

Mixing Flexible PVC Compound

With the proper equipment, PVC can be mixed for flexible applications. Two types of mixing equipment are used today for this task, Low Intensive Mixers (LIM) and High Intensive Mixers (HIM). A dry flowable powder can be made using proper mixing procedures and equipment. This will be covered in this Technical Service Report.

The use of powder compounds requires a different screw design than cube or pellet compounds. Powder has a much lower Apparent Bulk Density (ABD) and requires different screws. The different ABD fills the screw with a different weight causing more or less frictional heat in the extruder.

PVC powder compounds are more affected by moisture than cube or pellet compound. This is because of the higher surface area presented by the powder in hot humid conditions. Even though PVC resin is not hygroscopic, there are ingredients used in PVC compounding that are. Moisture absorption on all PVC compounds may cause surface and impact problems.

HANDLING

The manufacturer will need at least two silos for the most efficient operation; (1) a silo for the PVC resin, and (2) a silo for the powder compound made. One can also place the powder in boxes or totes. A bulk conveying system will be needed for resin and powder transfer if powder silos are used. There are different needs in bulk conveying powder vs. cube/pellets to the extruder. These different needs must be taken into consideration. Dust collectors at each step or a central bag house will be needed.

Below is a list of equipment needed for bulk handling:

1. Mixer, silo, extruder dust collection equipment
2. Liquid tanks and scales for stabilizer and plasticizer
3. Resin and ingredient scales

WEIGHING EQUIPMENT

In the past, processors have weighed non-PVC ingredients by hand and automatically. The hand-weighing methods works very well as long as the weighers are provided with good scales and procedures. One of the most common mistakes is accumulative weighing which leads to inaccurate weighing. This method may seem faster, but small errors increase largely with each weighing. These errors may cause extrusion problems.

Automatic weighing scales are increasingly being used to eliminate inconsistencies, minimize random weighing errors, and reduce required manpower. In addition, if total weight is above or below recipe weight, the automatic weighing equipment will shut down. The automatic shut down will allow time for mixing personnel to find and correct the weighing problem.

The following weighing equipment would be needed:

1. Automatic weighing scale (may be load cells)
2. Conveying system for minor ingredients and resin
3. Platform for scales
4. Dust collectors and venting

MIXING AND COOLING

The mixer and coolers are the heart of the mixing system. This includes the control panels for mixer/coolers, silos, and conveying systems. These are computer controlled in more modern systems. The following two types of mixers are used in flexible compounding.

1. Low Intensive Mixer (LIM)

LIMS are ribbon blender-type mixers that are jacketed for heating and cooling. They have closed barrels and spiral blades which normally run about 25 to 75 RPM. The blades are designed to move the material to the center of the barrel providing good mixing. The tip speed is normally about 6 meters per second.

Frictional heating is very minimum. This causes large heat gradients within the ribbon blender. Depending on the hardness of the flexible PVC compound being made, mixing times can be from one to six hours. Batch size may be up to 5000 pounds. Heating and cooling must be provided to this type of mixer.

2. High Intensive Mixer (HIM)

HIMs are like kitchen blenders with very high RPM's (500 to 1000). They achieve most of their heating from frictional heat. Depending on the manufacturer, one can have a variety of blades and blade designs. There are 2 to 4 blades in a normal mixer. Three blades are typical for flexible mixing and four blades for rigid mixing. The blades are designed to give homogenization to the resin and other ingredients. The tip speed is normally around 30-40 meters per second. Mixer size ranges from 10 to 1000 pounds. A typical cycle time will be from 4 to 10 batches per hour.

It is very important to have a good, deep vortex during most of the mixing cycle. The material must always be turning over and achieve a dry state before dropping to the cooler. If one looks down into the mixer, the material goes through several states. As resin is added, there is an uneven flow. When adding the plasticizer, this state continues. Around 160°F, the resin starts to absorb the plasticizer and the vortex decreases. The material must continue to turn over to get a good mix. At powder peak, all plasticizer is absorbed and the flow in the mixer is nice and smooth. Mixer amperage should be observed and/or recorded. HIMs give the most uniform temperature for the entire batch while achieving uniform temperature the quickest.

After mixing is complete, the powder material must be cooled by dropping it into a cooler. Cooling is usually done in a low intensive mixer. Water is pumped through the water jacket to speed the cooling process. Coolers may be ribbon blenders, round-like pots, or barrel type, all of which are closed-type bowls. Some have blades or plows. The blades have an RPM of 50 to 100 with a tip speed of 6 meters per second. After cooling, the material should be screened for mixer build-up and foreign material. Screen size is normally from 10 to 30 mesh depending on the end product to be extruded.

