Fractional Element Geometry in high-speed deep-flighted twin-screw extruder

The co-rotating twin-screw extruders have evolved through the years. Deeper flights lead to increased efficiencies and reduced shear rates in a twin-screw extruder. This feature is advantageous to increase the screw speed thereby maintaining mixing rates and increasing the volumetric capacity of the machine. An improvement in process efficiency is realized due to the reduction in viscous dissipation per unit mass of material. The ability to process material has benefited from improvements made in diameter ratio and specific torque. The advantages with deeper screw flights are higher intake capacity (especially in starve feed), lower melt temperature due to decreased shear stress, greater devolatisation capacity. Further, the ability to process certain shear and temperature sensitive materials is greatly enhanced in an extruder with deeper flights. The increase in melt temperature due to the kneading elements at high speeds is solved by fractional lobed element geometry with unequal tip angles. This geometry can easily replace standard kneading elements.

Forty years ago, Erdmenger had determined the need for fractional elements. Erdmenger has said that, "One disadvantage that was hitherto encountered in apparatuses of this type (twin-screw extruders) was that it was only possible to vary the dimension lying in the axial direction but not the dimension lying transversely to the axis, e.g. the thickness of the layer of material used, which often has an important effect on the transfer of heat or the transfer of material or the course of the reaction, which in practice is the most important alteration".

The standard twin-screw elements have equal tip angles for all lobes. These limit the types of elements that operate in a twin-screw extruder if the geometry is based solely on the design of Erdmenger. For example, in an eccentric trilobed kneading element, the small tip angle leads to higher wear rate. Increasing the tipangle gives a circular shape to the element and reduces the free volume available in the extruder. Elements having different tip-angles have been invented by Padmanabhan. These elements continue to work as conjugate pairs while suiting the needs of twin-screw extrusion. The new element geometry provides greater flexibility in design of individual elements, especially in enhancing "Elongational strain", that is critical to dispersive mixing.

The end profile of a fractional element formed as a result of transforming a one-lobe to a four-lobe profile as shown in Figure 1. This shows the profile at a location that is halfway through the transformation. At every step of the transformation the profile obtained has to be intermeshing and fully wiping. Figure 2 clearly shows the basis for the classification. The last two digits provides the location of the transformation from one-lobe to two-lobe profile. If '*n*' is the number of lobes on one end with less lobes and '*N*' is the number of lobes on the other end with more lobes, then the condition for perfect transformation is that '*N/n*' should be a whole number. Figure 3 shows the configuration of the extruder screw where the regular kneading blocks are formed with fractional lobed geometry. The screw speed and configuration are the two key variables. The zone temperatures are shown on the barrel segments. The kneading length in the mixing zone of both the configuration are maintained at 180mm and also increase in pressure matches both configuration.

The fractional lobed geometry shown in this configuration is selected based on certain observations made on the changes in cross-section during rotation of the corresponding geometry. The motivation was to avoid high pressure points during the full 360 degree turn of the flights. Processing on various materials with fractional-lobed elements have already been carried out. This involved processing of polymers with a high filling of carbon black, organic pigments, glass fibre, etc. Fractional elements were also used on PVC compounding. Using fractional elements, it is possible to finely control the compounding process to a greater extent than what is considered possible with standard elements.

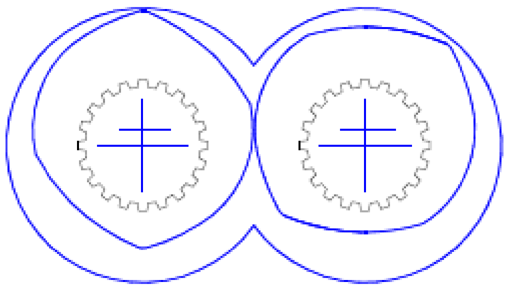


Figure 1 - Fractional Four-lobed Element Geometry 1.4.50

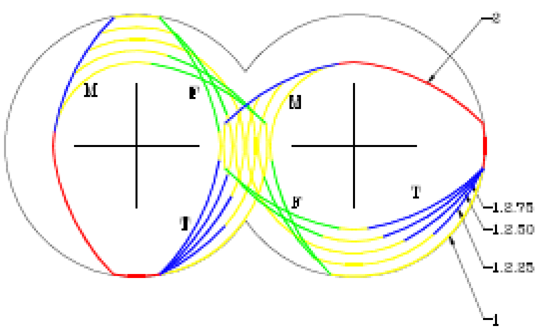
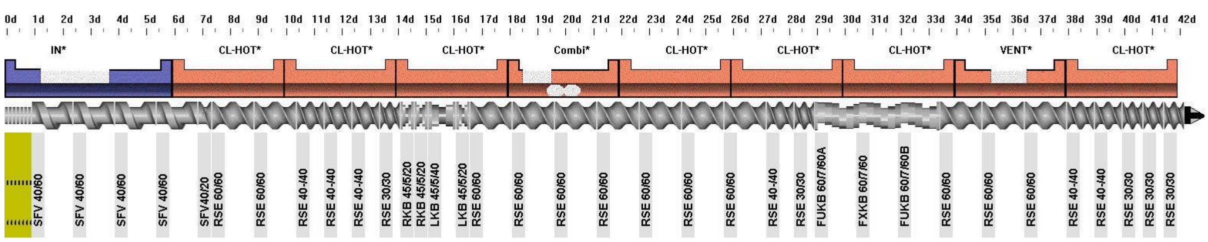


Figure 2 - Generation of Fractional Geometry



Plant : Steer ADC	Extruder : Omega 40	Shaft Length : 1680 mm	Diameter : 39.7 mm
Line Code : ADC2	Author : Dr. Babu	Max. RPM : 600	Offset : 0 mm
Configuration Code : LLDPE Tio2 Fr	Revision Number : 0	Max. KW : 70	

*CL-HOT - Closed Hot Barrel
*Combi - Combi Barrel
*IN - Intake Barrel
*VENT - Vent Barrel

Figure 3 - Configuration with Fractional Kneading Blocks