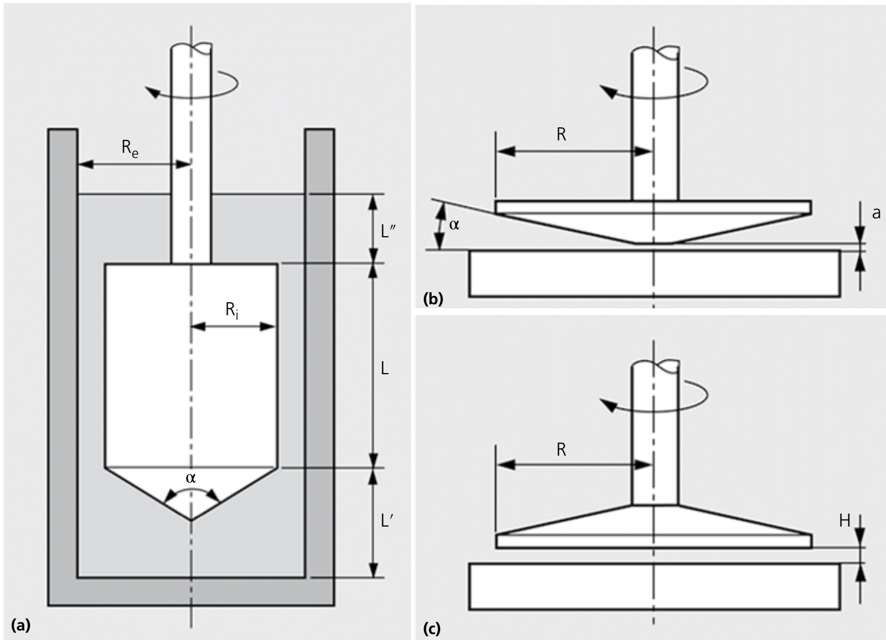

Figure 11.10 Geometries for rotational viscometers: (a) cup and bob, (b) cone and plate, (c) parallel plate. Reproduced with permission from Mezger (2006).

Figure 11.11 Bob types for concentric cylinder viscometers.

When using concentric cylinders, chocolate is poured into a temperature-controlled cup and a bob immersed in it. There are two types of bob in common use, as illustrated in Figure 11.11. As the bob turns there is a situation like Figure 11.2, with a constant distance between two parallel surfaces that are moving at different rates. The apparent viscosity is then directly related to

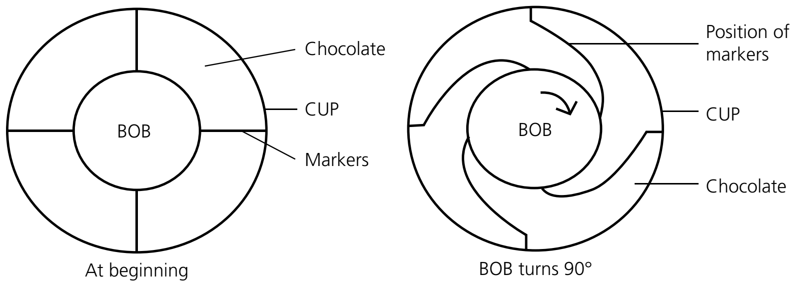

Figure 11.12 Flow in a concentric cylinder gap.

the force trying to stop the bob moving at a given speed. At the base of the bob the flow of the chocolate is different and difficult to calculate. The bobs shown have therefore been designed to minimise this end effect.

It is also important that the chocolate moves uniformly in the gap between the bob and cup. If the gap between the two is too wide this will not be the case, as only the chocolate near the moving bob will be affected, see Figure 11.12. The distance into the chocolate being moved will also depend upon how fast it is turning and upon the viscosity of the chocolate itself. The faster it turns the more of the chocolate within the gap is moved. This means that the lower shear rate (speed) readings are too low. Similarly a thinner chocolate may be measured across the full gap, but a very thick one for only half of it, which makes the thick one appear to be thinner than it actually is. For this reason it is recommended (ICA, 2000) that the ratio of the bob diameter to the cup should be greater than 0.65. There are viscometers available which do not have the outer cup and often have a spindle with a narrow cylinder (sometimes coneshaped). For the above reason they cannot be used to give precise viscosity measurements, especially at low shear rates or over a wide range of viscosities. Their use should be limited to determining whether samples lie within a particular range, which has previously been determined using the viscometer concerned. However, Joye (2003) has published shear rate and viscosity correction factors for a Casson fluid in cylinder geometries. The narrow gap type and a cylinder in a semi-infinite medium such as a spindle rotating within the sample (e.g. Brookfield) are included and the results compared to literature data as well as cone and plate data. For the reasons mentioned above the agreement with cone and plate is not very good at low shear rates.

In the most widely used instruments the internal coaxial bob rotates, with the shear rate being fixed by a drive motor and the shear stress measured by means of a torsion spring connected to the rotating bob. A cross-section of a concentric cylinder gap, including the velocity profile, is illustrated in Figure 11.12 for the case of the narrow gap arrangement. In this arrangement the velocity profile is nearly linear across the gap akin to the two plane model (Figure 11.2).