Application Example

Feeding and Conveying in the Production of Battery Masses

Background

With the advent of electric vehicles and their use becoming more mainstream each day the capability of an electric vehicle now expands from not only short-range personal transportation but to off-road utility as well as long-distance commercial use. The ever-expanding market is driving the need for rechargeable batteries, in particular Lithium-Ion Batteries (LiB).

The growth of the LiB market is not just a trend for electric vehicles. Indeed they are used within many conveniences throughout our lives, allowing us to disconnect our favorite devices and go completely portable for hours on end. Whether it's a more environmentally friendly car, longer life for your mobile phone or being able to cut the lawn free of an electric cord, LiBs are transforming our way of life. They are also allowing us to be kinder to our planet, driving the move to a circular manufacturing model that allows recycling, as well as being emission free with a smaller CO_2 imprint during its usage.

How Does It Work?

At the heart of LiB technology are battery mass materials. Recent innovations in this technology and leaps in battery capabilities have been achieved by using more refined materials, thus resulting in higher energy densities. The key for these battery mass materials lies in the production of the cathode and anode materials, usually made in a slurry process.

These processes are often batch, although there is a strong trend towards continuous processing using extrusion, with many added efficiencies. The production of the slurry requires the precise combination of active, conductive, binder and other ingredients. The active ingredients are often harmful materials, which adds some challenges in the form of containment, in order to keep these materials away from the environment, and any operator, or to protect the materials themselves from atmospheric conditions which could prove detrimental to the performance of the materials.

Regardless of the various ingredients being used, the precise combination, or recipe formulation, is critical to the optimal performance of the resulting battery masses – this is where Coperion K-Tron excels.

The Challenge

Central to any project is the material to be handled. Selection of the correct equipment is based on the properties of the individual bulk materials. There are many ways to classify materials; however, to define the correct feeding or conveying device, there are a few key techniques. For granular materials which interact in a uniform way it is often possible to model the material behavior with a good deal of success; however, once a more difficult material is considered it becomes essential to perform trials with a sample of the material to ensure an optimal equipment configuration for feeding and conveying such materials.

Some examples of difficult bulk materials used in battery mass production include:

- Active Cathode ingredient (lithium-based compounds), bulk density 2.2 kg/dm^3, 20 micron D90, poor flowing and toxic
- Graphite, bulk density 0.1 kg/dm^3, 20 micron D90, poor flowing
- Liquid binder, specific gravity 1 kg/dm^3, viscosity 20 cP @20°C

Feeding Powders

Solids tend to compress and change form, even to degrade or de-mix while being handled.

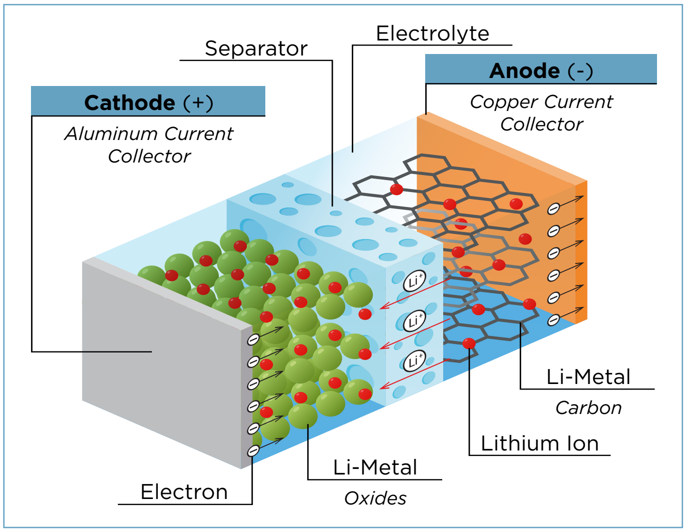

Fig. 1 - Principle of a lithium-ion battery

This means great care has to be taken to not disturb them while keeping a consistent material form — consistent mechanical handling is a major part of accurate feeding. For a particle size of 20 microns the material would be classed as a powder and, generally speaking, powders are best handled by twin screw feeders, because:

- Powders have a tendency to adhere to machines and a twin screw can self-clean.
- Powders tend to flow poorly and twin screws have a greater inlet volume compared to a single screw, and carry the material to the outlet more reliably – this works similar to a pump.
- Twin screws commonly have a double winding (two profiles on each screw element) this reduces the pulsing effect at the screw discharge, improving short term accuracy.
- Twin screws are very versatile because by changing a screw profile many forms of material can be fed successfully.

