Polymer Compounding Technology

I.Ghasemi

Filled Compounds	PP, PE, PVC	Talc, $CaCO_3$, silica, clay	Automotive parts, pipes, packaging
Reinforced Compounds	PP, PA (Nylon), PBT, PEEK	Glass fiber, carbon fiber, aramid fiber	Car bumpers, housings, aerospace
Polymer Blends/Alloys TPE/TPV	ABS, PC/ABS, PP/EPDM, SAN/PMMA	Compatibilizers, impact modifiers	Appliances, automotive, electronics
Flame-Retardant (FR)	ABS, PA, PBT, PC	Halogenated FRs, phosphorus compounds, ATH, $Mg(OH)_2$	Electrical parts, construction, transport
Conductive/ESD Compounds	PP, PE, PC, ABS, Nylon	Carbon black, graphene, metal fibers, CNTs	EMI shielding, antistatic trays
Color Masterbatch	PE, PP, PS, PET	Organic/inorganic pigments, dyes	Packaging, films, toys
Additive Masterbatch	Any thermoplastic	UV stabilizers, antioxidants, slip agents, lubricants	Films, pipes, consumer goods
Biodegradable Compounds	PLA, PBAT, starch blends	Natural fibers, $CaCO_3$, biodegradable additives	Compostable bags, cutlery
Medical Grade Compounds	PP, PE, TPU, PVC-free blends	Biocompatible stabilizers, antimicrobial agents	Syringes, catheters, tubing
Reactive Extrusion	PE-g-MA	MA	Multilayer Films and Pipes, SPC compounds

Masterbach Types

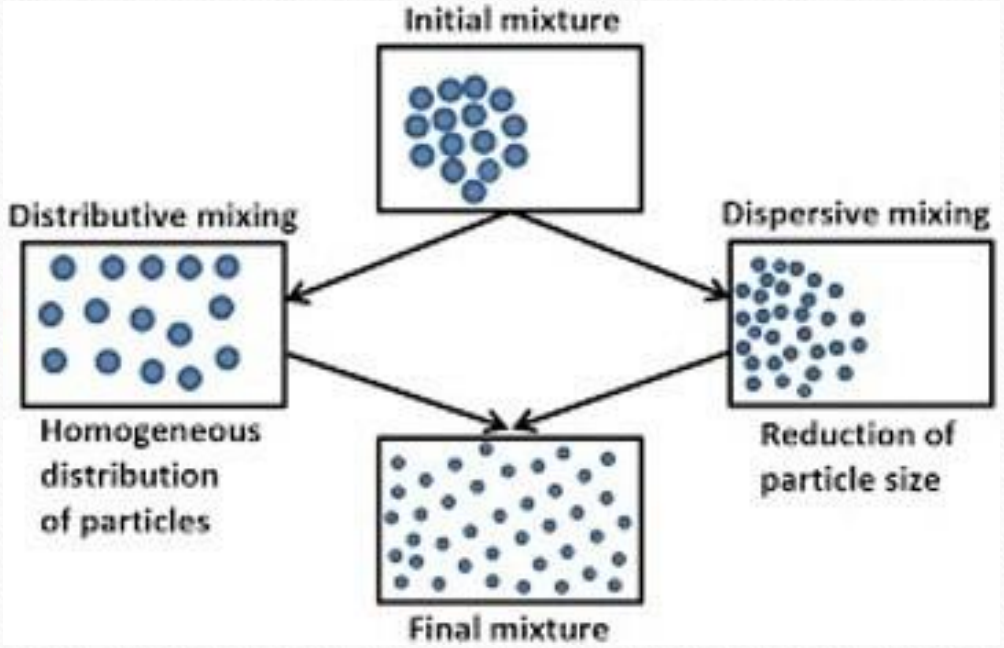
- **Color Masterbach (for coloring the plastics)**
- **Additive Masterbach (for certain chemical & physical properties for end uses)**
- **Filler Masterbach (for cost reduction)**

- ✓ Coloring pigments(20-90%) + carrier polymers (>10%)
- ✓ Carrier polymer selection is basis compatibility of the raw polymer which is used for the products.

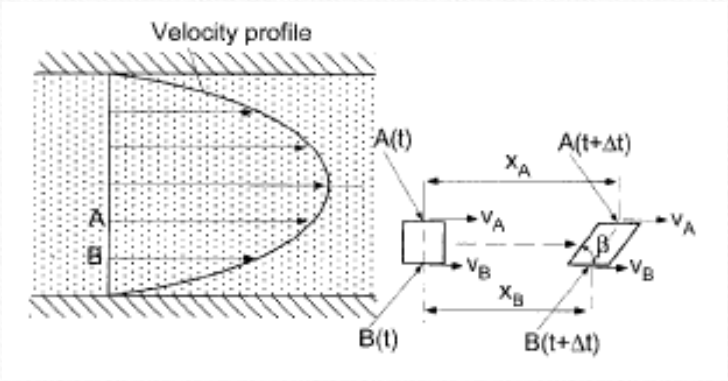
- ✓ Anti static
- ✓ Anti block
- ✓ Anti fogging
- ✓ Anti oxidant
- ✓ Cling agent
- ✓ Anti UV
- ✓ Optical brightener
- ✓ Clarifying agent

