10 Floating Ring Mixing Devices

10.1 Introduction

Floating ring mixers for extrusion use an interactive rotor and stator in which the stator floats as an uncoupled internal sleeve within the bore of the barrel. They are derived from the mixing version of the check ring used at the screw tip in an injection moulding machine. The potential disadvantage of reduced mixing capacity due to limited stator bore and short length can be more than compensated by the high mixing performance of interacting moving and fixed elements. In the extrusion version, retrofitting will require substitution of the last few screw turns, thereby reducing the effective screw length.

10.2 Injection Moulding Check-ring Mixers

It is not surprising that the melting and mixing limitations in single screw extruders can also occur in injection moulding, as the screws used are very similar and often shorter than those used in extrusion. If the mould volume is large in relation to the maximum shot capacity, then the length of screw available for both melting and mixing will be short when fully retracted. On the other hand, as the cooling time is usually longer than pre-plasticisation time, the back pressure can be increased to aid mixing, provided the cooling time is not increased as a result of additional heat generation by the screw.

Maddock and pin mixing elements can be used, but the more efficient interacting pegs or cavities cannot be used in the same manner as for extrusion described in Chapter 9. The rotor and stator would move completely out of register as the screw reciprocates. Although techniques have been devised, they required greater space than is normally available [1, 2].

During the injection part of the cycle, backflow up the screw channel by the molten polymer is prevented by some form of non-return valve such as a 'check ring' (**Figure 10.1**). The check ring moves axially with the screw and rotates at a slower speed than the screw due to drag from a thin melt film between it and the barrel surface.

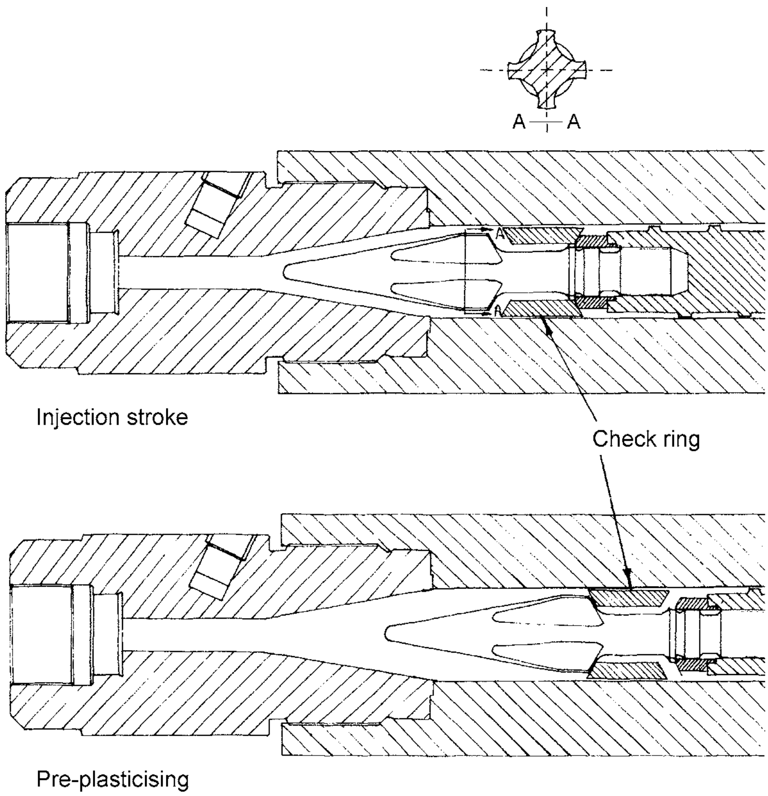

Figure 10.1 Injection moulding check ring.