There are of course some points of caution that need to be considered, derived from experience with the specific materials.

As an example, if the material is waxy, and tends to breakdown when subjected to mechanical working – such as that possible when passing through a twin screw – the correct screw profile

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needs to be confirmed. Also, if there is no experience with a particular powder material then it must be tested.

All feeder trials are conducted at the actual running conditions of the application, this not only guarantees that the material can be fed, but also allows our experienced laboratory test engineers to configure the most accurate and reliable feeder for the material and the application. This means when the equipment gets to the site, you can be sure the best combination has been selected without the need for long and costly commissioning/site trials.

Feeding Liquids

The challenge feeding a liquid is very different to that feeding a bulk solid. Liquids are mainly incompressible, which means their form and specific gravity do not alter during handling, and the challenge is really all about getting the material into the weighed tank and then getting it out again in the right proportion. For this there are many pump types available, each optimal for a certain type of liquid. Particular attention needs to be paid to the viscosity of the liquid. In battery applications the binder or solvent solutions generally have quite low viscosities, less than 100cPs, so using a gear-pump provides an excellent solution.

Feeding Toxic Materials

With toxic materials in either liquid or solid form, containment is essential. It is critical that containment designs be practically implemented so that the equipment can be handled and cleaned. While interfaces may have to be sealed to avoid contamination, they also have to be easy to dismantle. In this area, many lessons can be taken from the pharmaceutical industry.

The approach to the design is to have a gas-tight system. The feeder hopper and bowl can be considered as a closed vessel, and with the addition of jet-filter ventilation, essential for a loss-in-weight feeder, the unit can be allowed to breath, while not allowing dust particles to escape into the atmosphere. If required, the whole unit can then be set under a nitrogen blanket so that the material is handled in an inert environment. Upstream and downstream process connections then interface with the plant or the rest of the processing steps. Provided that those connections are closed, also dust-tight, then the entire system can safely contain the toxic material.

Conveying Powders

For pneumatic conveying, bulk materials are generally characterized via a bench test. This consists of a series of simple tests, such as:

- Flow angle analysis (poured, drained, slide)
- Sieve analysis (additionally checking for blinding and agglomeration)
- Conveying velocities (can, terminal, bulk)
- Abrasion

The bench test generally provides a good basis to determine how a material behaves, thus allowing a scale-up procedure to be performed. Using these parameters and the application conditions, such as horizontal and vertical distances, number of bends, etc., it is possible to calculate the size of the conveying components, such as filter areas, required pump and conveying line sizes. If it is not possible to satisfactorily complete the characterization via bench test, then a full-scale test must be performed.

Handling Toxic Materials

Similar to the feeder, the conveying receiver as shown in Figure 2 can be considered to be a closed vessel. Seals for components are dust-tight and the connection to the upstream and downstream process steps are also closed, i.e. through conveying piping and seals with no moving components, so containment is not an issue. For the vacuum connection, the system passes the conveying air from the process area containing the toxic material to the area which is clean, therefore a special filter medium is required, or in some cases a double filter mechanism.

