Technological Progress in Co-rotating Twin-Screw Extrusion

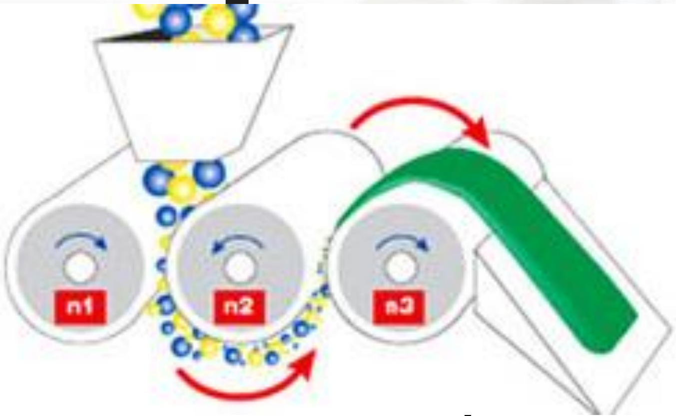
Transforming Materials.
Transforming Lives.

Types of Mixing Equipment's

Counter rotating twin extruder/ Elongational mixing 1907-1955

Banbury mixer/ Kneading action/melting Farrel (5 to 10 min)

Co – Kneader/stirring action
Buss and B&P Systems (***5-8min***)



Two and three roll mill/shear mixing 1830 (**mix on a 84" wide mill, 2 h for a 200 kg)**

Twin screw extruder *residence time 3-4 min*

STEER

Type of Mixing equipment and its Mixing Action

- **Shearing** (shear rate)
  - low shear rates cause heating/melting
  - high rates cause breakdown
- **Kneading**
  - Elongating (strain)
    - High strain causes tearing
  - Folding (frequency & amplitude)
  - Twisting (torsion)
  - Compressing (pressure)
    - sudden compression causes impact
- **Stirring** (stirring or churning rate)
  - high stirring rates cause erosion

Certain level of shearing causes size reduction - **Dispersing**

Certain level of kneading causes **Wetting**

Certain level of stirring causes homogenization - **Distributing**

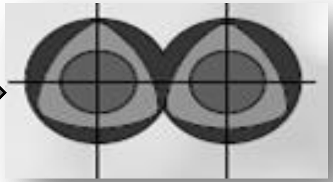
Types of Mixing Equipment's

Banbury mixer

Co – Kneader

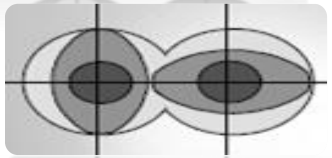
Progress During 20th Century

1956: 1st generation
$D_o/D_i = 1.22$
$n = 150\ mm^{-1}$

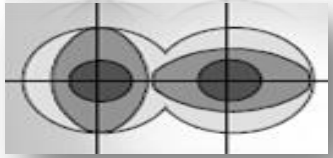


1970: 2 - flight
$D_o/D_i = 1.44$
$n = 300\ mm^{-1}$

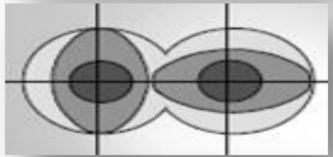
1983: SC
$D_o/D_i = 1.55$
$n = 600\ mm^{-1}$



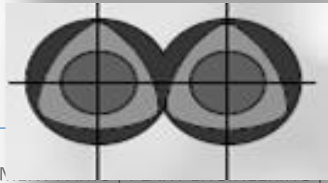
1995: Mc
$D_o/D_i = 1.55$
$n = 1200\ mm^{-1}$



2004: 21st generation - Omega
$D_o/D_i = 1.71$
$n = 1200\ mm^{-1}$



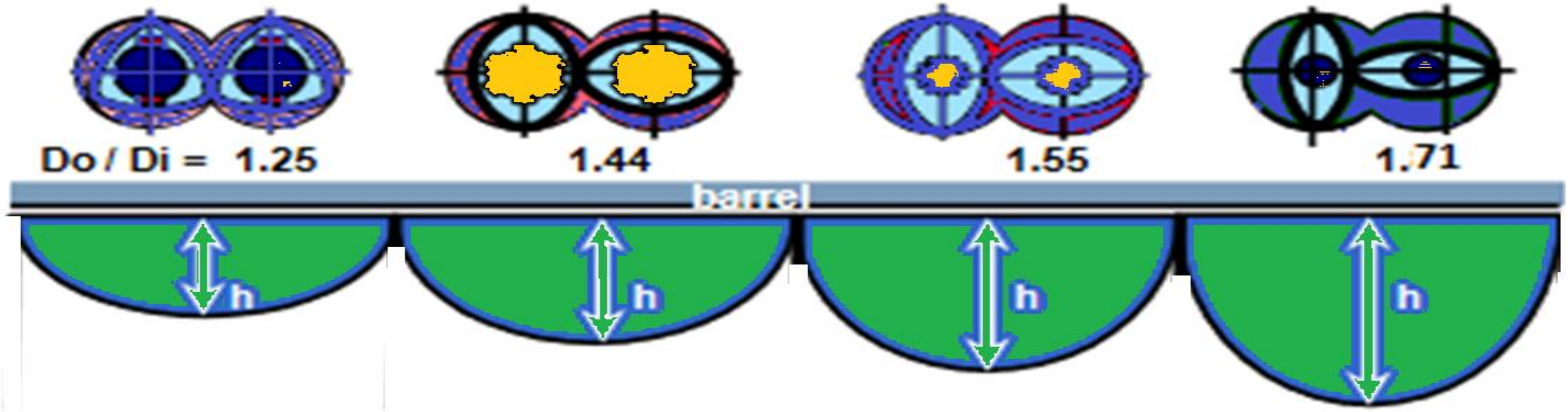
2009: Fractional geometry
$D_o/D_i = 1.71$
$n = 1200mm^{-1}$



Year	Motor Speed/Screw speed	Output	Mean Residence time (s)	Mean shear (1/s)	Total shear
1956	150	25	410	150	61500
1970	300	100	120	170	20400
1983	600	500	25	300	7500
1995	1200	800	16	400	6400
2004	1200	150-200	12	350	5400
2009	1200	900	4	544	2404

Effect of Do/Di & RPM on average shear rate

Increase torque and free volume

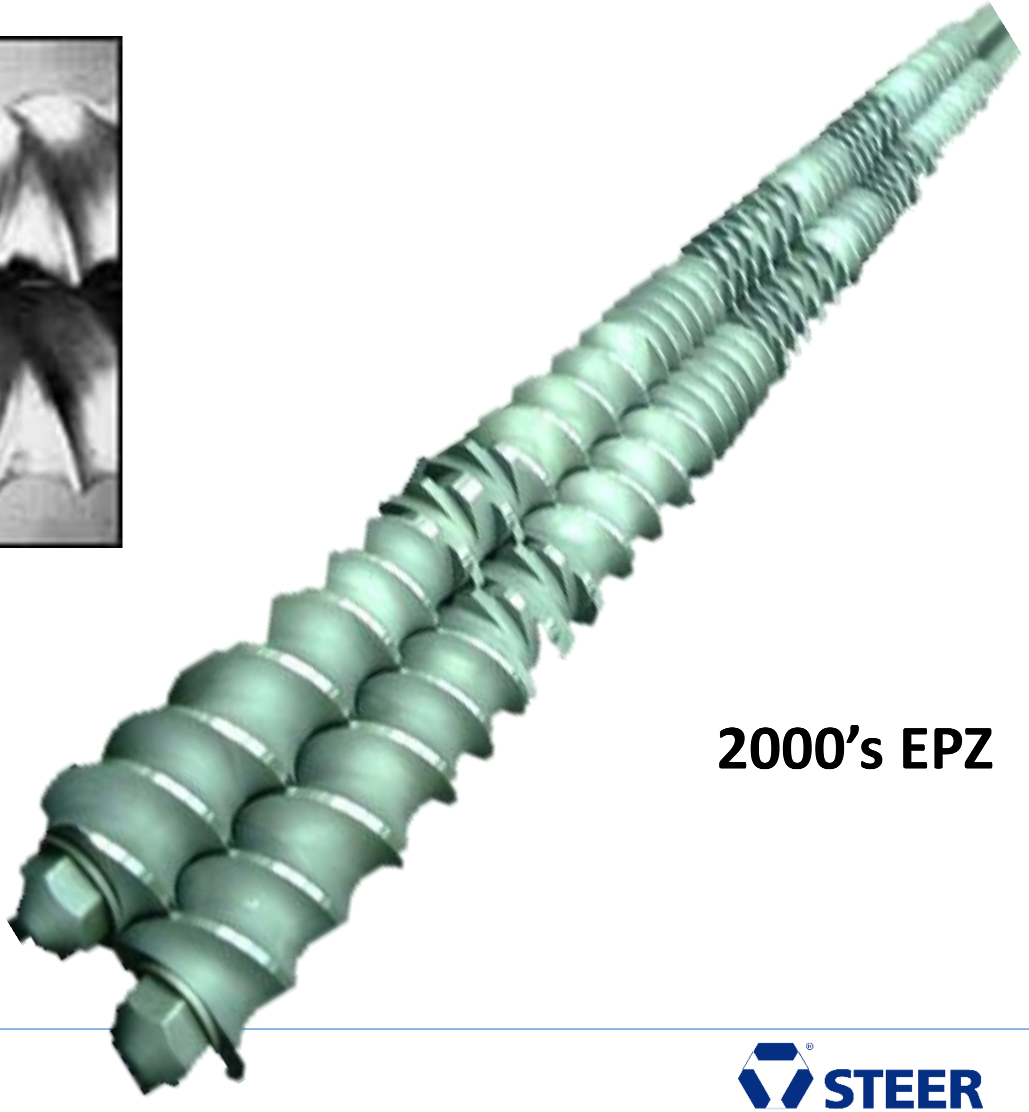


Higher screw speeds compensate for **lower average shear rates** of **filled channels** at the **same total shear** and **temperature stress**

Evolution of the Modern Twin Screw Extruder Process Zone

1950’s EPZ

1960’s EPZ



2000’s EPZ

20th Century Extrusion Technology

Evolution of the Modern Twin Screw Extruder 20th century

Advantages

- Higher screw speeds
- Higher torque handling capability
- Larger drive motors
- Greater throughput
- Reduced residence time