Mixing as Vital Criteria in Compounding

- Dispersive Mixing
- Distributive Mixing

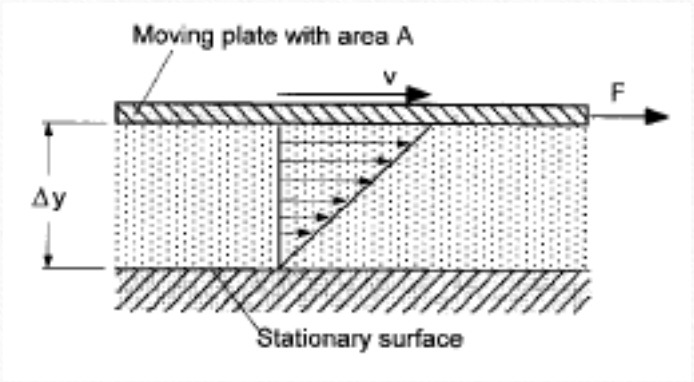


- **Shear flow**

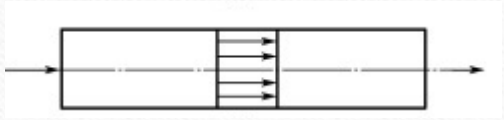


- ✓ **Pressure flow**

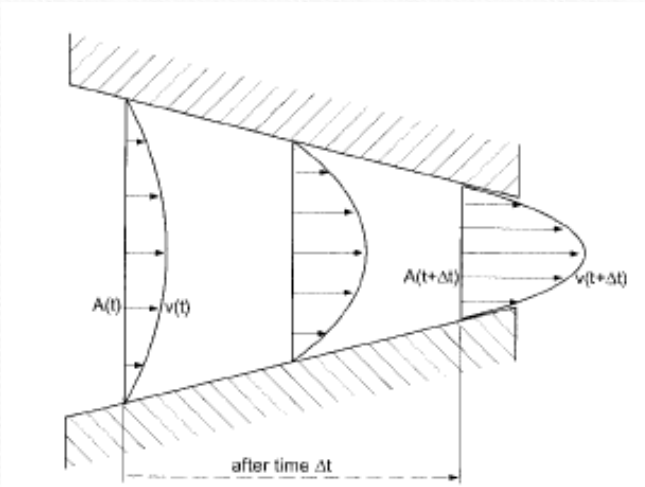
- ✓ **Drag flow**



- **Plug flow**



- **Elongation flow**



Machine Markets for Compounding

- Single screw extruder (SSE)
- Twin screw extruder (TSE)
- Boss-Kneader
- Farrel continuous Mixer (FCM)
- Internal mixer- SSE package

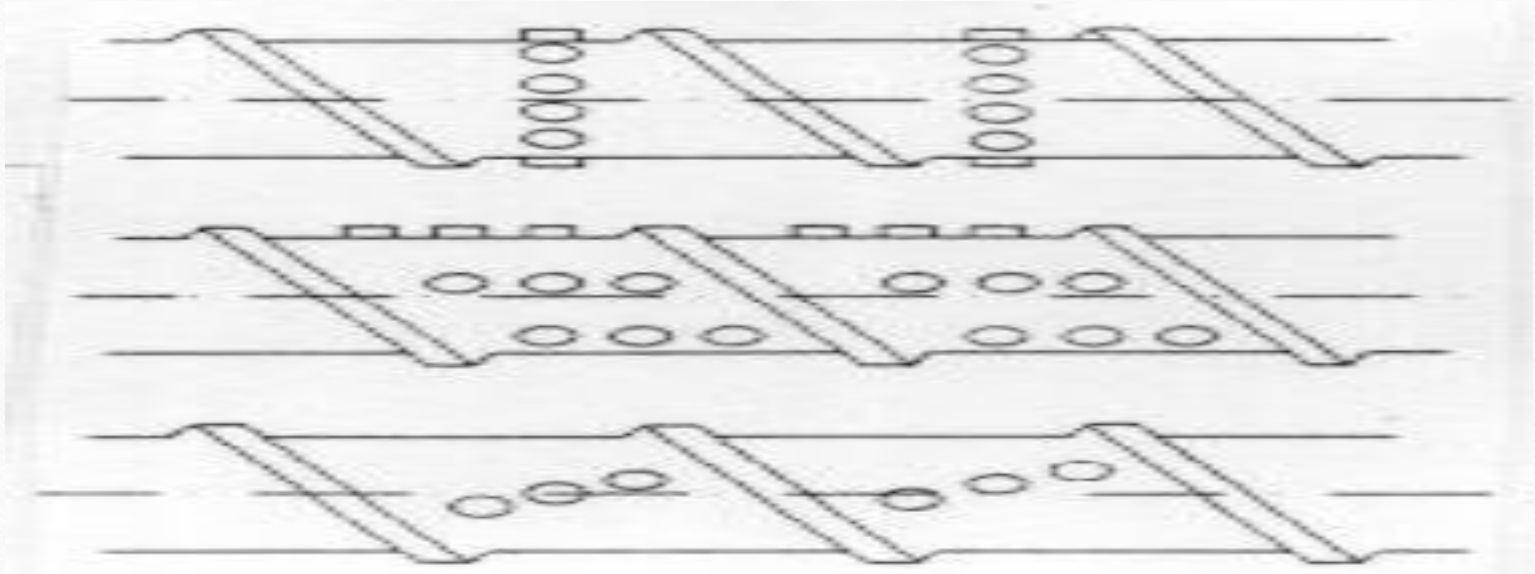
Distributive Mixing Sections in SSE

- Plastic melt subjected to significant shear strain.
- Flow should be split frequently with reorientation of melt.

