STEER BEST PRACTISES

CONTROLLING SHEAR TO PRODUCE BRILLIANT EFFECT PIGMENT MASTERBATCHES WITHOUT DAMAGE TO THE MICA PLATELET STRUCTURE

Mica - An integral part of most effect pigments

Mica is a delicate, natural mineral is an integral part of effect pigments used to greatly enhance the visual appeal of products. Once extracted, it is cleaned, ground and coated with metal oxide/s to form a layer-substrate pigment that interacts with light to produce a variety of effects – matte, lustre, sheen, glitter, luminescence, multicolour and so on.

Difficulties with processing Mica

The efficacy of these coated mica crystalline platelets depends on the ability to restrict damage to the platelet structure while processing, particularly when compounding high concentrations of the pigment for masterbatch production. Mica crystalline platelets are extremely sensitive and **any alteration or change in size of the structure** will hinder effective coloration and alter the appearance of the pigments and plastics, resulting in a higher reject rates of the final molded part.

An understanding of the steps involved in compounding effect pigments:

The biggest cause of attrition to the platelet structure is **exposure to shear** during the various processing steps – ***Wetting, Dispersion, Distribution and Stabilisation.*** Quality, appearance and economy depend on an in-depth understanding and execution of these steps.

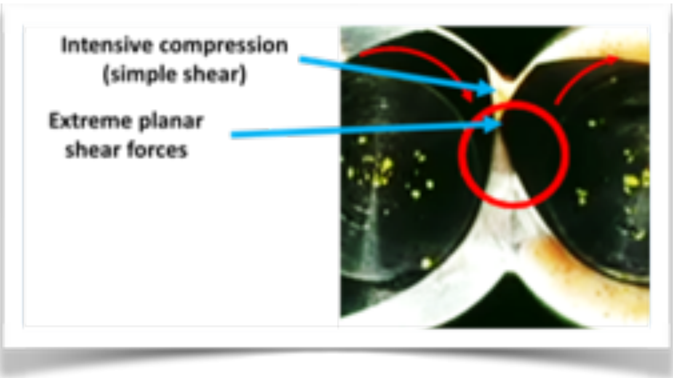
> **WETTING** - is the process of bringing two materials close enough to adhere together and 'pre-wetting' prior to dispersion becomes ectremely critical. If high loadings of pigments are exposed to elevated shear rates without pre-wetting then particle-to-particle friction occurs. The dry pigment is compressed and the particles abrade against each other, often at extreme pressures, resulting in attrition of the platelet structure, physically damaging the pigment., besides, very high localised temperatures cause oxidation and/or discolouration of the sensitive coatings.

For effective wetting the compression of raw pigment should be avoided. Mixing should be through elongation and laminar means in a non-filled process section. If dry powder becomes constrained prior to wetting, the compression of the dry particles can occur resulting in attrition of the mica structure. Elongation in a non-constrained (filled) environment is a very effective and efficient means of mixing. As the melt pool is stretched tensile forces gently pull the pigment particles away from each other. Surface renewal through frequent splitting and recombination of the melt pool is also a highly effective method for low energy mixing and wetting of pigment particles. *Special mixing elements can help accomplish this task during conveying through special features that can include pins and grooves, while retaining a fully intermeshing and self-wiping characteristic.*

Effective wetting also occurs in the intermeshing zone between the adjacent rotating screws as the melt pool is transferred from one rotating shaft to the adjacent shaft. As the melt pool is transferred from one screw to the next the melt folds or rolls enhancing surface regeneration. The resin pool is then quickly stretched into the root of the receiving screw creating effective elongation. To increase this mixing effect shorter lead angles for conveying and mixing elements should be used to increase the frequency of folding.

