Optimizing your tablet press tooling can help increase production and tool life while reducing costs and downtime. This article discusses several aspects of tooling optimization and explains how to start small by optimizing the tooling for one product at a time.

Tablets come in many shapes and sizes, and tablet formulations have a range of physical characteristics and tableting properties, such as abrasiveness, corrosiveness, lubricity, and compressibility. With this in mind, it makes sense that a one-size-fits-all approach to tablet press tooling is unlikely to provide the best results for companies that manufacture a range of pharmaceutical or nutraceutical tablets. By optimizing your tooling to suit the product being manufactured, you can minimize tableting problems such as picking, sticking, fracture, and excessive wear.

The main factors to consider when optimizing your tooling are the tablet and tool design, the steel used to make the tooling, and the coating, if any, applied to the tooling. Once you have a good understanding of how these factors influence tableting performance, you can evaluate your existing tooling and your tableting processes to identify where optimization may have the most impact.
Tablet and tool design

Tool optimization starts with tablet design. A tablet’s shape and characteristics, such as a bisect or logo, can have a major impact on how well the tablet will resist sticking and picking or how challenging the tablets may be to coat. Effective tablet design can help you avoid problems both during compression and downstream from the tablet press.

I highly recommend getting a copy of the Tableting Specification Manual (TSM), which you can purchase online. The TSM is a very useful reference that covers all aspects of tablet and tool design as well as terminology, maintenance, and troubleshooting production problems. Becoming familiar with the basic principles of tablet and tooling design can be helpful as you work with your tooling vendor to optimize your tooling or solve a tooling problem.

For example, compression force is a critical factor in tablet and tool design. The tooling must be designed to handle the tablet’s specified compression force. Excessive compression force can damage tooling, particularly the punch tip, so it’s a good idea to keep the compression force as low as possible while still producing a quality tablet. Also, over-compression increases tablet hardness, which can prevent the tablet from disintegrating completely in vitro and affect the bioavailability of the API.

It’s important to understand the compression tonnages of your tablet presses and how to adjust the tonnage, weight control, and other press parameters. Keep this information at your fingertips when designing and optimizing tooling, because you’ll need to know whether the presses you’ll be using have a high enough tonnage to adequately compress the tablets and whether the formulation will require precompression.

If you don’t know your presses’ operating parameters and how to adjust them, ask your press manufacturer for that information. Changing the design of your tablet and tooling will do little to optimize your process if you don’t use the correct compression force and other settings during operation.

Tool steels

Different tool steels have different characteristics—including toughness, hardness, and compressive strength—that influence tableting performance and affect how long the tooling will last under normal operating conditions. Toughness is a measure of how far the steel can be bent or otherwise deformed before fracturing. Hardness is a measure of how well the steel resists wear and local deformations, such as dents and scratches to the tool surface. Compressive strength is the steel’s ability to resist failure under compressive loads.

Early tablet presses weren’t very accurate, so tablet tooling was designed for toughness. This allowed the steel to flex and compensate for alignment errors without damaging either the tool or the press. Modern tablet presses are manufactured to very tight tolerances, so toughness is no longer the most important tool steel characteristic; instead, hardness and compressive strength are often more important because of their influence on wear resistance.

Figure 1 shows the characteristics of some common tool steels. Standard tool steel is S7, on the left in the figure. As the figure shows, S7 steel has more toughness than D2 steel, but D2 steel has more wear resistance and compressive strength. On the right in the figure are several grades of powdered metal. Powdered metal is created by melting a standard metal and then using a blast of air to atomize the liquid, creating tiny metal pellets or powder particles.
The powder is then placed into a cast that's welded shut and subjected to a high amount of pressure. The pressure changes the steel's molecular structure and rearranges the carbides in the steel into a matrix that improves the steel's compressive strength and wear resistance.

Tooling vendors consider the steel's characteristics when choosing the optimal tool steel for a particular product. When designing your tooling, the vendor should ask questions to try to understand how your formulation will behave in the press—whether it will corrode the tool surface, how abrasive it is, its compressibility, and other factors. The vendor will then use this information, along with their experience and knowledge of tool-steel characteristics, to select the best steel for the application.

If your current tool vendor isn't talking about different steel options, ask how they selected the steel for your tooling and whether an alternative steel might perform better for your application. Be sure the vendor knows your formulation's characteristics, which will help them navigate the maze of tool steels to choose from.

Tool coatings

The principle behind tool coatings is to start out with a really good tool steel for a base and then apply a thin layer of material over it to improve the tool's lubricity and/or wear resistance. Like tool steels, tool coating choices can be difficult to navigate, and a coating that's good for one tablet may not be the best for every other tablet.

All equipment used to manufacture pharmaceutical and nutritional products, including tooling, is regulated by the FDA. FDA regulations specific to equipment used in the manufacture of solid dosage tablets are found in 21 CFR 211.65, which states, “Equipment shall be constructed so that surfaces that contact components, in-process materials, or drug products shall not be reactive, additive, or absorptive so as to alter the safety, identity, strength, quality, or purity of the drug product beyond the official or other established requirements.”

Not every coating can achieve this requirement, and choosing the wrong coating for an application can actually cause problems or make an existing problem worse. It's a good idea to review the many choices with your tool vendor and confirm that any coating you use won't react with, wear off into, or absorb any ingredient of the formulation you're tabletting.