- 1- Cavity Mixers
- 2- Pin Mixers
- 3- Slotted Flight Mixers
- 4- Variable Channel Depth Mixers
- 5- Variable Channel Width Mixers

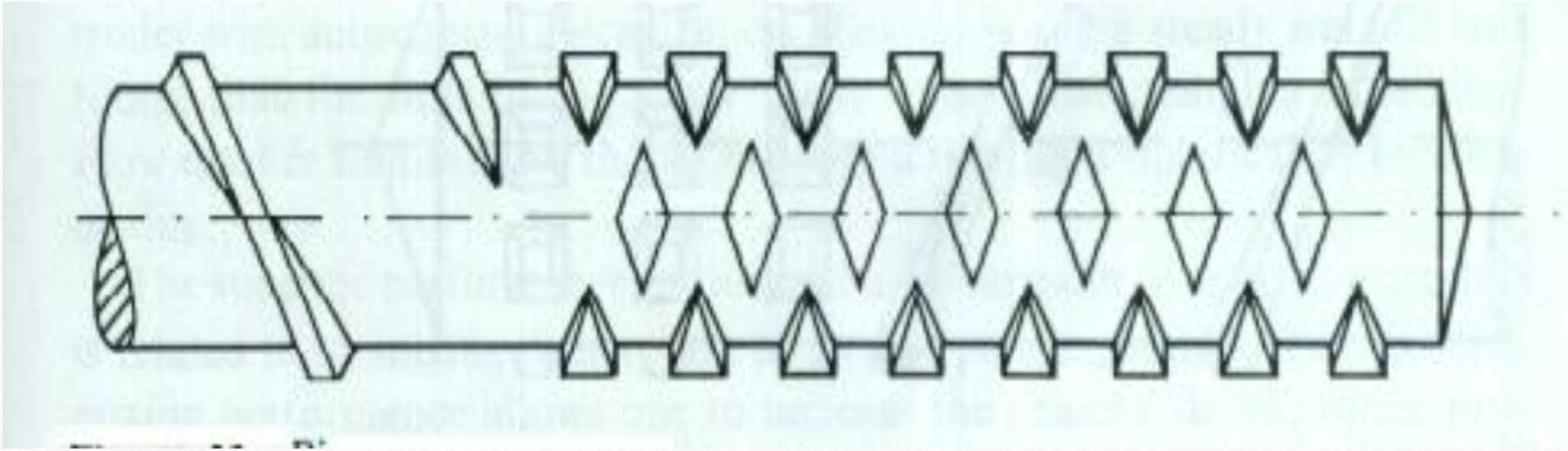
Pin Mixers

- Pin mixers are common and come in many sizes and shapes: Circular,Rectangular, Diamond-shaped



