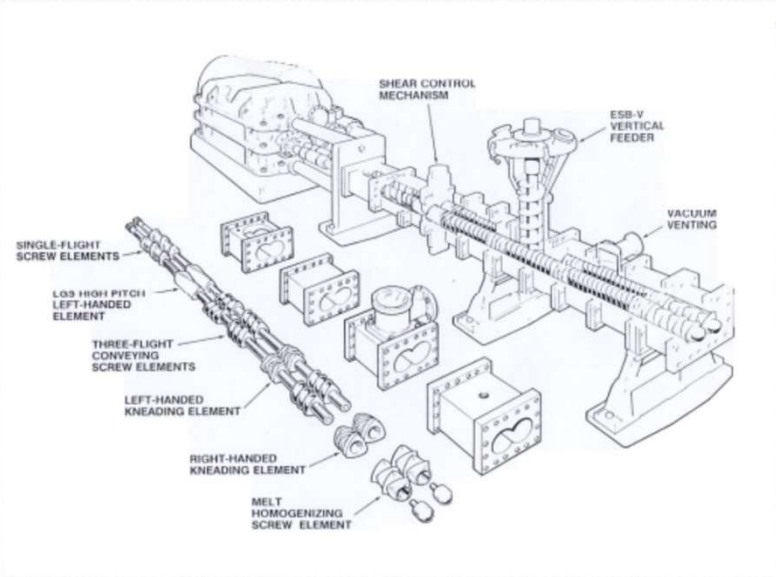
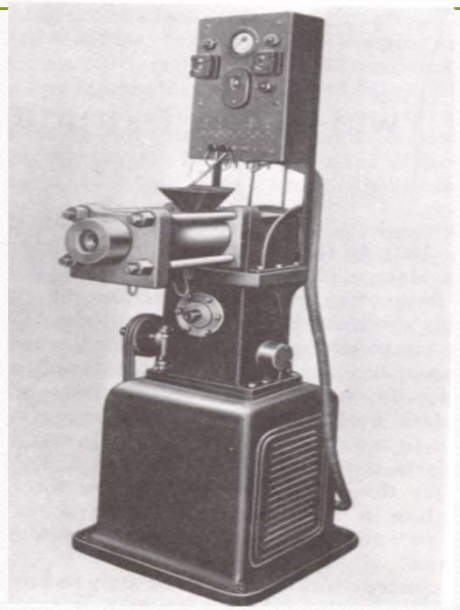
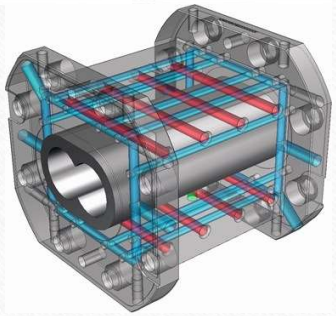
Co-Rotating Twin Screw Extruders

I.Ghasemi

Modular Design







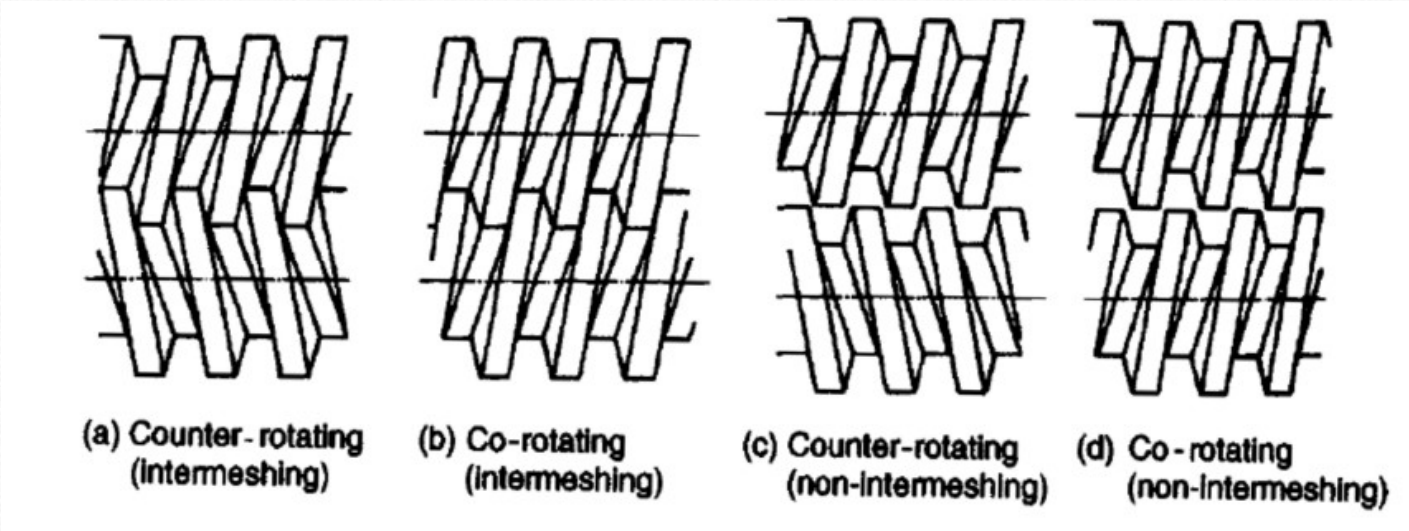
Classification of TSE

Classifications are based on:

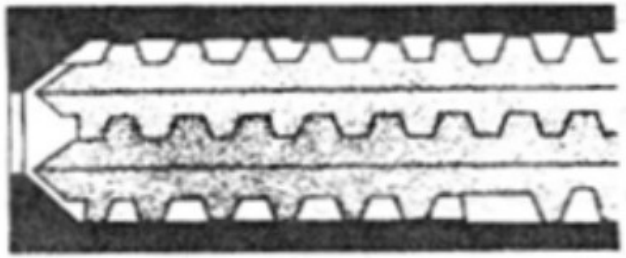
- Intermeshing & Nonintermeshing
- Rotation Direction
- Conjugation

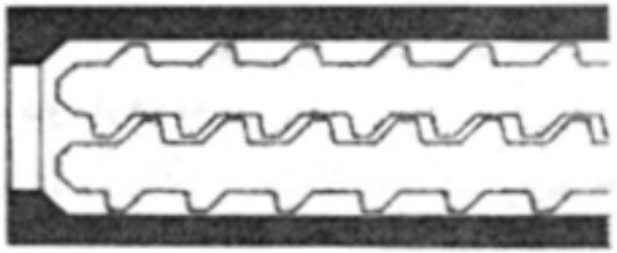
Erdmenger , DP (862668)

Intermeshing & Nonintermeshing



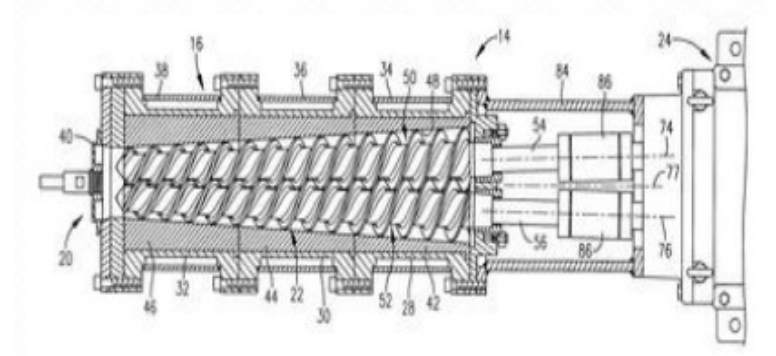
Conjugated & non-Conjugated



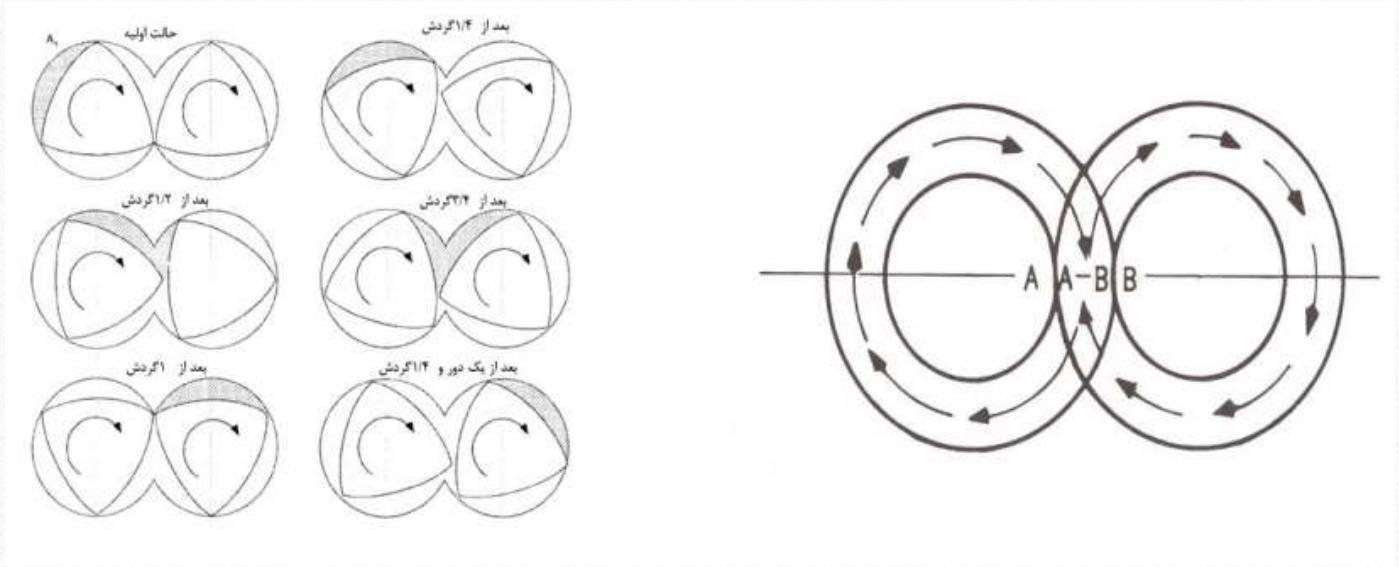


Conical Twin Screw Extruder

- Screw diameter decreases from hopper to metering section.
- D=184 mm decreases to 92 mm in discharge section.
- It is useful and suitable for temperature sensitive polymers like PVC.

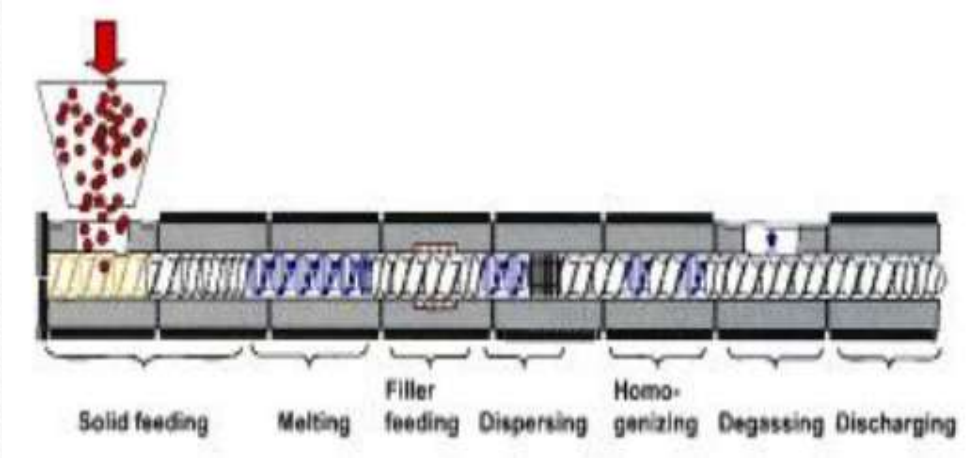


Flow Mechanism in Co-Rotating TSE



Functional Process

- Feeding section
- Plasticating
- Melt conveying
- Distributive mixing
- Dispersive mixing
- Devolatilization
- Pressure build up



Feeding Zone

- The feed capacity depends on free screw volume (channel depth, number of flights) , pitch, screw speed and bulk density.
- Three channel for Do/Di< 1.3 and for two channels Do/Di> 1.3
- L= 4-6 D and pitch is 1.5 D and reduce to 0.75-1 D in plasticating zone.

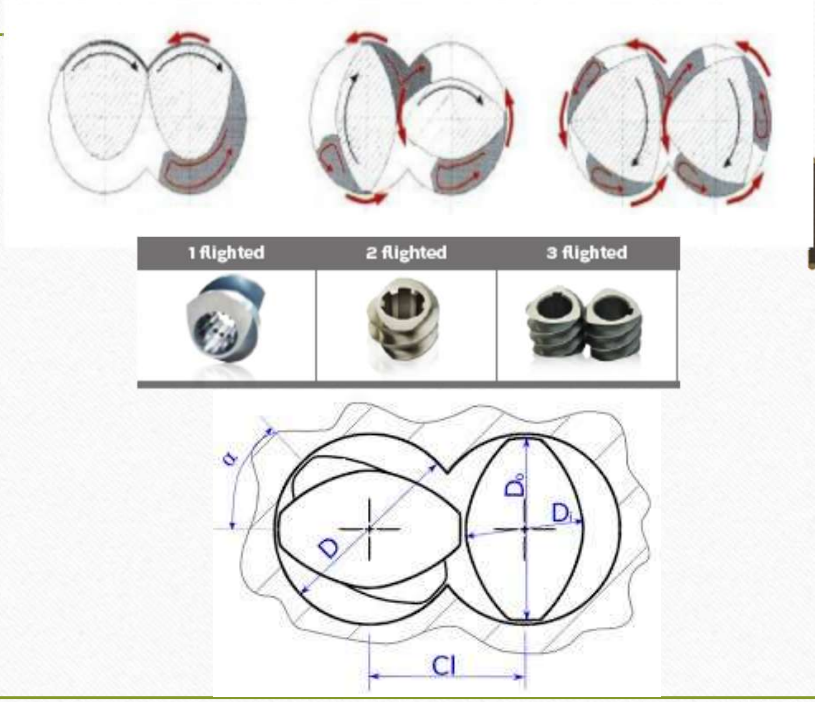


TABLE OF INTAKE ZONE ELEMENTS

ELEMENTS		CHARACTERISTICS			POTENTIAL USE
NOMENCLATURE	GEOMETRY & PROFILES	CONVEYING EFFICIENCY	FREE VOLUME	TENDENCY TO BREAKUP AND COMPACT	
Single Flight 'V' Element		Highest	Medium	Medium	All Types
Forward Screw Element		Low	Medium	Medium	Pellets
Deep Flight Schubkanten		Low	Highest	Medium	Tri-lobed Force-fed Extruders
Schubkanten Element		High	High	High	Powders, Mix of Powders and Granules
Special Schubkanten Element		Low	Highest	Medium	Bi-lobed Force-fed Extruders
Single Flight Elements		Medium	Low	Low	Alloys & Blends with different melt characterization

Melting Zone

- Significant melting starts at point where the screw is initially fully filled
- Material properties (crystallinity, viscosity).
- Typically double or triple-flight kneading blocks are used to facilitate melting.
- Up to 80% of mechanical energy input in twin screw extruder takes place in plastificating zone.

