# Material Handling and Construction of Energy Storage Devices

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Few will argue the magnitude of the energy storage gold rush that is happening right now. We are in a time where demand is pushing innovation harder than ever. The pressure to scale up from proof of concept to full blown commercial production is immense and unyielding. In this article, we will look at some of the hurdles for taking these new battery technologies from proof of principal to mass production.

You would have to literally be living under a rock to be unaware of the EV boom that is happening right now. Just ten short years ago, seeing an electric vehicle on the road was a rarity, almost a spectacle. Now seeing a Tesla on the road is commonplace, and it's not just Teslas. All the big players have launched electric vehicles. Ford has the F150 Lighting and Mach E Mustang, Chevy is rolling out EV versions of their flagship models this year, and then there are newcomers like Rivian and Lucid Motors. As part of the Infrastructure Investment and Job Act, 2.8 billion dollars are being made available through grants to foster additional manufacturing capacity. It's apparent that electric vehicles are here to stay.

The biggest initial hurdle for general converting of EV battery components is the sheer volume that is in demand. A typical mono cell consists of an anode, a cathode and a separator. A prismatic battery may contain fifty or more of those mono cell sub-assemblies (Figure 1). Additionally, that one mono cell is only a small fraction of the total battery assembly, as these vehicles need multiple batteries connected in series and parallel for the voltage and capacity required. The volumes of discrete components add up fast. Doc Brown's 1.21 gigawatts almost seems laughable in these modern times.

What does it take to convert these new materials and turn them into functional battery components? At the basic level, there are three components of a battery that will need to be converted: a cathode, an anode and a separator. There are some very interesting emerging designs that diverge from the traditional mediums, but for the most part the cathode and anode components are typically coated, thin metal foils. Some of the coatings on these foils can be quite delicate and susceptible to moisture. They need to be processed in a dry environment. The separator materials are usually very thin polymer films or nonwovens. Cut geometries are usually simple but can require tight tolerancing. The cathode and anode will often have a coating edge that needs to be registered to a tab profile that will be used to make the internal connections once the battery is assembled. The separators can sometimes require heat staking, or folding and sealing. Because of the very thin and delicate nature of these materials, it's often best to assemble them into a mono cell during the conversion process as handling them once singulated would prove difficult. There are also the efficiencies afforded of overlapping operations that have to be considered. While there are a multitude of cutting methods capable of converting most battery materials, some such as plotter knives and water jet are simply too slow or non-compatible. Flatbed, rotary, and laser however, offer excellent throughput and tolerance capabilities. Each have their own advantages and challenges when it comes to converting for the energy storage market.

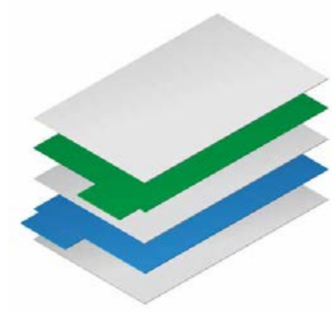

**Figure 1**

Flatbed die cutting typically offers the best dimensional cut tolerances and can utilize a wider gamut of tooling options. Most common is the steel rule die, but it's also popular to run chem etched dies, or class A male/female dies. Dimensional tolerancing varies based on the type of tooling used, with steel rule dies being the least expensive/lowest tolerance, and matched metal dies being the most costly/highest tolerance. While chem etch dies are relatively inexpensive and offer excellent dimensional tolerancing, they are limited by material thickness and have fewer options when it comes to blade profiles. Iron contamination can be a concern when converting for hydrogen fuel cell applications. And with the limited ferrous contact area of a steel rule die, this can be advantageous. Most all electrodes will have a tab which is typically an uncoated section or a welded addition where the internal contacts are made. This often means there is a need to register the die to either the coating or the welded tab. Since the material is stationary during cutting, the vision registration and registration verification on flatbed systems will offer the tightest tolerances when compared to rotary processing (Figure 2). Typically, the foil and tab material and/or thickness will dictate the type of tooling used. If there is a welded tab it's not uncommon to use a matched metal die to ensure a burr free edge. Along with die cutting, flatbed presses also lend themselves well to heat sealing and embossing or forming. Since the entirety of the rule is in contact with the material during the down stroke, the active dwell time to seal is much higher than in a rotary application where the moment of contact is constrained by the tangent of the blade to the anvil. With some battery technologies requiring the mono cells to be pouched and sealed, this offers an advantage. Flatbed

**Figure 2**

presses can also accommodate sheeted materials or roll-to-roll which offers some versatility, but since they operate with intermittent motion, tend to have lower throughput than other methods of die cutting.

