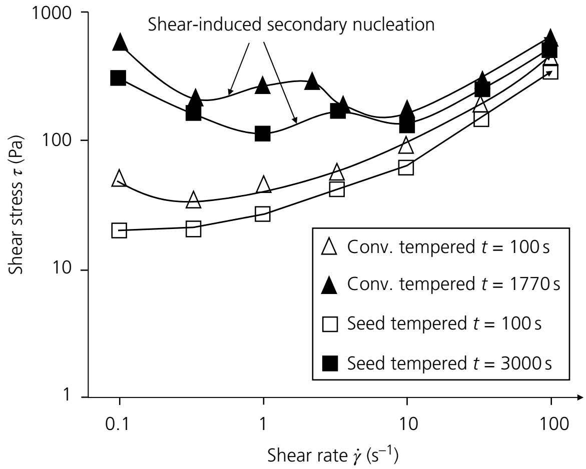

Figure 13.6 Thermorheometry measurements. Transient development of flow functions (shear rate range: 0.1–100 s^{-1}) for conventionally and seed tempered milk chocolate under holding conditions [temperature: 28 °C (82 °F); shear rate: 1 s^{-1}]. Rheometer: Paar/Physica UM 300 with concentric cylinder geometry.

at 28 °C (82 °F) are shown in Figure 13.6 for two different tempering processes: conventionally shear-tempered in an AMK 50 (Aasted Mikroverk ApS,) tempering unit (conv.) and seed tempered using a Seed Master *Cryst Mix* (Bühler AG; seed).

13.4.4 Nuclear magnetic resonance

Nuclear magnetic resonance (NMR) spectroscopy measures the proton spin relaxation, which in chocolate systems provides a signal correlating with the solid fat fraction and can consequently be used for the solid fat content measurements (SFC; see also Chapter 24). To obtain sufficient accuracy at solid fractions ≤1%, (relevant for tempered chocolates) requires optimised temperature adjustment of the NMR magnet as well as a defined sampling routine, such as is described for direct SFC measurements by Breitschuh and Windhab (1998). Figure 13.7 demonstrates the SFC of a milk chocolate masse as a function of holding time at 28 °C (82 °F) over a time period of about 370 s. This simulates again solidification behaviour under processing conditions, for example in the depositor of a moulding or enrobing plant. As can be seen in Figure 13.7, an equilibrium solid fat content of about 25% is reached after about 350 s.

13.5 Tempering processes

There are several ways to temper chocolate, known as "hand", "batch" or "continuous" processes. This section is primarily concerned with continuous machinery relevant for industrial chocolate production, although the principles involved are applicable for all methods.

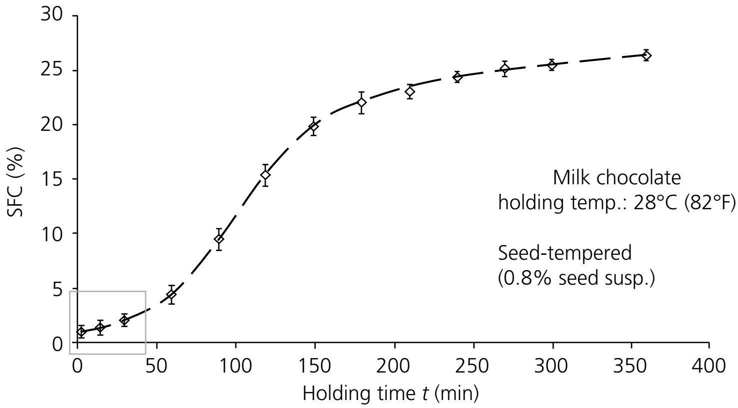

Figure 13.7 NMR measurements. Increase of solid fat content (SFC) in seed tempered (0.8 % cocoa butter seed suspension containing 15% solid seed crystals) milk chocolate during holding at 28 °C (82 °F) and stirring at1 s^{-1}.

13.5.1 The principle of conventional continuous chocolate "stir/shear-tempering"

Conventional stir/shear-tempering is carried out in a continuous flow through stirred vessel systems, generally divided into three temperature zones: (I) pre-cooling, (II) cooling and (III) reheating. The chocolate passes in the order I to III and with the stirring elements normally designed in such a way that shear gaps are formed between stators connected to the vessel walls and rotating sections attached to a central shaft, as shown schematically in Figure 13.8. The higher shear rates are mainly applied in the shear gaps between the rotor and stator elements or between the rotor and the inner vessel wall. In addition wall-scraping blades may be added onto the rotating stirrer parts. The residence time distribution of the chocolate within the temperer is planned to be as narrow as possible (all the chocolate spends approximately the same time within the machine).

There is a wide range of different tempering devices commercially available with widespread combinations of shear rate, temperature and residence time distributions.

The following sections discuss the most relevant factors (i.e. temperature, shear and time) and how they influence tempering quality in conventional stir-/shear-temperers.

13.5.2 Impact of temperature/temperature control

Controlled tempering generally assumes that the continuous chocolate in-feed to the temperer is completely free of fat crystals. However this chocolate is typically at about 45 °C (113 °F), and may even be lower for energy conservation reasons [e.g. 41–42 °C (106–108 °F)]. At this temperature there are a number of high-melting triglycerides contained in cocoa butter, as minor fractions that are still