Limitations

- Feeding limitations
- High peak shear
- High melt temperatures

Circa late 1950's

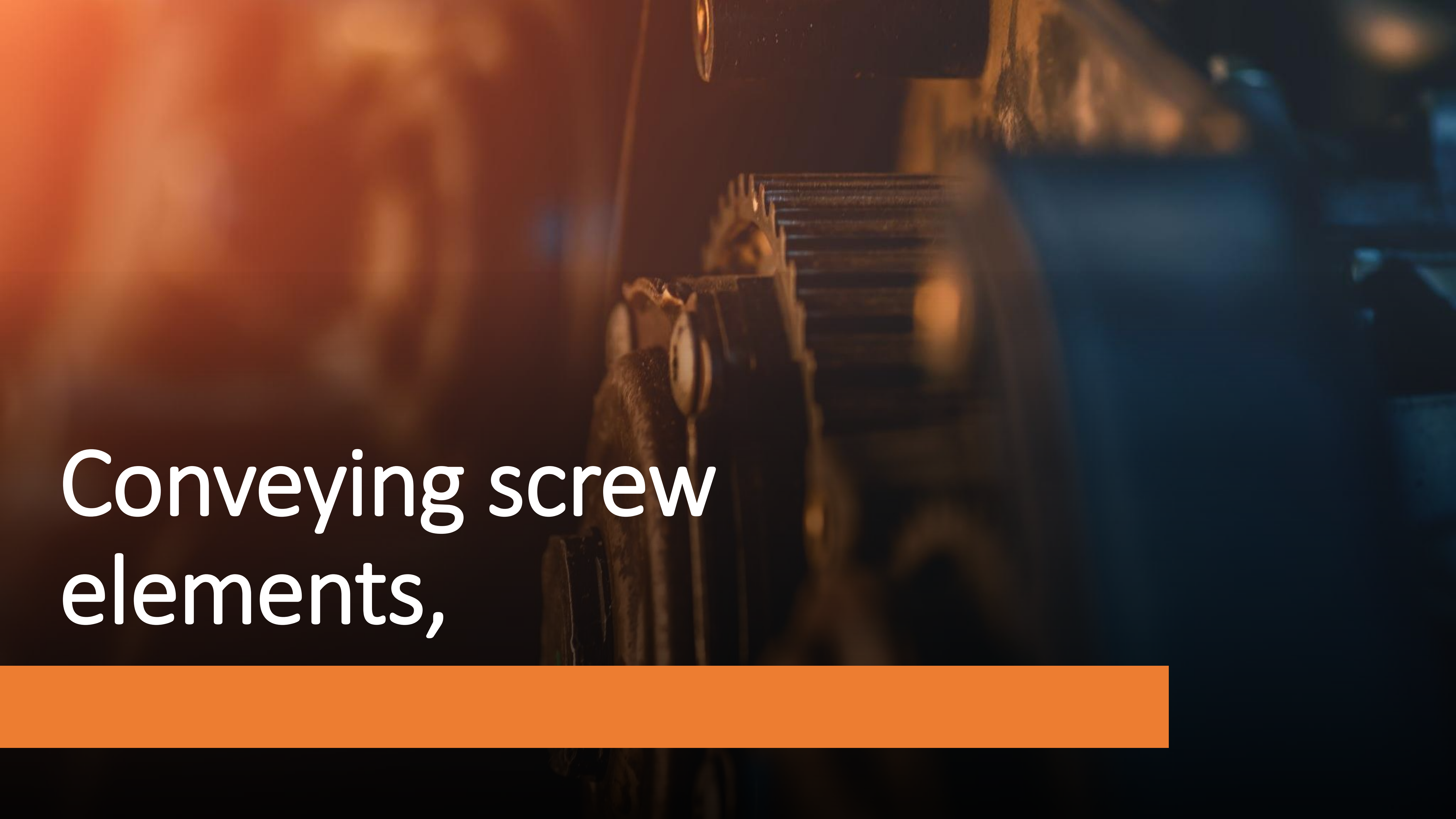
- **The Modern Extruder Has Evolved Much Faster Than the Evolution of the Process Zone (EPZ)**

Process challenges with Standard Elements(TSE) 20th century

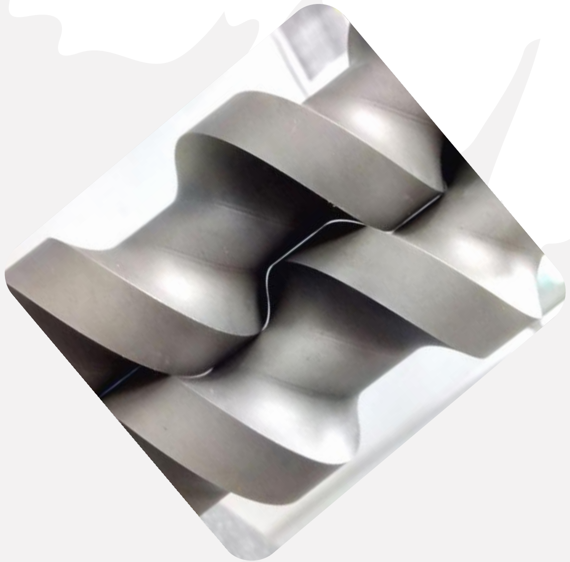
It is evident that shear sensitive material Polymer can not process effectively due to following reasons:

- Shear sensitive Materials **development is compromised**
- **Peak shear rate which results in decomposition** of polymer materials
- **Restriction of high screw speed** operation
- Feed limitation and lower output
- Lower mechanical properties

Conveying screw elements,

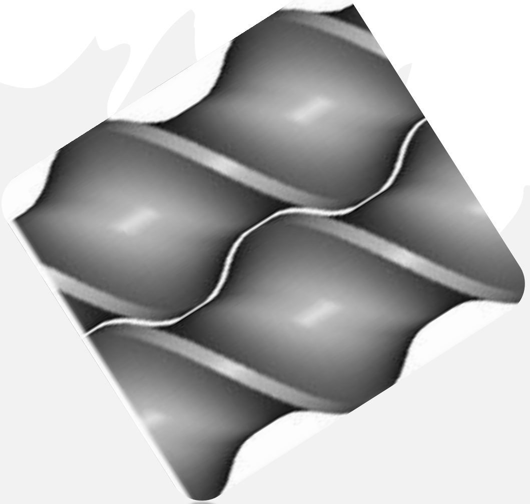


Conveying Elements during the 20th Century



SFE

SKE



RSE

- SFE & SKE elements causes stagnation of material in the roots of the screw
- SFE crushes the material due to wider flight.
- RSE element lacks conveying lower free volume.

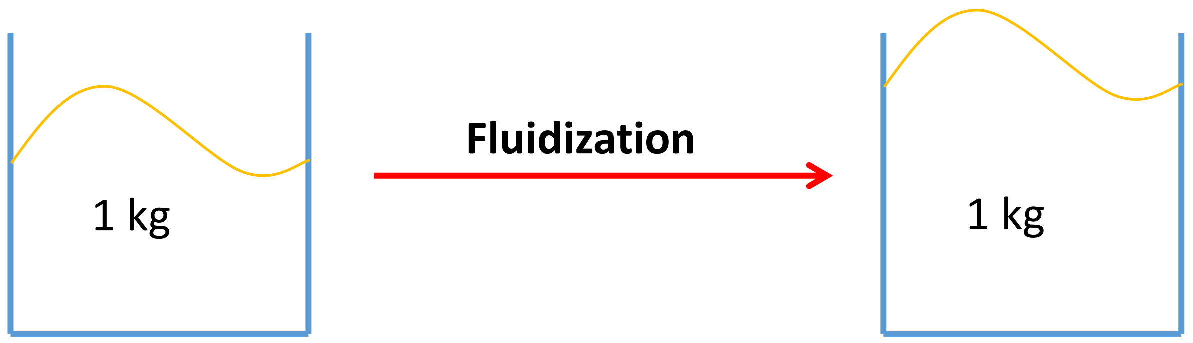
Hopper chocking /Stagnation of material

Fluidization of Low Bulk Density Materials

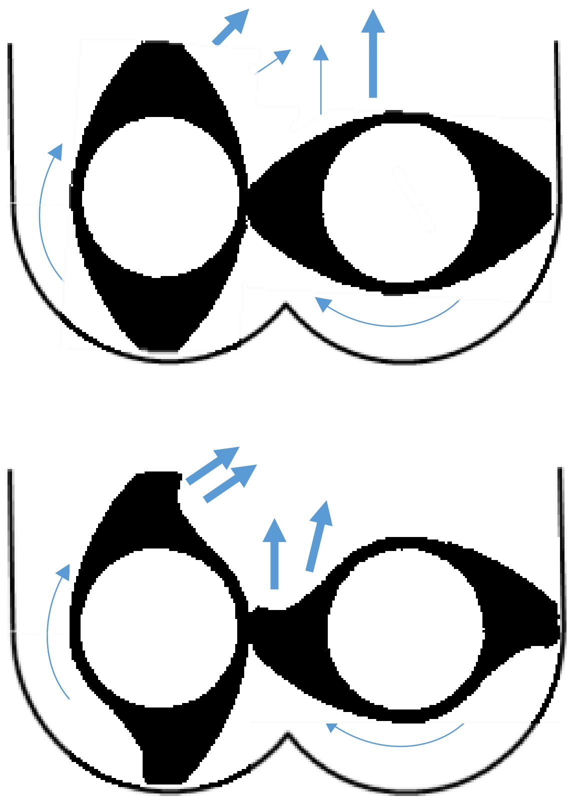
Fluidization: entrapment of air resulting in a further reduction of bulk density

Causes:

- Entrapment of air during feeding
- Entrapment of air during the decent to the intake zone
- Entrapment of air due to turbulence within the intake zone
- Inability to disengage air within the intake zone (intake is flooded)



Fluidization Resulting From Turbulence



- Radial forces exist from the rotating elements
- Radial and impingement forces propel material outward away from the screw shafts
- Neutral face angle of SK elements reduces the negetive effects of impingement however centrifugal force still throws materials out away from the shafts
- ***As screw speeds are increased it is common for actual throughput to decrease due to mechanical fluidization***

Difficulty in feeding low bulk density material with modern high speed TSE's results in capacity being feed limited, capacity entitlement cannot be attained

Kneading Elements

Kneading Blocks during the 20th Century

RKB

NKB

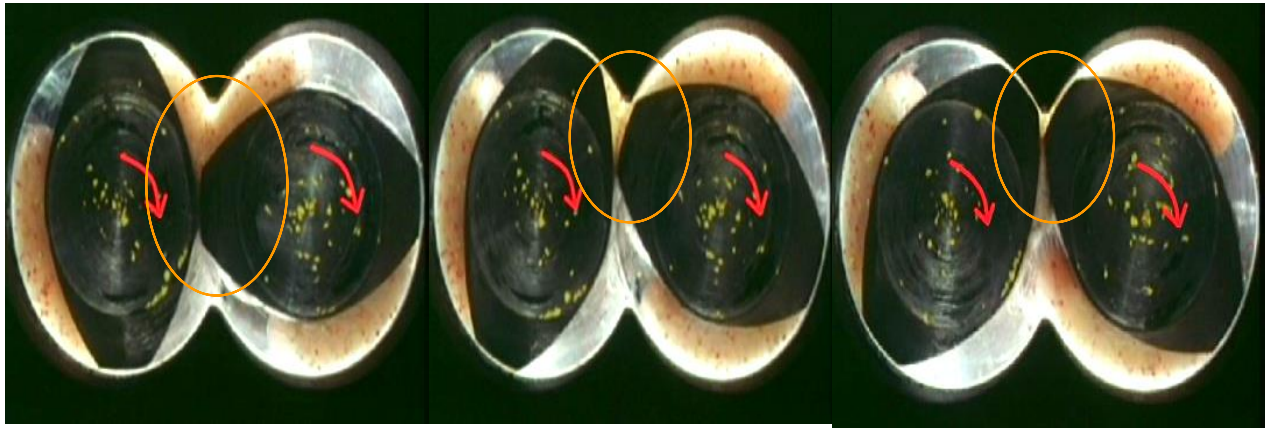
LKB

- For nearly six and a half decades the **Erdmenger** type kneading block has been the predominant kneading   Melting and mixing element.
- High Energy is consumed , Higher melt temperature
- Shear peaks occur where a small fraction of melt is subjected to **high shear rates is unavoidable**

Rudolf Erdmenger introduced the standard kneading block in 1949

Kneading Elements during the 20th Century

- Shear peaks occur as a **small amount of the melt pool is forced through the narrow gap .**
- Intermeshes screw experienced very high shear rates when the material is forced through the gap.
- **3% of the melt pool exposed to high shear will experience a rapid temperature rise .**
- Degradation can occur in shear sensitive materials.