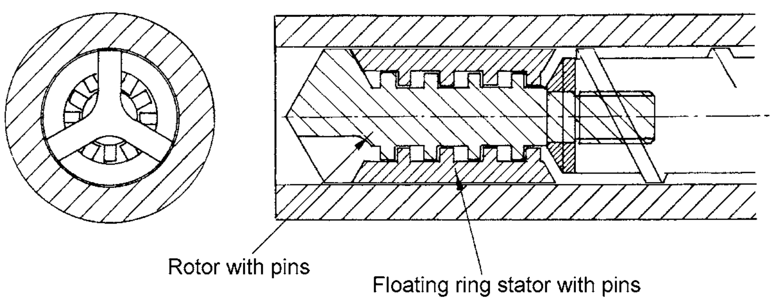

Figure 10.2 Potential adaption for extrusion of the injection moulding check ring mixer by Elbe.

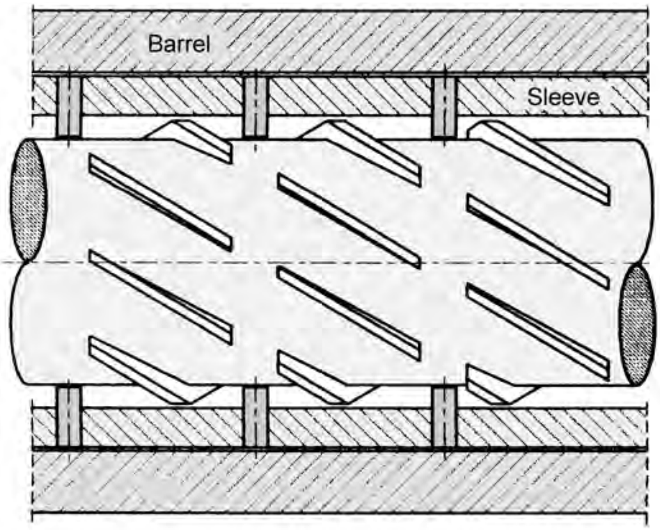

Figure 10.3 Vortex mixer with pins interacting with flights.

Interacting elements can be incorporated providing the spacing accommodates the small axial displacement between the open and shut-off positions. Spacing of interacting pins in the 'turbine arrangements' of Chapter 9 such that intermesh is avoided has been described by Elbe [3]. A schematic diagram by the author showing a possible adaption of Elbe's pegged check ring mixer is shown in **Figure 10.2**. Slots or flutes resembling the outlet, placed at the mixer inlet might allow minimal relative axial ring movement and smaller clearances, but at extra cost. For good distributive mixing of colour masterbatches, wide spacings may be adequate. A check ring mixer using interacting pins in the stator ring has also been described by Rauwendaal for use in both extrusion [4] (see **Figure 10.3**) and injection moulding [5].

A mixer developed by Twente University [6-10], the Twente Mixing Ring (TMR) using this principle has been shown (like other interacting rotor/stator devices) to outperform more commonly used Maddock and pin mixers [11] (see Section 8.6). The rotor and stator arrangement is similar to the prototype cavity transfer mixer (CTM) in Figure 9.11. A complete injection moulding unit of this type is shown in **Figure 10.4(a) and (b)**. A re-arrangement of the holes in the ring from a staggered pattern to separate rows can be used to strengthen the ring to withstand injection pressures. Lack of cavity alignment during injection is of no consequence as there is no mixing requirement at this point in the cycle, and there are no potentially intermeshing projections. An example of injection mouldings with a colour masterbatch, with and without such a device is shown in **Figure 10.5(a) and (b)**. Note that the check

Figure 10.4 18mm Injection moulding (TMR type) check ring cavity mixer. (a) Components, (b) Assembled.

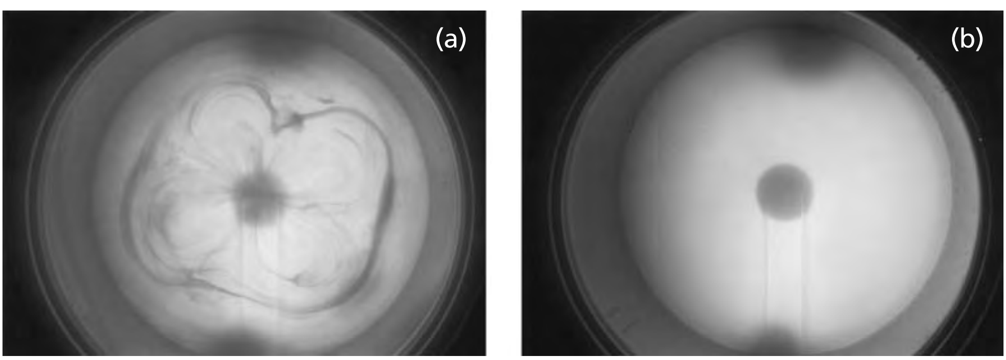

Figure 10.5 View inside injection moulded caps with back lighting. (a) Without check ring mixer, (b) With check ring mixer.