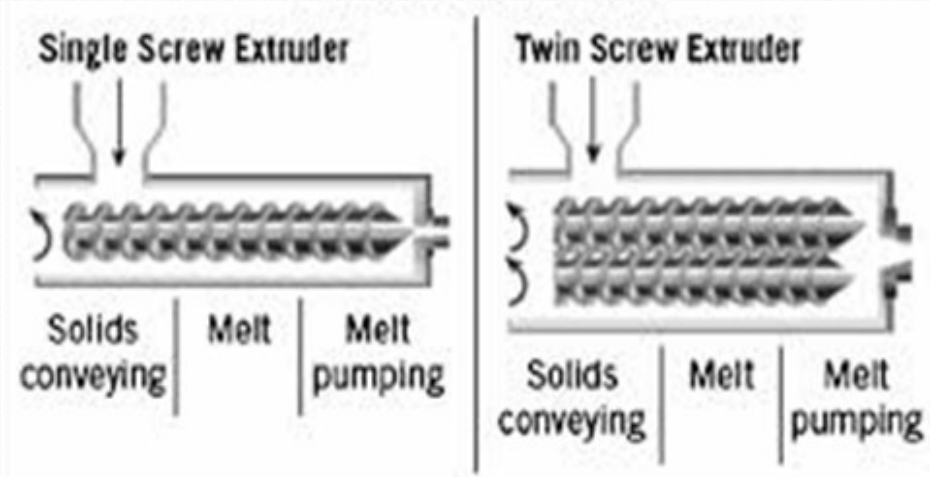
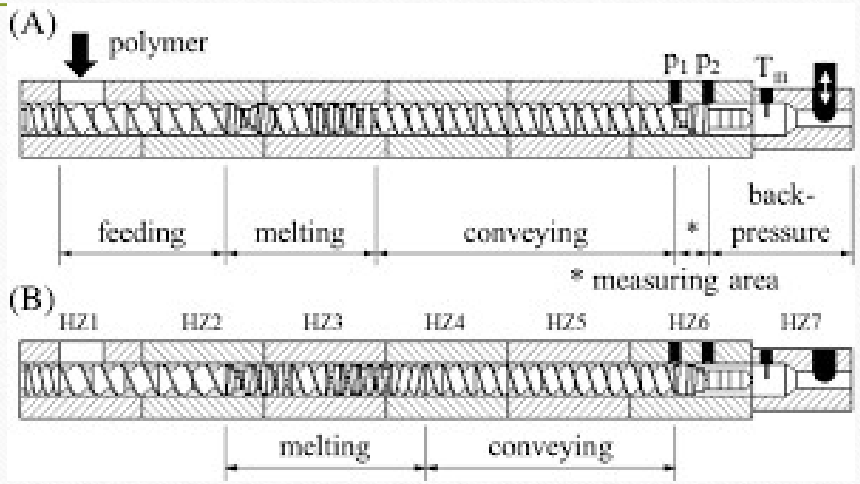


TABLE OF MELTING ZONE ELEMENTS

ELEMENTS		CHARACTERISTICS				POTENTIAL USE
NOMENCLATURE	GEOMETRY & PROFILES	MELTING ABILITY		DISPERSIVE MIXING ABILITY	SHEAR UNIFORMITY	
		AMORPHOUS	CRYSTALLINE			
Fractional Kneading Element		Highest	Highest	Highest	High	All types of Melting and Dispersive Mixing
Forward Kneading Element		Low	Medium	Low	Medium	Easy to Melt Crystalline Material
Reverse Kneading Element		Medium	High	Medium	Medium	Crystalline Material
3KB Kneading Elements		High	Highest	High	Medium	Amorphous
Neutral Kneading Elements		Medium	High	High	Low	Not usually recommended for Melting Used for Mixing

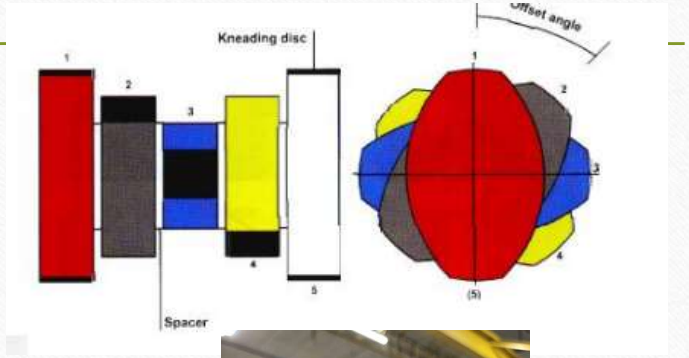
Melt Conveying Zone

- For simple melt conveying pitch=1D are commonly used. If there is side feeder the pitch should be 1.5 D for faster transportation.
- This zone is generally partially filled.

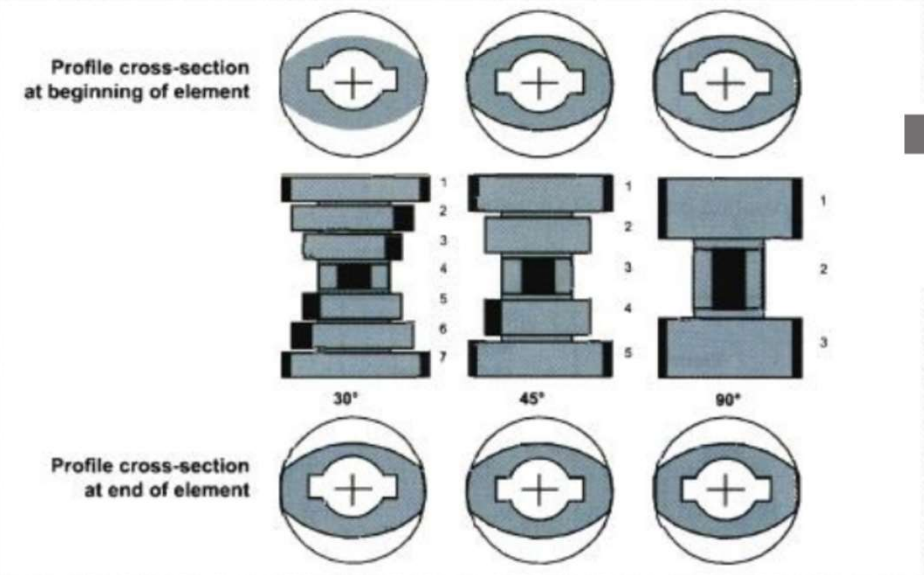


Dispersive elements; Kneading blocks

- The kneading elements mainly contribute to the mixing capability of the twin screws.
- Mixing occurs by shear and elongation during extrusion and performs both distributive and dispersive mixing actions, depending on its geometry.
- Distributive mixing evenly spreads the dispersed phase without breaking down particles.



Stagger Angle

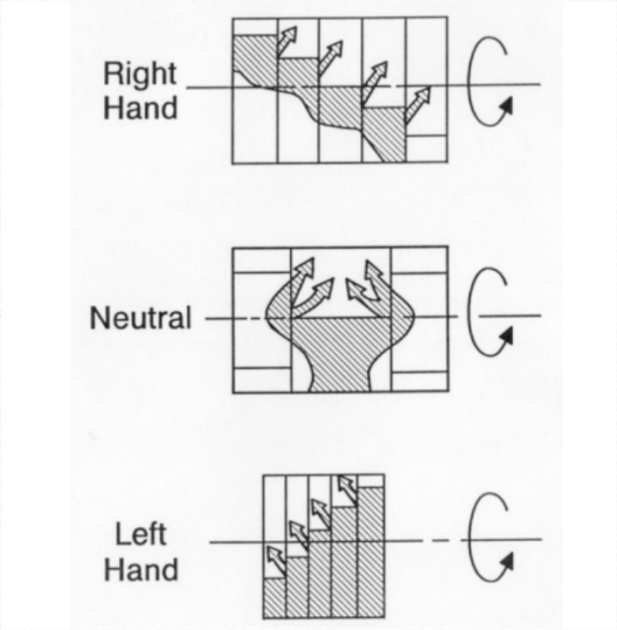


The Effect of Stagger Angle

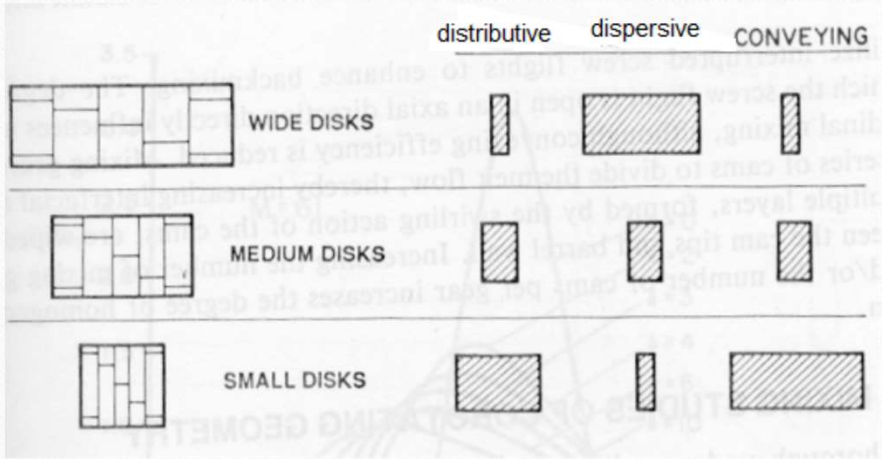
30°	45°	60°	90°	-60°	-45°	-30°
Least Severe			Neutral			Most Severe
Forward Conveying			None			Reverse Conveying

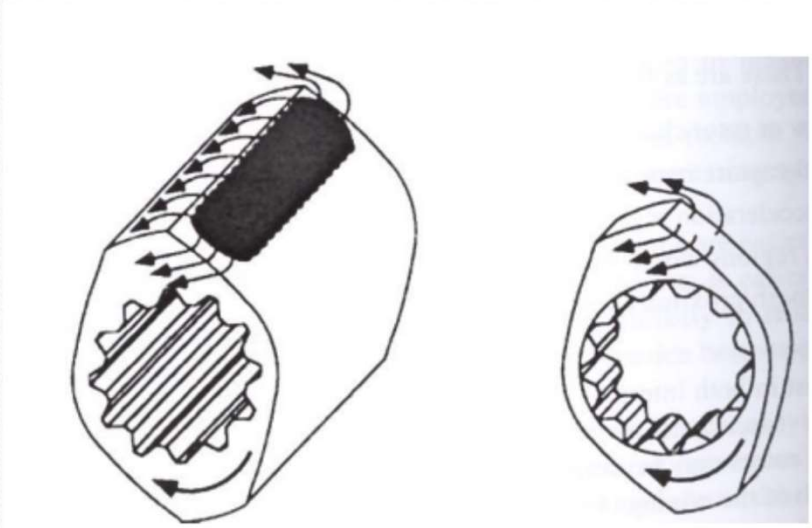
Reverse Kneading Block

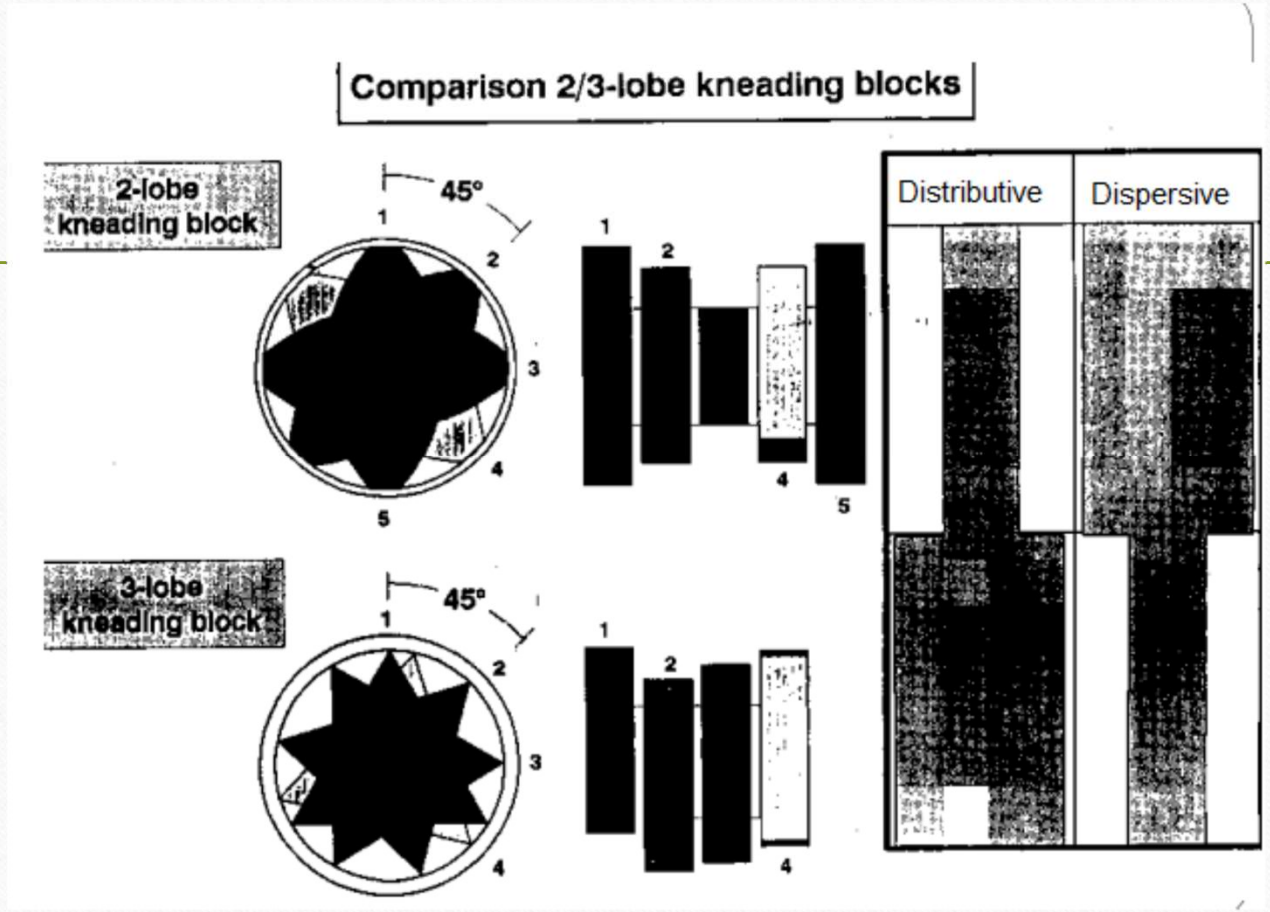
- As such, a reverse-conveying element has flights or discs that rotate counterclockwise.
- These manufacturers designate the reverse-conveying elements using the same nomenclature as for the forward-conveying elements followed by “LH.” The LH stands for Left-Handed, as these are left-handed elements and forward -conveying elements are right-handed.



Wide & Small Disk






Comparison 2/3-lobe kneading blocks
2-lobe kneading block
45°
1
2
3
4
5
3-lobe kneading block
45°
1
2
3
4
Distributive
Dispersive

KB 45/5/28

Smaller disc width

KB 45/5/14

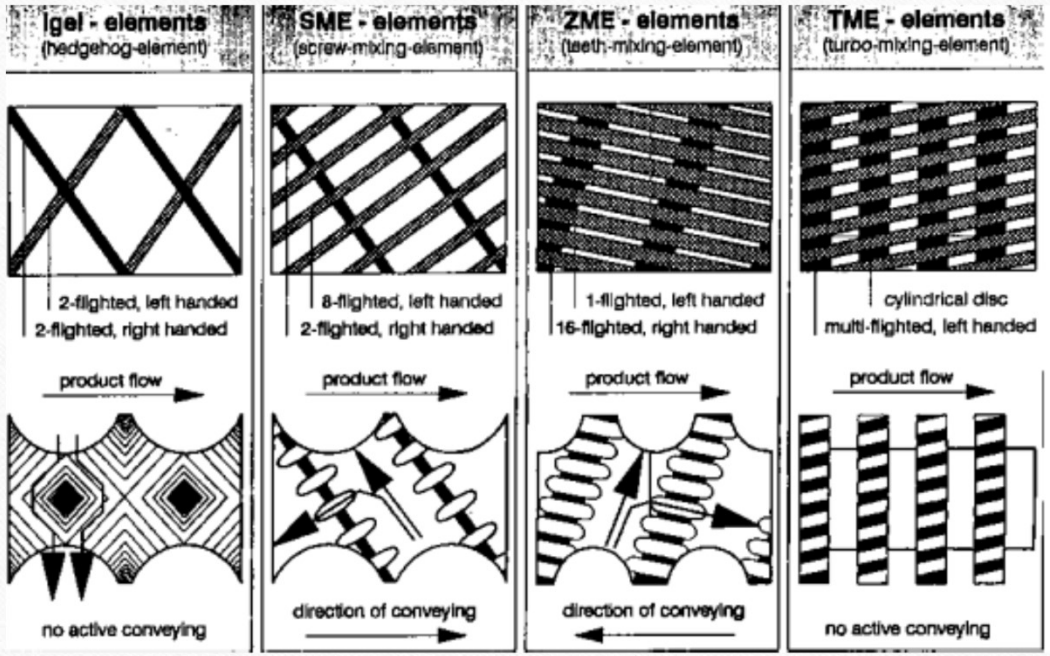
- *Enhanced mixing effect*
- *Reduced shear*
- *Increased product transport*