Uncontrolled Peak Shear

RKB

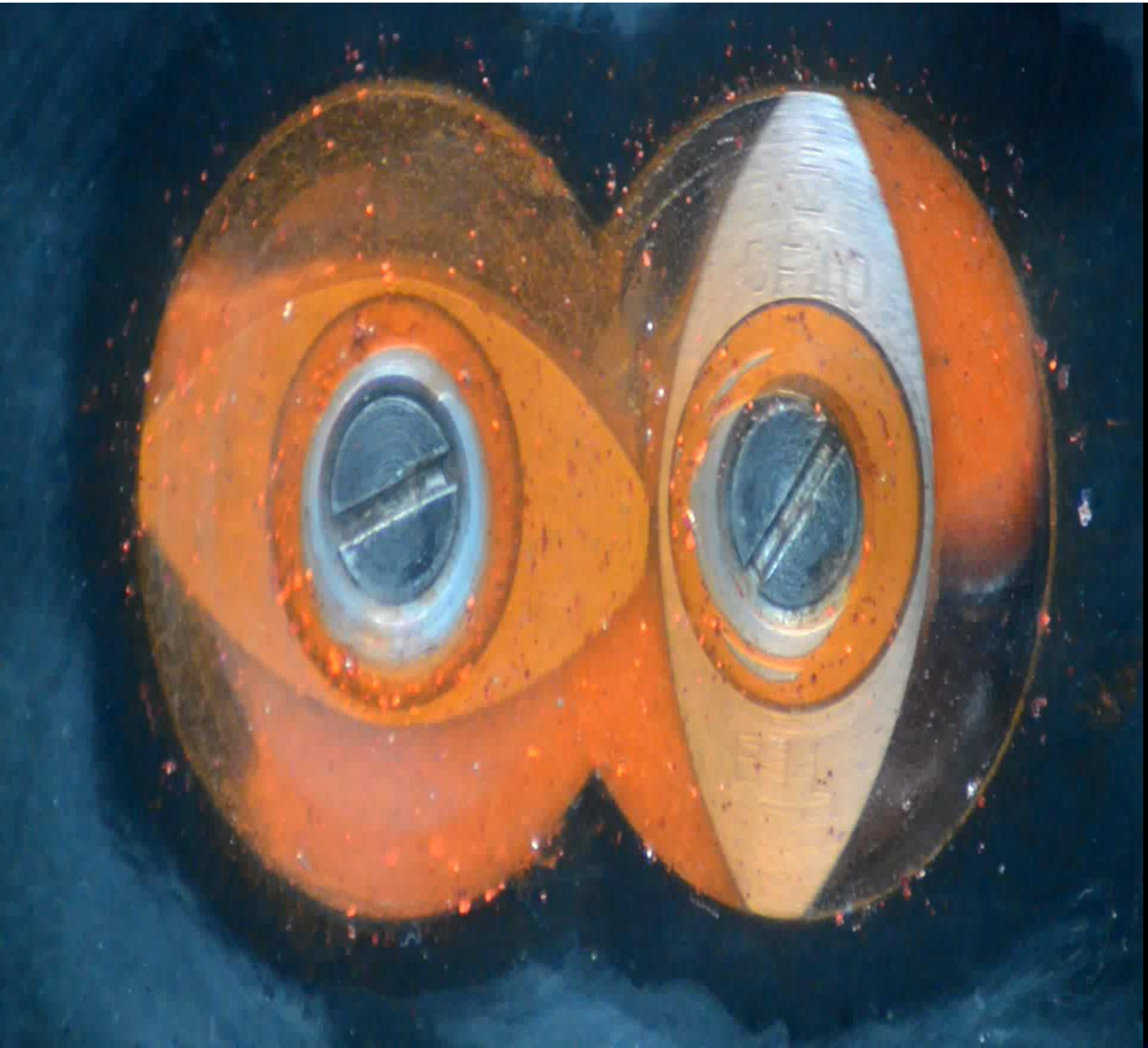
NKB

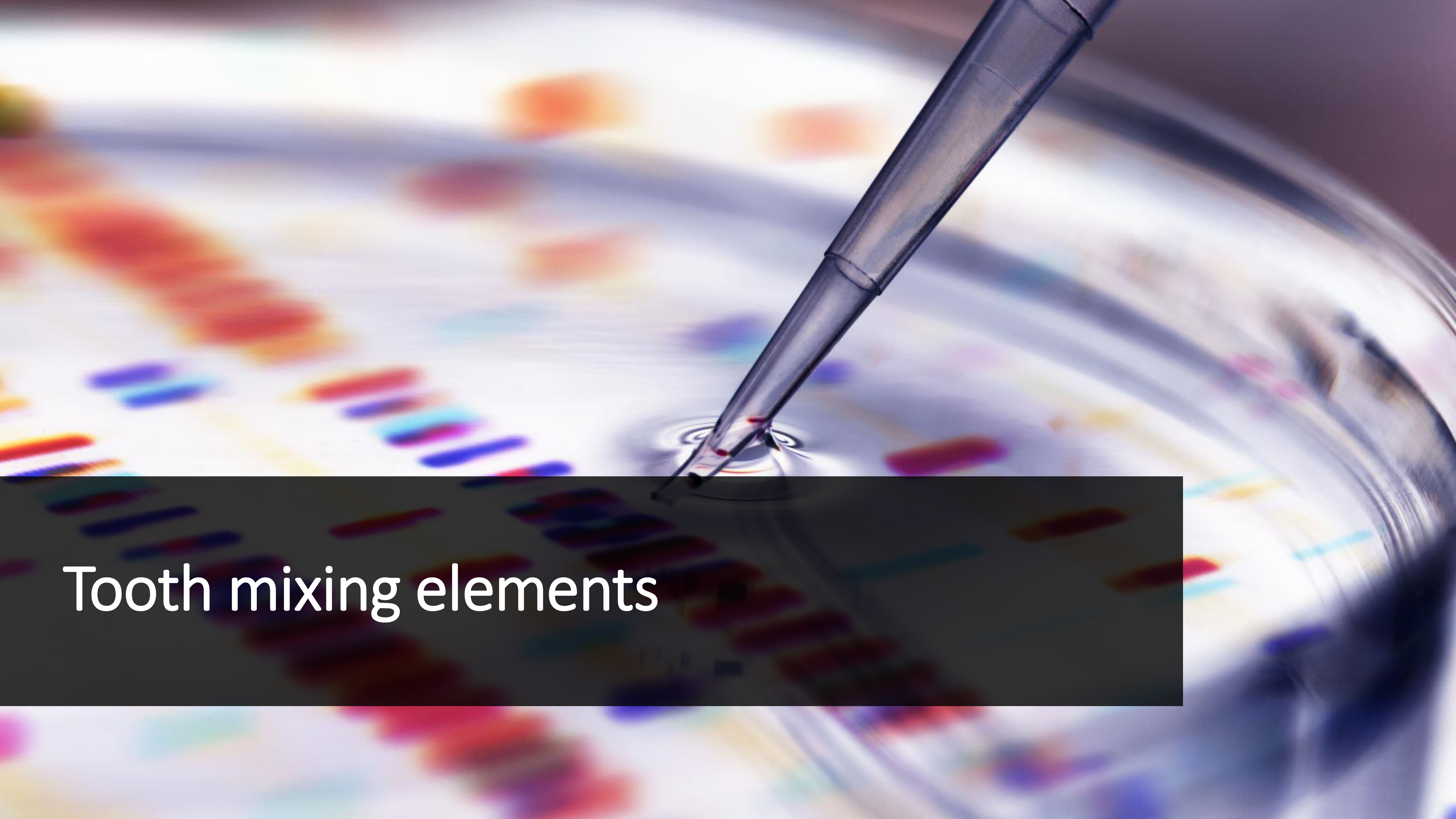
LKB

Polymer degradation

Shear peaks are cannot be avoided in Bi lobe type kneading blocks

Stranded Bi lobed Elements





Tooth mixing elements

Mixing Elements during the 20th Century

Tooth mixing elements

- ❖Stagnation and degradation of material.
- ❖Non self wiping

Driven by

Fractional Geometry Technology 21st Century

INTELLIGENT™ COMPOUNDING

FUNCTIONALISE. OPTIMISE. ADVANCE.

