Helpful Data for Tests with Extruder Sensors

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This laboratory report is a revised version of the well known LR-04E dating back to 1989. With the introduction of the Thermo Scientific PolyLab A (1995) and in the Thermo Scientific PolyLab OS (Fig. 1, 2005) Torque Rheometer systems got more flexible, in response to growing customers demands. The listed data (Tab. 1a/b) is obtained during laboratory testing and should be regarded as recommendations. Deviations are possible.

Extrusion process

This continuous process is used for the production of semi-finished goods such as films, sheet profiles, tubs and pipes. Laboratory or so called measuring extruders are used for the same applications, to create small amounts of specimens and study the feasibility of new materials, processes, additives. By using capillary dies and evaluation software the laboratory extruder is used as a rheometer to measure the viscosity and other rheological properties.

Plastic material (pellets / powder) is loaded into a hopper and then fed eventually by a metering feeder (Force Feeder, twin screw or single screw) to the extruder barrel. By the action of a continuously revolving screw the polymer is transported and molten. At the end of the heated barrel, the molten plastic is forced out through the die that is cast in the shape of the finished product (Fig.2).

Depending on the polymer special screws (Fig. 3), temperature profiles, pre drying, venting is required for optimal performance. E.g. PET needs pre drying, while PVC dry blend produces best results in conical counter rotating extruders (Fig. 4). Table 1a/b summarizes the valuable data and give a good starting point for new developments on new products. Most raw material manufactures use the CAMPUS database [1] as platform for commercially available grades, also here are general hints for processing and the setup of an extruder are given.

The overview focuses on the Single Screw extruders, for some polymers Conical Counter rotating Twin-screw extruders (CTW) are recommended. Co rotating Parallel Twin-screw compounders (PTW) are not just discussed in detail, just indicated for some materials. Temperature ranges apply, while the compounding process itself is far more complex.

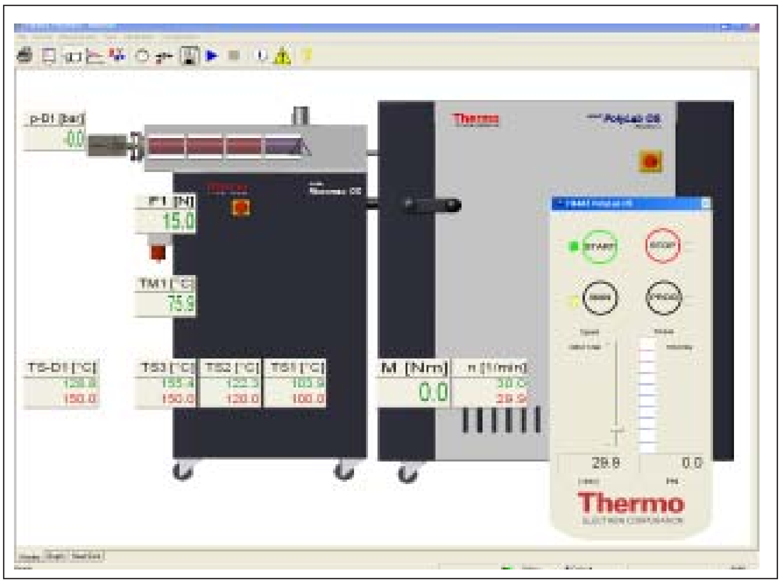

Fig. 1: Monitor Software: modular PolyLab OS, Rheodrive RD4 with Rheomex 19/25 OS

Trouble shooting

Influence of molecular weight:
The molecular weight influences the Melt flow index and viscosity. Low molecular weight results in lower viscosity, these polymers can be processed at lower temperatures.

Streaks or die lines:
These are generally caused by build-up in the die or damage to the die. You will likely need to clean your die. Use a purge resin like HDPE.