Larger staggering angle

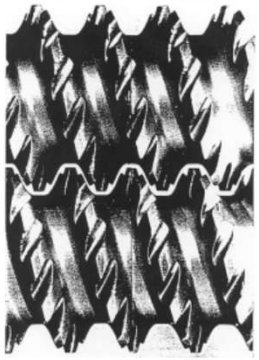
KB 90/5/28

- *Enhanced mixing effect*
- *Reduced product transport*

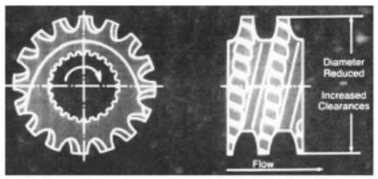
Distributive Mixing Element



Distributive Mixing Element



ZME



TME

Igel

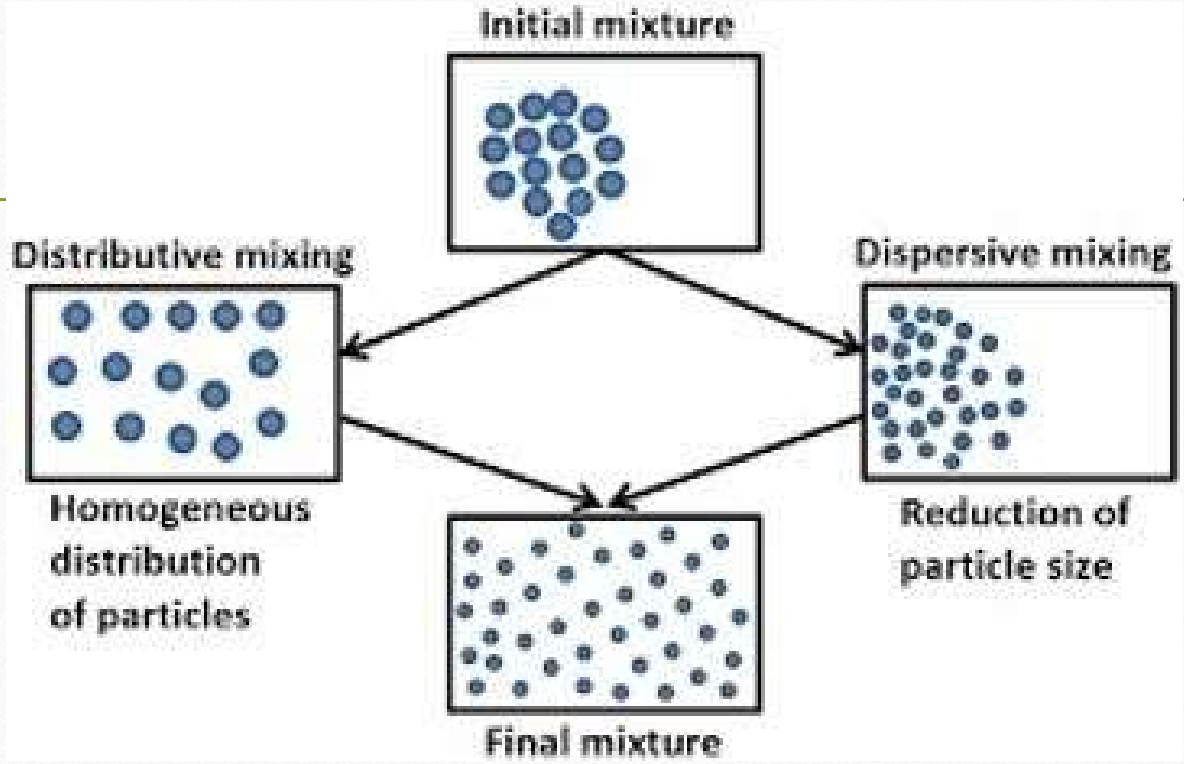
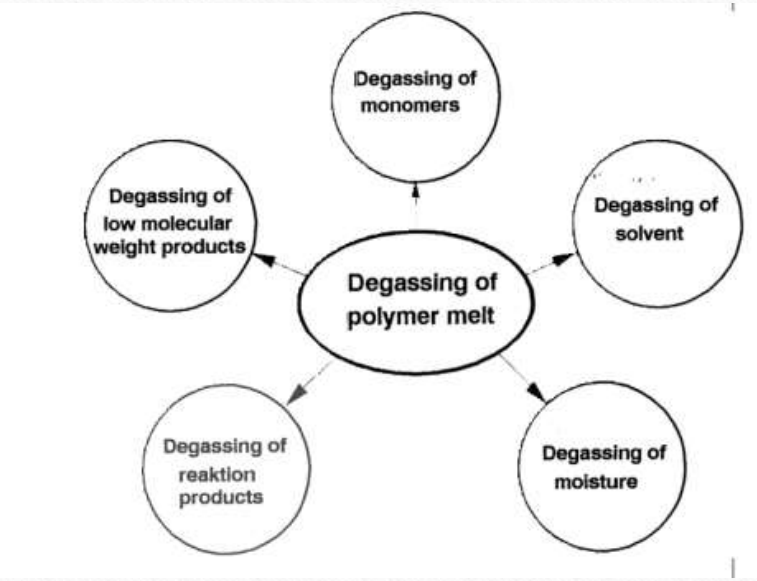

Initial mixture
Distributive mixing
Dispersive mixing
Homogeneous distribution of particles
Reduction of particle size
Final mixture

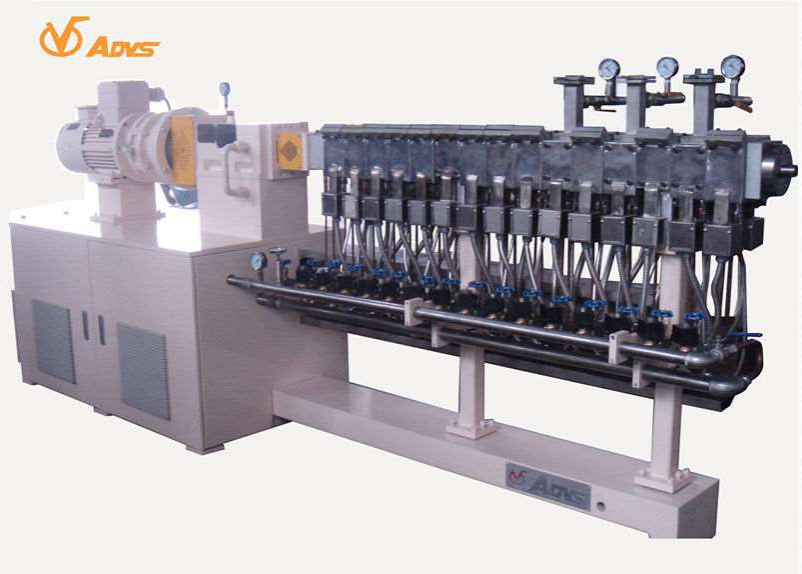
TABLE OF MIXING ZONE ELEMENTS							
		CHARACTERISTICS					POTENTIAL USE
ELEMENTS	GEOMETRY & PROFILES	UNIFORMITY IN SHEAR	ELONGATIONAL MIXING ABILITY	DISPERSIVE NATURE	CLEANING ACTION	WETTING ACTION	
Fractional Kneading Elements		High	Highest	High	High	Highest	Kneading of highly filled materials with Talc, Mica
Forward Kneading Elements		Medium	Low	Low	Highest	Low	General purpose mixing requirement
Reverse Kneading Elements		Medium	Low	Medium	Medium	Medium	Kneading under Compression
Neutral Kneading Elements		Low	Low	Highest	Low	Medium	Intense localised shear or dispersion of agglomerated Pigments
3KB Kneading Elements		High	Medium	Medium	High	High	A better substitute of RKB for general Purpose Mixing Requirement
Screw Mixing Elements		High	Low	Low	Low	Low	Use for Fiber dispersion with reduced attrition
Toothed Block		Medium	Medium	High	Low	Medium	Used for distributive Mixing in shallow flighted extruders
Tooth Mixing Elements		High	High	High	Low	High	Used for high stirring action while blending two or three different polymers
CME: * Erdmenger Type		Highest	Medium	Medium	Low	High	Generally with high clearances between elements, Effective in introducing uniform high intensity shear action
CME: * Sakagami Type		Highest	Highest	Low	High	Highest	

Devolatilization; Degassing; Venting

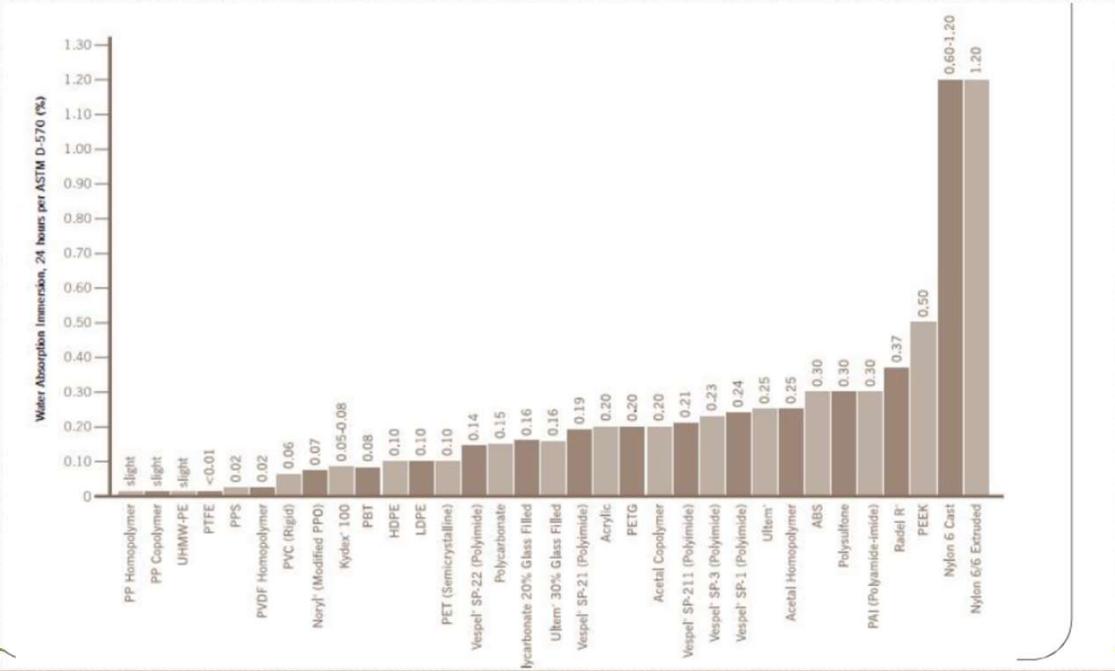


Devolatilization; Degassing; Venting

- Load of Volatiles Is below 1% Weight One Vent Port.
- Load of Volatiles Is 1-10% Weight More than One Vent Port.
- High Concentration of Solvents, Condensation Polymerization, etc.3-5 Ports.

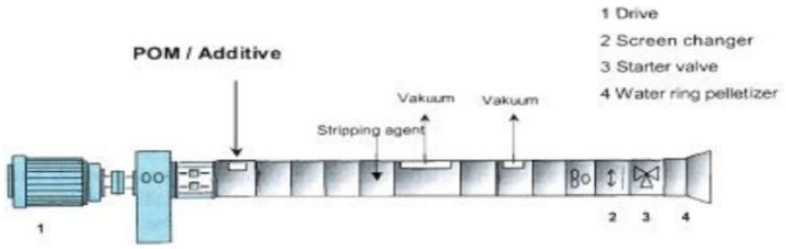


Hygroscopic Polymers

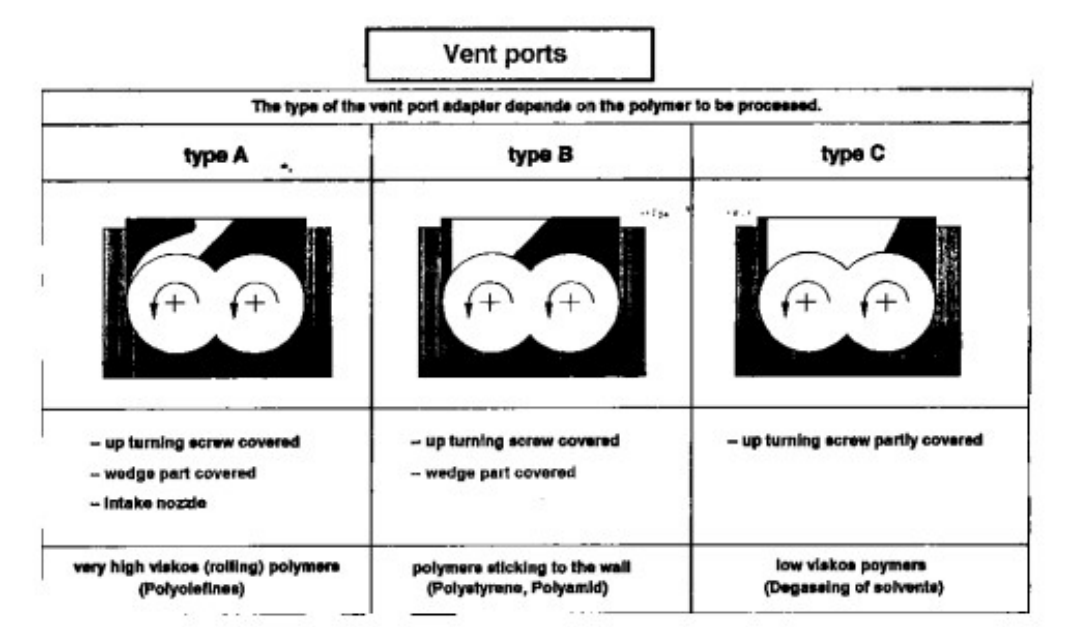


Stripping Agent

Stripping agent	H_2O	N_2	CO_2
Molecular weight	18.02	28.01	44.01
V [m^3/h] at P_0 = 1013 mbar	2.16	1.38	0.88
V [m^3/h] at P_0 = 100 mbar	21.85	14.05	8.94
ΔT/°C	~15	–	–



Design of Vent Port Throat

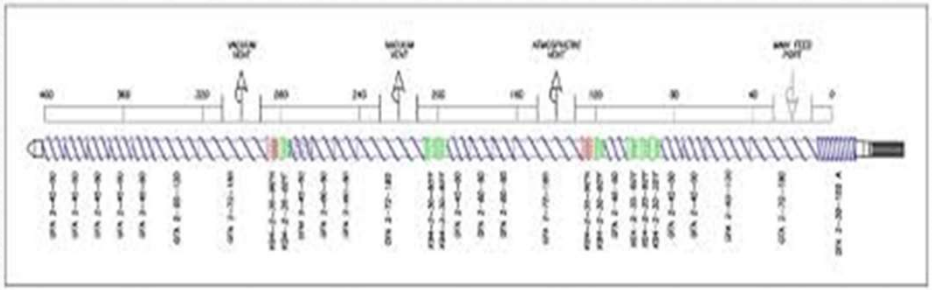


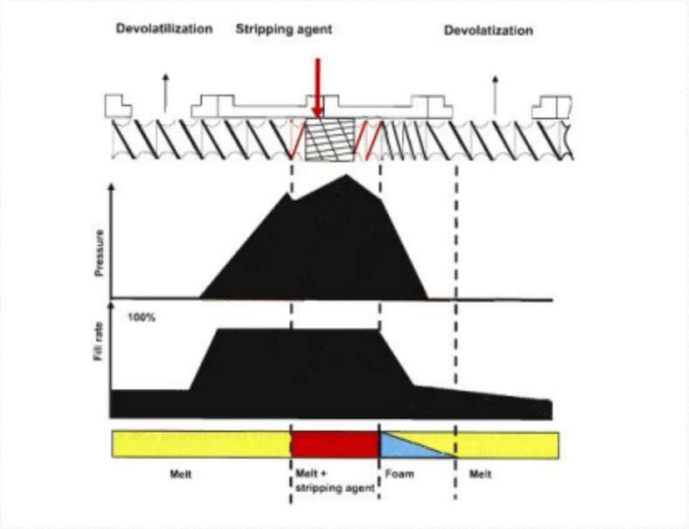
Vent ports

The type of the vent port adapter depends on the polymer to be processed.