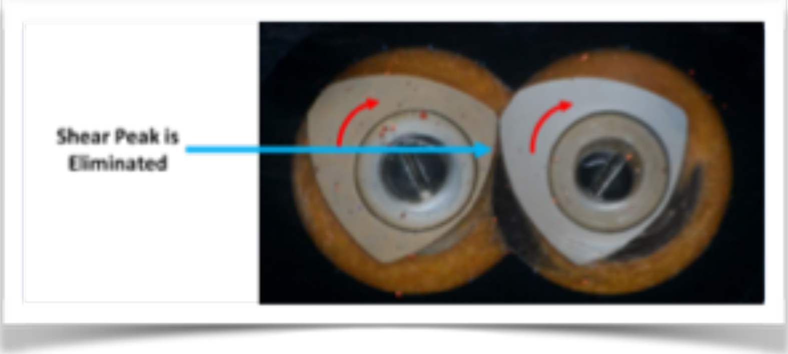
To improve wetting capability and reduce energy requirements for such operations it is advised to keep melt temperatures high and melt viscosity low prior to adding the pigment, particularly with high volumes of pigment. The mica will need to be heated which will inherently reduce resin melt temperatures and increase viscosity. If moisture or other volatiles are present the drop in melt temperature will be greater. At a higher viscosity more energy will be required to transport and wet the mica which could cause damage to the pigment.

> DISPERSION: Most modern twin screw extruders utilise two lobe kneading blocks for energy input to facilitate dispersion. A negative attribute of bi-lobe kneading blocks pertains to the existence of shear peaks during the compression of melt as one lobe of a kneading block intermeshes with the lobe of the kneading block on the adjacent shaft. During this occurrence, up to 3% of the melt experiences a very high shear environment as it is exposed to extreme compression that forces materials between the two



lobes at the tips of the barrel apexes. Material passing through this environment will experience a significant amount of shear energy input and high temperatures from frictional heating. If the solids content within the resin is high, as is experienced in masterbatch production, additional abrading of the mica can occur from particle-to-particle friction.

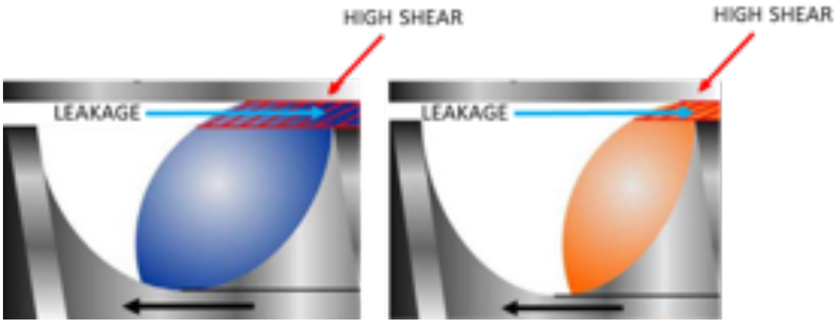
These shear peaks cannot be avoided, and exert a non-homogeneous transmission of energy into the polymer. Some of the polymer/mica will be exposed to extreme pressure and shear while other pools of polymer/mica may pass through the kneading blocks and experience little energy input. This can have many negative effects, such as a significant spike in melt temperatures within the intermeshing zone, excessive mean melt temperatures from inefficient energy transmission, degradation of shear sensitive materials, degradation of fibre reinforcements or friable fillers, and consumption of energy that could be better used for other functions. ***Specialised melting and mixing elements significantly reduce or eliminate shear peaks and still maintain a fully intermeshing and self-wiping characteristic.*** Moreover, since shear peaks are reduced/eliminated the energy input into the polymer is much more controlled, improving both efficiency and effectiveness.



