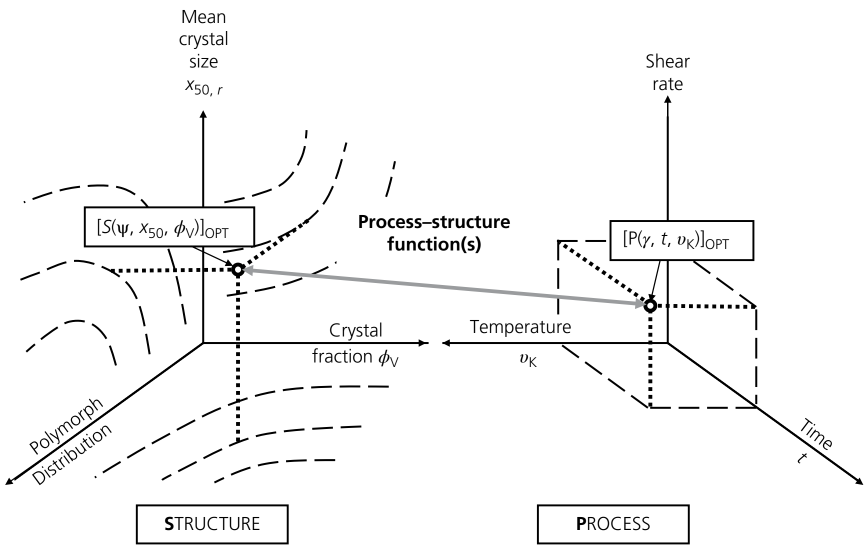

Figure 13.9 Process–structure relationship: correlation between qualitative "optimum spaces" for the structure $[S(\psi,\xi_{50},\varphi_V)]_{OPT}$ and the process $[P(\gamma,t,\upsilon_K)]_{OPT}$ (ψ,ξ_{50},φςr, ξ_{50} mean diameter/size, φ_V volume fraction, γ shear rate, t time, υ_K cooling temperature).

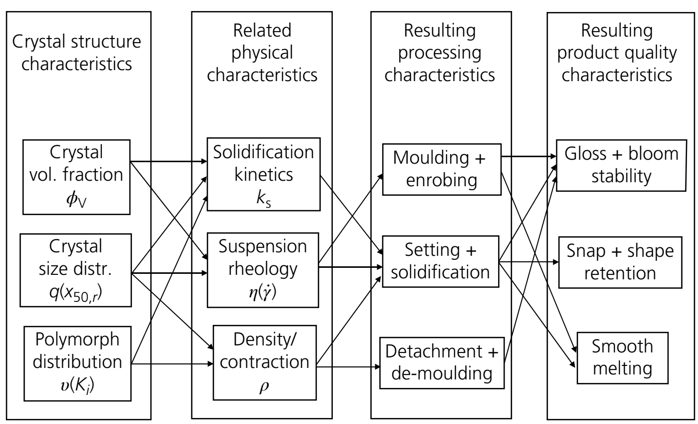

Figure 13.10 Relationships between: (i) fat crystal structure characteristics, (ii) related physical characteristics of a chocolate system, (iii) resulting processing characteristics and (iv) the final product quality properties for a system with a given fat/triacylglycerol (trigyceride) composition.

75% of β_V polymorph crystal nuclei produced under higher homogeneous shear crystallisation conditions ($\geq 750\,s^{-1}$) within a residence time period of as short as <60 s and cooling wall temperatures between 5 and 15 °C (41 and 59 °F; Windhab and Zeng, 2000).

However, as was stated earlier, a temper state reached under conventional tempering conditions will generally not be completely stable if typical temperature fluctuations of ±0.5–1 °C (1–2 °F) occur during further processing treatment of the tempered chocolate masse. This is certainly due to the fact that the typical temperature range for tempered chocolate processing is about equal to the outlet temperature of the tempering unit, which also lies in the melting temperature range of the β_V cocoa butter crystal nuclei [29.0–33.5 °C (84–92 °F) and which in the case with about 10% added milk fat (milk chocolate) reduces due to mixed crystallisation to about 26–30.5 °C (79–87 °F)].

Shear rates affect mixing and heat exchange rates in a tempering machine. There are limits to the amount of shear that can be applied to chocolate in the tempering phases. Too much shear will produce heat, too little, poor mixing and poor heat exchange.

From experience, local maximum shear rates acting in tempering machines vary from about 500 to 12000 s^{-1}. However it has to be noted that the highest shear rate values are in general only applied in a very small part of the flow gaps. Thus an average shear rate can be significantly (up to two orders of magnitude) smaller. Typical maximum shear rates in tempering equipment are given in Table 13.2.

The maximum shear rates are usually measured at the outer periphery, where the clearance gap between the heat exchanger wall and the rotor or scraper flight can be accessed. The highest shear rates given in Table 13.2 relate to the narrowest gaps between scrapers/stirring elements and the cooled wall. In the case of a rotating disc or scraper arm the radial dependency of the shear rate has to be considered, and the apparent shear rate can then be calculated by dividing the local circumferential velocity by the respective shear gap width. For more precise calculation the viscosity dependant local velocity field has to be known. High shear crystallisers with narrow concentric cylinder shear gaps as are used in the generation of seeding suspensions apply highest average shear rates in the range of 1000–3000 s^{-1}. This value is however very constant throughout the machine.

In order to avoid confusion in shear rates quoted by manufacturers, it is necessary to look at the different mixing/scraping tools and calculate the local ratio between tool-velocity and respective gap width. From this it can be seen

Table 13.2 Approximate maximum local shear rates in tempering machines.

Type of tempering device	Maximum shear rate range (s^{-1})	Examples of producers of tempering devices[1]
Kettle type scraped	500–12 000	
Screw type	500–3000	Hosokawa Kreuter
Stacked plate multi-zone	3000– 6000	Aastedt, Sollich
Stacked plate multi-chambered	4000–8500	APV

[1] The producers of tempering machines mentioned here are only examples; a more complete list of manufacturers is given in the Appendix of this chapter.