Narrow and constant

Low Temperature

High Output

Self wiping Shear

High Torque

Control the Peak Shear enable high-output and high speed operation

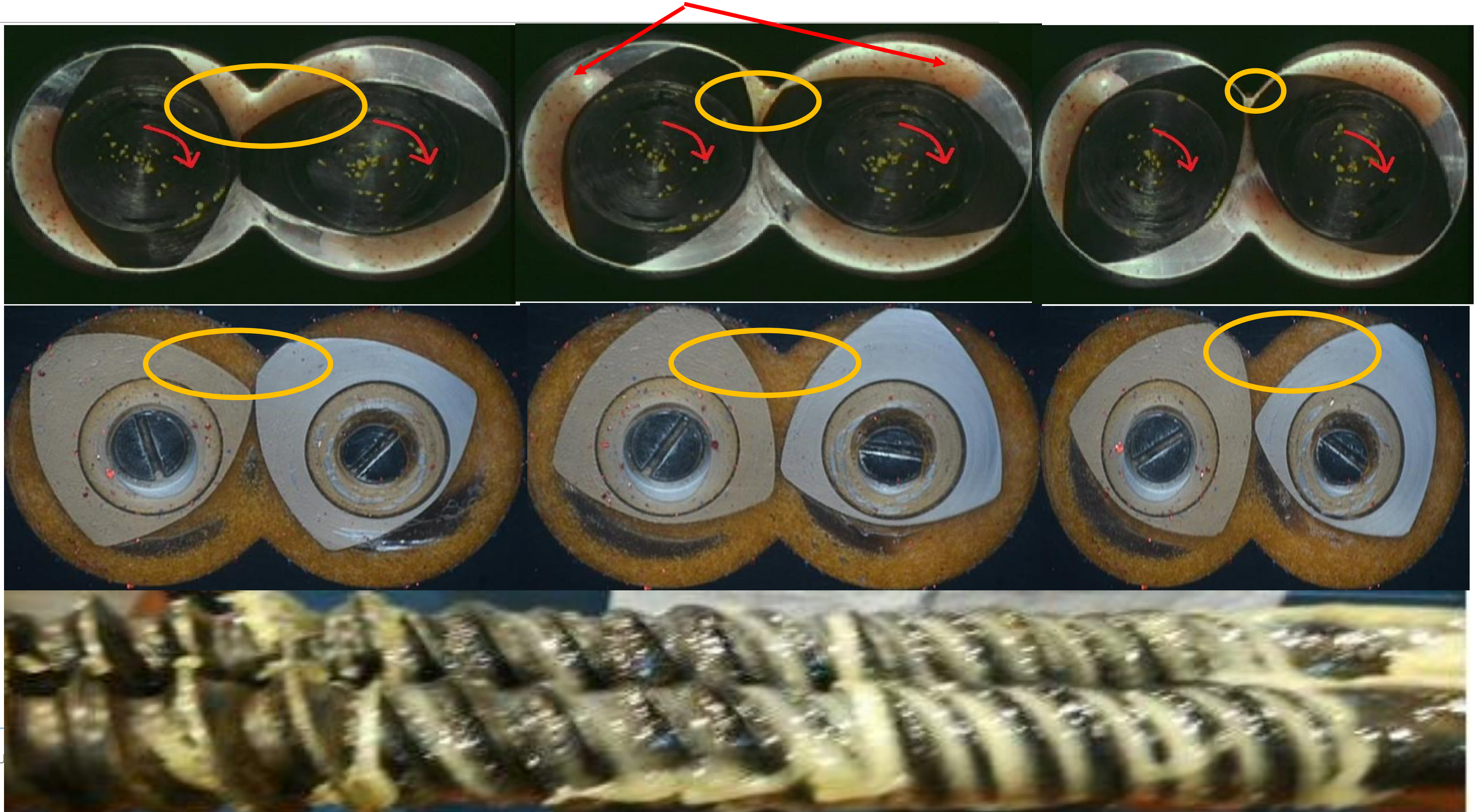
Deeper Groove Do/Di 1.71

Fractional Geometry Technology V/S Standard screw element.

It is not possible to eliminate **shear peaks** in Erdmenger Integer Lobe geometry. Minimizes shear peaks by using FGT.

Bilobe

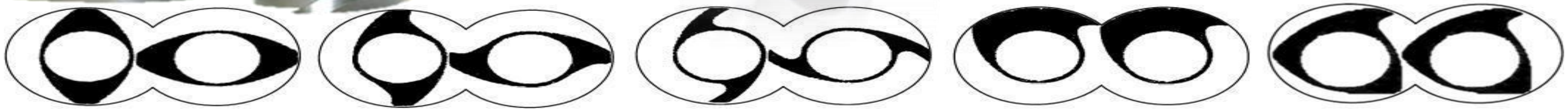
Fractional Lobe



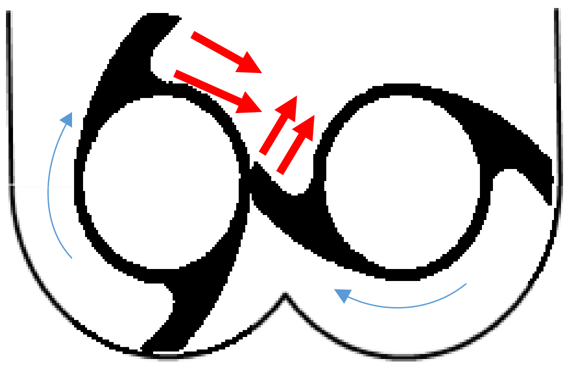
FKB and RFV

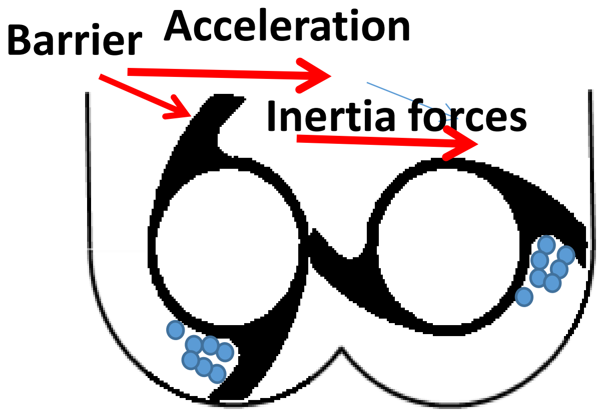
Conveying screw elements,

Feeding Elements Are Finally Evolving 21st Century



Understanding Solids Conveying of Low-Density Materials

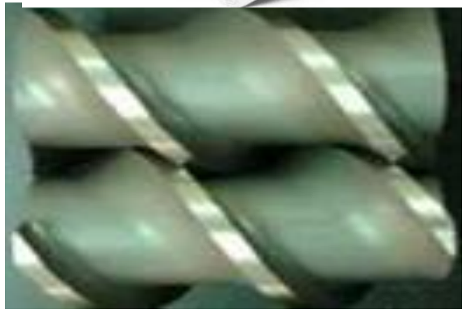
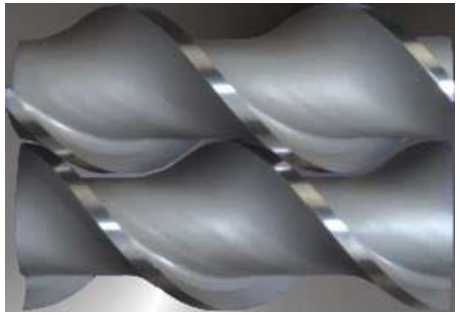


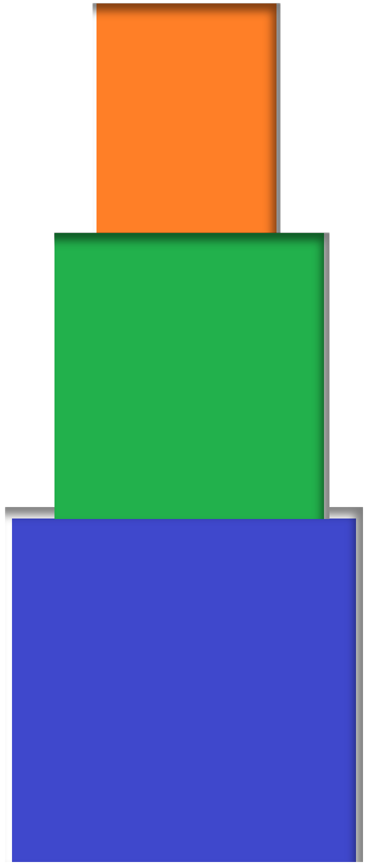


- There is a correlation between an increase in fluidization and a reduction in feeding capacity
- The leading flight should have a negetive angle such that **impingement forces materials forward and inwards (to the shaft)**
- A barrier is needed to minimize the escape of materials outwards due to centrifugal forces
- Inertia from the materials being rapidly accelerated and transported forward forces the materials to remain confined within the screw root
- The negetive angled flight acts as a barrier

Starve feeding

Conveying elements Efficiency in 21st Century

	Element Type	Free Volume	Conveying efficiency	Area of application
	**Right hand screw element (3RSE)**		Medium	Pellet, flake etc, intake zone, compression zone, metering zone
	**Schubkanten elements (SKE)**		High up to 15 % than 3 RSE	Pellets ,Powder, flake etc. intake zone/ side feeding, Devolatilization / venting zone
	**Regular flight shovel element (RFV)**		Highest up to 20% than 3RSE	Pellets ,Powder, flake etc. intake zone/ side feeding , Devolatilization / venting zone



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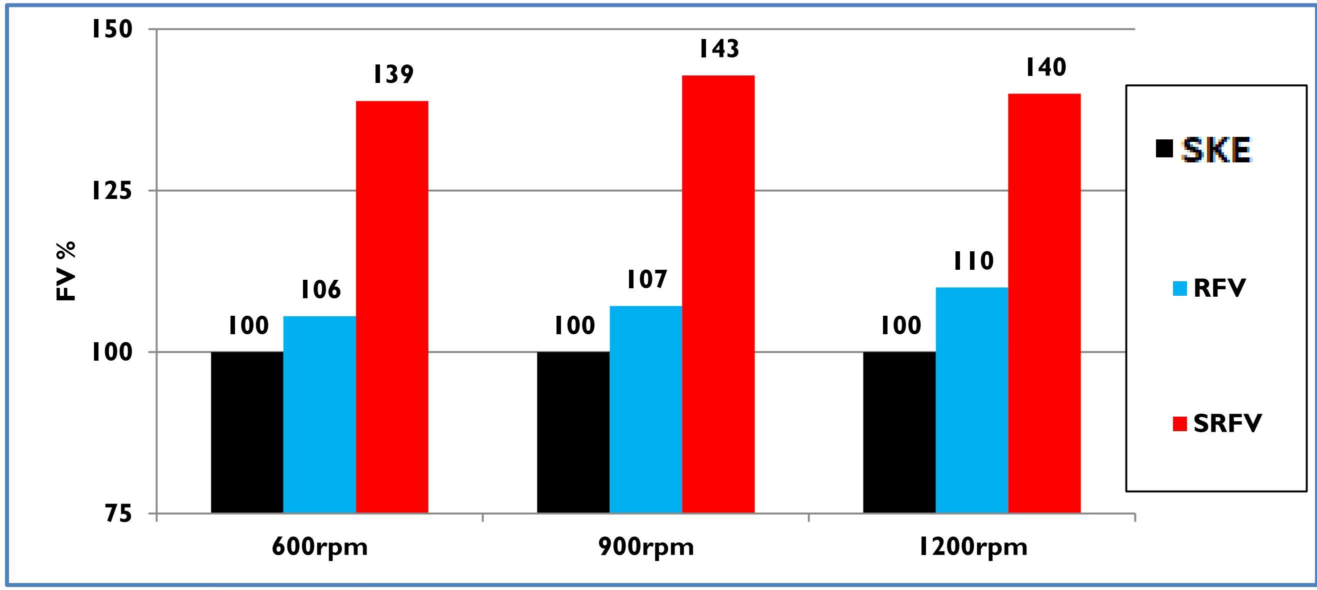
OMEGA OET® Output Enhancement Technology

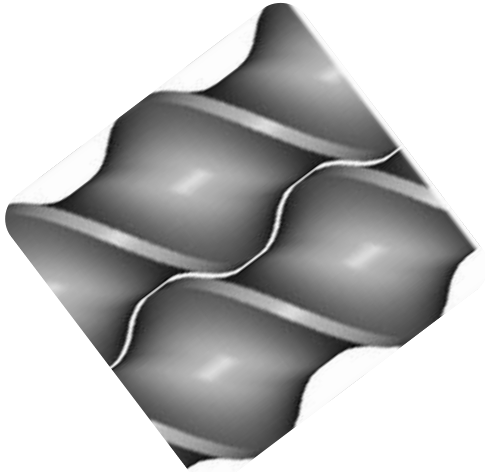
Overcomes feed limitations of low bulk density materials