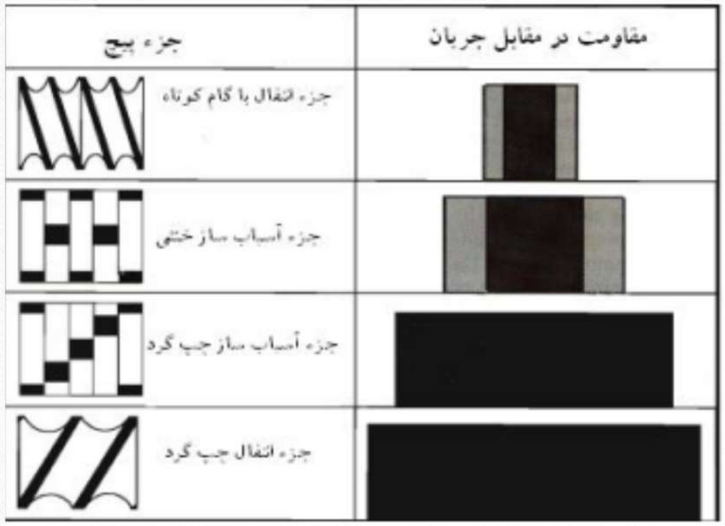
type A	type B	type C
– up turning screw covered – wedge part covered – intake nozzle	– up turning screw covered – wedge part covered	– up turning screw partly covered
very high viskos (rolling) polymers (Polyolefines)	polymers sticking to the wall (Polystyrene, Polyamid)	low viskos poymers (Degassing of solvents)

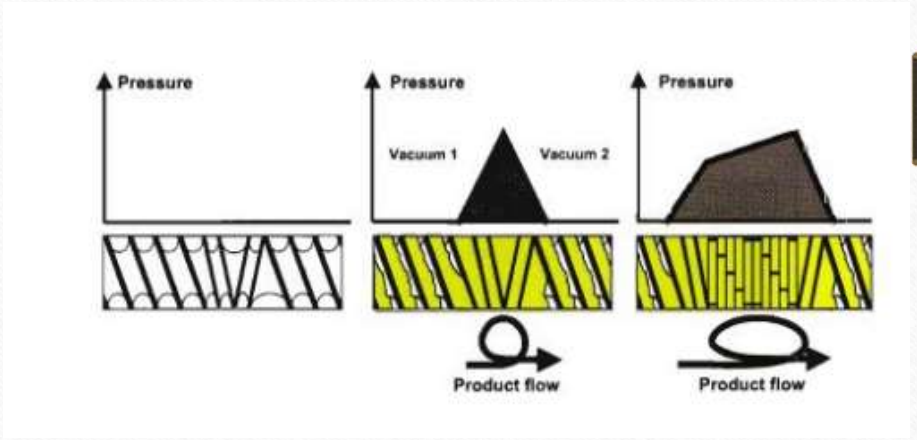
Typical Screw Configuration





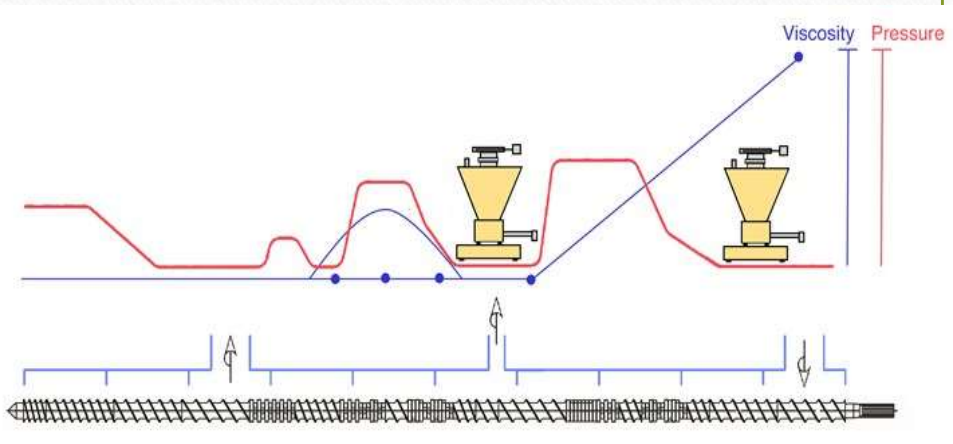
Rear Elements

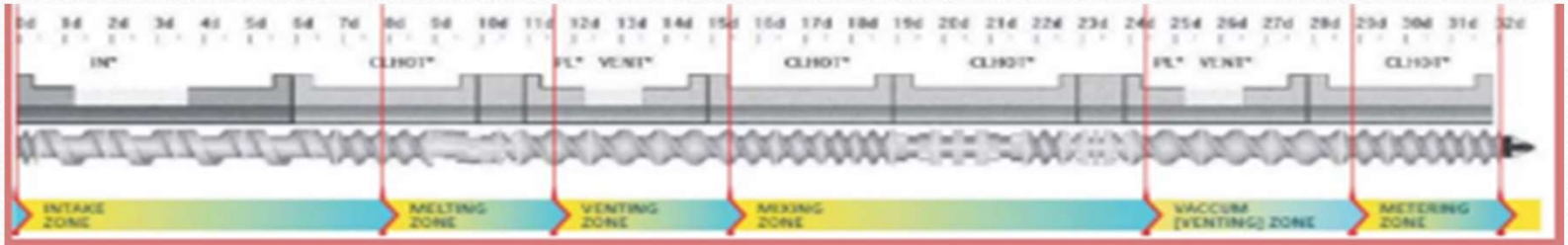




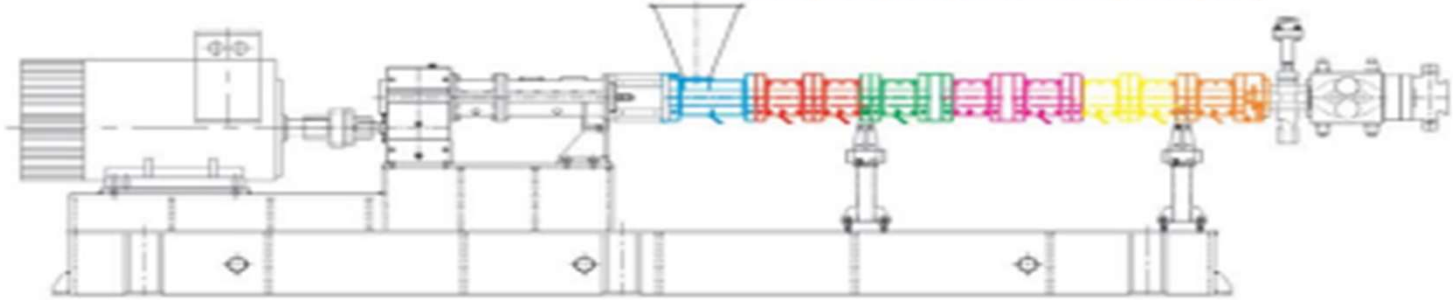
Pressure Build up Zone

- This zone is located in the extruder in the discharge zone and the upstream of each backward pumping screw extruder.
- The aim of the design is generally to generate of required pressure consuming as little energy as possible.
- Single flighted conveying element (with low pitch 0.2- 0.6) can generate the pressure with less energy input.

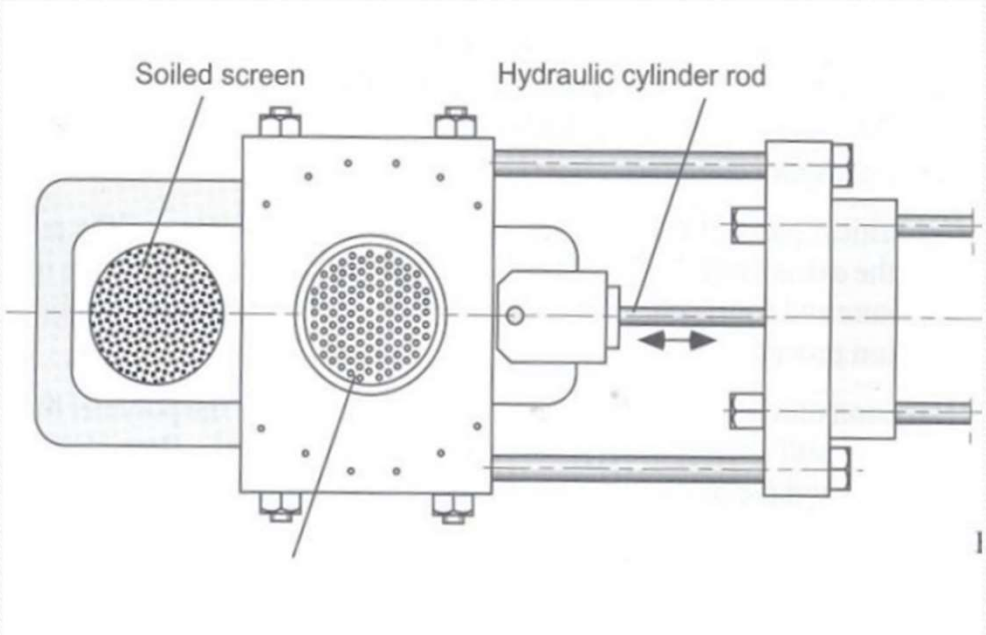


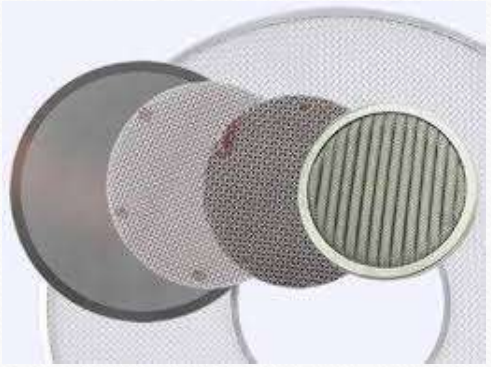


Zone 1	Intake zone	For introducing the material into the extruder.
Zone 2	Melting zone	For heating and melting the material and achieve partial or total mixing.
Zone 3	Venting zone	For removing volatiles and moisture.
Zone 4	Mixing zone	For ensuring proper mixing.
Zone 5	Vacuum zone	For completely removing the volatiles and moisture to the required levels.
Zone 6	Metering zone	For building up the required pressure at the die.



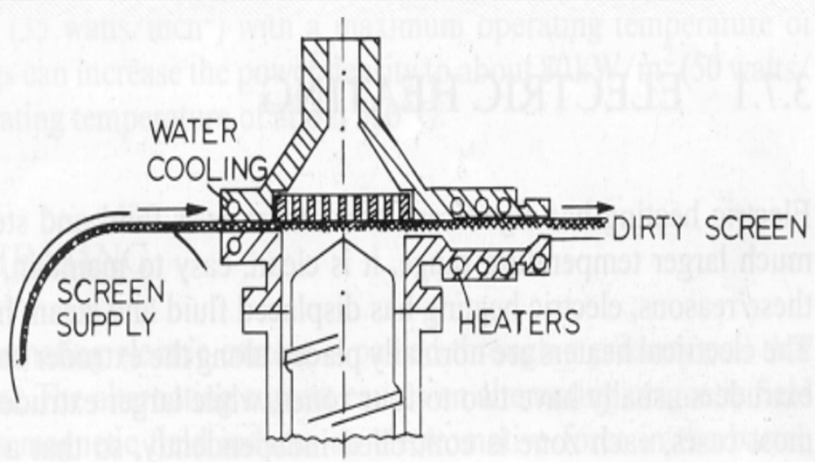
Slide Plate Screen Changer





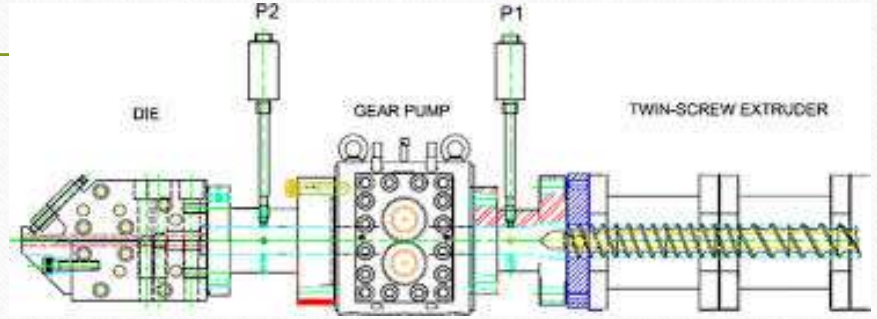
Screen Pack

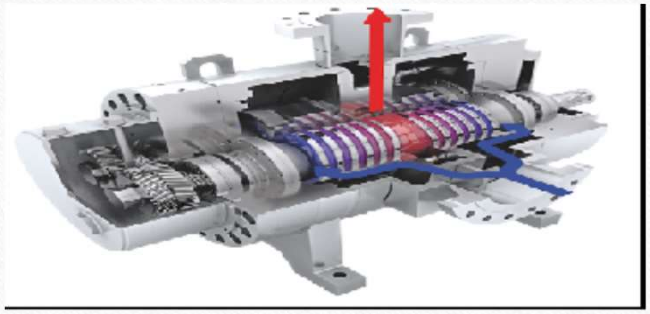
	Wire mesh, square weave	Wire mesh, Dutch twill	Sintered powder	Random metal fiber
Gel capture	Poor	Fair	Good	Very good
Contaminant capacity	Fair	Good	Fair	Very good
Permeability	Very good	Poor	Fair	Good



Gear Pump

- Extrusion gear pumps increase the outlet pressure in extruders and make it more uniform.
- The material coming out of the extruder has an excellent pressure stability.
- It is the only solution for all applications that require high pressure at the extruder outlet.





Pelletizing

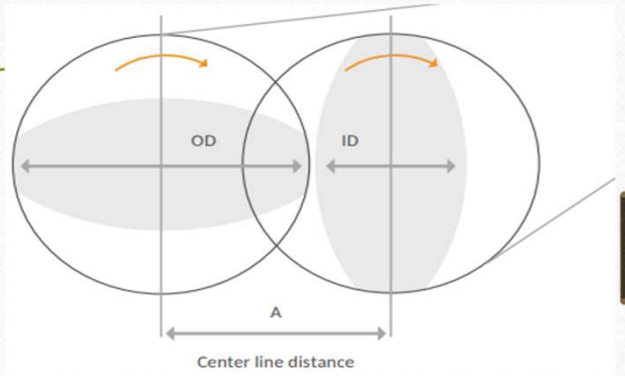
- Strand pelletizing
- Under water pelletizing

Torque Classification of TSE

- Low torque
- High torque(Mega Compounder)

- Specific torque Md/a^3 [Nm/cm^3]
- More than 30% increase of specific torque.
- Up to 100% increase in the throughput rate.
- Increased energy efficiency by reduced specific energy input
- Greatly improved productivity

Screw diameter (mm)	Max. torque per shaft (Nm)	Specific torque Md/a^3 (Nm/cm^3)	Max. screw speed (min^{-1})	Max. motor power (kW)
27	145	13.6	1200	37
36	405	15	1000	90
51	1190	15	1000	250
63	2100	15	1000	450
71	3240	15	1000	680
93	7110	15	900	1350



SAT Series(Safety, Accuracy, Torque)

Diameter (mm)	Max. Speed (rpm)	Motor (kW)	Specific Torque (Nm/cm3)	Output (kg/hr)
41	800	75	10.9	150-250
51.4	800	132	9.9	350-500
62.4	800	220	9.3	500-900
71	600	280	10.3	700-1200
93	600	600	10	1300-2400
110	400	650	10.1	1800-3000

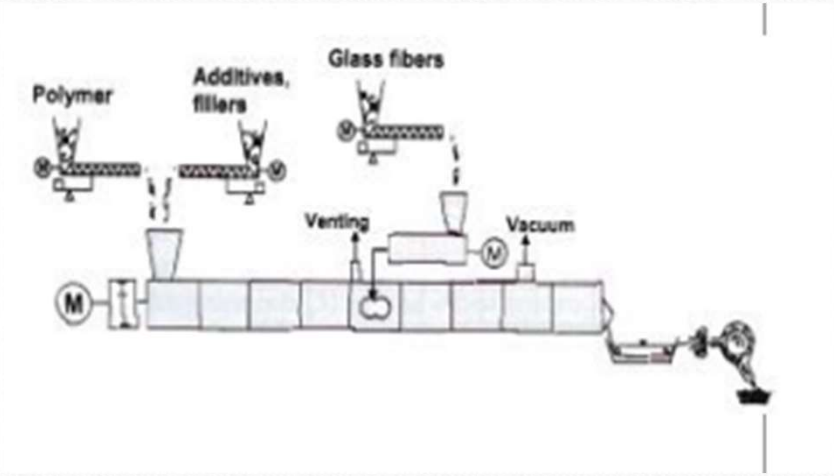
SAT series extruder feature the excellent self-wiping functions. Combining with screw torque and free volume, the Do/Di of SAT is optimized at 1.55 that provide sufficient torque while remain enough free volume.