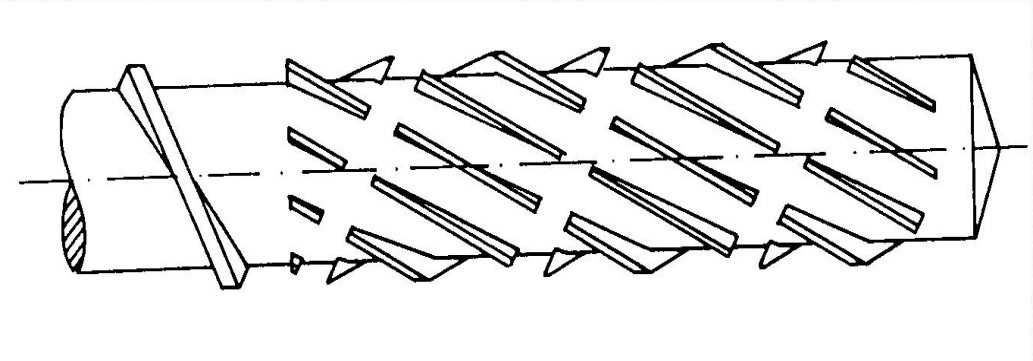
Pin Mixer

Pineapple Mixing Elements



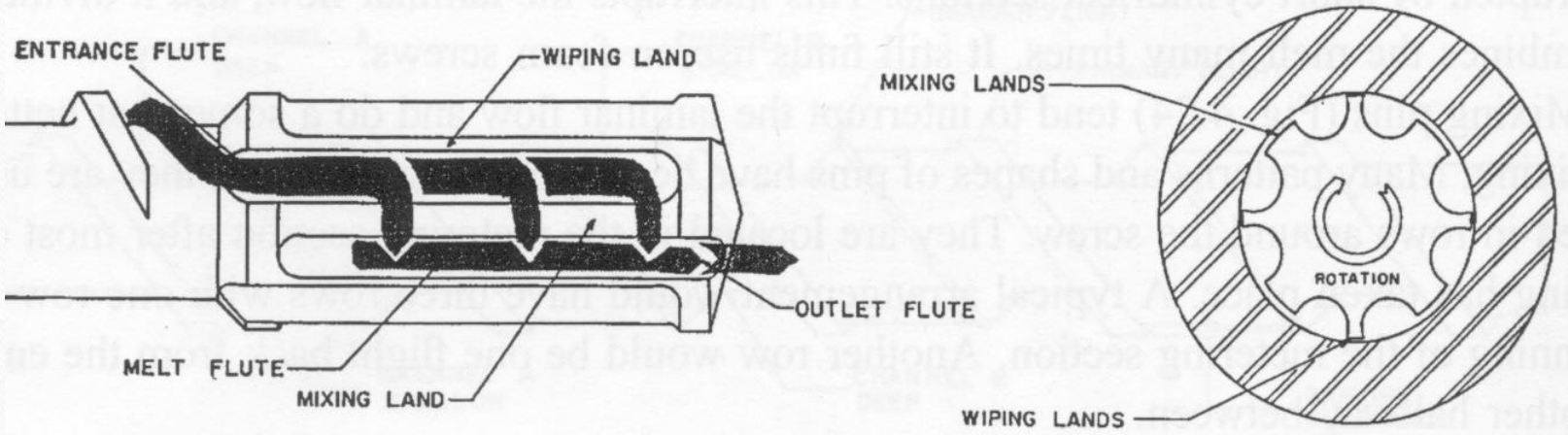
Saxton Mixing Section

- Developed by Dopunt Company.
- Helical grooves instead of tangential.
- Good distributing mixing ability with a low pressure drop.



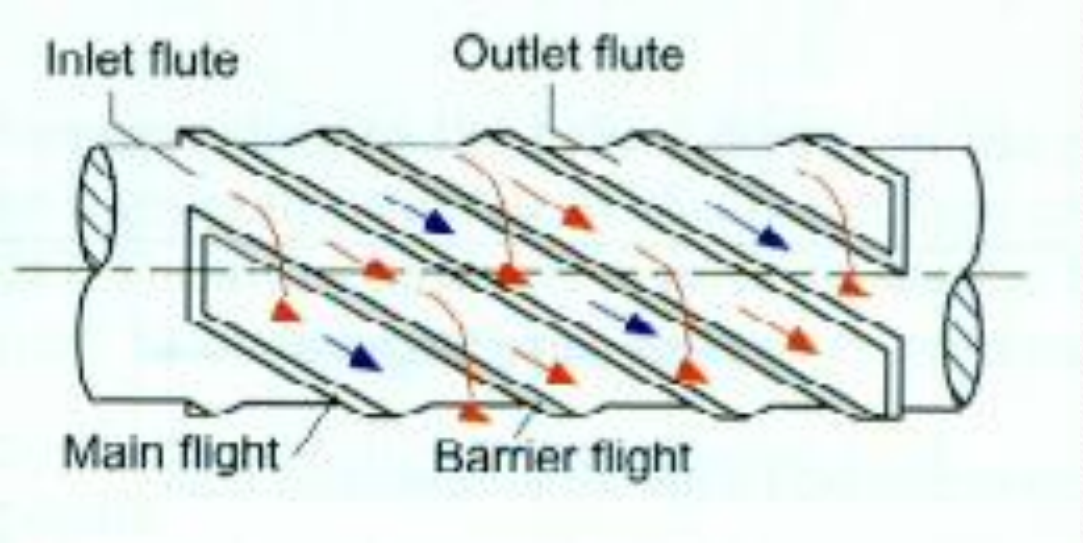
Maddock Mixing Section

- No forward pumping capability and thus high pressure drop
- Most common for single screw extruders
- Poor helix angle design(90)

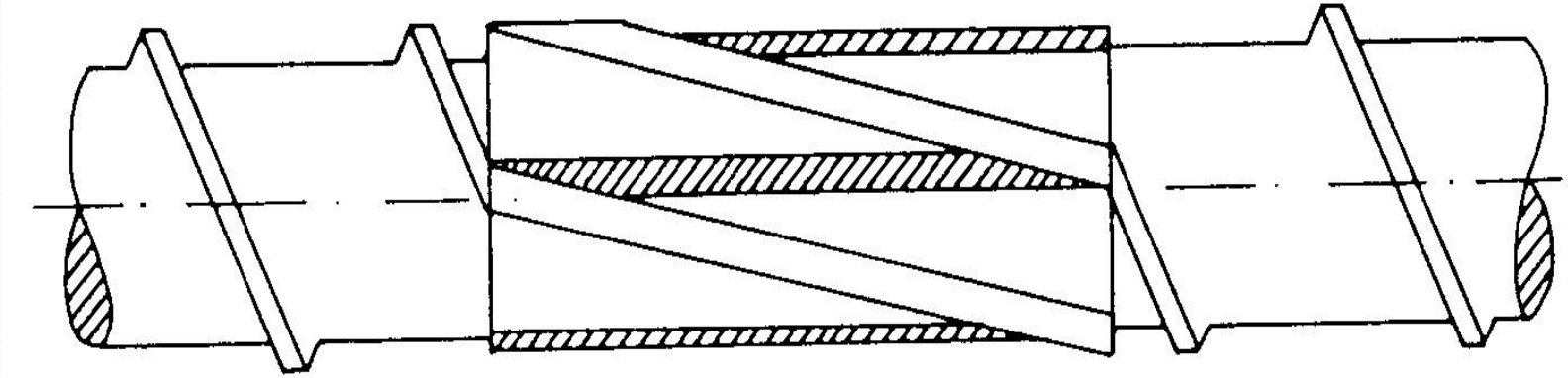


Egan Mixing Section

- Flutes have helical orientation
- Poor helix angle design(30)