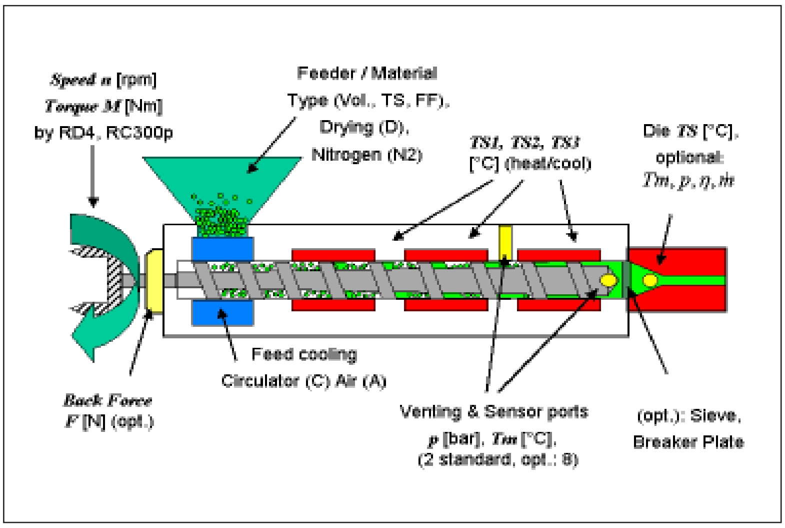

Fig. 2: Principle sketch of a measuring extruder (single screw).

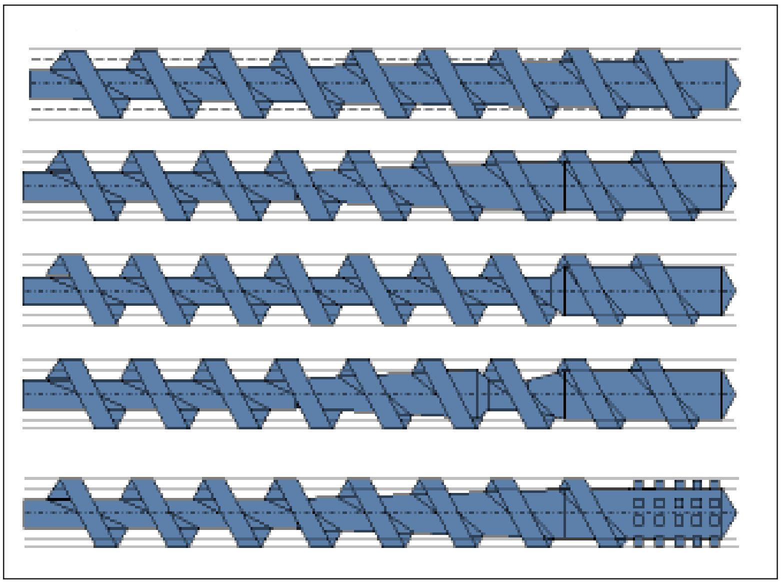

Fig. 3: Single Screw Extruder, screw types: standard conical core, metering (met.), short metering (short met.), venting(v), mixing.

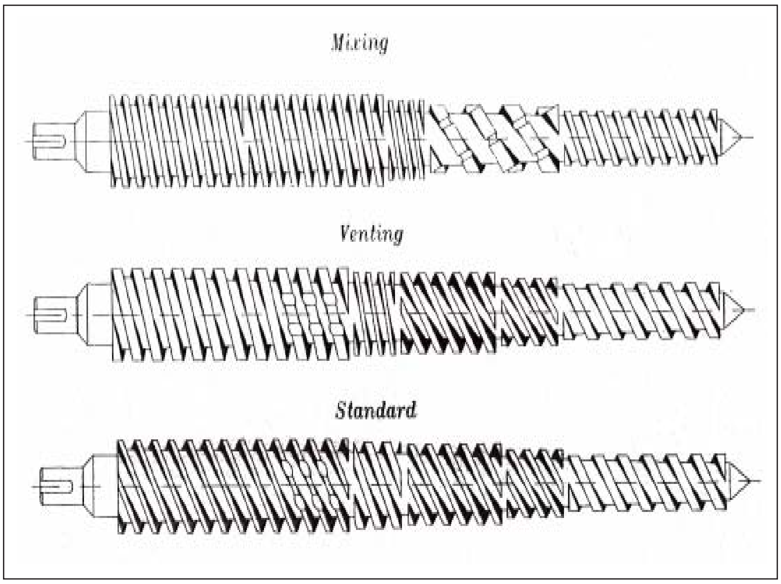

Fig. 4: Conical counter rotating twin screw extruder, screw types (CTW): intensive mixing (i), venting (v), standard screws (s) for PVC dry blend.

Bubbles or off gassing:
Check the moisture level of the resin. If moisture is acceptable, then the melt may be too hot, so lower the temperatures (e.g. additives).