MIXING PROCEDURES

There are significant differences between mixing procedures of low intensive mixers and high intensive mixers. The same is true between rigids and flexibles. Rigids have not been successfully mixed in a LIM. On a HIM, the order of addition and power peak are important for both rigid and flexible compounds. Order of addition not only affects the shape of the power curve but the quality of the mix. Attention to this point must be observed in either LIM or HIM mixing as in rigids and flexibles. The following are different mixing procedures for flexible PVC:

LOW INTENSIVE MIXING (LIM)

Procedure A:

1. Start mixer, add resin
2. Heat resin to 150 to 160°F
3. Add stabilizer and plasticizer
4. Mix until plasticizer has been fully absorbed
5. Add lubricants
6. Add fillers and pigments
7. Mix until homogeneous. Mixing temperature should be somewhere between 190 to 210°F.
8. Cool to below 110°F before packaging.*

HIGH INTENSIVE MIXING (HIM)

Procedure A:

1. Start mixer at high speed, add resin
2. Mix to 150 to 160°F
3. Add stabilizer and plasticizer
4. Mix until power peak, usually between 180 to 200°F
5. Add lubricants
6. Add fillers and pigments
7. Mix for additional 5 to 10°F above power peak
8. Drop into cooler
9. Cool to below 110°F before packaging*

Procedure C:

1. Start mixer at low speed
2. Add resin, stabilizer and plasticizer
3. Shift to high speed on mixer
4. Mix to power peak, usually between 185.
5. Add lubricants
6. Add fillers and pigments
7. Mix for additional 5 to 10°F above power peak
8. Drop into cooler
9. Cool to below 110°F before packaging*

Procedure B:

1. Start mixer, add resin, stabilizer and plasticizer
2. Heat to absorbance of liquids, usually about 180 to 190°F
3. Add lubricants
4. Add fillers and pigments
5. Mix until homogeneous. This should be between 190 to 210°F.
6. Cool to below 110°F*

Procedure B:

1. Start mixer at high speed, add resin, stabilizer, and plasticizer
2. Mix until power peak, usually between 180 to 200°F
3. Add lubricants
4. Add fillers and pigments
5. Mix for additional 5 to 10°F above power peak
6. Drop into cooler
7. Cool to below 110°F before packaging

*If one is conveying powder some distance, this may allow higher drop cooling temperatures. The conveying will help cool the powder.

PROBLEMS

There are several common problems in mixing flexible PVC compound. Some problems are over or under-mixing, too much material in the mixer, non-homogeneous mix, no Vortex, not dropping during a free flow phase, and dropping raw resin into the mixed compound. The following section will cover several common mixing problems.

HIGH INTENSIVE MIXER (HIM)

1. Overloading the Mixer:

Overloading the mixer will cause poor mixing and poor to no vortex. The material may also stick to the top of the mixer and cause gel problems.

2. Underloading the Mixer:

Underloading the mixer will create poor powder mixing. There is not enough work from the blades to homogeneously mix all ingredients. All powders should be mixed for X amount of time. The time needed to generate a homogenous mix varies with each compound.

3. Not Reaching Power Peak.

The correct power peak can be observed in two different ways. The first is to watch or chart the motor amperage curve of the mixer. At power peak, the mixer should have a more smooth and reduced sound. Mixer vibration will also be less at power peak. The second is to observe the material in the mixer. The material should change from a jelly state to an even flow. Power peak is where all liquids are absorbed into the resin.

4. Overmixing:

Overmixing causes the powder to become very dusty and dry. Non-PVC ingredients come off the resin particle which can lead to segregation of fillers and lubricants.

5. Dropping Mix from Mixer While in the Jelly Phase:

If the mix is dropped while still in the jelly phase, there will not be any powder flow. The plasticizer has not been fully absorbed into the resin, and the mix will look and feel wet. A jelly-like mix will not bulk convey or flow well.

6. Gels:

Gels may have several causes, many of which relate to the different levels of plasticizer absorption in the PVC resin. A major source of gels is caused by raw (unplasticized) resin dropping onto material which is being mixed or cooled. A second source of gels is the result of a failure to add the plasticizer to the vortex of the mixer. The plasticizer should be added to the wall of the vortex, about halfway down. Another cause of gels may be from poor mixing. Again, poor mixing may be a result of overloading, underloading, or failure to have the deviator blade angled so that the top of the mix is turned into the vortex.

7. Worn Mixer Blades:

Worn blades may cause mixer bowl and blade build-up. This build-up will come off and be caught on a screen. As blade wear increases, screen build-up will increase. The vortex is not as deep and poor mixing entails. The higher the Short "A" hardness of the compound, the more wear is achieved. Some rigid PVC compounds can wear out a blade within 6 months. Continually check the blades so a replacement may be made before any problems arise.

8. Vortex of the Mixer:

It is necessary to have good, deep vortex. Not having it will lead to more non-homogeneous mixing problems. One should be able to see the top nut holding the blades in place. This is a good, deep vortex.