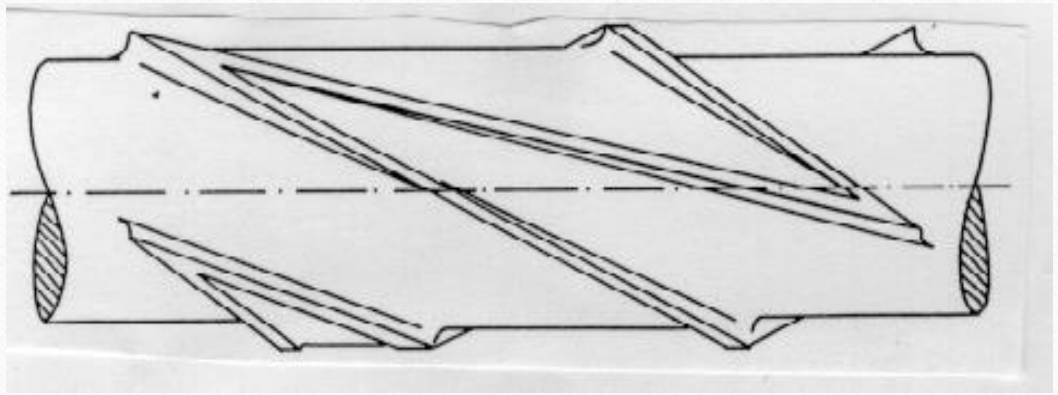


Troester Mixing Element



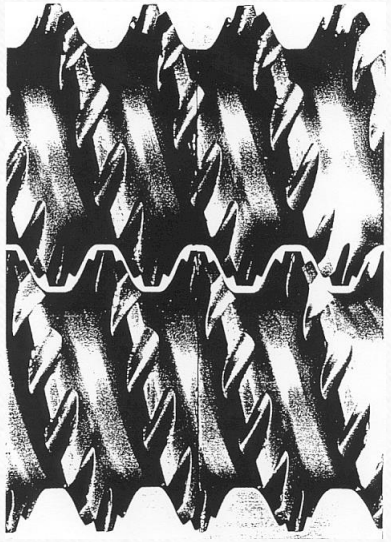
Zorro Mixing Element

- Helix angle of the barrier flight is larger than main flight.
- Width of inlet channel reduces and width of outlet channel increases.
- Barrier flight less than 90°.