40 mm Omega TSE
50% Talc + LLDPE Powder

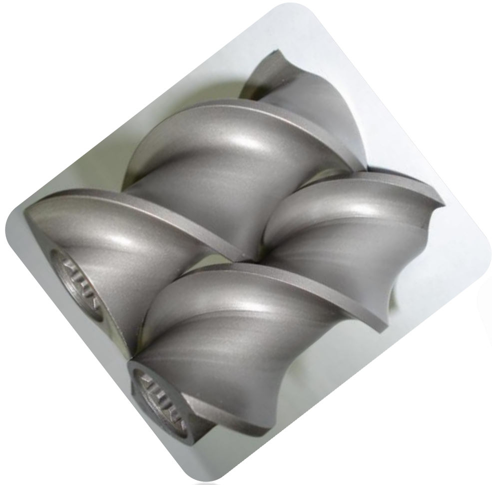
Japan Patent Number 4977683

Comparison of different technology of feed elements





RSE



SKE

RFV

SRFV

Fractional Geometry Technolog

- Shear Uniformity
- Melt Temperature Reduction
- Extensional Flow
- Fiber Length Retention

2.5 D

OSE

FKB

FME

1st Generation -2000

DSE

2nd Generation 2012

3 D

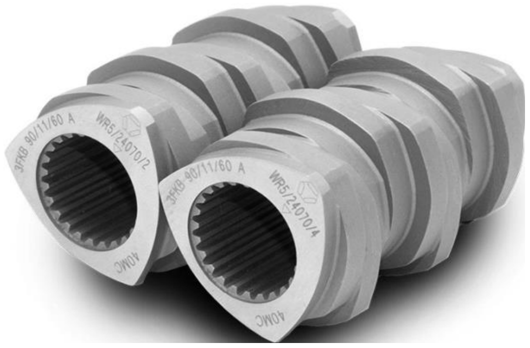
MFE

3nd Generation 2015

MKE

3nd Generation 2018

21st Century kneading elements



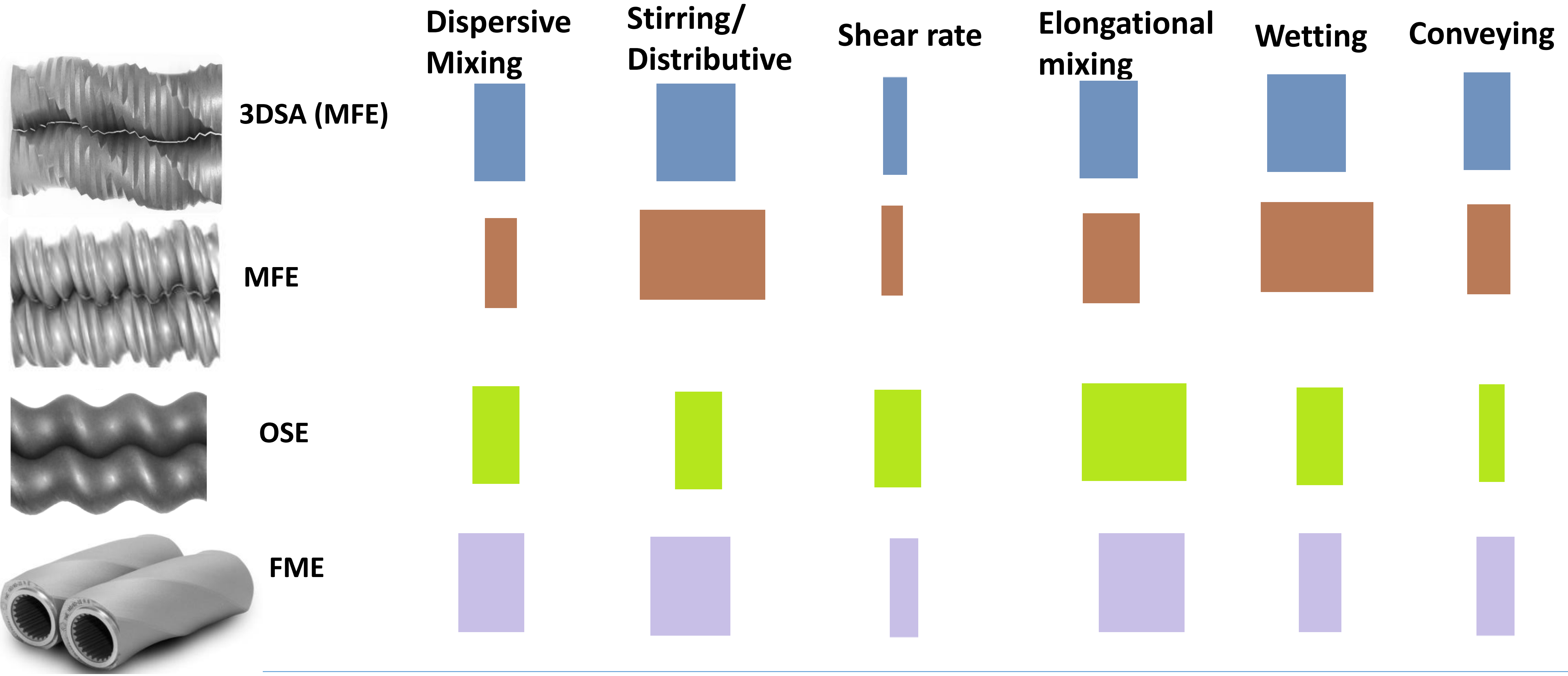
3FKB

3RKB

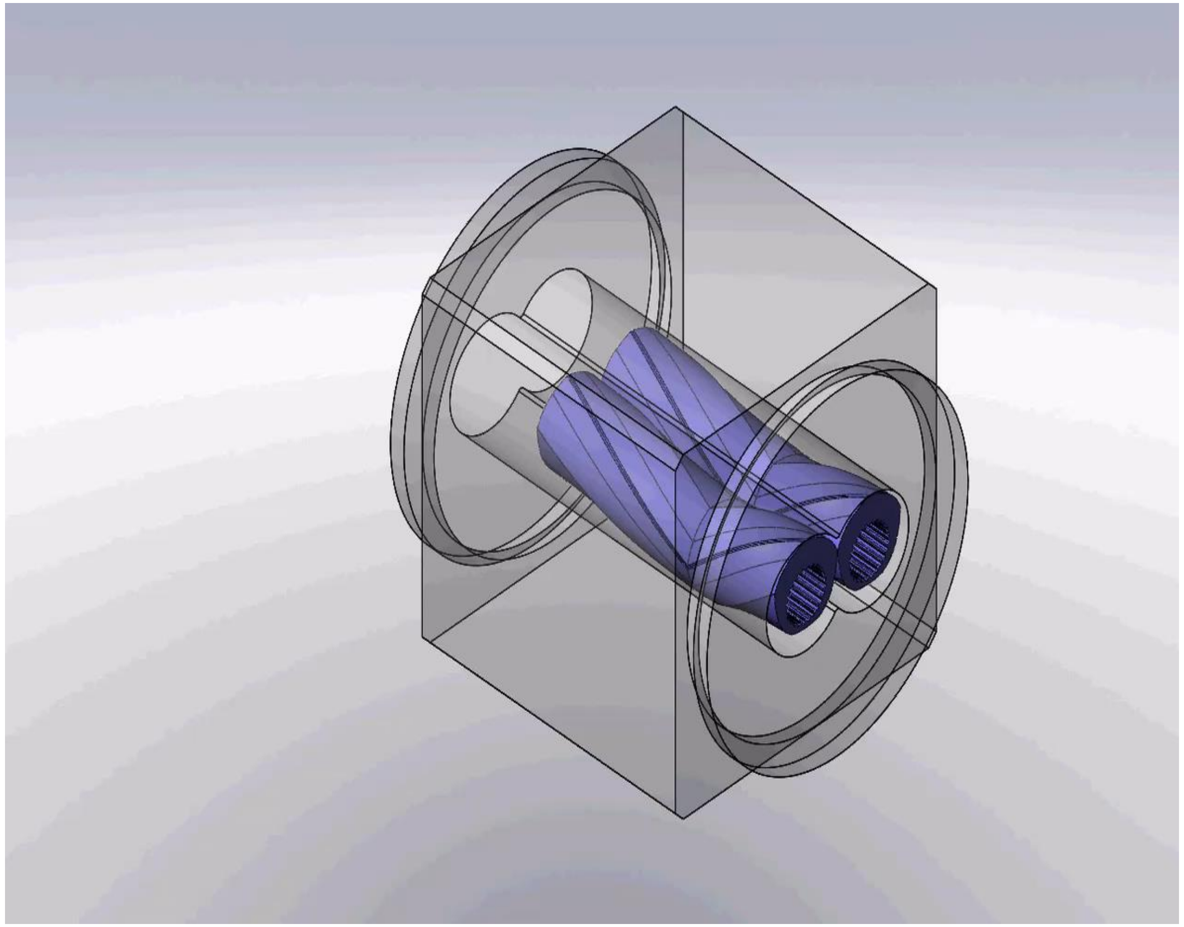
3RKB

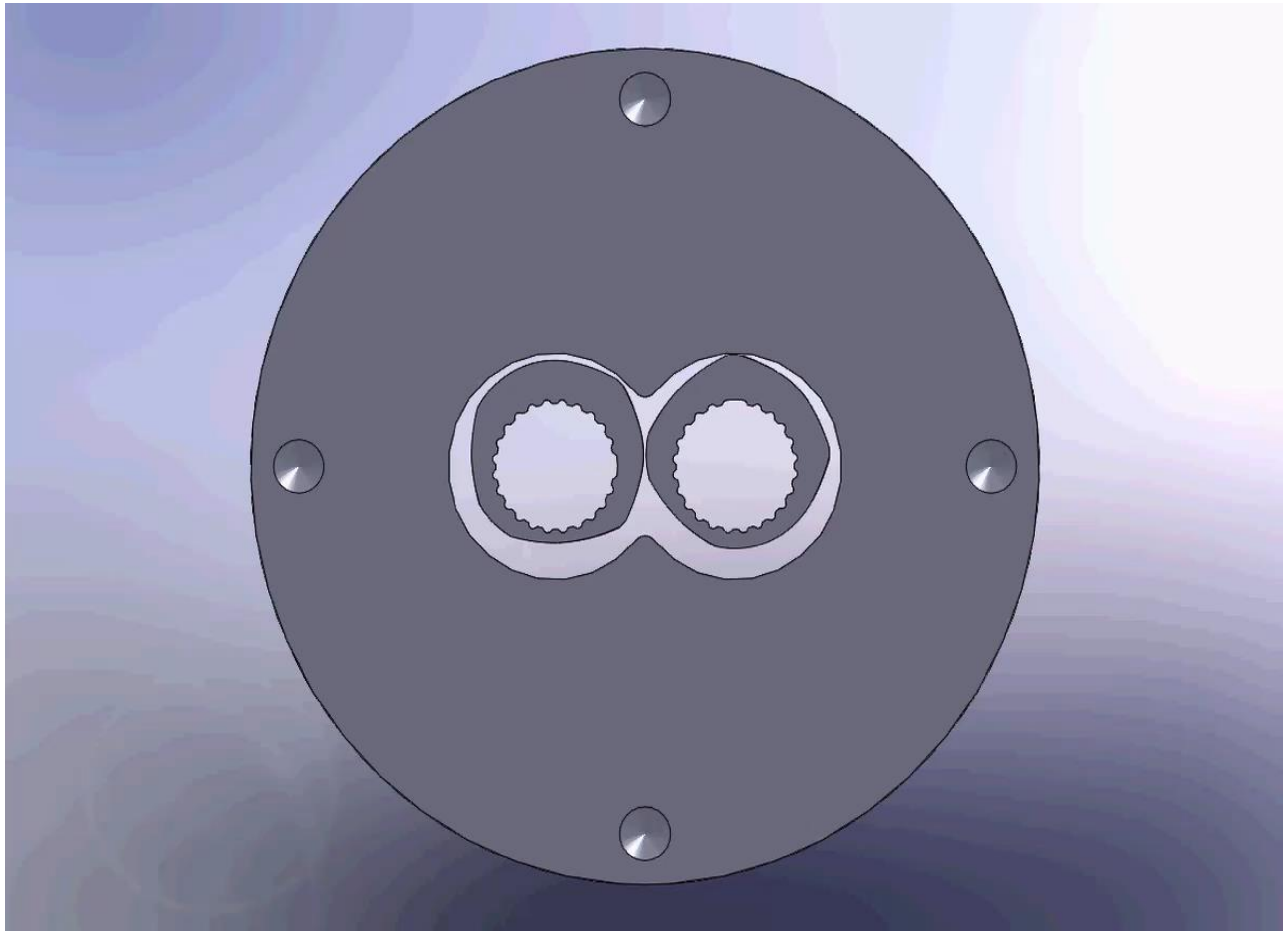
- STEER advance technology enhanced **uniform melting and mixing** when compared to standard kneading screw
- Its ability to **stretch, fold, and squeeze material** in tightly controlled kneading cycles.
- Melt **Temperature Reduction**