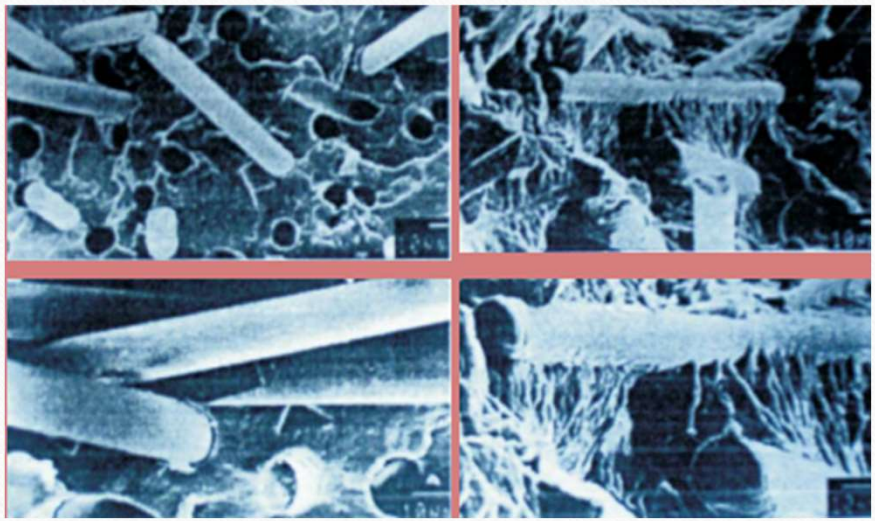
Process Example by Co-Rotating Twin Screw Extruder

- Incorporation of glass fiber
- Incorporation of filler masterbatch
- Production of masterbatch
- Powder Coating (Thermoses materials)
- Reactive Extrusion

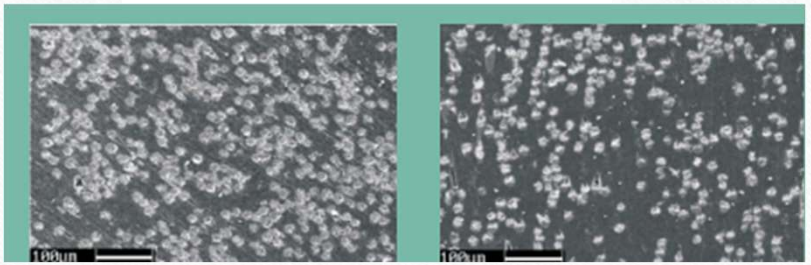
Glass Fiber Reinforced Polymers

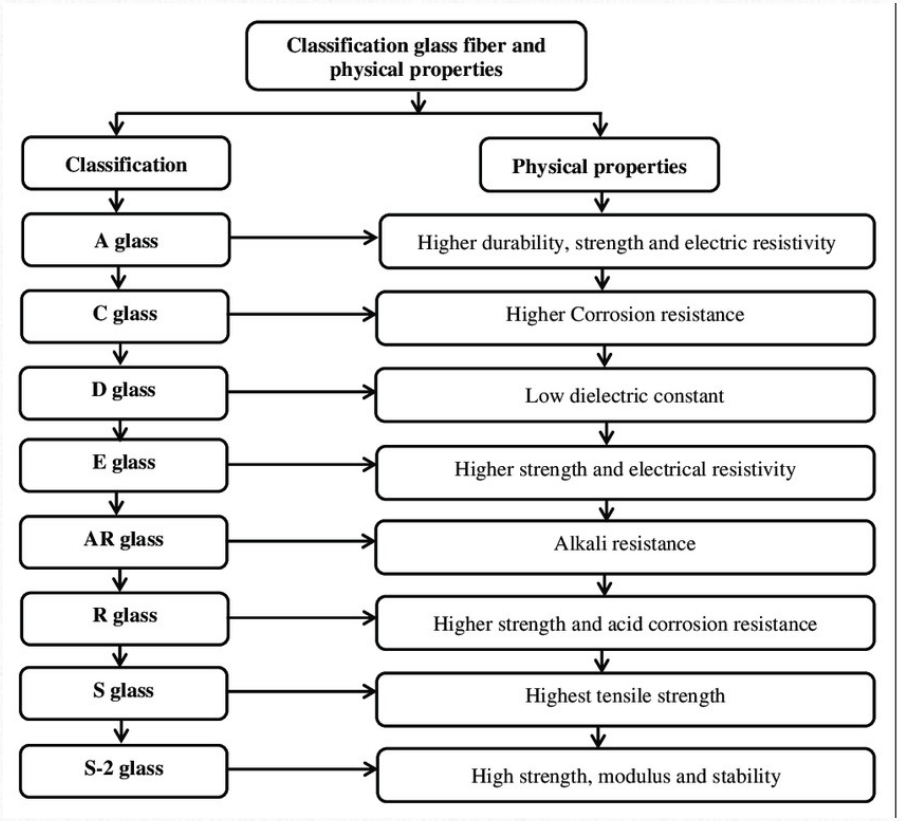
- Chopped strand up to 3mm.
- Long glass fiber (25-30mm).
- Fibers are generally added after melting of polymer.
- The melt temperature is sufficiently high before adding the glass fiber.
- Glass fiber incorporation is balanced by two factor: distribution and size reduction.
- The greater glass fiber content leads to more size reduction.





poor wetting (left) and good wetting (right)





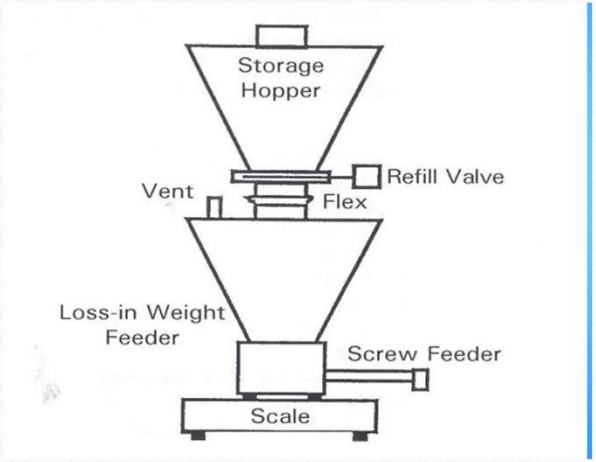
Chemical ingredients	%
Silicon dioxide	55
Calcium oxide	20
Baron oxide	12
Aluminum oxide	14
Sodium oxide	1
Potassium oxide	1
Magnesium oxide	4

Proportional Weighting

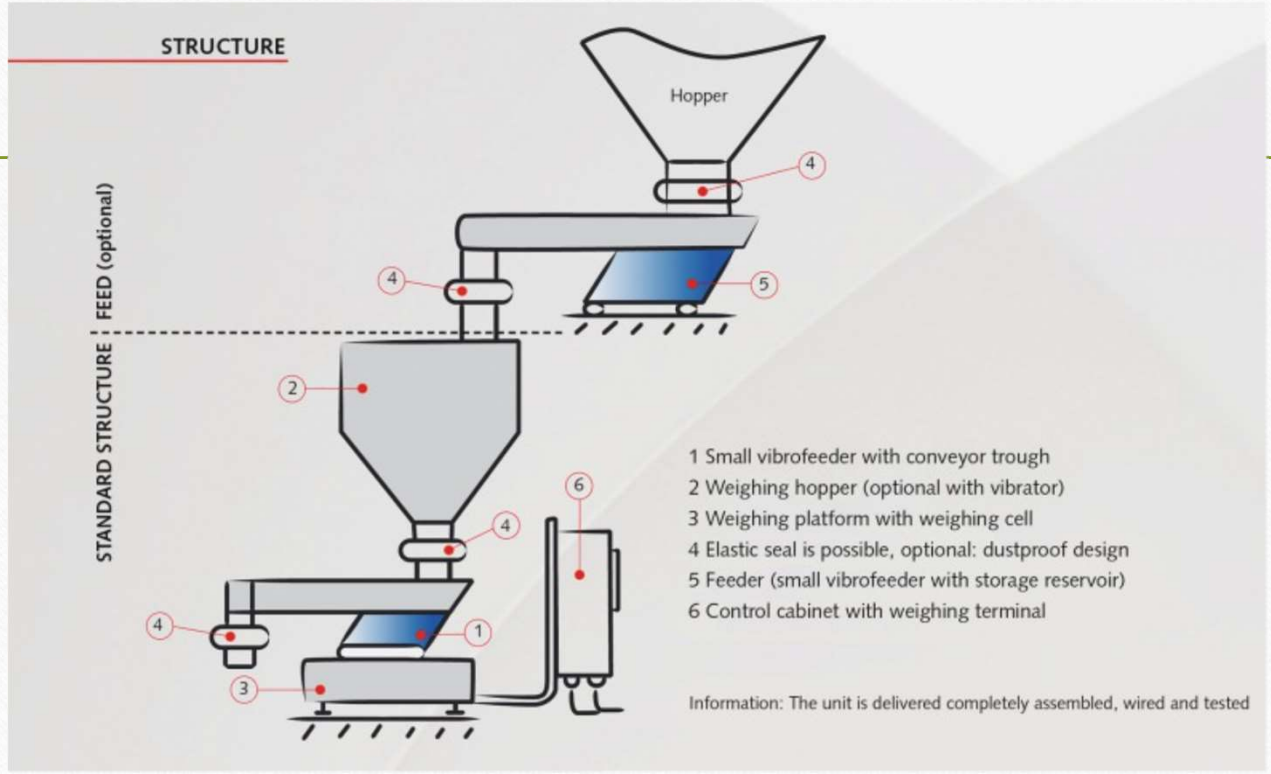
The basic classification

- Volumetric
- Weighting

Loss in Weight Feeder



STRUCTURE



Information: The unit is delivered completely assembled, wired and tested

Conveyor

set limits.

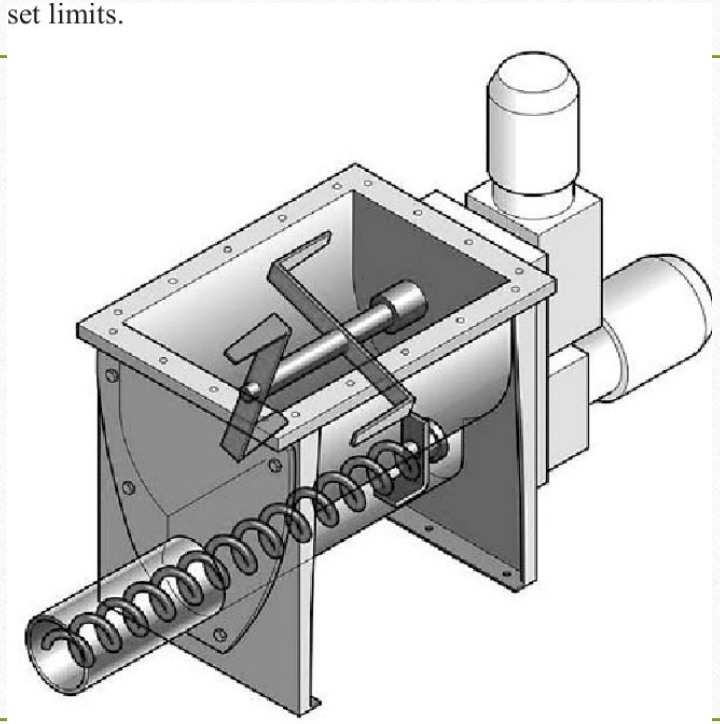
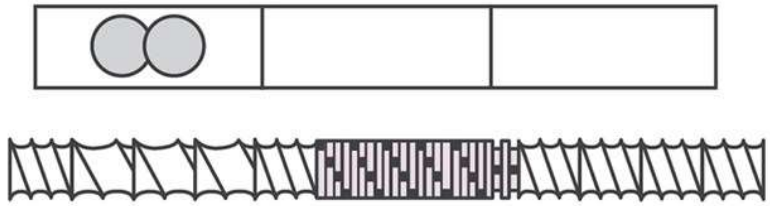


Figure 6: A typical screw feeder assembly incorporating a

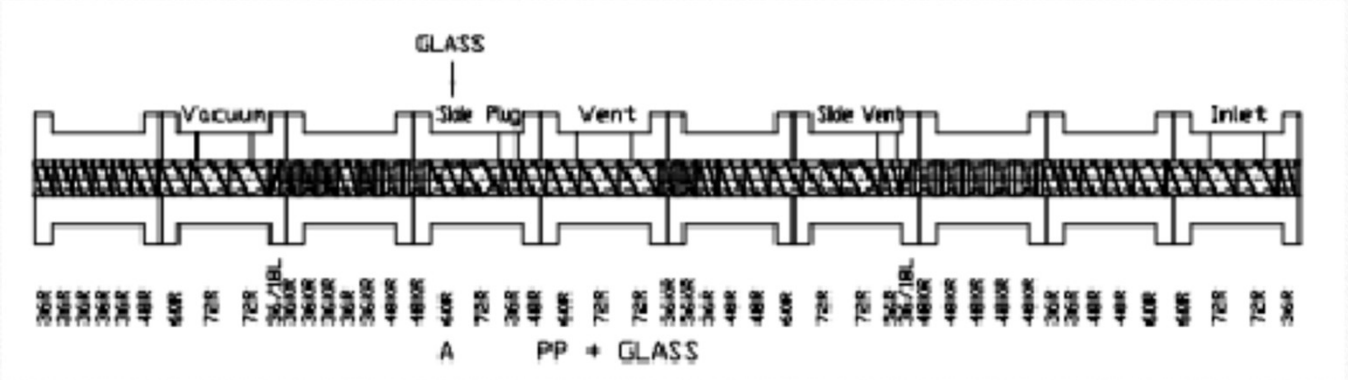
Side feeder for Fiber Feeding

Screw arrangement for Glass Fiber Wetting

- At this point, the pitch of the screw element can tighten up as needed based on the available.
- A series of forward, narrow disc kneading elements can distribute and incorporate the fibers throughout the polymer. These kneading blocks should immediately be followed by a neutral (90-degree) kneading block. The 90-degree kneading block creates a minor backup of material to ensure the fibers are fully integrated.

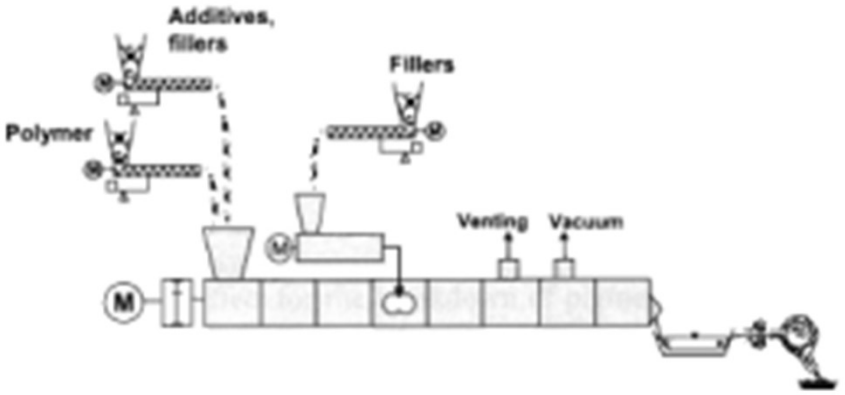


Typical Arrangement for PP/GF



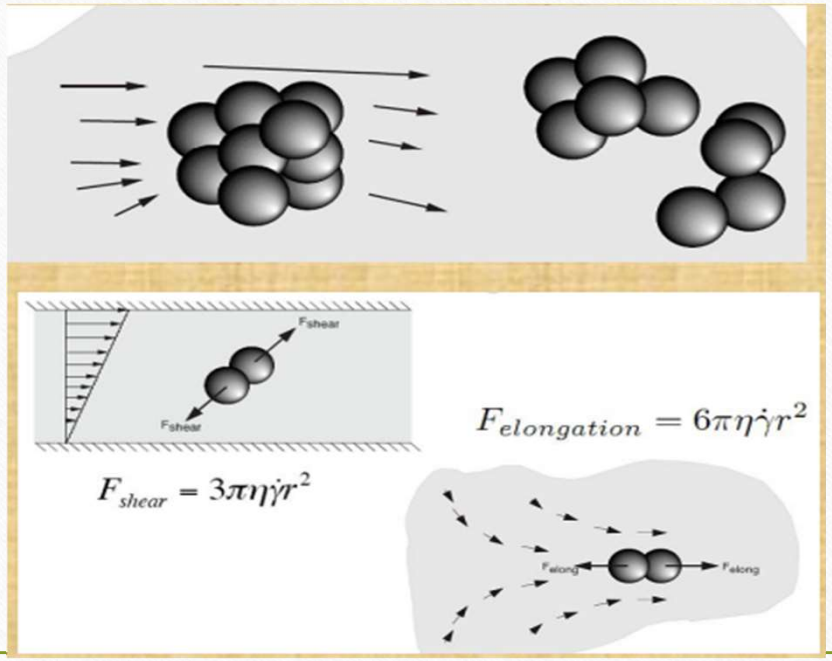
Filler Masterbatch

- Filler masterbatch is a compound of calcium carbonate, primary Polyethylene resin and other dispersing plastic additives.
- This product is used as a filler – filler masterbatch to reduce costs, increase productivity and shape the end product.
- The product is granular so it is easy to use and mix with different ingredients easily. Mixing ratio ranges from 5% to 50% depending on the specific product.



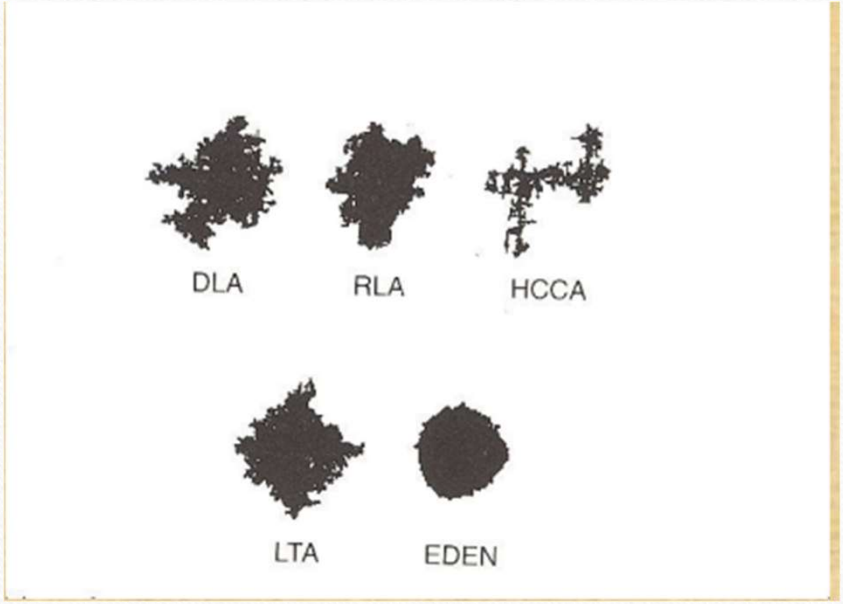
Mixing Mechanism

- Dispersive mixing of solid agglomeration.
- Most of the existing models focus on the two competitive forces : - forces of cohesion within the cluster and
- hydrodynamic forces inducing their break up.