9. Power Peak:

As stated before this point (power peak) in the HIM for flexible mixing is extremely important. In each resin, plasticizer, and combination, there may be a slight (1-5°F) difference in power peak between different lots of resin or plasticizer. These differences are normal in the manufacturing cycle. To select the correct power peak, one must observe the flow in the mixer, the peak amps, and the sound (vibration) of the mixer. Close attention to these three will lead you to the correct power peak to use for a given compound.

LOW INTENSIVE MIXER (LIM)

1. Not Spraying the Plasticizer on the Resin:

If the plasticizer is not sprayed on the resin, some resin particles may not receive the same amount of plasticizer. This will cause gel problems.

2. Overmixing:

Because of the longer time needed to absorb the plasticizer in LIM vs. HIM, it is easy to overmix. Overmixing causes a sandy surface on the extruded parts and lumping of the powder in the mixer. Reduction in mixing time and temperature (230 to 200°F) will usually check this.

3. Undermixing:

Because LIM takes longer to achieve a homogeneous mix, it is just as easy to undermix as overmix. There usually is not a power peak here as on HIM. Temperature must be controlled and watched. It is usually between 180 to 210°F with dry powder in the ribbon blender. Material that is undermixed will feel and look wet. It will not flow.

4. Gels:

In LIM, gels can be caused from raw resin getting into partially or fully absorbed plasticized resin. Sometimes only 80% of the mixed compound is removed from the mixer. Then with 20% of the old batch in the mixer, raw resin and plasticizer are added. The old partial batch now absorbs more plasticizer causing it to have a lower hardness than the new resin will have. This method of mixing will give non-homogeneous blends and/or gels.

GENERAL

1. Overmixing causes lumps in any mixer.
2. More plasticizer, than a chosen PVC resin, can absorb causing lumps.
3. Not being able to dry up a batch may be from too low resin porosity, not enough mixing time, or wrong type/amount of plasticizer.
4. Sandy surface is normally from overmixing or raw resin getting into the mix.
5. Poor or uneven cooling can cause lumps coming out of the cooler.

PELLETIZING PVC POWDER

Some flexible extruders pelletize the flexible powder. This eliminates the problem of feeding powder to a single screw extruder without a crammer. It reduces the problems with moisture and minimizes housekeeping. Single screw extruders normally were designed to run CUBES or PELLETS, not POWDER. Running powder can be done, but at a cost. The equipment needed to pelletize:

1. Multi or single screw extruder
2. Pelletizing head
3. Bulk handling equipment
4. Dust collectors

TESTING EQUIPMENT

After mixing and cooling, there are several quality control tests necessary before storage or extrusion:

Test	Equipment	Form	Reason
Apparent Bulk Density	Graduated Cylinder and Balance	PTL/PWD	Consistent Fusion and Production Rate
Hardness	Mill or Brabender Strip Shore Hardness Tester	PTL/PWD	Correct Recipe
Specific Gravity	Graduated Cylinder and Balance	PTL/PWD	Correct Recipe
Flow Time	Funnel	PWD	Bulk Handling Extruder Feed
Bench Type Extruder	1. Brabender 2. Krause Maffei	PTL/PWD	Correct Recipe/ Runnability

COMPOUND TESTING

Flexible compounds have special needs vs. rigid compounds. Apparent Bulk Density (ABD), Flow Time (FT) and Fluxing Rates are common tests between the two. Hardness and Specific Gravity are more specific to flexible compound.

The ABD and FT can be done by ASTM D-1895 test method for powder. Even though this test method was designed for powder, the same method may be used to find ABD of pellets. ABD is very important in both pellet and powder extrusion because all extruders take up material by volume, not weight. The more consistent the weight per unit volume, the more consistent the extruder output and fluxing of the compound will be.

Although Flow Time is more important for powder than pellets, it should not be overlooked in pellets. FT tells how dry or moist, and how much static is on the powder. The static is then related to the feeding rate of the extruder screw.

The bench extruder measures both torque, and fluxing rate of the compound. If the compound has been miscompounded, a large variation in torque (>400 meter-grams), fusing point (>4 minutes), and the shape of the curve will occur. Reminder: compound failures are massive, not small subtle things. For a procedure of one method of testing compound, see Technical Service Report #8.

Compound Hardness and Specific Gravity are more specific to flexible compounds. Specific Gravity is measured on rigids, but does not have the same importance. Both tests can be used to check the correctness of the recipe. A melted strip or piece of compound is needed to test Specific Gravity. Test method should be done according to ASTM D-792. Values greater than five hundreds of a point should be looked at very closely. Greater values may suggest recipe problems.

Hardness must be tested on a strip of material according to ASTM D-2240. Time on the strip is very important and must be kept the same. This test will tell you if you achieved the desired compound hardness. It will also tell you if you put the correct amount of plasticizer in the recipe.

All of these tests or a combination of them will help make sure you produced a GOOD COMPOUND or at least will help you catch a BAD COMPOUND.