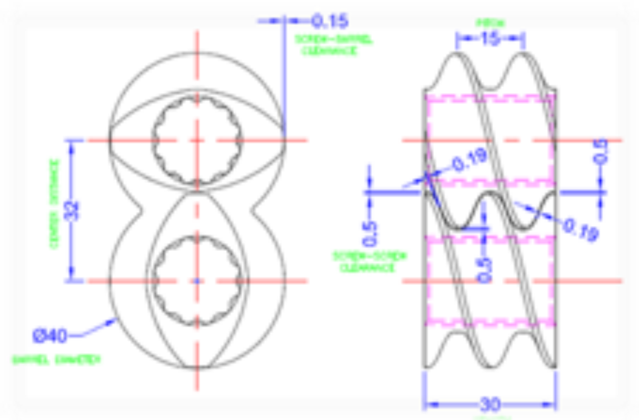
> **DISTRIBUTION AND STABILISATION:** Distributive mixing should take place to ensure a homogeneous distribution of effects pigment within the resin matrix. Uniformity of pigment dispersion is necessary to prevent any anomalies in the appearance of the molded parts. Many of the newer generation mixing elements described above have inherent distributive mixing characteristics as well as dispersion, eliminating the need for a separate distributive mixing function within the extruder process section. If a separate distributive mixing function is required there are many effective distributive mixing elements available. Some are comprised of blade like structures or "gears" projecting off a cylindrical core. Distributive mixing characteristics of such elements are highly effective, however at higher screw speeds it is possible to damage mica pigment through impingement as it passes between the blades. Most of the effective distribution elements do not have fully intermeshing and self-wiping characteristics, which can allow resin to accumulate in the un-wiped section of the elements and degrade. Char formation can occur in such regions and can re-enter the resin pool after degrading creating a color body, or black speck, within the resin. This is particularly true with heat sensitive plastics. Since the use of screen filters is usually not recommended for mica pigments (large platelet structure of mica, high and damaging extruder screw energy input to overcome pressure drop) the contamination cannot be removed from the plastic. The presence of color bodies will result in a higher reject rate of the final molded part. ***To ensure effective distribution, specialised distributive***

mixing elements are required that exhibit fully intermeshing and self-wiping characteristics. Some of the elements are designed to facilitate distributive mixing characteristics while generating pressure. It is possible to use these particular elements in the metering (discharge) process section just prior to the die. Another beneficial attribute of these elements is to facilitate melt homogenization prior to discharge from the extruder. This can improve strand stability if a stranding system is used, or dimensional accuracy if direct shape or form extrusion is to be done.

Extruder Selection:



Extruders possess different shear signatures depending on make and model. ***Selecting an extruder with a lower shear signature can reduce pigment damage.*** The ***root depth*** of the extruder screw can determine how much of the melt pool is exposed to the barrel wall of an extruder during compounding operations. Root depth is expressed as a ratio of the outer diameter of the screw as compared to the inner diameter, expressed as Do/Di. A deeper root depth, or larger Do/Di ratio, draws more of the resin into the screw root and away from the shear forces that occur where the melt contacts the barrel wall.



Perhaps ***more damaging to effect pigment is the shearing that can occur when plastic containing the pigment "leaks" back into the trailing screw channel.*** This occurs when the screw-to-barrel or screw- to-screw dimensions are large enough to allow leakage of the polymer. For example the OEM tolerances for screw to barrel clearance can range from 0.15mm to 2mm or more depending on the supplier and model of the extruder. Effect pigment passing through these high shear regions can suffer from attrition. It is possible to have tolerances so small that leakage will only occur under high pressures.

Another consideration is that low-bulk density can reduce the capacity of side feeders used to introduce the pigment to the polymer melt. This can cause the extruder to be operated below design capacity. Side feeder elements are available where the leading flank has a negative angle (vs. positive on standard element) that forces high volumes of powders into the side feeder, thus eliminating line rate restrictions.

Understanding Gaps in today's technology and adopting the right technology & process expertise to address the gaps

Most of the technology available today does not account for some or all of the following;

>*Efficient mixing means*

>*Control over shear and elimination of shear peaks*

> *Stagnation and Degradation and the resulting char formation*

>*Efficient energy transmission*

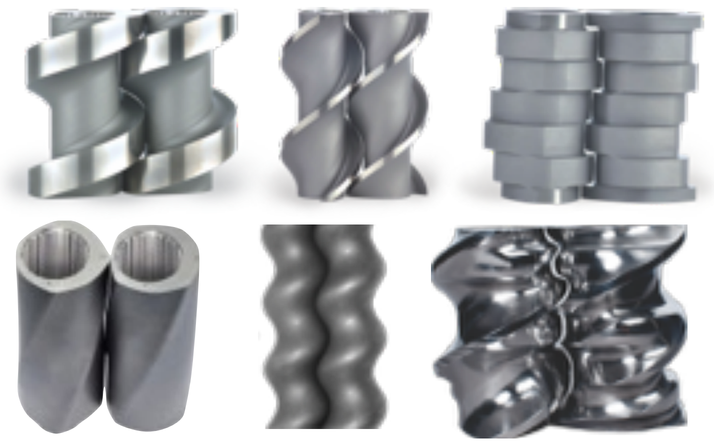
>*The issue of 'leakage' and subsequent damage due to shearing*