21st Century Mixing Elements:

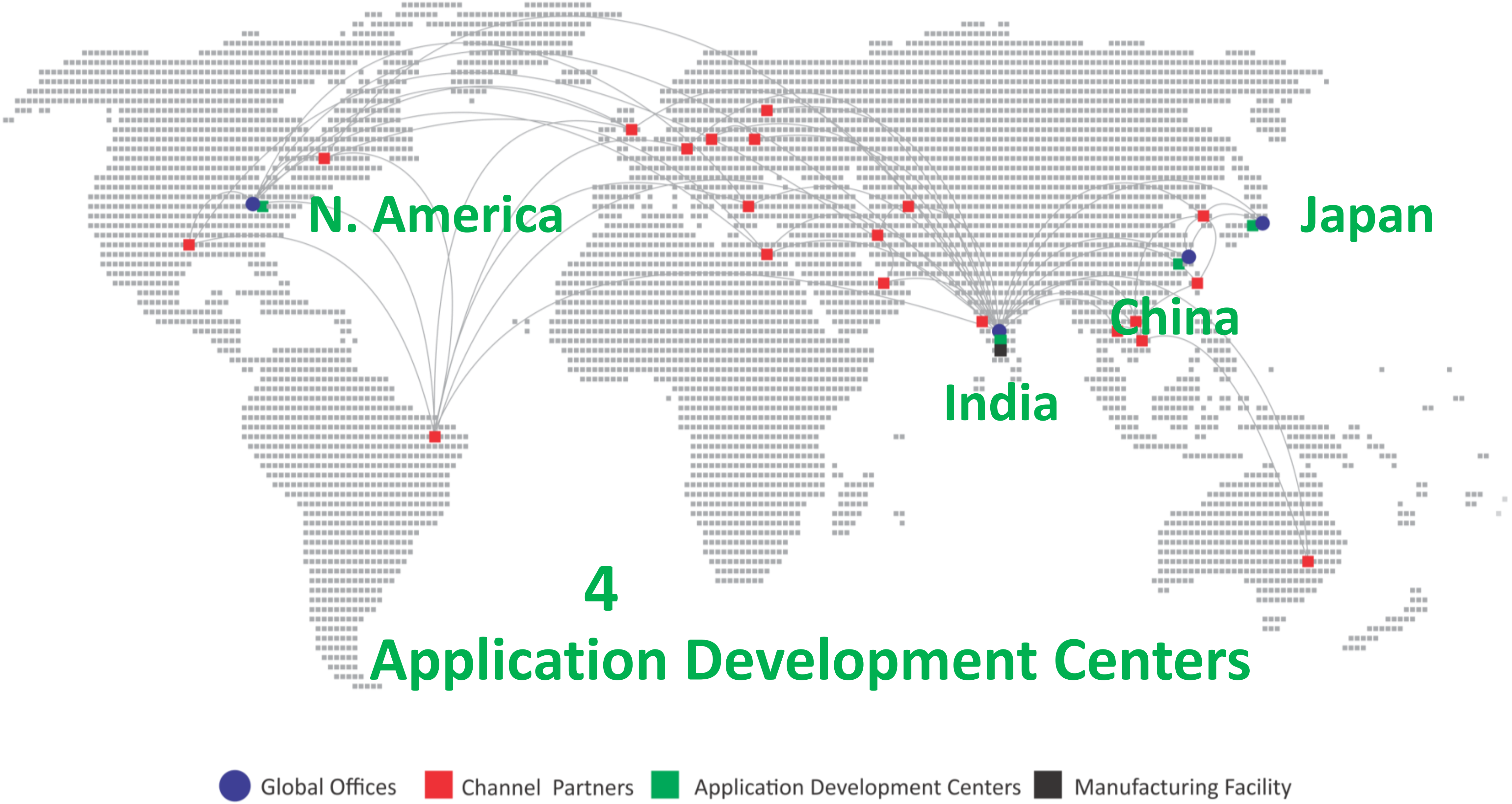


Stretchy Dough





STEER ADC - Global Presence



STEER India Application Development Centre

STEER America - ADC

STEER Japan - ADC

STEER China - ADC

PSDC Facility – NABL Accredited India

21st century Case studies

Low Energy Extrusion Process Using Fractional Geometry Technology

- **Elongation Flow minimizing Sear force to compound**

特許第７０７５７０７号
(PATENT NUMBER)

発明の名称
(TITLE OF THE INVENTION)
溶融混練押出装置の運転の際に必要なエネルギーを低減可能とする方法

特許権者
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出願番号
(APPLICATION NUMBER)
特願２０２１－２１３９９８

出願日
(FILING DATE)
令和　３年１２月２８日(December 28, 2021)

登録日
(REGISTRATION DATE)
令和　４年　５月１８日(May 18, 2022)

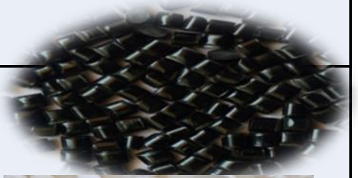
この発明は、特許するものと確定し、特許原簿に登録されたことを証する。
(THIS IS TO CERTIFY THAT THE PATENT IS REGISTERED ON THE REGISTER OF THE JAPAN PATENT OFFICE.)

令和　４年　５月１８日(May 18, 2022)

特許庁長官
(COMMISSIONER, JAPAN PATENT OFFICE)

森　清

Value proposition of STEER technology (FGT/FLP)

Sl No	Applications	STD	FGT	Pellets photo
1	PET/ CB 30%	IV -0.417 Dl/g FPV @5mic - 0.58 bar/gm **SME--0.28 KWh/kg**	IV -0.434 Dl/g FPV @ 5 mic -0.28 bar/gm **SME--0.21 KWh/kg**	
2	PA6 / GF 30%	TS-- 176 MPa IMS-- 13.8 KJ/m2 FM-- 8623 Mpa **SME--0.23 KWh/kg**	TS--179.5 Mpa IS-- 13.84 KJ/m2 FM-- 9490 Mpa **SME-- 0.19 KWh/kg** MT-- (283 ^{0}C)10 C less than STD	
3	PA6 / GF 50%	TS-- 165.1 MPa FM--245.1 Mpa IS-- 10 KJ/m2 **SME-- 0.25 KWh/kg**	TS-- 166.7 MPa FM-- 255.5 Mpa IS--15.7 KJ/m2 **SME-- 0.21 KWh/kg**	
4	PC / CNT 15%	SR-- 10^6 Ohm SME--0.60KWh/kg	SR--10^4 Ohm@ 3 % loading SME-- 0.51 KWh/kg	
5	PBAT / Starch 50%	MT-- 140 Deg C	MT-- 128 C Surface smooth and no bubbles	

6	EVA / UV Regrind	MT-- 108 Deg C Surface rough and scorching	MT- 97 Deg C Surface smooth and no rough	
7	PP/ Short GF 30%	TS-- 70 MPa Impact strength = 8 KJ/m2 **SME -- 0.17 KWh/kg**	TS- 92.7 Mpa Impact strength -12.67 KJ/m2 **SME --0.12 KWh/kg**	
8	Polyketone + 40% Chopped GF	TS- 135 Mpa **SME-- 0.27 KWh/kg**	TS- 152.3 Mpa **SME -- 0.22 KWh/kg**	
9	Polyketone with additives	TS- 62 Mpa **SME --0.22 KWh/kg**	TS- 64.1 Mpa SME = 0.19 KWh/kg	
10	Poly Carbonate + Carbon Black 40%	**SME -0.66 KWh/kg** FPV - 3 bar/g	**SME - 0.44 KWh/kg** FPV - 2.6 bar/g	

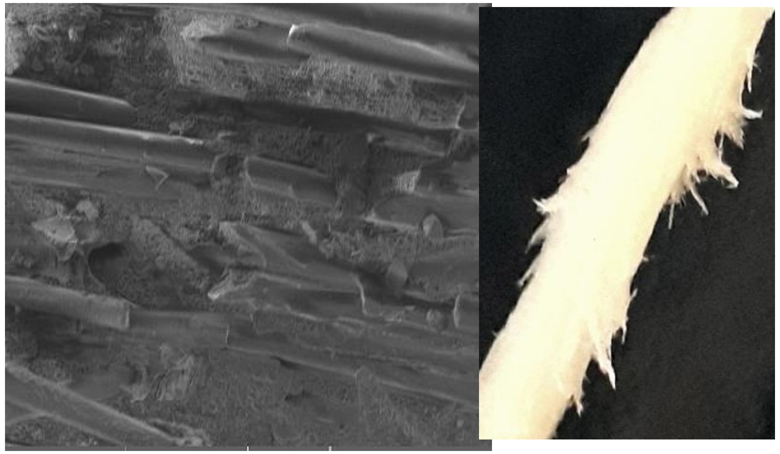
Nylon 6/ GF 30% -3

Benchmark

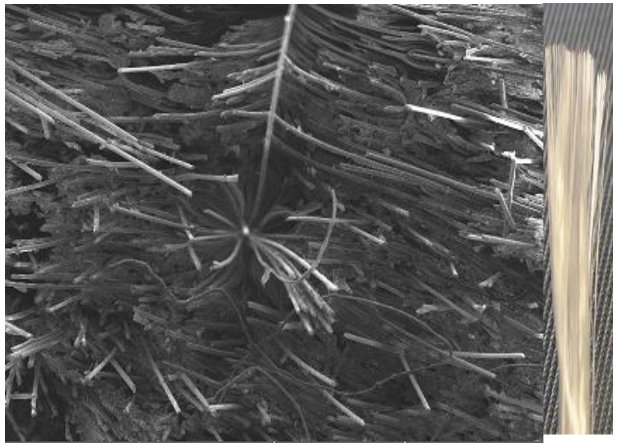
- Tensile strength > 170 Mpa.
- Impact strength >13 Kg2cm/cm.
- Flexural modulus - > 8.5GPa.