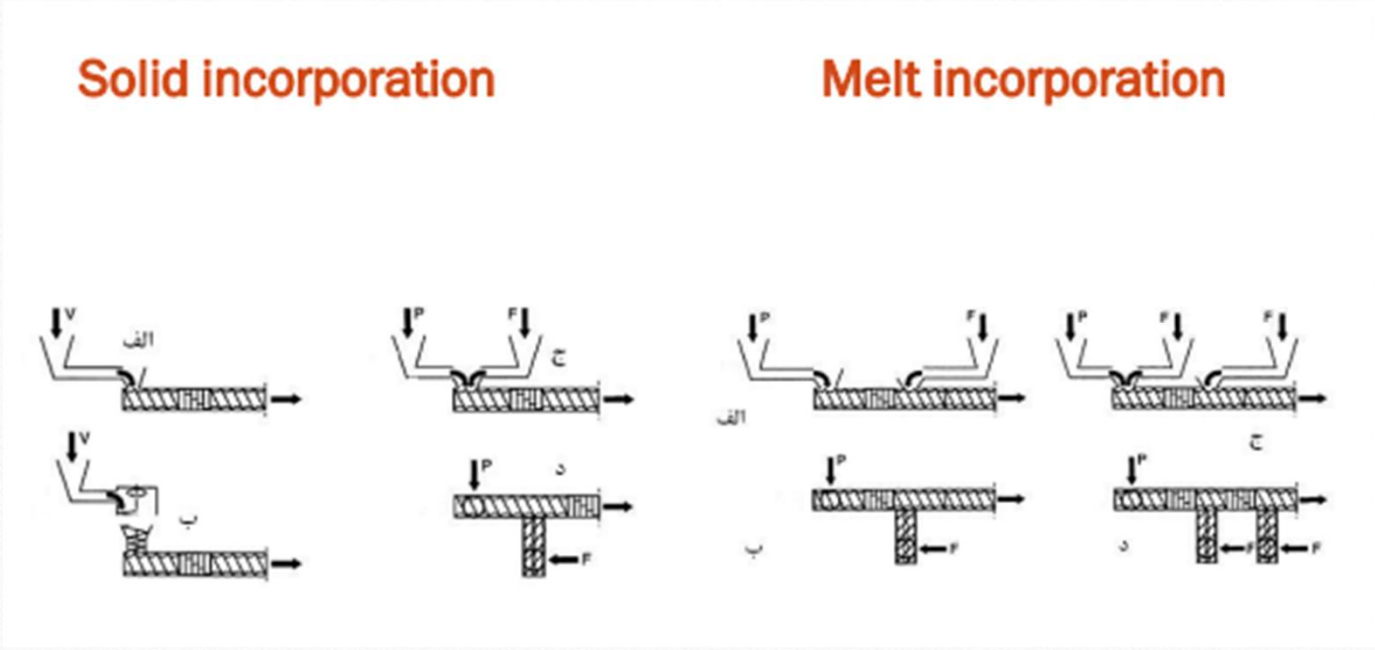


Typical Structure of Agglomerates

- DLA: Diffussion-limitted
- RLA: Reaction limited
- HCCA: Hierarchical cluster-cluster
- LTA: Linear trajectory
- Eden: Eden model



Filler Incorporation Methods

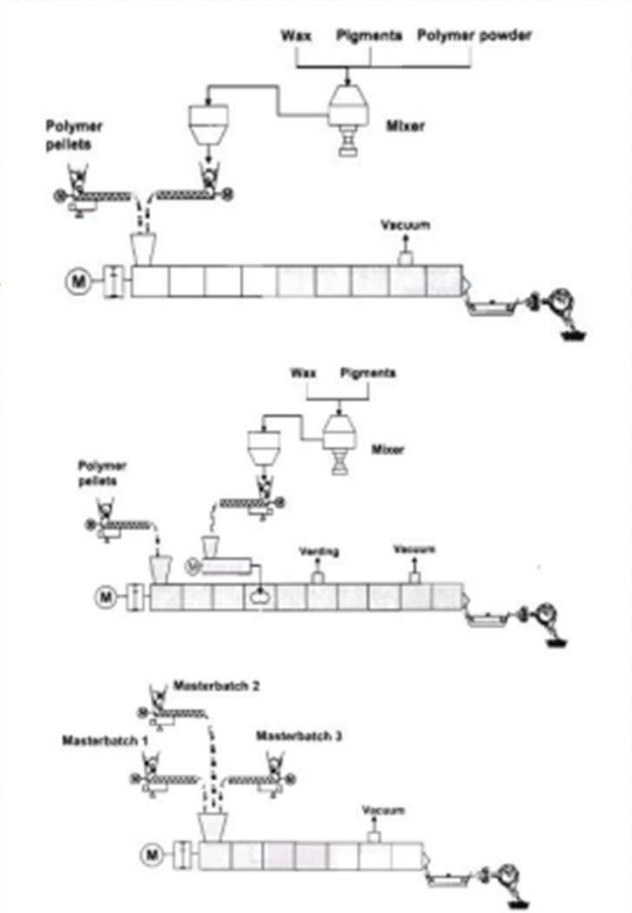


A reverse kneading block or even a reverse conveying element (the most severe pumping element). The purpose for this is to ensure the degree of fill in the mixing section is such that the mixing is reasonably efficient.

Production of Masterbatch

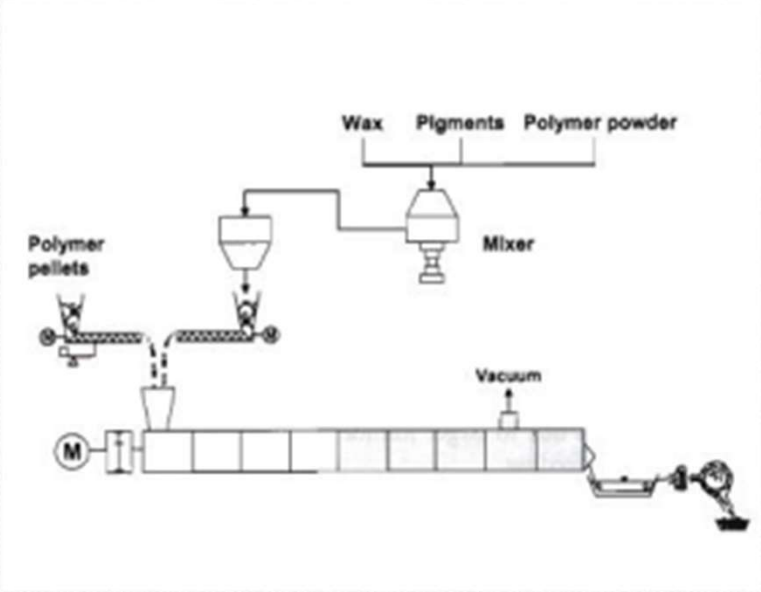
There are three types of arrangement:

- premix
- split feed
- color matching



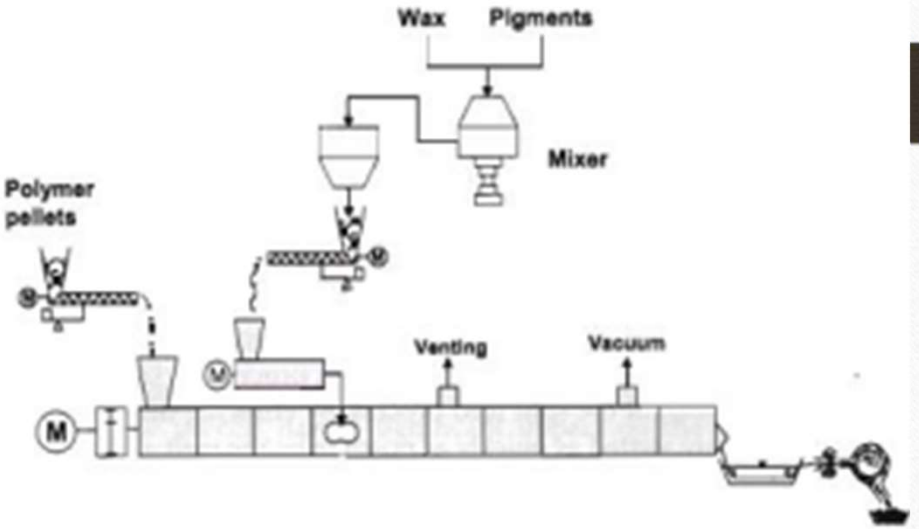
Premix Method

- All additives are premixed in a mixer and feed in to extruder using volumetric feeder
- A portion of the polymer is generally mixed with the pigment in powder form
- No production loss at start up , relatively low investment



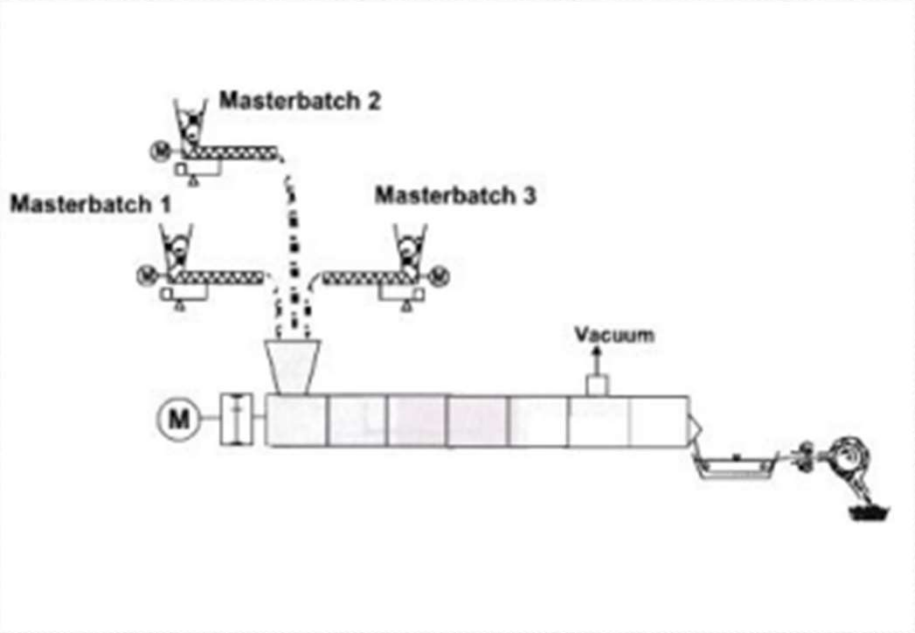
Split feed Process

- Additives are fed in to the polymer melt using side feeder after plasticating zone
- This system is suitable for large batch sizes
- Minimum wear of screw and barrel
- Long cleaning time
- High investment



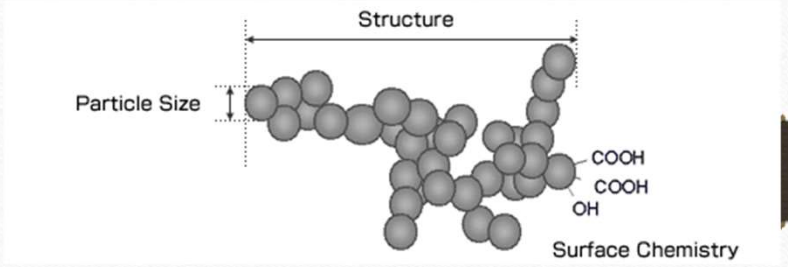
Color Matching

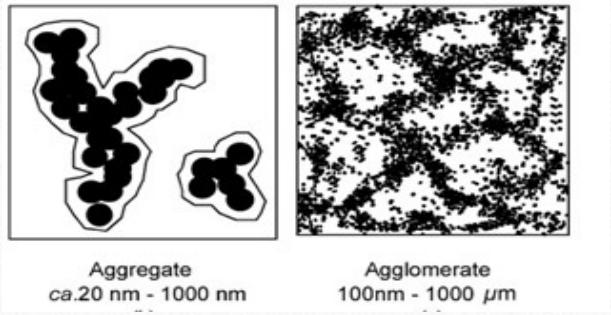
- Various masterbatch containing a single pigment type (monobatch) are fed.
- Extremely good dispersion.
- High cost.



Carbon black Masterbatch

Carbon Black Type	Designation	ASTM Designation	Particle Size nm
Super Abrasion Furnace	SAF	N110	20–25
Intermediate SAF	ISAF	N220	24–33
High Abrasion Furnace	HAF	N330	28–36
Easy Processing Channel	EPC	N300	30–35
Fast Extruding Furnace	FEF	N550	39–55
High Modulus Furnace	HMF	N660	49–73
Semi-Reinforcing Furnace	SRF	N770	70–96
Fine Thermal	FT	N880	180–200
Medium Thermal	MT	N990	250–350





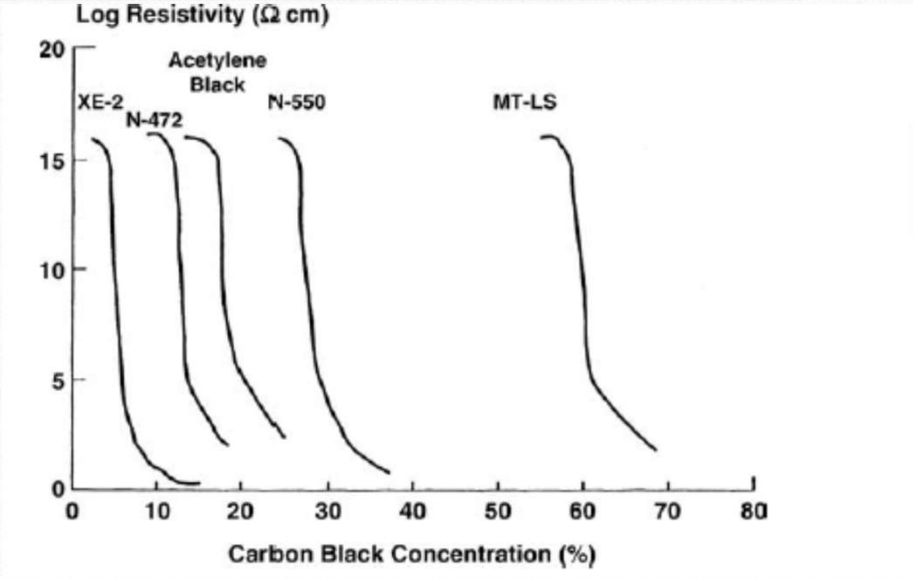
P Type Carbon Black

- P type blacks are specially designed carbon blacks with extremely high physical and chemical cleanliness to ensure excellent dispersibility and organoleptic properties for pressure pipes.
- Low sulfur and toluene, Low grit and ash, Particle size less than 25 nm , Excellent UV performance.

TYPICAL PROPERTIES		
PROPERTY	DATA	TEST METHOD
Iodine number (mg/g)	79	ASTM D-1510
OAN (cc/100g)	104	ASTM D-2414
Moisture as packed (%)	<1.0	ASTM D-1509
325 mesh residue (ppm)	<20	ASTM D-1514
Ash (%)	<0.1	ASTM D-1506
Total sulfur (%)	<0.1	ASTM D-1619
Particle size (nm)	<25	ASTM D-3849
Toluene extract (%)	<0.03	ASTM D-4527

Carbon black Masterbatch

- UV Protection: The carbon black masterbatch's capacity to provide UV resistance is another noteworthy quality. By absorbing and dispersing UV light, carbon black particles stop the polymer matrix from deteriorating from exposure to sunshine.
- Electrical Conductivity: Plastics may also acquire electrical conductivity by adding carbon black to them. This feature is helpful in situations where the regulated dissipation of electrical charges is essential, such as electrostatic discharge (ESD) protection in electronic components and packaging materials.