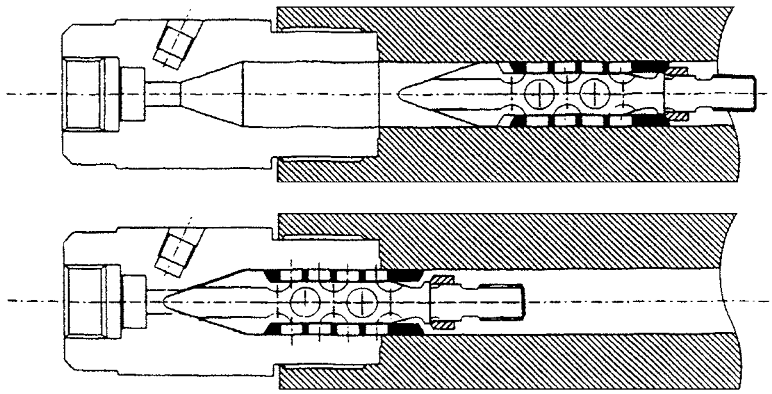

Figure 10.6 Check ring mixer in forward and rear position with bore extended into nozzle.

ring mixer used was extended into the nozzle (**Figure 10.6**) making it longer than the original in **Figure 10.1**.

10.3 Adaption of the Check Ring Mixer to Extrusion

By transferring the check ring mixer concept to extrusion, the mixer can be accommodated within the barrel as part of the screw. Being without the non-return valve function required for injection moulding it can be described as a 'floating ring mixer'.

As the stator is free to turn, it will rotate with the screw approximately half the screw speed or less, depending on the barrel clearance. Compared with a fixed stator configuration, for floating ring devices generally there is reduced mixing between the rotor and turning stator ring, but with the TMR, there is compensation for the reduced mixing from the rotor/sleeve interaction by the through cavities in the rotating sleeve interacting with the barrel surface (**Figure 10.7**). This will also reduce the risk of polymer stagnation in the sleeve/barrel gap, particularly if the cavity rows overlap (**Figure 10.4**). The advantages for extrusion is that there is no requirement to accommodate an extension between barrel and die, as will be the case for the interacting units described in Chapter 9. This is particularly useful for retrofitting to many blow moulding machines where splitting the clamp unit from the extruder is impracticable. There can be other situations where providing extra space between barrel face and die is difficult or expensive with existing extrusion installations.

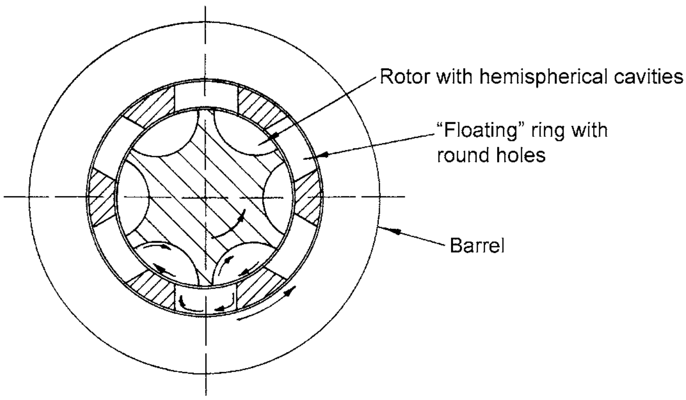

Figure 10.7 Cross section of TMR type floating ring mixer showing flow patterns.