>*The ability to work with low-bulk density or shear-sensitive materials*

Selecting the right technology to process effect pigments with minimum damage to the mica structure – The STEER Advantage:

> EFFICIENT MIXING WITH STEER'S PATENTED FRACTIONAL-LOBE ELEMENTS:

Fractional-lobe mixing elements allow for mixing through elongation and laminar means in a non-filled process section. This allows for frequent splitting and recombination of the melt pool. Besides the mixing elements have fully intermeshing and self-wiping characteristics to help with effective wetting in the intermeshing zone. The shorter lead angles increase the frequency of folding.



> SOLVING THE ISSUE OF SHEAR PEAKS:

Special mixing elements reduce/eliminate shear peaks and still maintain a fully intermeshing and self-wiping characteristic. This reduction/elimination of shear peaks (through the use of multiple lobes) results in controlled energy input, improving both efficiency and effectiveness. Moreover the element geometries facilitate a controlled energy input depending on task – Simple shear for the reduction of cohesive aggregates and agglomerates, planar shear for high energy dispersion, low energy elongation.

> PREVENTING STAGNATION AND DEGRADATION:

Distributive mixing elements with fully intermeshing and self-wiping prevent stagnation and degradation and the resultant char formation. They facilitate distributive mixing characteristics while generating the right pressure. Besides, they also provide the ability to facilitate melt homogenisation prior to discharge from the extruder improving strand stability or dimensional accuracy.

> ADDRESSING THE ISSUE OF 'LEAKAGE':

As mentioned earlier, one of the biggest causes of damage to the pigment is the shearing that can occur when plastic containing the pigment, "leaks" back into the trailing screw channel. This occurs when the screw-to-barrel or screw-to-screw dimensions are large enough to allow leakage of the polymer. With STEER's OMEGA 1.71 DO/DI co-rotating twin-screw extruder the 'Barrel to Screw Gap and Screw to Screw Gap' are maintained at less than 0.25mm to have fully wiping effect rather than shearing effect.

> DEEPER EXTRUDER ROOT DEPTH:

STEER's OMEGA 1.71 DO/DI or the deeper root depth, draws more of the resin into the screw root and away from the shear forces that occur when the melt contacts the barrel wall.

> ABILITY TO PROCESS LOW-BULK DENSITY MATERIALS:

The OMEGA 1.71 DO/DI co-rotating twin-screw extruder provides manufacturers the ability to work with shear-sensitive and low-bulk density materials, making it the ideal equipment of choice for working with mica-based pigments. The patented conveying elements increase throughput by 5x while reducing the attrition that can occur with standard conveying elements.

Trials & Results in producing brilliant effect pigment masterbatches with the OMEGA 1.71 Do/Di co-rotating twin-screw extruder with patented special elements:

(Trials conducted at STEER's Application Development Center (ADC) in Bangalore, India)

EQUIPMENT:
STEER's Do/Di=1.71 Technology platform OMEGA 40H; L/D=44 Special Design Elements by STEER Loss-in-Weight Feeders Strand pelletizer

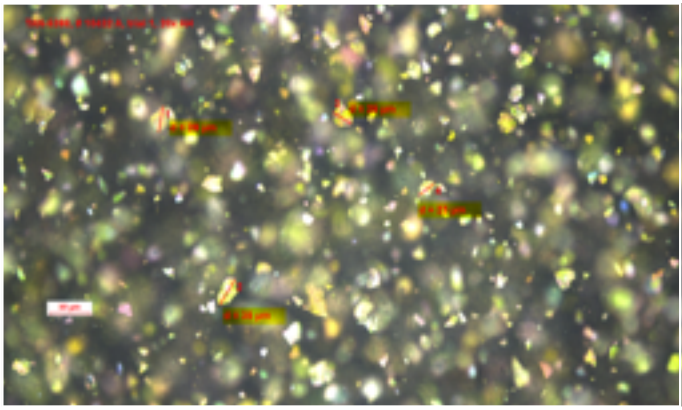
MATERIALS:
70% LLDPE, 30% Pigments Iridion 305 Solar Gold Iridion 305 WM10 (PEWax dispersion) Iridion 305 Pearlets PO (70% MB in PE) Antioxidant, Additives….