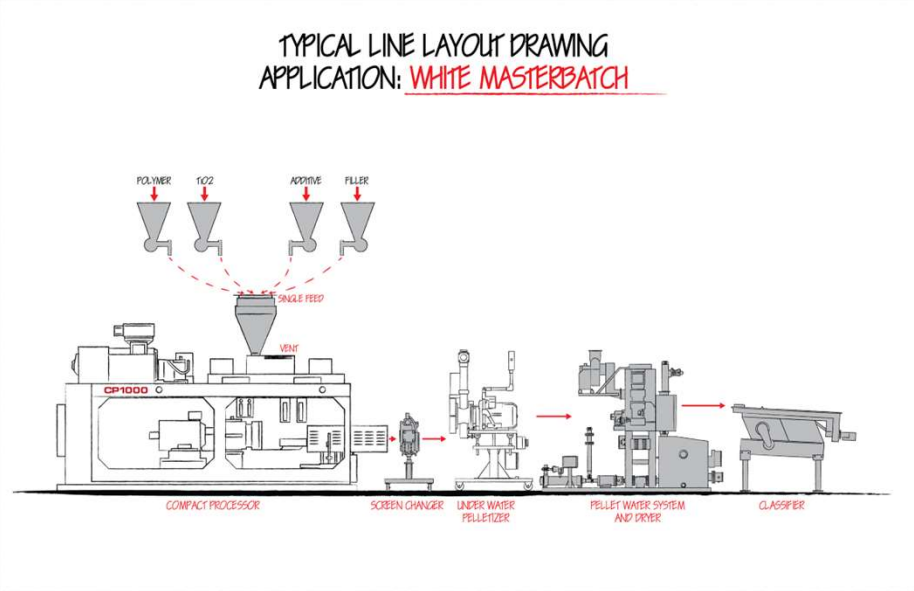


Typical Screw Arrangement for CB Masterbatch

Config	element	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	length(mm)	240	28	84	40	28	40	28	84	80	40	28	112	80	56	28
	type	**45/5/40**	**45°/5/28**	28/28	45/5/40	60°/4/28	90°/5/40	**45°/5/28**	28/28	90°/5/40	45/5/40	**45°/5/28**	28/28	45°/5/40	60°/4/28	**45°/5/28**
2	length(mm)	40	28	40	28	196	224	28	56	80	28	28	56	80	56	28
	type	45/5/40	60°/4/28	90°/5/40	**45°/5/28**	28/28	**45/5/56**	**45°/5/28**	28/28	90°/5/40	60°/4/28	**45°/5/28**	28/28	45°/5/40	60°/4/28	**45°/5/28**
3	length(mm)	40	28	40	28	196	80	28	28	56	80	56	28	56	224	28
	type	45/5/40	60°/4/28	90°/5/40	**45°/5/28**	28/28	90°/5/40	60°/4/28	**45°/5/28**	28/28	45°/5/40	60°/4/28	**45°/5/28**	28/28	**45/5/56**	**45°/5/28**
4	length(mm)	224	28	112	40	28	40	28	84	80	28	28	112	80	56	28
	type	**45/5/56**	**45°/5/28L**	28/28	45/5/40	60°/4/28	90°/5/40	**45°/5/28L**	28/28	90°/5/40	60°/4/28	**45°/5/28L**	28/28	45°/5/40	60°/4/28	**45°/5/28L**
5	length(mm)	240	28	84	40	28	40	28	84	80	40	28	112	80	56	28
	type	**45/5/40**	**45°/5/28**	28/28	45/5/40	60°/4/28	90°/5/40	**45°/5/28**	28/28	90°/5/40	45/5/40	**45°/5/28**	28/28	45°/5/40	60°/4/28	**45°/5/28**
6	length(mm)	224	56	84	40	28	40	28	84	80	28	28	112	80	56	28
	type	**45/5/56**	**45°/5/56**	28/28	45/5/40	60°/4/28	90°/5/40	**45°/5/28L**	28/28	90°/5/40	60°/4/28	**45°/5/28L**	28/28	45°/5/40	60°/4/28	**45°/5/28L**

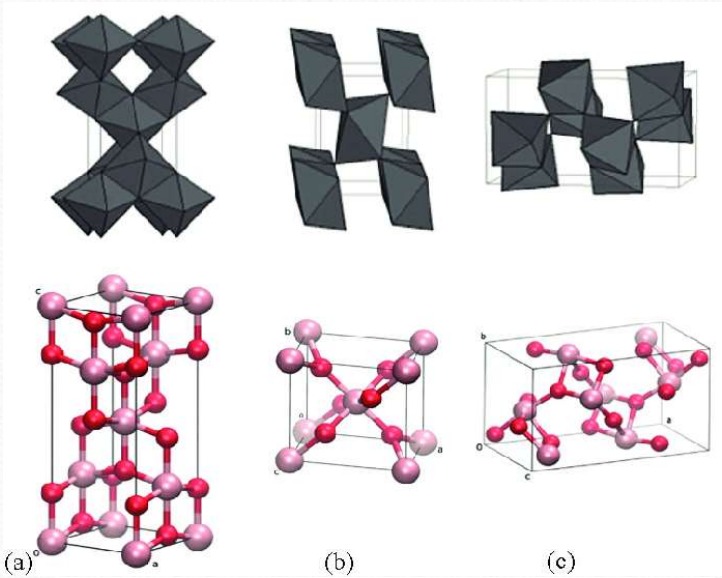
White Masterbatch

- White masterbatch is a highly useful ingredients in the plastic industry that is used to impart a bright, white color to plastic products.
- The primary property of white masterbatch is its ability to impart a bright, white color to plastic products. It improves the opacity of plastic products, making them less transparent and opaquer.
- In addition, white masterbatch can enhance the thermal stability and outdoor durability somewhat.

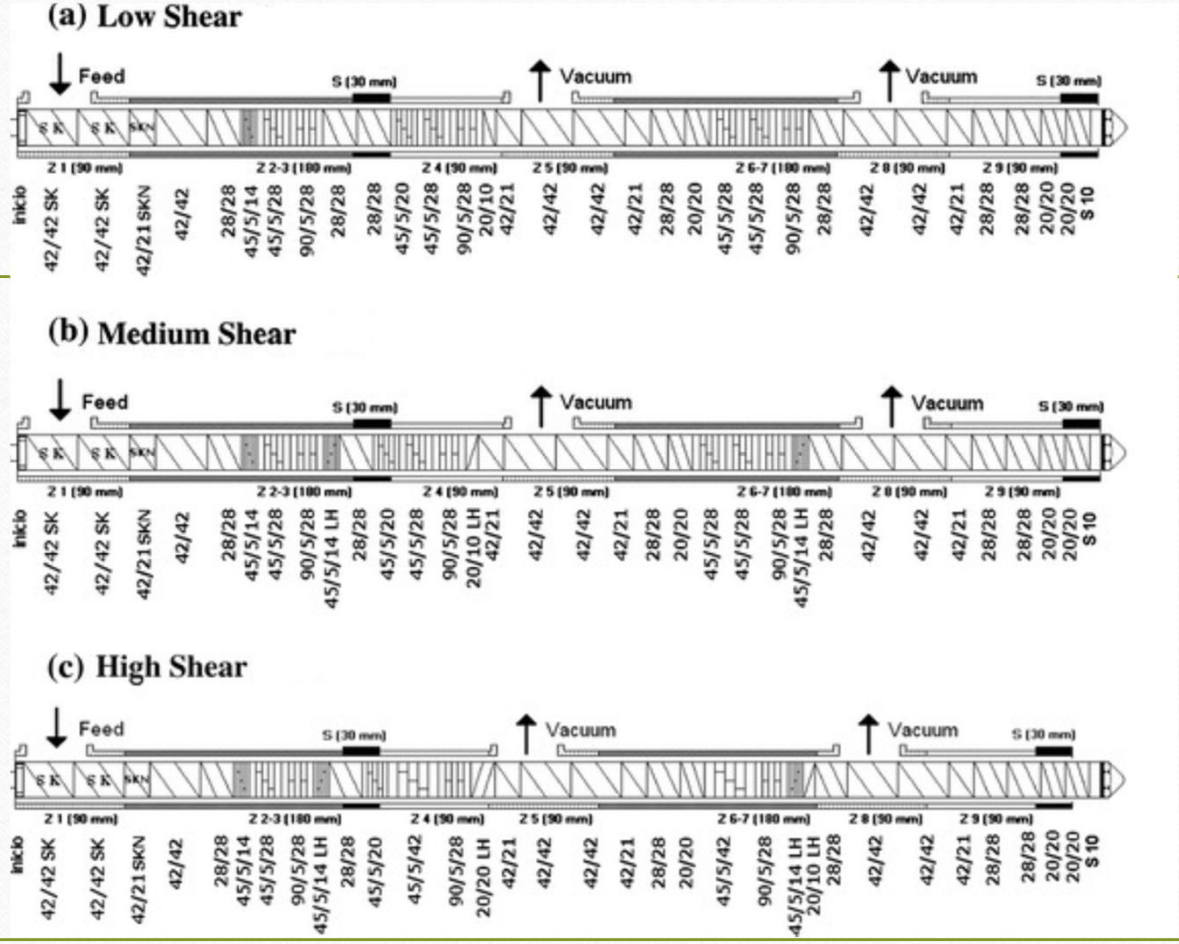


White Masterbatch

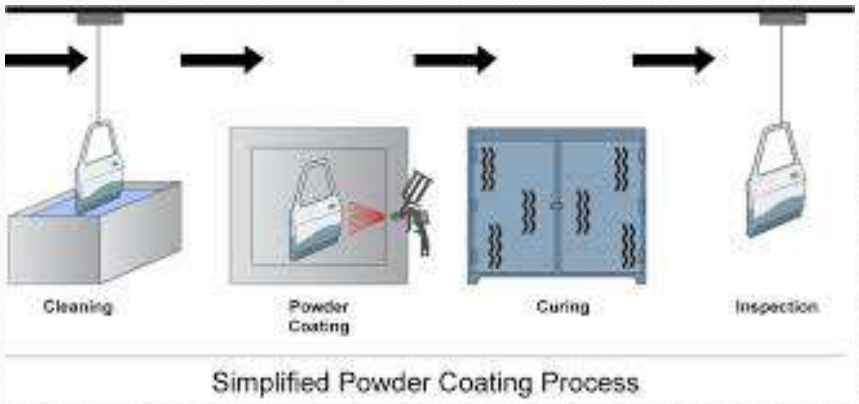
- TiO_2 exists in two forms: amorphous and crystalline.
- Crystalline TiO_2 exists in three forms: anastase, rutile, and brookite.
- Anatase and rutile have a tetragonal structure.
- Rutile can be mined directly, but anatase is obtained through the processing of ilmenite, a natural iron titanate.



(a) anatase, (b) rutile, and (c) brookite


(a) Low Shear
Feed
S (30 mm)
Vacuum
Vacuum
S (30 mm)
S K
S K
SKN
Z 1 (90 mm)
Z 2-3 (180 mm)
Z 4 (90 mm)
Z 5 (90 mm)
Z 6-7 (180 mm)
Z 8 (90 mm)
Z 9 (90 mm)
Inicio
42/42 SK
42/42 SK
42/21 SKN
42/42
28/28
45/5/14
45/5/28
90/5/28
28/28
28/28
45/5/20
45/5/28
90/5/28
20/10
42/21
42/42
42/42
42/21
28/28
20/20
45/5/28
45/5/28
90/5/28
28/28
42/42
42/42
42/21
28/28
28/28
20/20
20/20
S 10
(b) Medium Shear
Feed
S (30 mm)
Vacuum
Vacuum
S (30 mm)
S K
S K
SKN
Z 1 (90 mm)
Z 2-3 (180 mm)
Z 4 (90 mm)
Z 5 (90 mm)
Z 6-7 (180 mm)
Z 8 (90 mm)
Z 9 (90 mm)
Inicio
42/42 SK
42/42 SK
42/21 SKN
42/42
28/28
45/5/14
45/5/28
90/5/28
45/5/14 LH
28/28
45/5/20
45/5/28
90/5/28
20/10 LH
42/21
42/42
42/42
42/21
28/28
20/20
45/5/28
45/5/28
90/5/28
45/5/14 LH
28/28
42/42
42/42
42/21
28/28
28/28
20/20
20/20
S 10
(c) High Shear
Feed
S (30 mm)
Vacuum
Vacuum
S (30 mm)
S K
S K
SKN
Z 1 (90 mm)
Z 2-3 (180 mm)
Z 4 (90 mm)
Z 5 (90 mm)
Z 6-7 (180 mm)
Z 8 (90 mm)
Z 9 (90 mm)
Inicio
42/42 SK
42/42 SK
42/21 SKN
42/42
28/28
45/5/14
45/5/28
90/5/28
45/5/14 LH
28/28
45/5/20
45/5/42
90/5/28
20/20 LH
42/21
42/42
42/42
42/21
28/28
20/20
45/5/42
90/5/28
45/5/14 LH
20/10 LH
28/28
42/42
42/42
42/21
28/28
28/28
20/20
20/20
S 10

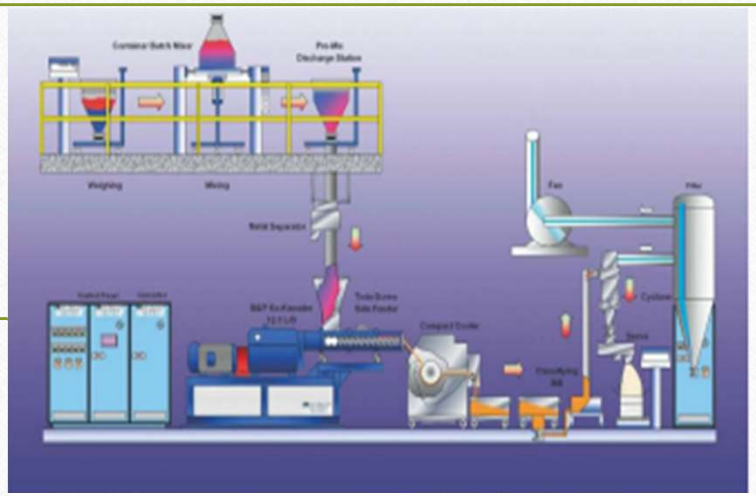
Powder Coating

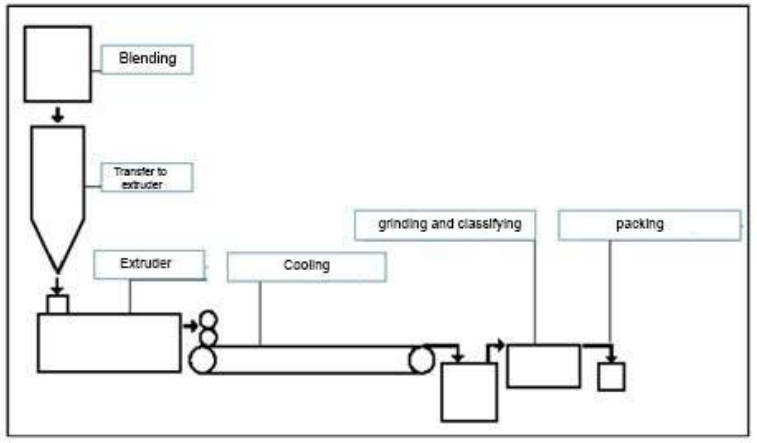


Simplified Powder Coating Process

Powder Coating

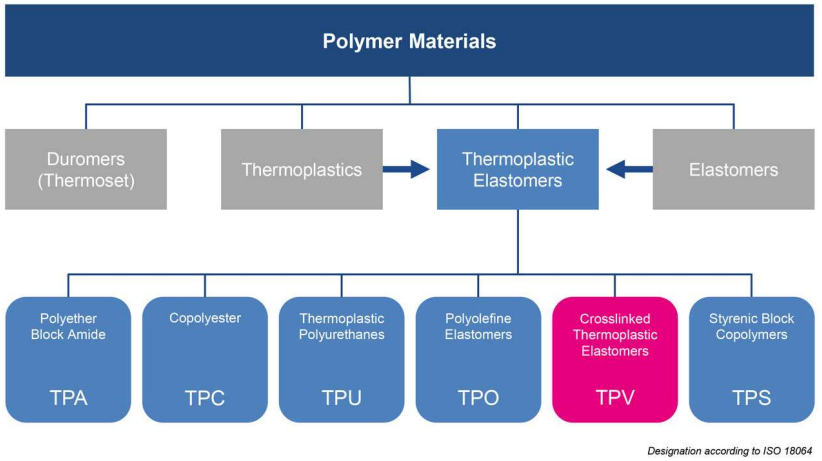
- The powder may be a thermoplastic or a thermoset polymer. It is usually used to create a thick, tough finish that is more durable than conventional paint.
- Thermoset materials like Polyester. Epoxy.
- Processing temperature must be under curing temperature.





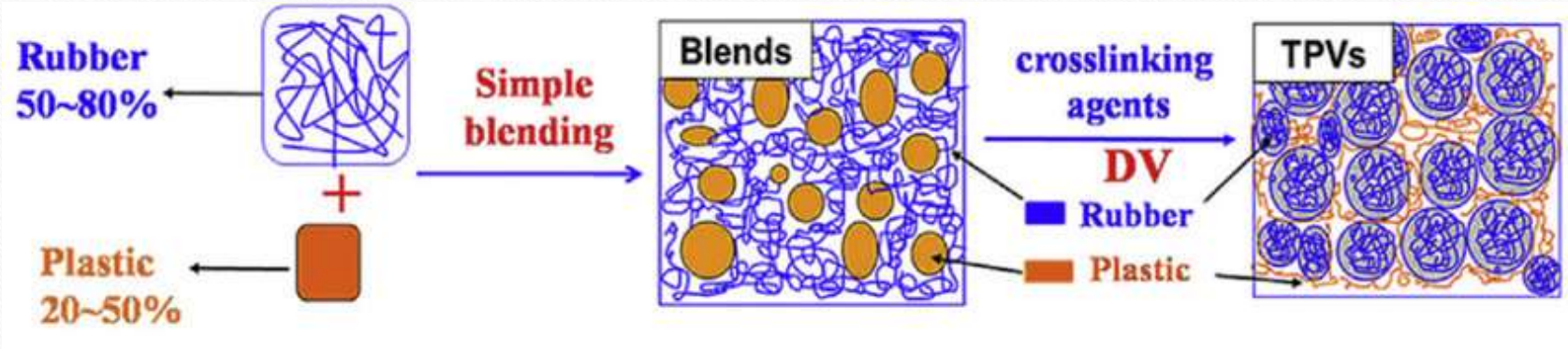
TPV & TPO Production

- The various TPV materials are usually manufactured by reactive extrusion. In the classic case, they consist of the two main components polypropylene (PP) and ethylene-propylene-diene rubber, which are mixed together. The EPDM phase is dynamically vulcanized in this blending process.