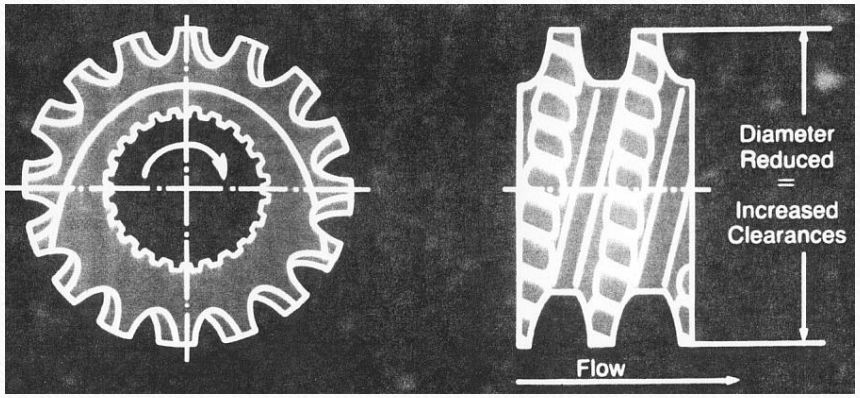


Kneading Block (KB) in CRTSE

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	



- ZME



TME

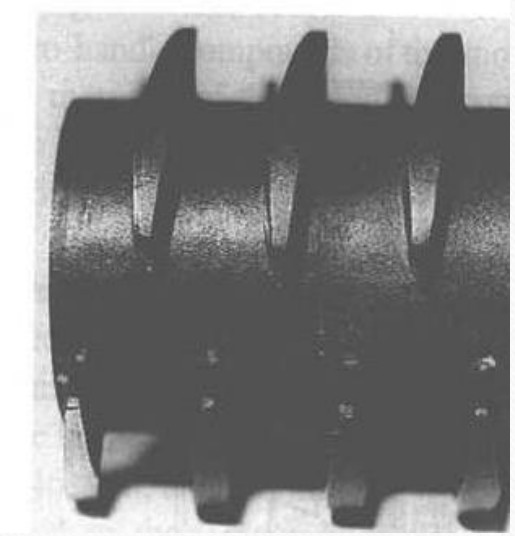
Igel

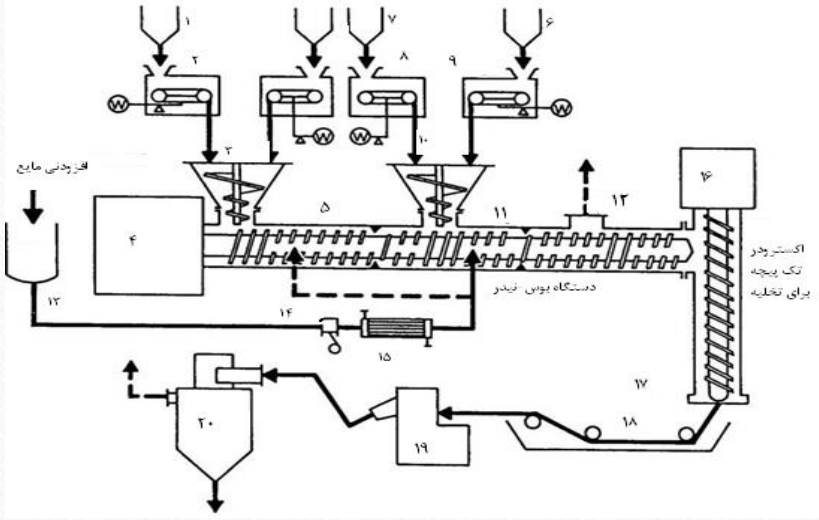
Torque Classification of TSE

- 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.**

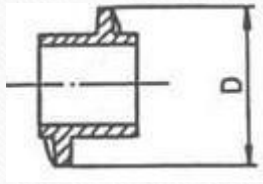
Buss kneader Extruder

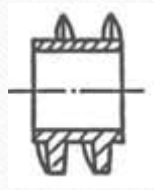


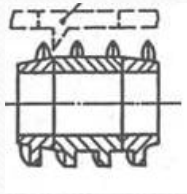


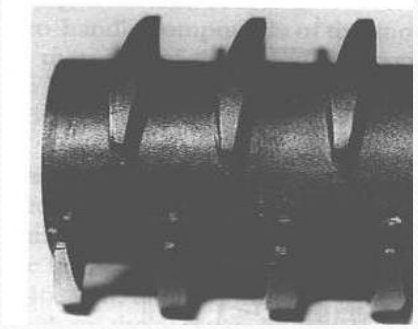
Buss kneader Elements

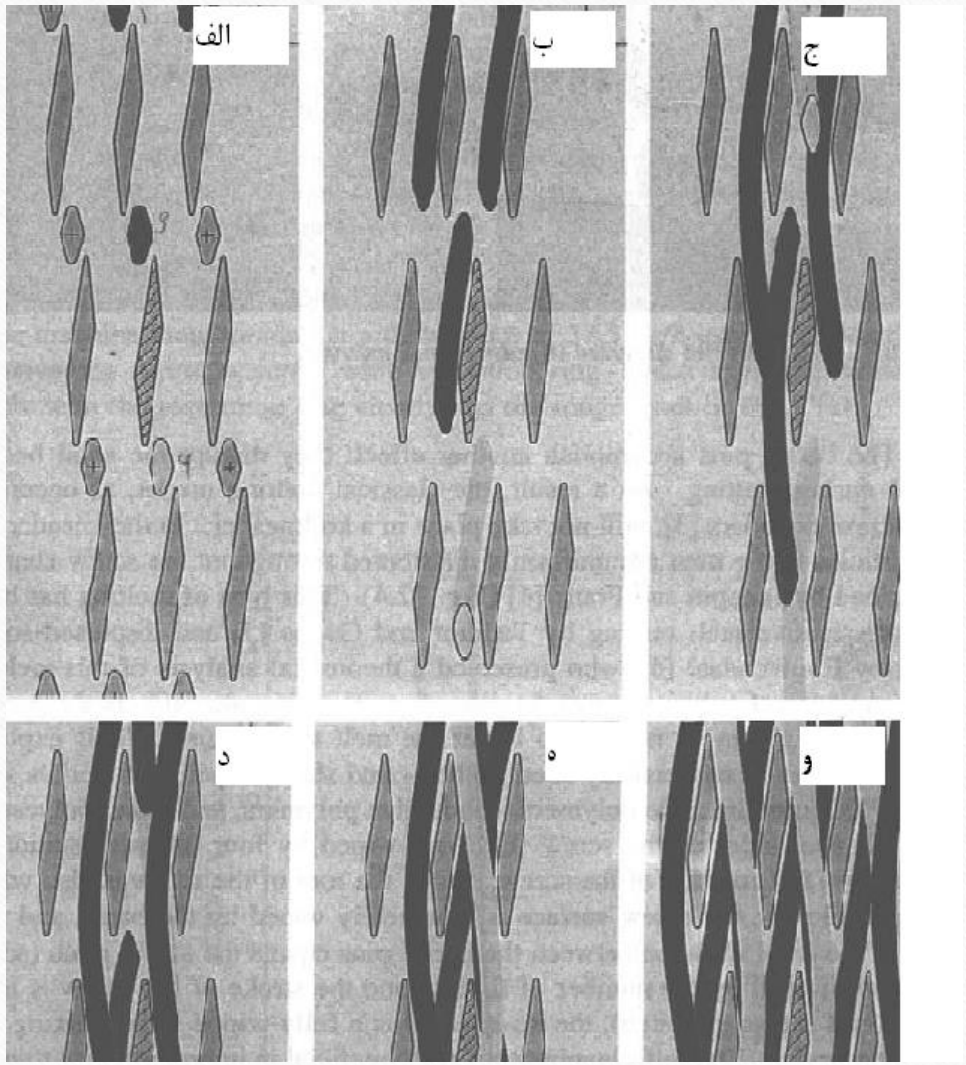
- Solid conveying (EZ)
- Kneaders with closed channel (GS or KN)
- Staggered elements (OS or KNV)
- Kneader with open channel (KE)







