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Influence of Screw Design and Processing Parameters on Residence Time Using Twin-Screw Extruders.

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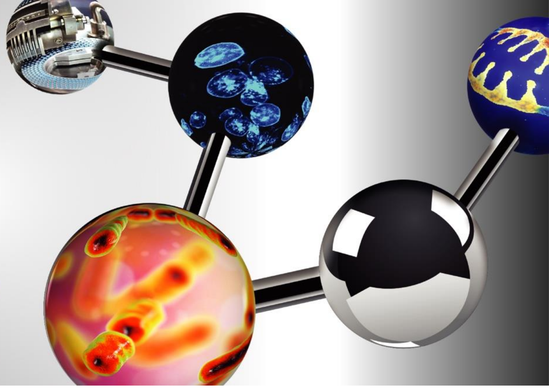

PURPOSE

To evaluate the effect of screw design, rpms and throughput rate on residence time (RT) and residence time distribution (RTD) in co-rotating intermeshing twin screw extruders (TSE) for melt extrusion using a simple formula. The goal is to give an understanding of potential thermal exposure of thermally sensitive API's and polymers to elevated temperatures during melt extrusion in a TSE process section.

METHOD(S)

A Leistritz ZSE 27 MAXX co-rotating TSE with 28.3 mm screws diameter at 40:1 L/D (1.66 OD/ID, 14.3 cc/dia free volume) and a Leistritz ZSE 18 HP co-rotating TSE with 18 mm screws diameter at 25:1 L/D (1.5 OD/ID, 3.2 cc/dia free volume) were compared to test for residence times based on screw design and changes in process parameters. 5 & 10 MFI polypropylene were used for residence time evaluation on the 27 mm and Copovidone was used on the 18 mm. Throughput rates and rpm were varied to see the effect on residence time and processing temperatures were adjusted based on material properties and requirements. Color tracers were added to the main feed throat of all machines and the residence time was visually assessed.

$$Degree\ of\ Fill = \frac{(Rate * 0.2777)}{\left(Free\ volume * \left(\frac{screw\ rpm}{60}\right) * 5.6 * 0.35\right) * 100}$$

$$RT\ for\ Filled\ Section = \frac{\left(3.08 * \left(\frac{Lf}{h}\right) * \left(\frac{h}{10}\right) * \left(\frac{D}{10}\right)\right)}{Q}$$

$$RT\ for\ Starved\ Sections = \frac{\left(A * \left(\frac{DOF}{100}\right) * \left(\frac{Ls}{100}\right)\right)}{Q}$$

Free Volume = cc/diameter; Lf = length of filled section in mm; Ls = length of starved section in mm; h = flight depth in mm; D = Screw OD in mm; A = open cross-sectional area; Q = Flowrate in cm^3/sec.

RESULT(S)

Equations 1 – 3 were used as a baseline to understand what type of residence times should be expected at various rates, rpms, and screw designs. Overall, the results match (figures 2-4) with a largest difference between calculated and actual of 7 seconds (Orange = actual RT, Blue = calculated RT). Trends were as expected, and no outliers were seen. As free volume in the system increases, so will the RT. As the screw speed increases with a constant throughput, the RT will shorten slightly and the RTD will increase. As the rate increases with a constant screw speed, the RT will shorten and the RTD will decrease.

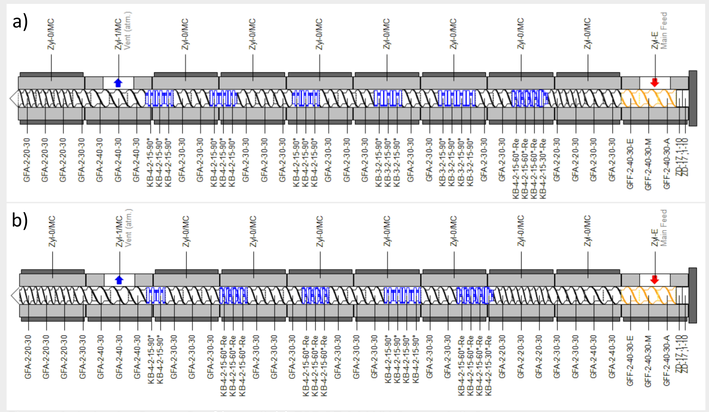

Figure 1: Leistritz Screw Profiles a & b) ZSE 27 MAXX Screw 1 & 2.