**Figure 3**

Rotary die cutting on the other hand is typically much faster than flatbed as it is designed for continuous motion and high throughput. It's very easy to achieve cutting speeds that produce more singulated parts than can be collected. However, dimensional tolerances on the cut geometry tend to be lower, especially in the feed axis. This is in part due to the inconsistency in the feed rate of the material compared to the rotational speed of the die. Imagine the die is profiled with a perfectly round circle. Should the die be rotating slightly faster than the rate of the material, the circle becomes a short oval in the direction of feed. The inverse is true should the die be turning slightly slower. It's nearly impossible to ensure a true one-to-one ratio between the die and the material feed, and if the die is making a registration move, this can compound the issue. The continuous motion of a rotary system by nature means that it is also well suited for overlapping operations such as lamination, slitting, and island placements (Figure 3). One of the drawbacks to flatbed cutting is that some amount of waste matrix is often needed to move the cut pieces out of the platen area, which leads to added waste and material cost. With island placement, the parts can be cut very close together or with geometry allowing a cut with common rule and then spaced out onto a carrier material. This greatly reduces or can even eliminate waste. When looking at methods to construct mono cells in-line while converting, island placement becomes an asset. Cathodes and anodes can be cut and then island placed into mono cell stacks as part of a wholistic operation. Opportunity for in-line coating processes is also a reality. Rotary processing however is typically limited to roll-to-roll processing and not usually well suited to sheet feed applications.

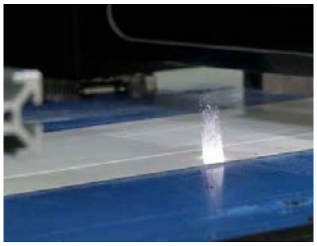

**Figure 4**

Laser cutting can offer us extremely accurate dimensions and is capable of processing either sheets or roll-to-roll. Along with cutting, the laser is also capable of sealing, ablating, welding, or heat treating. Lasers are unrivaled in their ability to create extremely small and complex cuts, as they are not bound by the physical constraints of a machined tool. The impossibly small features found in medical devices such as heart stints and microfluidic devices are all possible due to amplified and focused light. However, there is a unique set of challenges with laser cutting that isn't a consideration for hard tool cutting. Since the laser is a single point cut, the beam must essentially trace the cut pattern on the material. Therefore, speed can be slower depending on the total linear inches needed to be cut. Although in some cases it can be considerably faster. For example, long lineal with short cross web patterns can be achieved with minimal beam direction. It should be noted though that one of the biggest determining factors for the cut speed of the laser is the material itself and the power of the laser. There can also be heat-effected zones near the cut with a chance of contamination from debris caused by the vaporization of the material being cut by the laser (Figure 4).

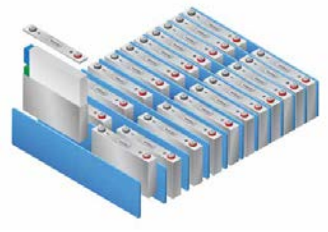

**Figure 5**

All things considered, roll-to-roll is almost always the preferred method of material handling. Roll-to-roll offers multiple advantages over sheet handling such as easier placement, overall control, and minimal handling labor. However, some designs simply cannot facilitate roll processing due to the availability of substrates. Physical limitations due to rigidity and/or coating integrity can also be an issue. To maximize capacity and maintain the often-stringent dimensional tolerancing and processing requirements, we have often had to look towards hybrid systems. It's becoming more and more common to incorporate flatbed cutting into rotary and laser processing systems. This is especially true when heat sealing is needed as the dwell time needed would slow rotary sealing down far too much. Laser processing is easily integrated into just about any core system and is often the only option available when features become very small or non-contact cutting is required for open-faced adhesives, for example (Figure 5).

Is the gold rush for just electric vehicle energy storage? The answer to that question is a resounding "No". The internal combustion engine is being phased out, or at least optioned out at just about every level from homeowner lawn care equipment to forklifts. Converting opportunities don't just stop at the battery components either. Hydrogen fuel cells have some unique, but manageable converting challenges. Thermal management and fire mitigation components can offer some low-hanging fruit as well. Energy storage and creation is an industry that is expanding at a rate not often seen. There's enormous potential, and everyone from startups to the goliaths of industry are looking to take a piece of the pie.

| | Laser | Rotary | Flatbed |
|---|---|---|---|
| Intermittent Motion | Yes | Yes | Yes |
| Continous Motion | Yes | Yes | No* |
| Island Placement | Best | Best | No |
| Ancillary Operations | Best | Best | Better |
| Thick Materials | Better | Good | Best |
| Material Independent | Good | Better | Best |
| Slug Removal | Better | Better | Best |
| Cut Tolerance | Best | Better | Best |
| Cut-to-Cut Registration | Best | Better | Best |
| Fast Process Change Over | Best | Better | Best |
| Fast Die Change Over | -- | Better | Best |
| Multiple Tooling Options | -- | Better | Best |
| Sheet-Fed | Best | No | Best |
| Roll-to-Roll | Best | Best | Best |
| Through-Cut | Best | Best | Best |
| Kiss-Cut | Best | Best | Best |
| Multi-Height Cut | Best | Best | Best |

*Flatbed presses can be integrated into continous-motion systems with accumulators*