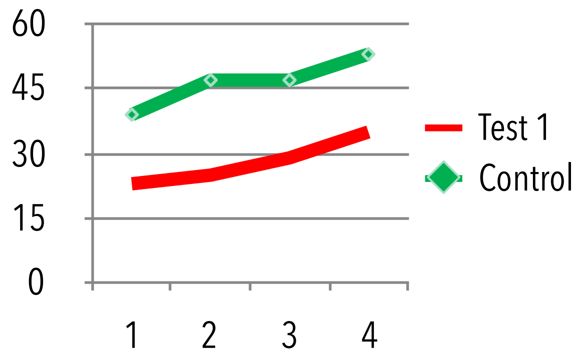
PROCESSING:
Three Screw Designs; "Standard" Hi-Shear & "Optimized" Special Elements Screw RPM fixed @ 600 for all trials 170-230C

TESTING:
Microscopic Examination at MERCK as per MERCK Standard Procedure

RESULTS AND CONCLUSIONS:

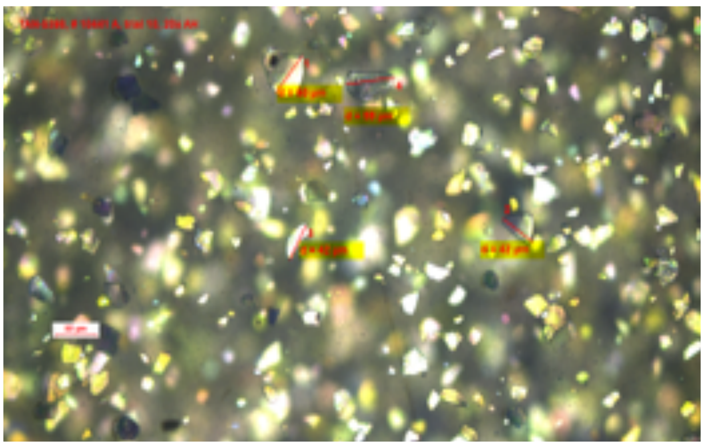
TEST 1: "STANDARD" HIGH SHEAR DESIGN

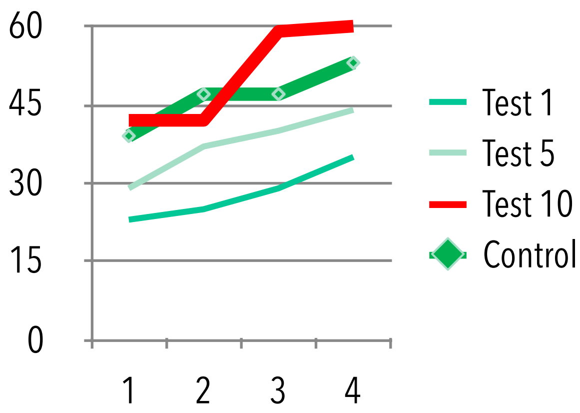




Pigment Top Cut = 60microns,
Top Cut in Compounded Masterbatch = 28microns

TEST 2: "OPTIMISED" USING STEER BEST PRACTISES AND SPECIAL ELEMENTS – SIDE FEED





Pigment Top Cut = 60microns,
Top Cut in Compounded Masterbatch = 60microns,
"OVERSIZE PARTICLE DETECTED INDICATING LEAST PARTICLE DAMAGE"

FOR MORE INFORMATION ON PROCESSING MICA-BASED EFFECT PIGMENTS WITH MINIMUM DAMAGE TO THE MICA PLATELET STRUCTURE, CONTACT SHYAM.PANI@STEERWORLD.COM