While containment can be realized relatively easily with the feeding or conveying equipment, it becomes much more difficult when the task of bringing material into the system is considered, as it is much more difficult to effectively automate the process and use a dust-tight design to enclose the material. This part of the process has to allow a degree of manual intervention, such as unloading sacks or tying off big bag spouts, where only the dexterity of manual operation will suffice. In these cases it is necessary to

Fig. 2: P-Series vacuum receiver

Benefits of Dust-Tight Design

- Safe and clean handling of toxic materials
- All leaks are inwards
- Ambient air in contact with product
- Easy to clean
- Modular
- Suitable for OEB/OEL certification

Various options available

- Suitable for OEB/OEL certification
- Pressure switch
- Level probe
- Polished finish
- Hazardous area

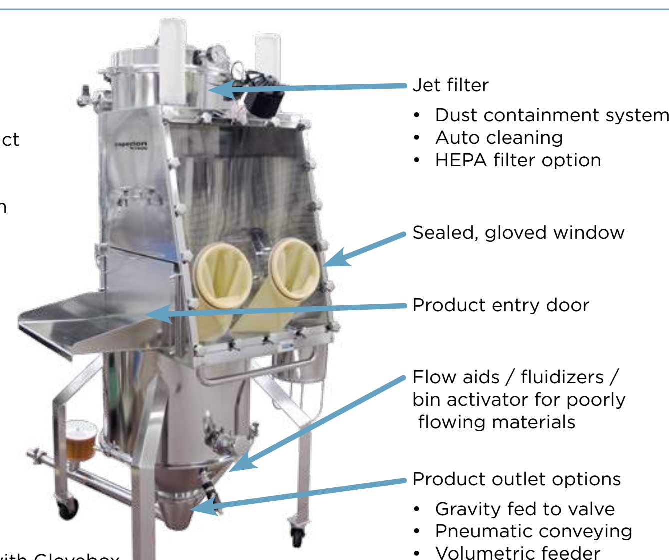
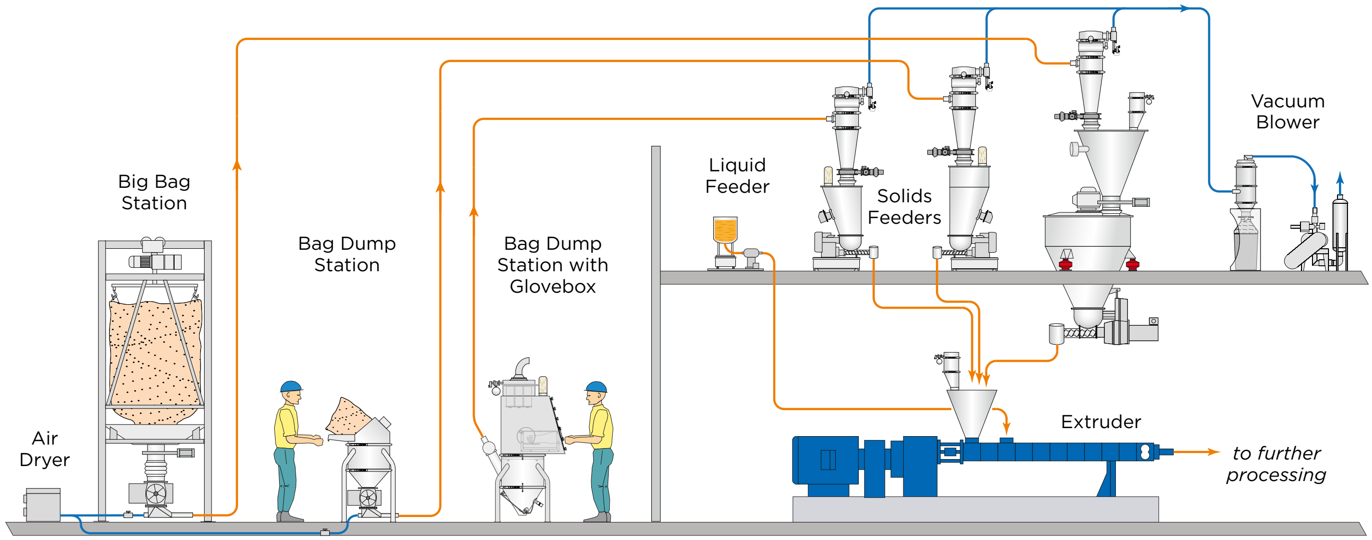


Fig. 3: Sanitary Bag Dump Station with Glovebox

Fig. 4 - Example of a Continuous Anode/Cathode Mass Production Line



Graphite powder is just one of numerous difficult materials to be conveyed and fed

provide safe, sealed operator boundaries, using devices like gloveboxes, airflow booths or even providing PPE, the least favorite solution due to the cumbersome and uncomfortable nature of the equipment.