Table 1: ZSE 27 mm MAXX Residence Times and calculations.

Screw #1					Screw #2				
5 MFI					5 MFI				
RPM	Rate	RT (sec)	Peak RT (sec)	RT (calc.)	RPM	Rate	RT (sec)	Peak RT (sec)	RT (calc.)
200	22	34	42	40.09	200	27	27	31	35.79
400	22	26	32	28.86	400	27	21	24	23.52
400	40	19	23	20.91	400	48	15	17	18.6
600	22	20	25	24.88	600	27	15	18	19.43
600	52	14	17	14.91	600	63	11	13	13
800	22	16	21	22.97	800	27	12	15	17.39
800	65	10	14	11.55	800	78	8	11	10.03
10 MFI					10 MFI				
RPM	Rate	RT (sec)	Peak RT (sec)	RT (calc.)	RPM	Rate	RT (sec)	Peak RT (sec)	RT (calc.)
200	28	30	35	36.39	200	32	25	29	34.03
400	28	23	27	24.98	400	32	18	21	21.76
400	50	16	19	19.01	400	50	14	18	18.34
600	28	17	21	21.17	600	32	13	17	17.67
600	63	12	14	13.64	600	68	10	13	12.65
800	28	14	18	19.27	800	32	11	14	15.63
800	75	9	11	10.77	800	83	8	10	9.79

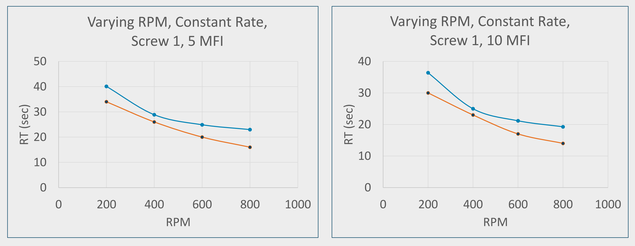

Figure 2: ZSE 27 MAXX Screw 1 RT Results with varying rpm.

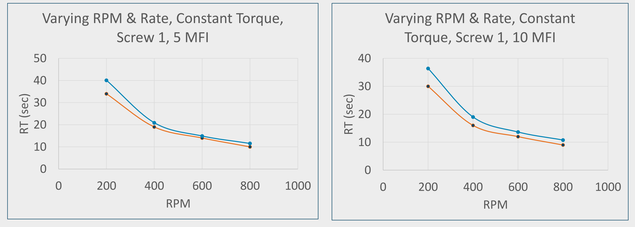

Figure 3: ZSE 27 MAXX Screw 1 RT Results with varying rpm & varying rate with constant torque.

CONCLUSION(S)

Overall, it can be concluded that both increasing the rpm and increasing the feed rate will reduce residence time. Using this simple calculation, which is meant to be insightful if not 100% accurate, the residence time can be approximated and evaluated to help gauge the thermal exposure a material will experience in a TSE process section. Optimum processing parameters can then be determined to help reduce API degradation and improve processing abilities.

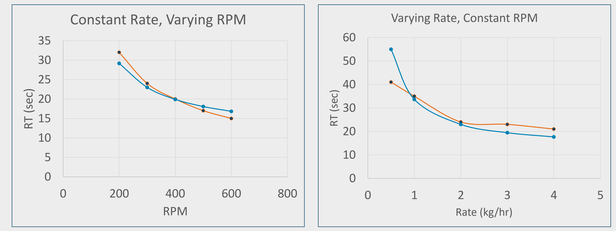

Figure 4: ZSE 18 HP RT results.

Table 2: ZSE 18 mm HP Residence Times and calculations.

RPM	Feed Rate (kg/hr)	RT (s)	RT (Calc)	RPM	Feed Rate (kg/hr)	RT (s)	RT (Calc)
200	2	32	29.16	300	0.5	41	54.96
300	2	24	22.99	300	1	35	33.65
400	2	20	19.91	300	2	24	22.99
500	2	17	18.06	300	3	23	19.44
600	2	15	16.82	300	4	21	17.66

Figure 5: Leistritz ZSE 18 mm HP Screw Profile.

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