Surging (pressure and torque widely fluctuating):
Check the feed throat cooling and focus on extruder zone 1 for resolution. Slowing the rate down may help. A different screw design (e.g. with metering zone) may help to stabilize continuous feed.

Gels or contaminants:
Make sure you are at the proper process conditions. Run hotter and slower if you can. Remove any additional components you are adding [5] (recycled materials, masterbatch, etc.).

Non-uniform thickness in the machine direction[5]:
Check the extruder output for surging. If the output is stable, you may be experiencing draw resonance. Reduce the take off speed. If this is not possible, attempt to heat up the melt and die.

Melt fracture:
Try a metering screw of same compression ration. Try to use a different die, e.g. bigger gap, bigger diameter. Reduce the output or increase temperature.

Bridging in feed zone:
For sticky, non free flowing materials, use a force feeder or volumetric twin screw feeder.
If the material is suitable (pellets free flowing powders and beads) it is usually a temperature issue. Use a circulator to cool the feed zone. Screw can be overheated or zone TS1 temperature too high. Screw speed is too low esp. with the use of metering feeders. Check material temperature, might be too high after drying.

Carbon specks:
Are caused by dirty equipment and too high residence times e.g. Extruder run dry at shut down and not cooled promptly[5].

Poor gloss or transparency:
Increased cooling power, reduced temperature on the take off system or increased melt temperature improves surface quality[5].

Material	Extruder	Compounder	Screws	Feed Zone
LDPE	19/25	PTW	2:1, 3:1, met.	C
HDPE	19/25	PTW	2:1 3:1 met.	C, A
PP	19/25	PTW	2:1, 3:1 met.	A
PS	19/25	PTW	3:1 met.	C
PS–HI	19/25	PTW	3:1 met.	C, A
ABS	19/25	PTW	2:1, 3:1 met. drying required	A, Nitrogen purge
SAN	19/25	PTW	2:1, 3:1 met.	A
EVA Copolymer	19/25	PTW	2:1, 3:1	C
TPE	19/25	PTW	2:1, 3:1	A, C
PUR	19/25	PTW	2:1, 3:1	C
TPU	19/25	PTW	2:1	A
PSU	19/25	PTW	3:1 met, die ring heater, drying required	A, C, Nitrogen purge
PEEK	19/25	PTW	3:1 met, die ring heater, drying required	A, Nitrogen purge
LCP	19/25	PTW	4:1 short met., die ring heater, drying required	A, Nitrogen purge
PA	19/25	PTW	4:1 short met., die ring heater , drying required	A, Nitrogen purge
PET	19/25	PTW	4:1 short met., die ring heater , drying required	A, Nitrogen purge
PBT	19/25	PTW	4:1 short met., die ring heater , drying required	A, Nitrogen purge
PMMA	19/25	PTW	3:1 met	C
POM	19/25	PTW	3:1 met.	A, C
PC	19/25	PTW	3:1 met., die ring heater, drying required	A, C, Nitrogen purge
Rubber	19/10		1:1, 2:1, roll feeder	X
PVC, rigid				
PVC dry blend	CTW		Intensive mixing screws	A, C
PVC pellets	19/25 CTW		2:1 - Intensive mixing screws	A
PVC, soft				
PVC dry blend	CTW		Intensive mixing screws	C
PVC soft, pellets	19/25 CTW		2:1, 3:1 - Intensive mixing screws	A

met. = metering
A = Feed section cooled by pressured air 1 - 2 bar
C = cooled by circulator 10 °C - 50 °C.