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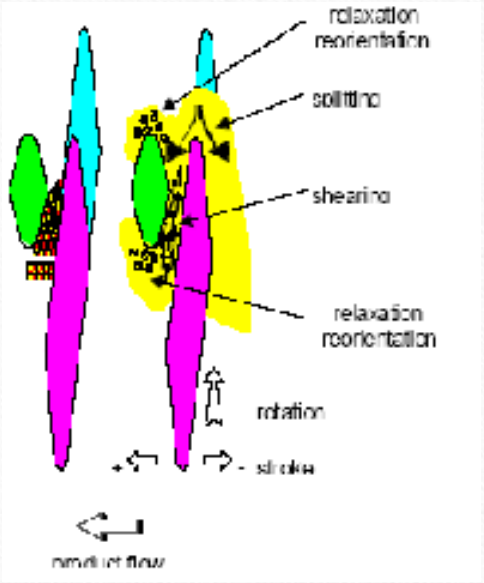
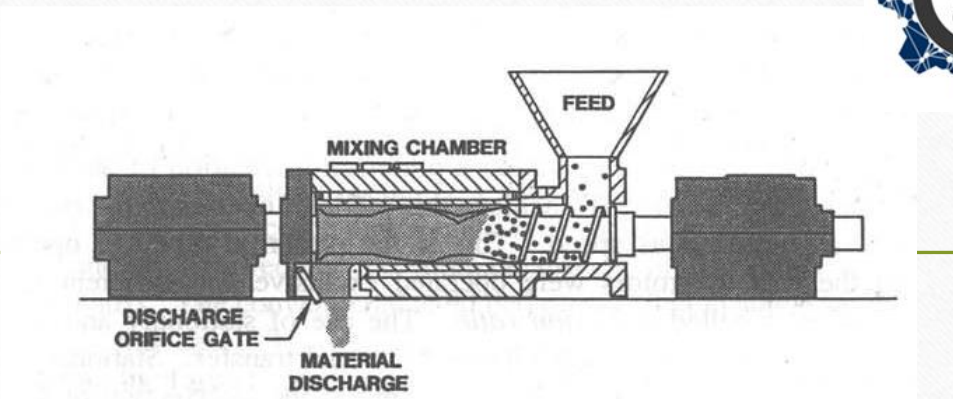
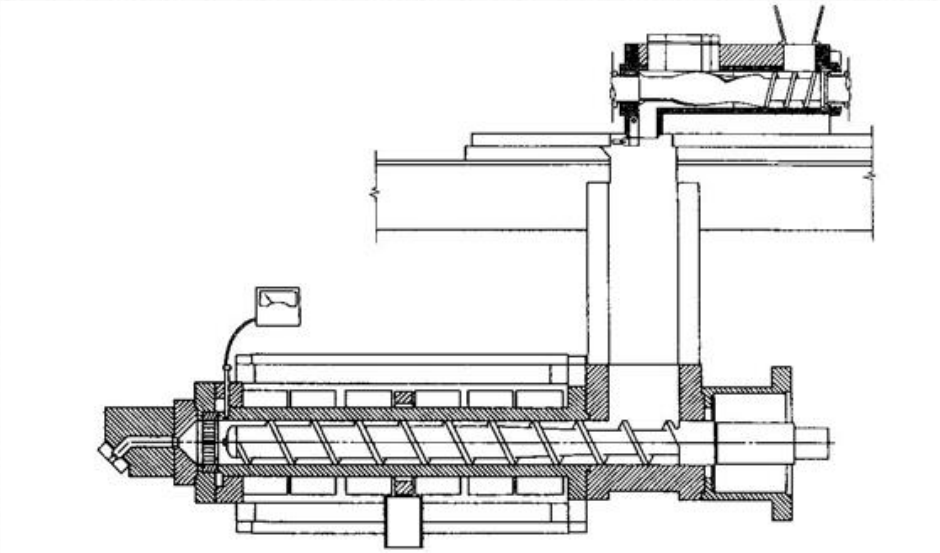

relaxation
reorientation
splitting
shearing
relaxation
reorientation
rotation

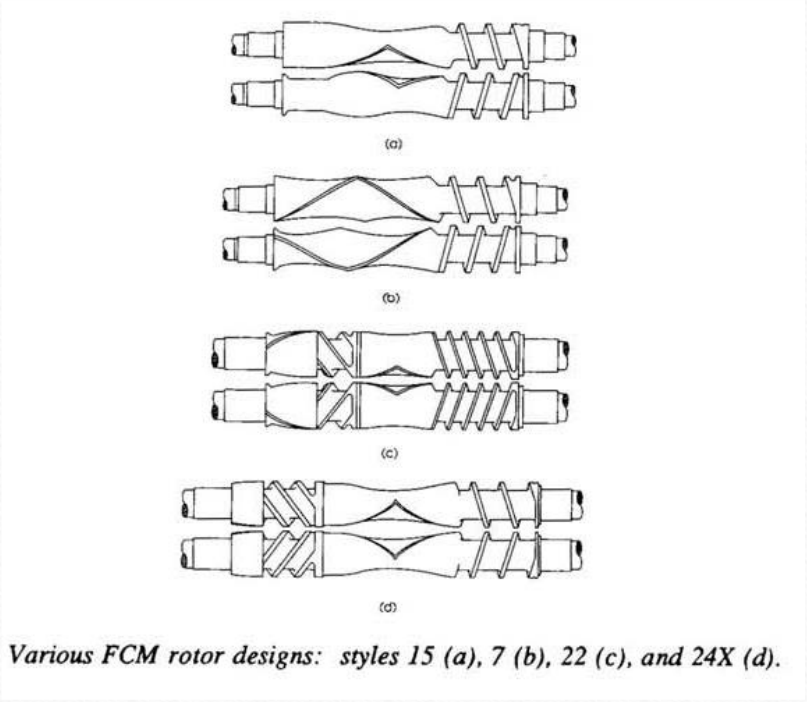
Farrel continuous Mixer (FCM)