The disadvantage is that there will be less screw available for melting/pumping, and the length of the mixer is restricted. Although initial costs will be lower than for add-on mixers, the need for occasional replacement of worn injection moulding check rings may also apply to extruders.

A comparison of three floating ring mixers has been made by Myers and co-workers [12] using a 63.5 mm diameter, 21D (diameters) extruder with the screw length reduced to 19D to provide space for the mixers.

The mixers compared were a TMR and two Barr mixers. The Barr sleeve mixer had elongated cavities in the rotor which joined pairs of circular cavities in the ring during rotation. The second cavity was connected to the next pair via a space between ring and barrel, the ring kept centrally by raised flanges between each diversion (**Figure.10.8**).

The Barr ring mixer had five rotor rings equally spaced on a central shaft with 6 floating rings alternating with the rotor rings (**Figure 10.9**). With holes in both rotors and rings, polymer was subjected to a mechanism partly resembling a CTM, but at right angles rather than in-line, i.e., between discs rather than between cylinders.

Experiments were performed using black and white acrylonitrile-butadiene-styrene pellets in a ratio of 220:1 white to black, with extruder speeds of 40 and 80 rpm. About 60% of the ABS entering the mixers was white with no black mixed in, which created big demands on the 2.4D mixers. Cross-sections of 1cm diameter strands showed the conventional screw had the most unmixed white sections, some of it unmelted.

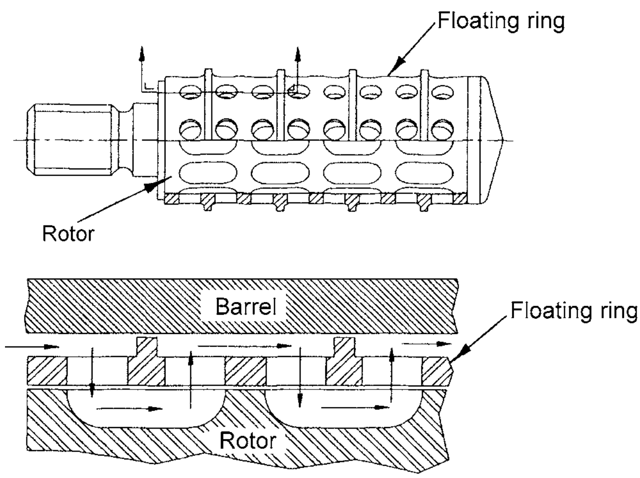

Figure 10.8 Barr floating ring mixer.

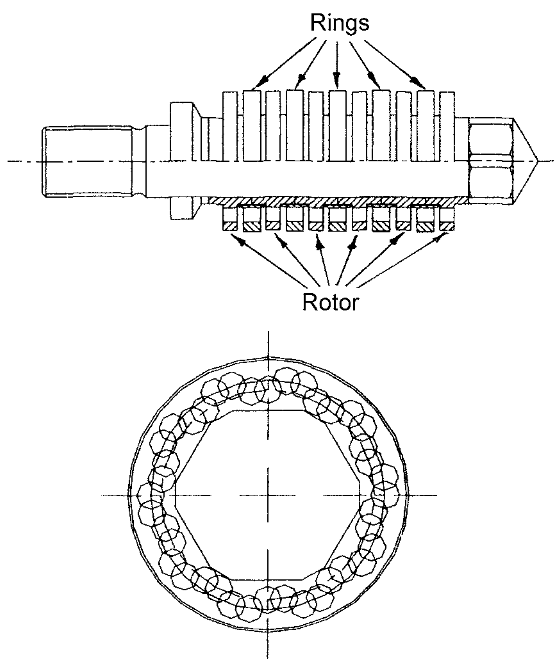

Figure 10.9 Barr multi-ring mixer.

The sleeve mixers were judged to perform well with minimal striations considering the amount of completely unmixed material entering the mixers. At a typical commercial 1:25 let-down ratio, mixing for the three mixers was adequate for acceptable extruded sheet. Trials with a Maddock mixer showed mixing to be considerably less than for floating ring mixers, confirming the conclusions of Esseghir and co-workers [11] presented in Section 8.6

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