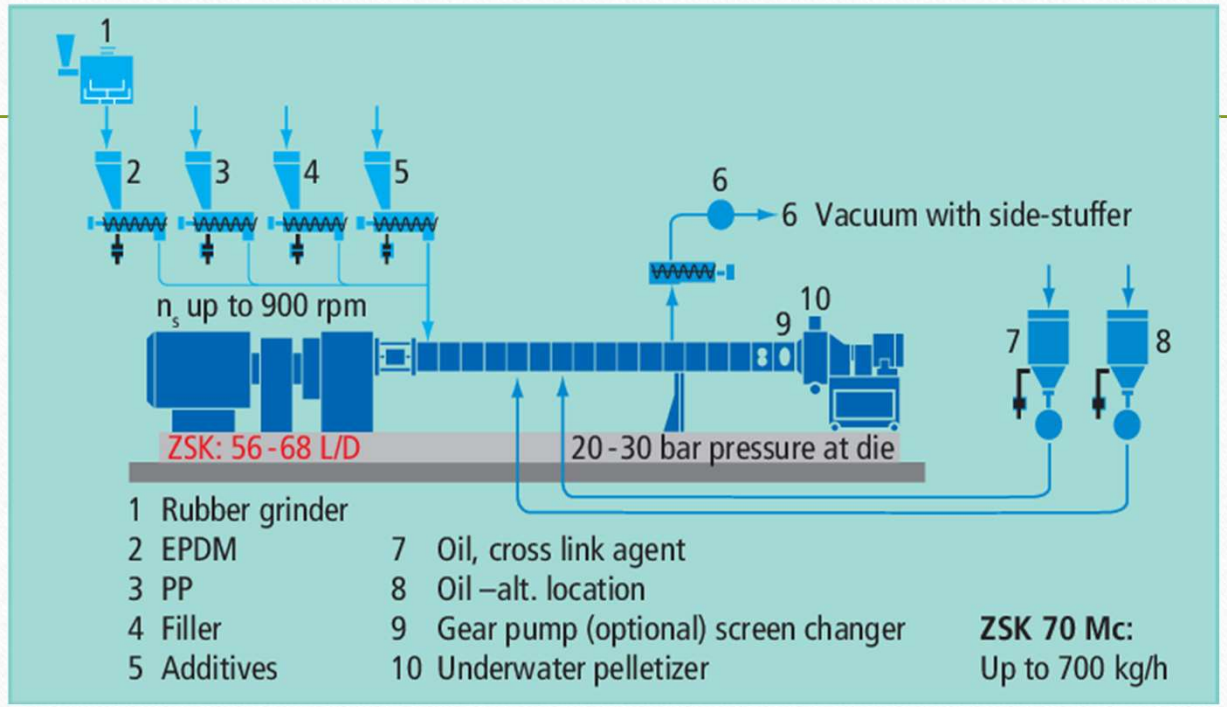


Typical TPO	Typical TPV recipe range
Rubber 14 %	EPDM 30–50 %
PP 19 %	PP 5–20 %
Oil 30 %	Filler <10 %
Filler 35 %	Oil 20–35 %

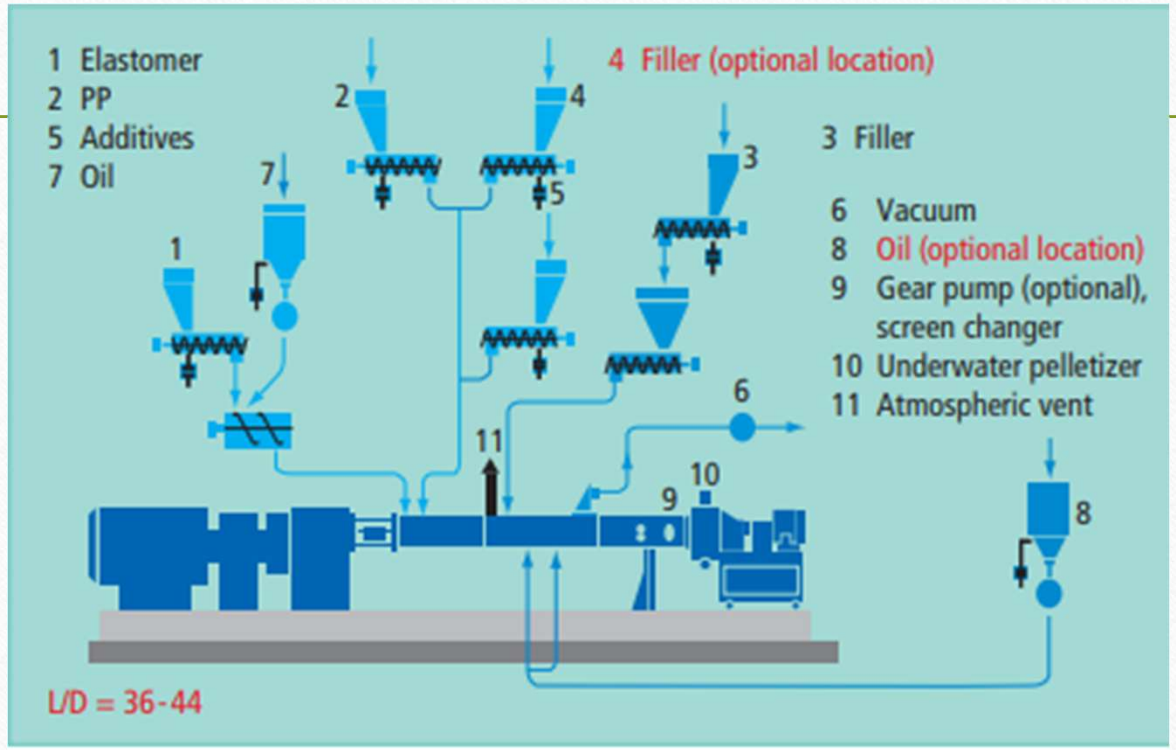
TPV Morphology



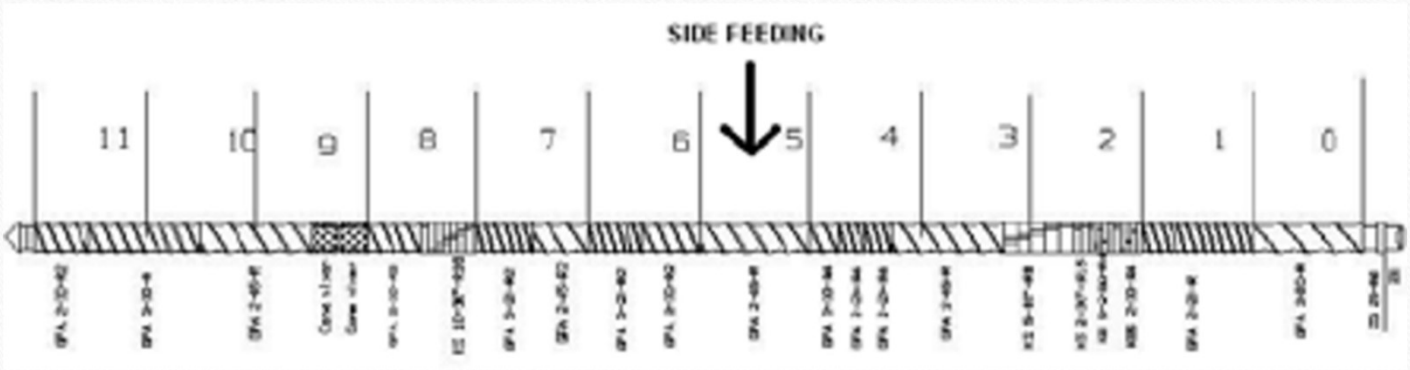
TPV Production Line Layout



TPO Production Line Layout

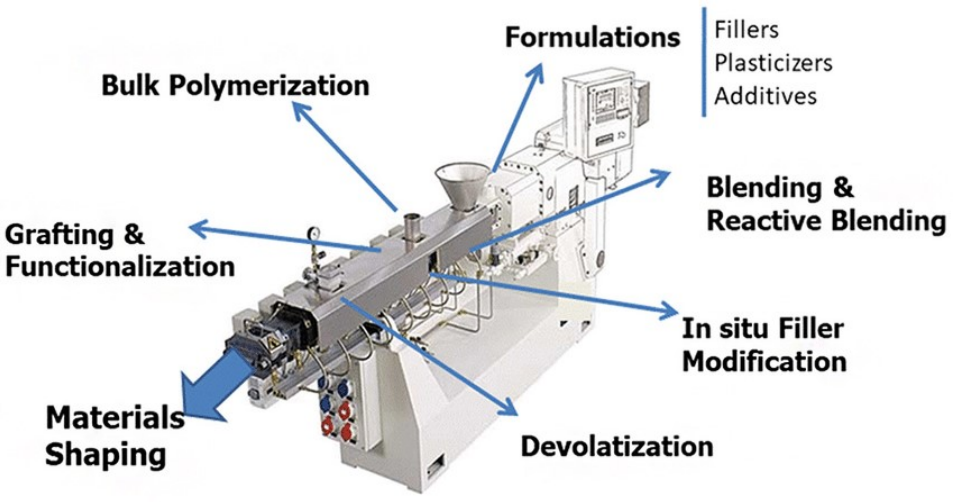


TPV& TPE



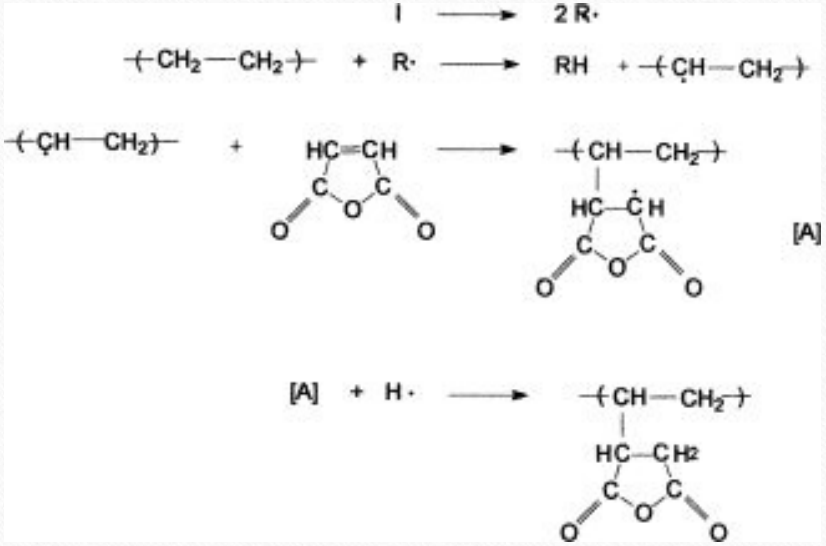
Reactive Extrusion

- Reactive extrusion (REX) is a manufacturing method that combines the traditionally separated chemical processes (polymer synthesis and/or modification) and extrusion (melting, blending, structuring, devolatilization and shaping) into a single process carried out onto an extruder.

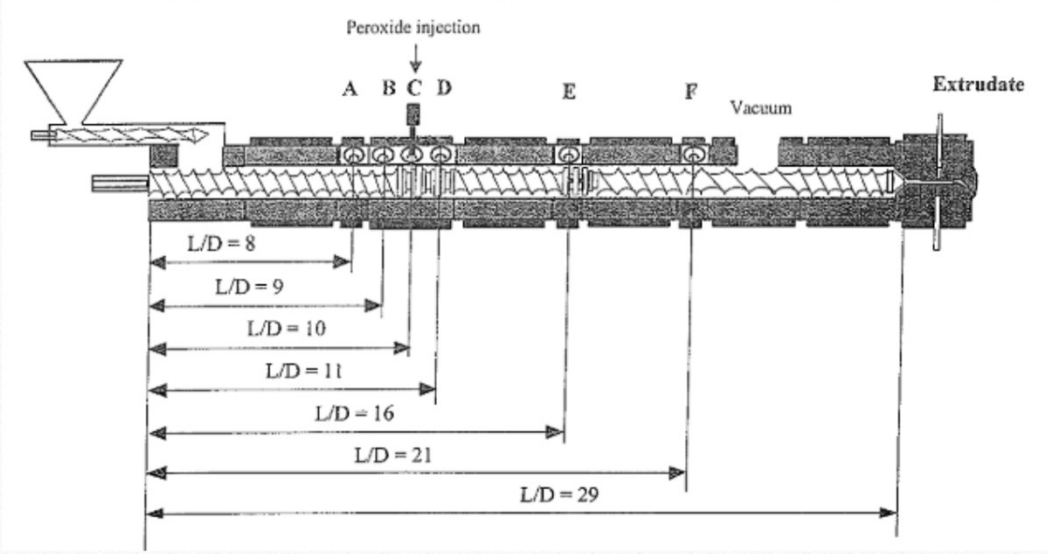


Polyolefin-g- MA

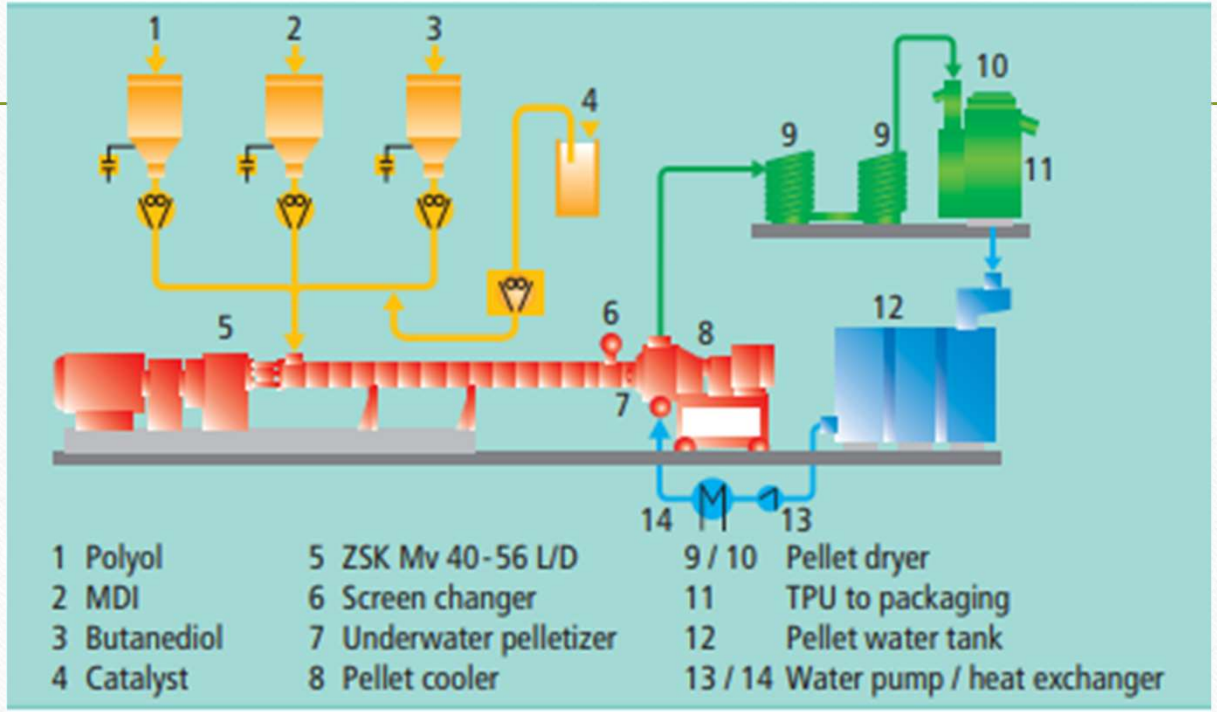
- One of the most common examples of polymer modification is the grafting maleic anhydride (MA) into polyolefins.
- These materials have application in : in situ compatbilization in blend; adhesive for multi layer systems; copling agent for glass fiber.



Polyolefin-g- MA



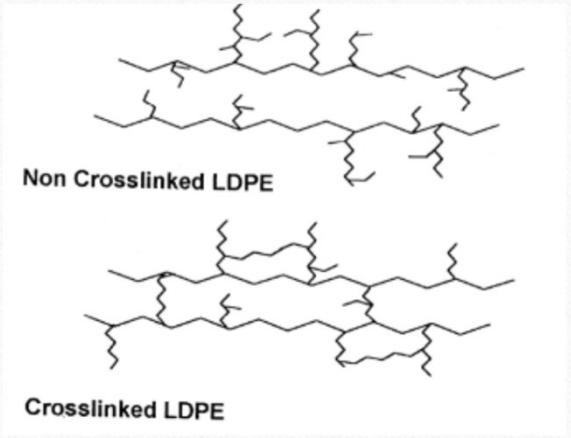
TPU polymerization line



Polyethylene Crosslinking (PEX)

- PE Crosslinked can be obtained via these methods:

- Peroxide crosslinking (PE-Xa) (75%)
- Silane crosslinking (PE-Xb) (65%)
- Electron beam crosslinking (PE-Xc) (60%)
- Azo crosslinking (PE-Xd) (60%) [1]



Silane Crosslinking