- Higher screw speed higher shear rate lead to fibre attrition and lower **mechanical properties**
- Higher Loading of Glass fiber and poor wetting of GF with polymer matrix, More voids on final compound
- Rough surface on the final composite

Process Challenges in GF Compounding

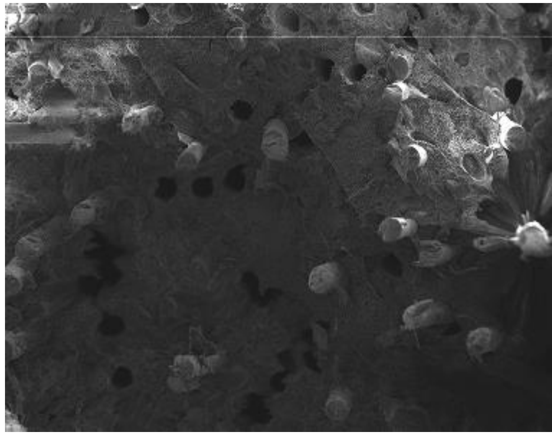


Glass fibre wetting



Glass fibre Bundle breakup.

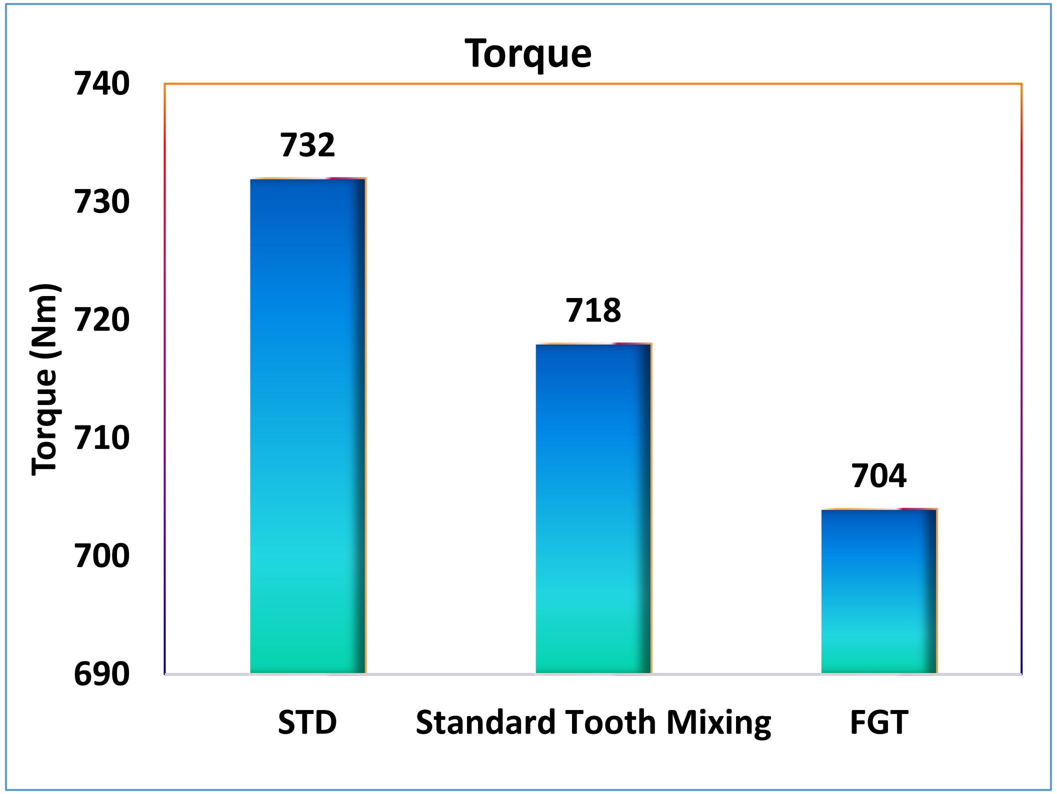
Glass fibre attrition

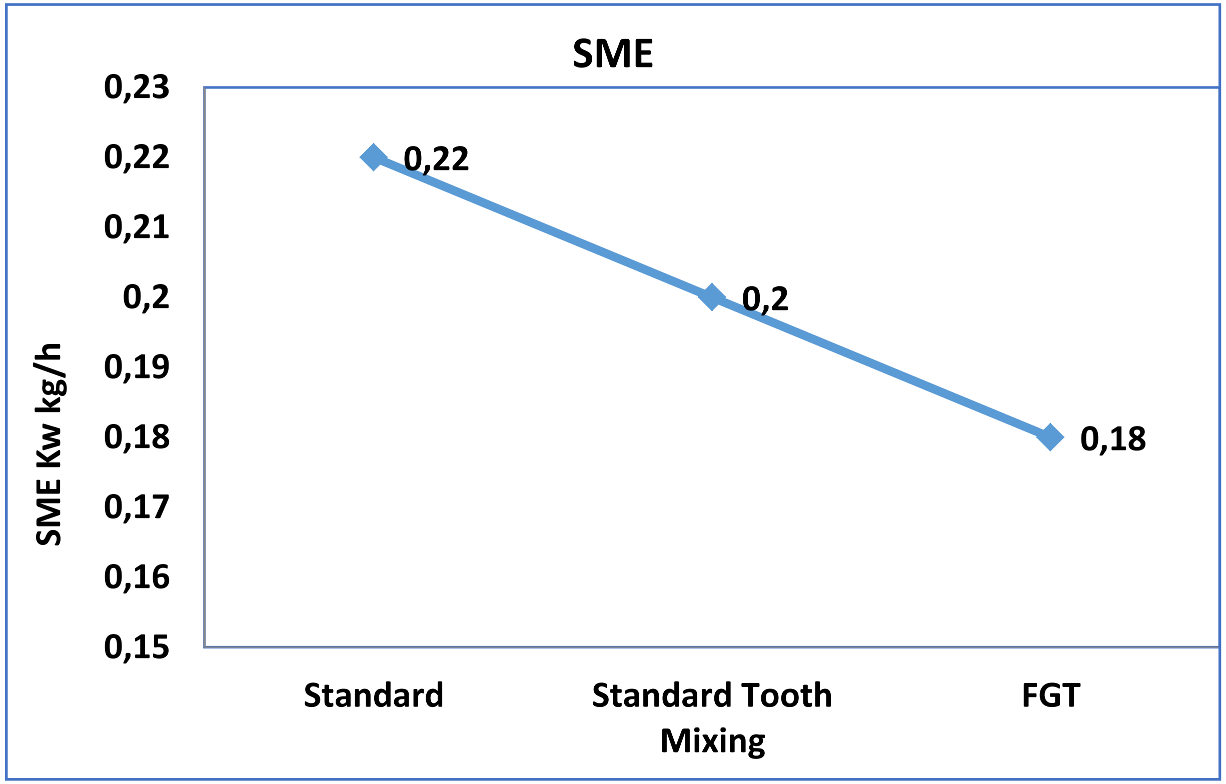


Glass fibre pull out

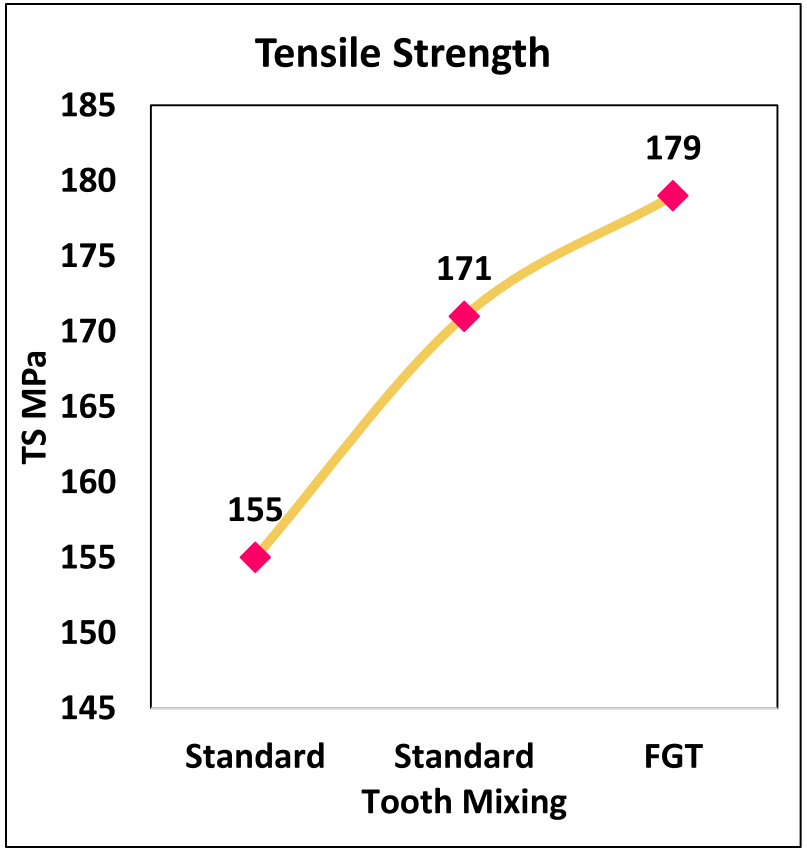
Compression STD/Tooth mixing /FGT mixing elements

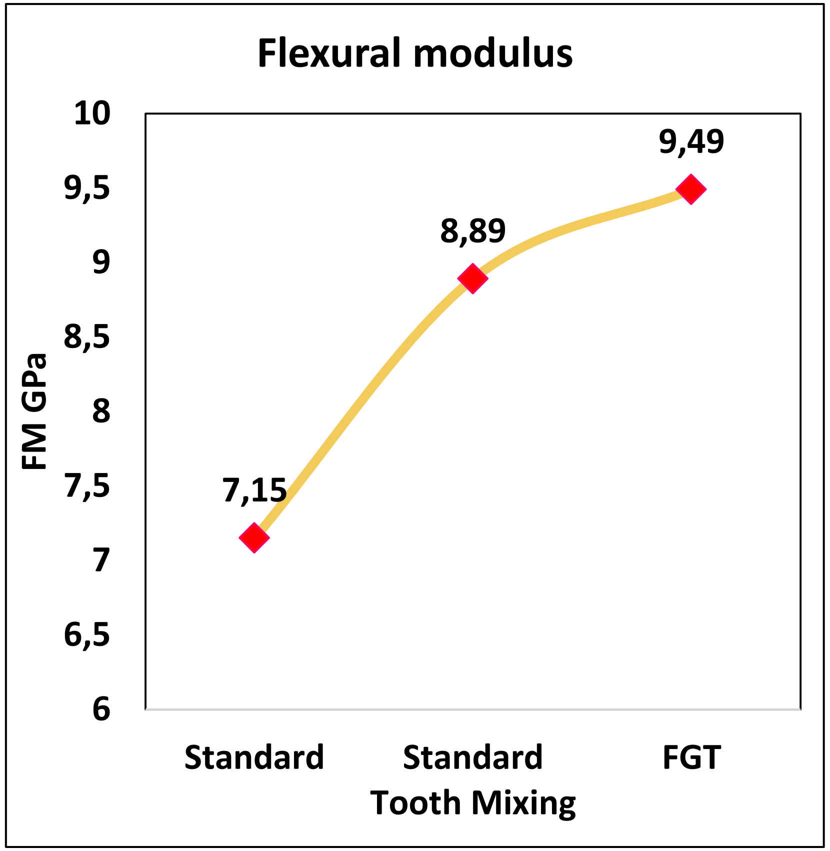
❖ Process run at 200 kg/hr output constant with all mixing elements to compare.