One solution here is the Sanitary Bag Dump Station with Glovebox, as shown in Figure 3. The goal of this equipment is to contain the dust caused when a bag is split – this is done by enclosing the bag within the glovebox during the operation, and sealing the whole process from the operator using a gloved interface. A ventilation system with a filter is used to remove any dust from the air before the glovebox is next opened. Now the only point of contamination is when the bag enters the unit, and this is prevented via a curtain of air passing through the door. The velocity of the air at this point is kept at a predetermined level to prevent any dust escaping. As soon as the door is closed the unit is then once again sealed. Waste bags can be discharged using a waste spout, which is again sealed using a continuous sleeve.

Batch vs Continuous

Batch operations are inherently inefficient because they are a start/stop process, where equipment has to stand and wait for the prior process step to be completed. Added to that are the requirements for cleaning between batches in order to ensure batch accuracy due to cross contamination or simply being unable to totally empty a piece of equipment.

Continuous operation is clearly the more efficient means of processing, as materials are constantly in flow and equipment can be designed to that specific condition and production can run constantly. Figure 4 shows an example of a continuous production line for battery masses. Unfortunately, in some processes the continuous equipment has not yet been developed for certain steps and for this reason many battery installations use the more conservative batch process. Whether the process is batch or continuous, high accuracy feeding is still a critical component for any process.

Accurate Feeding

Continuous Operation – Loss-in-Weight (LIW): In a loss-in-weight feeder the feeder, hopper or tank and bulk material in it are placed on a weighing device, either platform scale or load cells, and the unit continuously feeds bulk material into the process. The weighing device determines the exact mass flow leaving the feeder by sensing the difference in the weight of the unit as material is being fed into the process below. The more accurate the weighing device, the more accurate the data the controller uses to ensure the correct amount of bulk material is leaving the feeder.

Coperion K-Tron's highly accurate load cells and fast-reacting controls are capable of handling this process in a much more direct way than others, many of which have to employ special software tricks to compensate for the inability of a simple load cell to measure the true weight of the feeder. Thanks to its high frequency weight sampling of up to 450 samples/second, today's Smart Force Transducer technology used in Coperion K-Tron's scales and load cells can measure and eliminate any background influences such as vibrations from surrounding equipment from the weight signal.

On top of that, the new KCM-III controller can update the control signal at up to 20ms, thus the feeder is able to respond to varying process and material conditions and compensate the mass flow, rather than reacting to spurious samples from a misfunctioning load cell.

Simply put, the Coperion K-Tron LIW control continually and rapidly updates the screw speed based on actual deviations in mass flow.

Batch Operation – Loss-in-Weight-Batch (LWB): In loss-in-weight batch mode, a number of LIW feeders are programmed to feed a certain amount of bulk material into a collection hopper below simultaneously. In batch mode the priorities are a little different, rather than continuously updating the

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throughput you need to stop the machine at a precise weight. The batch control software uses three different stages to achieve the precise endpoint:

