding cylinder rheometers are described in this chapter.

While pressure flow rheometers are popular because of their simplicity and ease of use, they provide information only about the shear stress associated with steady shear. Thus, they are used primarily for the measurement of viscosity at high shear rates. Furthermore, since the shear rate is not uniform, it is not possible to obtain the true value of the viscosity at one shear rate from a single experiment. As is explained in Chapter 8 a somewhat elaborate treatment of data obtained at several flow rates is necessary to obtain the viscosity curve. With the possible exception of the first normal stress difference, reliable information about the viscoelastic
behavior of a material cannot be obtained by use of a pressure-flow rheometer, because uniform transient flows cannot be generated.

For these reasons, studies of melt viscoelasticity require the use of rheometers capable of generating a uniform deformation that can be precisely controlled as a function of time. Extensional flow rheometers capable of accomplishing this objective are described in Chapter 6. While for studies of nonlinear viscoelasticity, extensional and shear rheometers each reveal different aspects of the rheological nature of a material, either could, in principle, be used to determine the linear properties. However, because they are much easier to build and use, drag flow shear rheometers are always used to determine the linear viscoelastic properties of molten polymers.

Of course, drag flow shear rheometers have their own limitations and sources of error, and these are summarized in the present chapter. More complete treatments of rotational and sliding surface rheometers are given by Dealy [1] and in the book edited by Collyer and Clegg [2, Chapters 9, 12, 13].

7.2 SOURCES OF ERROR FOR DRAG FLOW RHEOMETERS

While each type of drag flow rheometer has its specific limitations, certain problems are common to all such instruments, and these are described in the present section.

7.2.1 Instrument Compliance

If the only relative motion of the confining walls of a drag flow rheometer is the displacement imposed to generate the desired shear deformation, then the shear strain, $\gamma$, in the sample is directly related to this imposed motion. However, if the instrument is compliant, i.e., if it deforms in response to the forces exerted on the test fixtures by the sample, then the relationship between the shear strain and the imposed displacement is more complex. Moreover, this relationship depends on the rheological properties of the melt, and it therefore varies with time during a transient shear experiment.

This does not pose a problem for a steady shear experiment such as the measurement of viscosity. However, for the measurement of transient properties such as the relaxation modulus or the storage