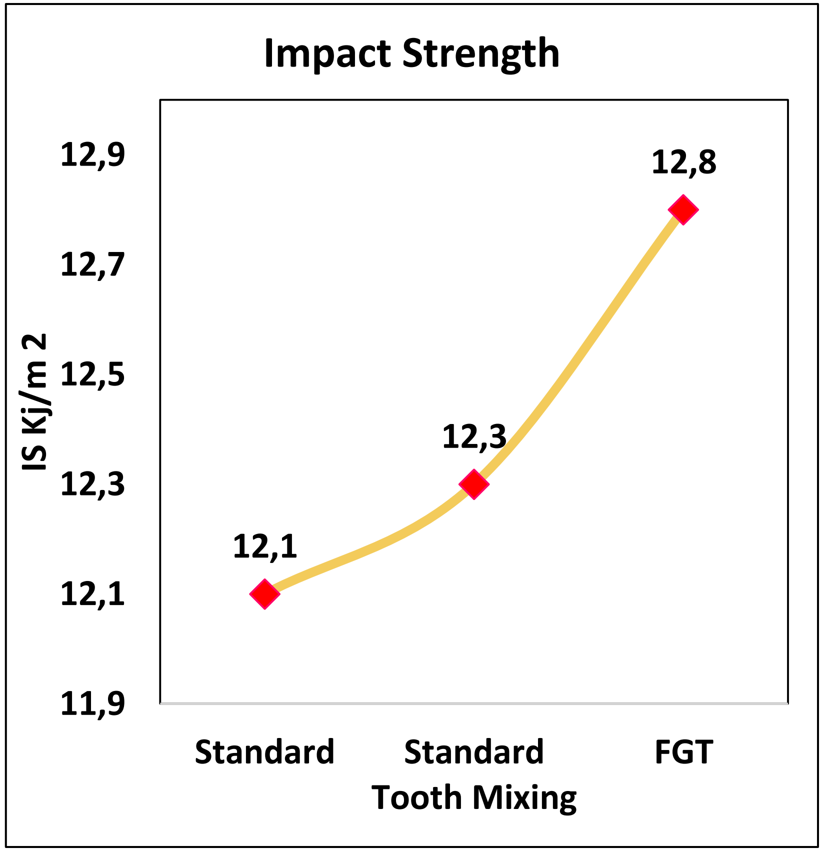




Mechanical properties







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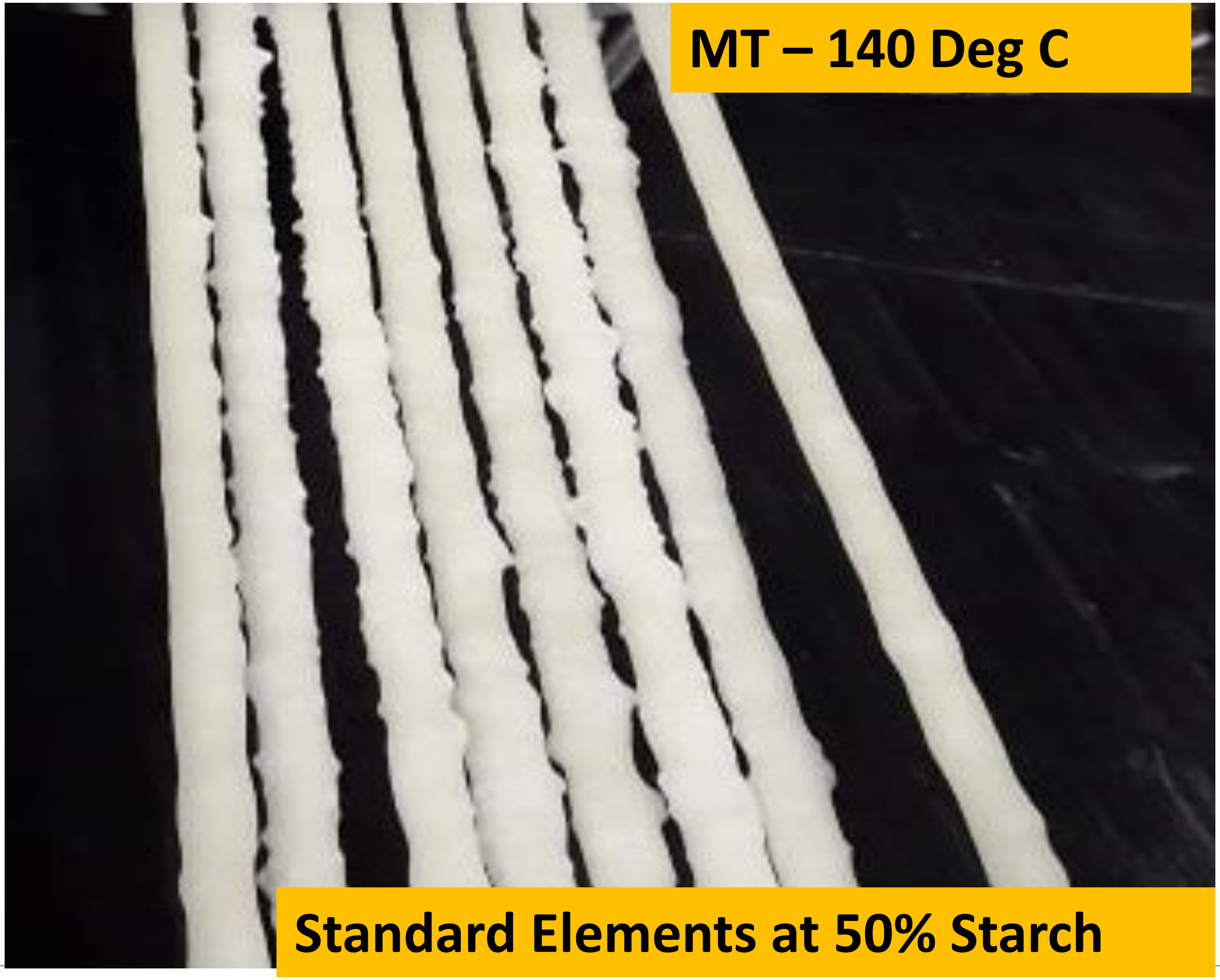
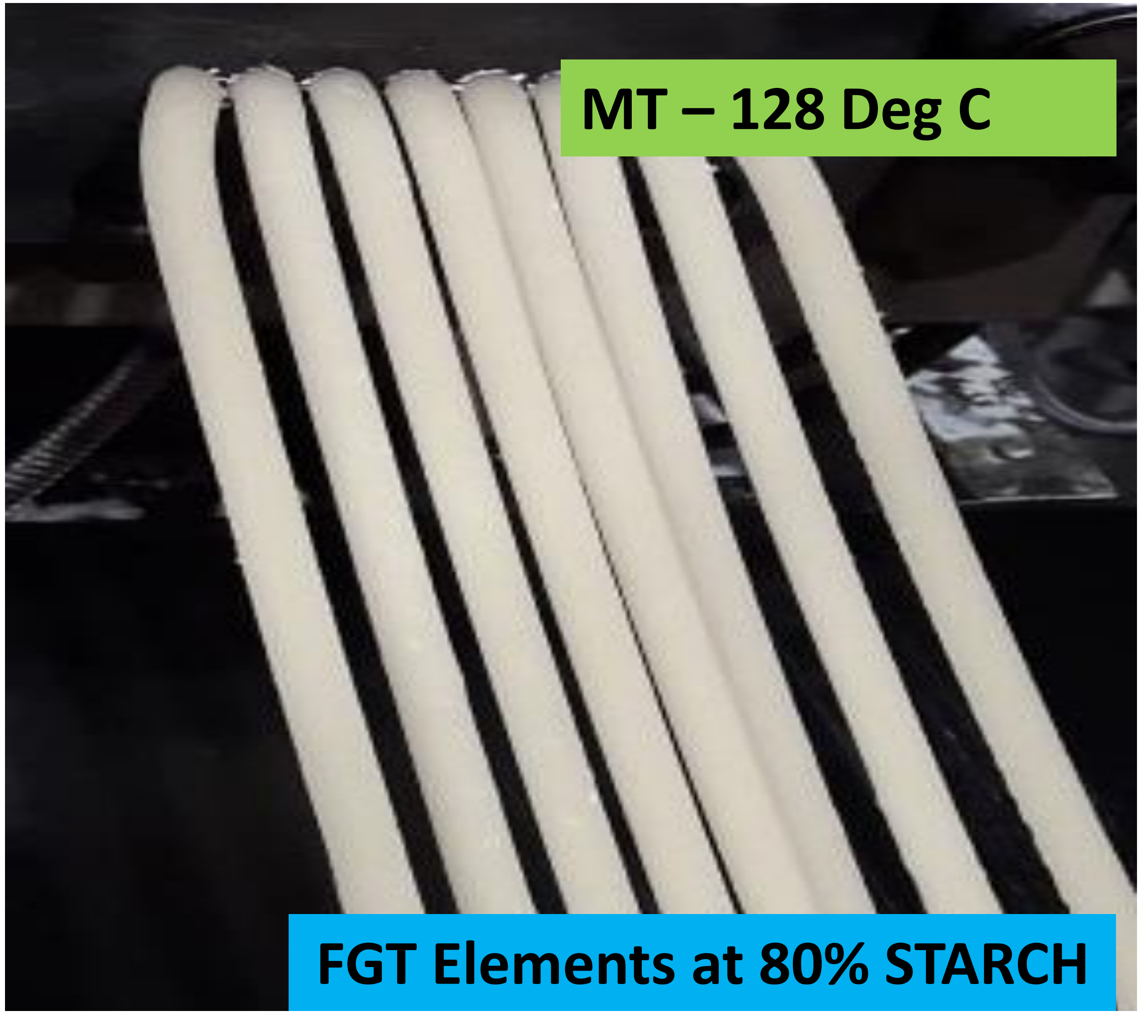
PBAT/ Starch

- Starch based Bio plastic are nonstable and having affinity to water since its hydrophilic in nature and exhibit poor mechanical property comparing to Petrochemical thermoplastic.
- Starch is one of the most effective and promising biodegradable material naturally available.
- Challenges in processing Starch are Feeding throat clogs due to high moisture content, Temperature sensitive of starch tend to degrade and form Foaming.

PBAT/ Starch


MT – 140 Deg C
Standard Elements at 50% Starch


MT – 128 Deg C
FGT Elements at 80% STARCH

Conclusion

21st Century Technology from STEER enables customers to innovate future products and improve current products & processes

Customers can achieve excellent product properties for many applications at the highest output with much lower energy consumption.

Processes can run with smoother torque, thereby machine reliability is enhanced

STEER

“Scaling New Heights, Creating a Center of Excellence”

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