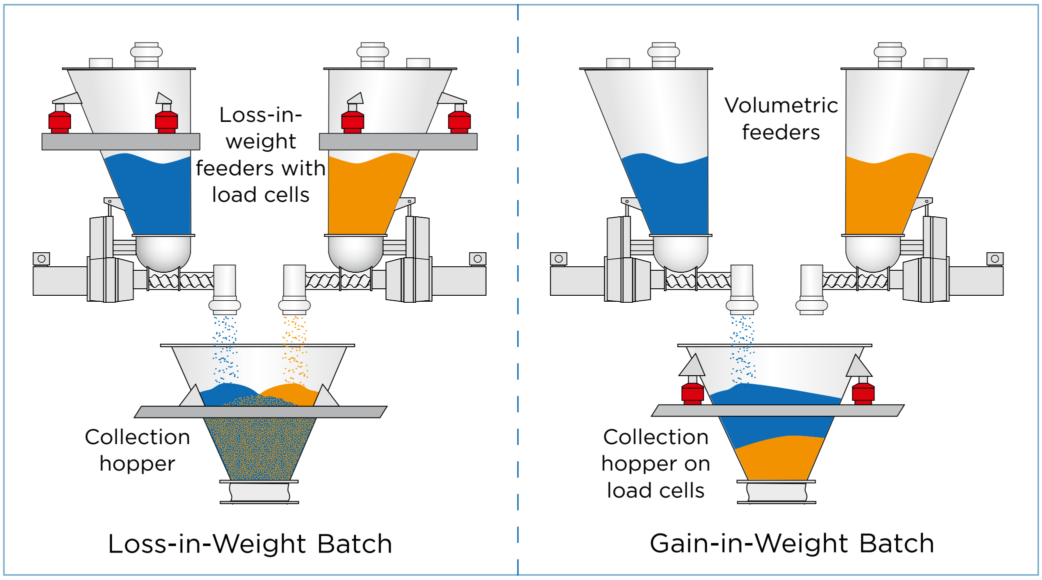
Phase 1: FAST – The feeder runs at the optimal speed for the majority of the batch. The objective is to reach the batch size as quickly as possible, and would typically be 90% speed, for 95% of the batch. In some cases, as previously mentioned, where materials are susceptible to lump formation in a mixing tank, these parameters can be tuned to the process.

Phase 2: DRIBBLE – The feeder slows, so that the stopping point for the feeder can be accurately predicted. If the system waits until the end-point is reached before stopping, it will always feed too much, therefore the feeder calculates, based on the mass flow, when it has to stop in advance. This leads to the best possible accuracy.

Phase 3: PREACT: Due to the inertia of the feeder, motor/screw/gearbox, a small amount of material is fed after the feeding device tries to stop. This value is nearly constant, but does vary slightly depending on the DRIBBLE speed. The PREACT value is subtracted from the total to be fed and the feeder stopped at that point. Using batch mode it is possible to maintain accuracies of around 0.1% of the batch size, and in the case of larger batches even better.

Undoubtedly LWB is the most convenient, flexible and accurate method for batching, as it offers:

- Automatic batch optimization



- Minimum batch time
- Single calibration for materials regardless of batch size
- Huge range of batch sizes possible with a single configuration
- Multiple refills per batch – the batch size is not limited to the size of the hopper
- Minimum equipment size
- Contained process

Batch Operation – Gain-in-Weight-Batch (GWB): Gain-in-weight batch mode works in the same way as LWB, as described above, but instead of weighing the feeders, a number of volumetric feeders sequentially feed bulk material into a weighed collection hopper. The weigh hopper measures the amount of material it is receiving and signals each feeder to stop when its batch is complete. GWB also uses the same three phases as described for LWB.

The advantages of a GWB system are:

- Single weighed system for multiple materials
- Suited to large batch sizes
- Can be used for batch weighing with pneumatic transport

Logically, since the bulk materials are being fed one after the other, the overall batch time is much longer than with LWB. Also, since the weighing device must be configured for the full batch size, it will be less accurate for any small ingredients that are added in small amounts.

A combination of LIW, LWB and GWB can be combined within a single system where required, this allows an ideal combination of technical requirements to be balanced with cost.

Conclusion

Whether feeding continuously or via batch the accuracy of addition is critical to the end quality and desired functionality of battery masses. While this is greatly impacted by the bulk materials themselves and the conditions, using the right tools to identify the best equipment will lead to the best possible system design. For handling of difficult materials, material tests are essential for determining optimal equipment configurations for both feeders and pneumatic conveying.

With Coperion K-Tron's wealth of experience, lab data, and technical expertise we can test and design systems for the most challenging of materials in any application, especially those for the battery industry.

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