Material	TS1 [°C]	TS2 [°C]	TS3 [°C]	Die [°C]
LDPE	140 - 160	150 - 165	170 - 200	170 - 210
HDPE	150 - 160	160 - 170	180 - 220	180 - 225
PE UHMW	190	250	275	280
PP	140 - 180	160 - 200	210 - 240	210 - 240
PS	150 - 170	160 - 210	170 - 220	170 - 225
PS–HI	200	225	240	245
ABS	195	200	200 - 220	210 - 220
SAN	170	200	200	200 - 210
EVA Copolymer	100 - 160	120 - 170	130 - 180	130 - 180
TPE	220 - 240	250 - 270	280 - 290	270 - 280
PUR	170	170	175	175
TPU	170	190	210	210
PSU	250 - 270	280 - 330	285 - 365	285 - 365
PEEK	380	400	400	400
LCP	220 - 230	260 - 280	280 - 350	280 - 350
PA 6	230	250 - 280	270 - 290	270 - 280
PA 6.6	270	270 - 290	280 - 300	280 - 300
PET	230	250 - 280	270 - 290	270 - 280
PBT	160	190	220 - 240	220 - 245
PMMA	150 - 160	160 - 190	180 - 220	180 - 220
POM	140 - 160	150 - 165	170 - 190	170 - 190
PC	200	270 - 290	275 - 290	275 - 290
Rubber	70 - 90	X	X	80 -120
PVC, rigid				
Dry blend	150 - 170	160 - 180	170 - 190	170 -190
Pellets	155	165	185	185
PVC, soft				
Dry blend	120 - 150	140 - 160	160 - 180	160 - 180
Pellets	120 - 150	140 - 160	160 - 180	160 - 180

The temperatures are guideline values. Please check also the recommended processing temperatures given from the supplier of the polymer.

Drying of polymers

Polymer	Permitted residual moisture [%]	Density [g/cm °C]	Drying temperature [°C]	Drying time [h]
ABS	< 0.1	1.05	80	2-3
ASA	—	1.07	80	2-4
ASA/PC blend	< 0.1	1.15	100 - 110	2-4
CA	< 0.15	1.28	60 - 65	2-3
CAB	< 0.2	1.18	60	2-3
CP	< 0.2	1.2	60	3-4
LCP	—	1.62	150 - 160	4
PA 6	< 0.05	1.13	80	3-5
PA 66, 610	< 0.05	1.14	80	3-5
PA 11/12	< 0.05	1.04	85	4-6
PAA 30% GF	< 0.3	1.51	80	4
PAEK	< 0.05	1.3	150	4
PEAK high temperature	< 0.05	1.31	180	3
PAI	0.05 - 0.01	1.4	180	8
PAR	< 0.02	1.22	150	4
PAS	< 0.05	1.37	135	4.5
PBTP	< 0.03	1.3	120	2-3
PC	< 0.02	1.25	120	2-3
PC/ABS blend	< 0.05	1,12	100 - 110	2-3
PC/PBTP blend	< 0.02	1.22	105 - 115	2-4
PC/PETP	< 0.02	1.2	105 - 115	2-4
PE	—	0.94	90	1-2
PE with carbon black	—	0.95	90	3
PEC	< 0.02	1.2	130	4-6
PEEK	< 0.05	1.32	150	2-3
PEI	< 0.01	1.3	150	3-4
PEK	< 0.05	1.3	160	4
PESU	< 0.05	1.3	120	3-4
PET	< 0.004	1.34	170	6
PETP	< 0.02	1.3	120	3
PETG	< 0.05	1.27	65	3-4
PI	—	1.4	120	2-3
PMMA	< 0.04	1.19	80 - 100	2-3
POM	< 0.1	1.41	100	2-3
PP	—	0.9	90	1-2
PP with talcum				
PP with carbon black	< 0.03	0.91	105	3-4
PPA	< 0.15	1.43	80	8
PPE	< 0.03	1.08	110 - 120	3-4
PPE/SB blend	< 0.1	1.06	80 - 100	2
PPO	< 0.02	1.1	110	2
PPS	< 0.01	1.35	150	3-4
PPSU	< 0.2	1.29	150	2.5
PS	< 0.05	1.05	80	1-2
PSU	< 0.05	1.25	120 - 135	2-3
PUR	< 0.02	1.2	90 - 100	2-3
PVC	< 0.2	1.4	70	1
SAN	< 0.1	1.08	80	2-3
SB impact resistant	< 0.05	1.06	80	1-2
TPE	< 0.03	1.2	110	2-3
TPU	< 0.05	1.35	100 - 110	1-2

The data are guideline values. Please check also the recommended drying temperatures given from the supplier of the polymer.

Literature

[1] http://www.campusplastics.com/

[2]A. Franck, K. Biederbrick, Kunststoffkompendium, S. 323, 2. Aufl., Vogel Fachbuch Verlag (1988)

[3]Operating Condition Guidelines Styrone, http://www.dow.com/sal/process/ext/opcond.htm Dow Chemical Company (2005)

[4]LR04-E/D Laboratory Information Gebrüder HAAKE GmbH, (1989)

[5] ESTANE Extrusion guide, (2002)

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