Coating types

The three most common coating types are electrostatic, physical vapor deposition (PVD), and chemical vapor deposition (CVD). Electrostatic coatings were the most commonly used coatings for early tablet tooling, while PVD and CVD are more modern technologies.

Electrostatic coating. Electrostatic coatings include chrome, flash chrome, and hard chrome. To apply the coating, the vendor places the steel tooling into a tank filled with the coating material and charges the tank with electricity. The electric charge attracts and bonds the coating material to the steel. An electrostatic chrome coating can provide twice the wear resistance of standard tool steel on average. Note that this doesn't mean that a chrome-coated tool will necessarily last twice as long as a standard uncoated tool.

A problem with electrostatic coating is that the coating material tends to ball up in the punch cups, leaving more chrome on one side than on the other, while PVD and CVD coating processes tend to result in a more even coating layer. Another potential problem with this method is that the chroming process can sometimes create a phenomenon called hydrogen embrittlement, in which the steel around the edge of the punch cup hardens. This reduces the toughness of this thin perimeter and limits the amount of compressive force the punch tip can withstand without fracturing.

PVD coating. Common PVD coatings include titanium carbo-nitride (TiCN) and chromium nitride (CrN). For PVD coating, the uncoated tools are placed in a tank in a coating machine along with gases and the coating material. For example, to apply a TiCN coating, the coating material would be a titanium plate. The machine raises the temperature inside the tank to approximately 825°F to 900°F and strikes the titanium plate with an electrical arc, which atomizes the titanium molecules. The atomized titanium molecules then mix with the gases and adhere to the steel tool surface, creating a very thin coating, a fraction of the thickness of a human hair. While thin, the coating is glasslike and very hard and resistant to material sticking to its surface. A TiCN or CrN coating can provide ten times the wear resistance of standard tool steel.

CVD coating. A CVD coating, such as diamond-like coating (DLC), is applied in a similar manner to PVD coatings except the coating forms as a result of a chemical reaction between the gases and the heated tool surface. CVD coating requires much higher temperatures than PVD coating, however, so only certain tool steels can withstand the process without becoming weakened or embrittled. The tablet design and surface features can also influence whether a steel can handle the heat involved in the coating process.

There are many more coating types available and numerous companies that specialize in their application. Again, talk to your tooling vendor for ideas about...
which coatings can be used in your industry, with your product, and with your particular tool. Starting with the base tool steel is always best. Select the steel that will provide the longest tool life for your product and then determine whether a coating can further enhance the tool’s performance.

**Evaluating your tooling**

While optimizing the tool steel and coating can make your tooling last longer, the benefits will vary from product to product. A tool’s service life ends when it no longer makes high-quality, marketable tablets. This is subjective to some degree and depends on the company’s requirements and quality controls.

When evaluating tool performance, it’s important to have a good baseline. For example, if you know how long the tooling lasts when you use a standard S7 punch and a standard D3 die, you can compare that with how long the tooling lasts when you make changes. Tooling vendors look at how many tablets a set of punches can make before the tablet parameters fall outside of QC requirements. That gives the vendor a baseline from which they can recommend alternative steels and/or coatings to improve on that performance. Vendors use a similar process to evaluate dies and determine, for example, whether carbide-lined dies (which often produce more than 100 million tablets before wearing out) are appropriate.

Have your tool vendor evaluate your tooling and determine whether you have a good baseline and can begin documenting performance information or whether you should look at replacing those tools and starting over. It’s a good idea to evaluate the condition of your press equipment as well, because a poorly performing press can contribute to premature tool wear.

**Start small**

Optimizing your tooling doesn’t mean that you need to redesign every single tool in your current inventory. Companies always have limited budgets and are generally working with a variety of tablet presses and tooling of various ages and conditions. Also, many companies work with customer-provided tablet designs and tooling over which they have little or no control. These factors make it very difficult to start with a clean slate and optimize all your tablet tooling at once.

A more practical approach is to start with one specific tablet. For example, if one of your products contains an ingredient such as magnesium or calcium that can cause oxidation on tool surfaces, you may want to design a specific tool set for that product. Or if one of your products consistently experiences sticking and picking problems, start with that product and design tooling specifically geared toward solving the problem. Then use the new tooling only for that tablet so you can document its performance and verify whether the tooling changes improved the process or not.

Having an optimized set of tooling for a problem product and a standard set for easy-to-run products will help you achieve maximum working life from each set and can save you thousands of dollars over the life of the tools. You may also want to consider using extended head flats on special sets. With extended head flats, the flat surface on the punch head is wider, which provides a longer dwell time (the time during which the tablet is under compression), allowing you maximize your press operating speed.

**Maintenance and handling**

Finally, while this article is about optimizing your tooling, successful tableting also requires a proper tooling maintenance program. Proper maintenance helps you track tooling performance, so you can see where problems or premature wear are occurring and make changes such as upgrading the tool steel or choosing a different coating or tablet design. Consult the section in the TSM that covers tooling procurement, inspection, and maintenance. Make sure press operators, tool-room staff and anyone else installing, removing, cleaning, transporting, or otherwise handling your tooling knows and practices safe handling methods. More tool damage is caused by poor handling than by anything that happens in the tablet press, and even the most optimized tools won’t last long or perform well if they’re not properly handled and cared for.

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