- Counterrotating non-intermeshing& intermeshing twin rotor mixer.
- Single or double channel feeding.
- Mixing section has two helically twisted wings approximately 180˚.
- Each wing consisted of pumping section followed by reverse section.
- Gear pump is usually used for control of mixing.





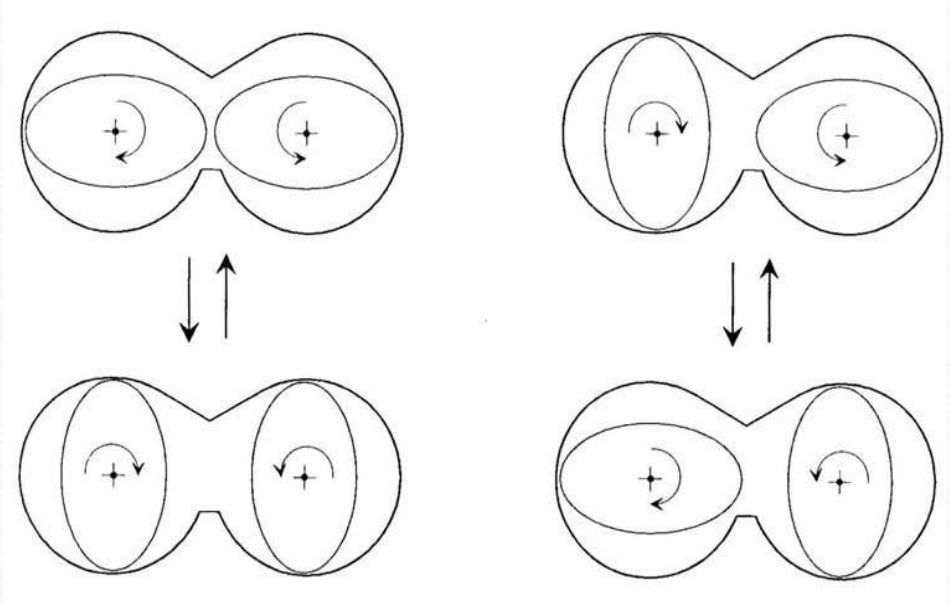
Rotor Design



Various FCM rotor designs: styles 15 (a), 7 (b), 22 (c), and 24X (d).

Mixing in FCM

- Shearing, elongation and squeezing flow.
- Shearing occurs in the region between the rotor wing tips and the wall and between interaction two rotors.
- Elongation is in the wedgelike region between the leading force of the rotor wings and chamber wall.
- Squeezing flow is in the window of interaction as opposing wings from the rotor cross each other.
- Distributive mixing is in the tip to flat.



Internal Mixer + Single Screw → best for EVA, PVC, and very high filler systems where strong initial batch mixing is essential.

Advantages	Disadvantages
High shear mixing → excellent dispersion of fillers and additives	Batch process in mixer → less continuous productivity
Can handle highly viscous, highly filled, or rubber-like compounds	Requires two stages (mixer + extruder), increasing handling steps
Precise batch control of formulation	Limited devolatilization capability
Good homogenization and melt stabilization in the extruder	Single-screw extruder has weak mixing ability compared to other extruders
Suitable for PVC, rubber, and highly filled systems	Longer overall thermal history (two heating stages)
Relatively lower equipment cost than advanced continuous systems	Lower throughput compared to modern continuous compounding lines

Comparison

Feature	Single Screw Extruder (SSE)	Twin Screw Extruder (TSE)	Buss Kneader	Farrell Continuous Mixer (FCM)
Mixing Efficiency	Moderate; suitable for simple blends	High; excels in complex formulations and high filler content	Very high; ideal for intensive mixing of high-viscosity compounds	High; continuous mixing of highly filled and temperature-sensitive materials
Throughput	Moderate; lower production volumes	High; large-scale production	High; handles large batch sizes efficiently	Very high; designed for continuous, high-volume processing
Temperature Control	Basic; limited control	Advanced; precise across multiple zones	Advanced; uniform control throughout mixing zone	Advanced; consistent and precise for sensitive materials
Flexibility	Low; limited to specific applications	High; adaptable to a wide range of materials	Moderate; specialized but customizable	Moderate; tailored but customizable
Maintenance	Low; simpler design	Moderate; complex design requires specialized maintenance	Moderate; requires specialized maintenance	Moderate; requires specialized maintenance
Cost	Lower; cost-effective	Higher; premium due to advanced capabilities	Higher; specialized equipment	Higher; continuous processing technology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