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WHITEPAPER

HOW CRUCIAL IS COMPACTION DWELL TIME?

Transitioning product from one tablet press to another during scale-up has been an ongoing challenge in the industry for many decades. Many different approaches and aspects must be considered, including the tablet press and punch design and powder characteristics.

When developing a new formulation scientists are equipped with a small-scale tablet press to study and understand their product's tabletability. These small-scale systems are very useful at the research level but do not always successfully transfer to the larger-scale manufacturing machines. Ideally, developing the product on a manufacturing press would eliminate the transfer challenges, but the amount of powder required to operate such a machine is very high and not cost effective.

Many stages that occur during tablet production on the rotary tablet press, and a full understanding of their functions is crucial to the success of producing a quality tablet.



Stages include:

- → Powder filling from the hopper into the feed system
- → Powder filling from the feed system into the die cavity
- → Proper fill cam and dosing cam settings
- → Centrifugal acceleration and the need for a pull-down cam
- → Pre-compression—is it needed and how much force?
- → Main compression consolidation time and rate
- → Main compression dwell time
- → Main compression decompression event
- → Ejection force and rate
- → Tablet take-off—sticking and picking adherence removal

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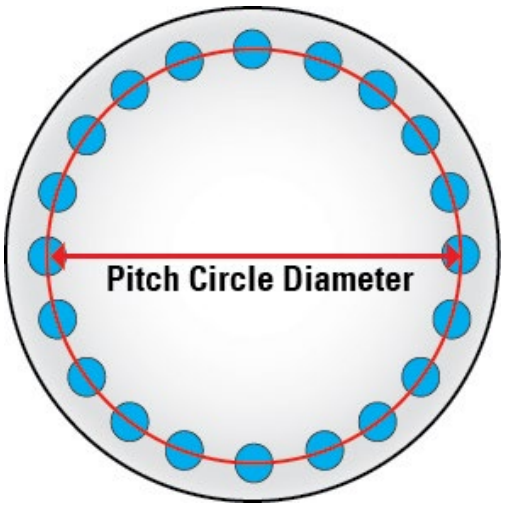
Every step in the tablet press process merits a full discussion, but this article will focus on the compression dwell time and how the tablet press and punch head designs affect this process.

Figure 1. Turret Pitch Circle Diameter



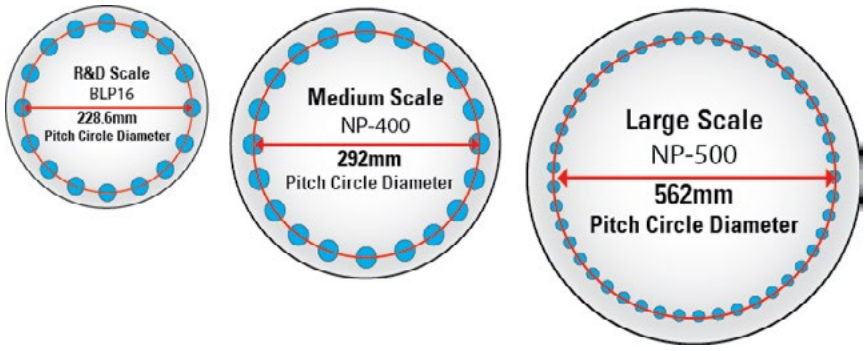
DISCUSSION

Dwell time expressed in milliseconds is the time in which the punches achieve maximum penetration in the die under the main compression rollers and the punches are no longer moving vertically. In other words, dwell time occurs when the compression rollers are in contact with the punch head flat. Dwell time is a contributing factor to tablet strength and a means for product transfer from one tablet press to another. Although turret RPM or tablets-per-minute are a common language for turret speed, it doesn't allow a true comparison for tablet presses with different turret sizes. The turret velocity is a normalization of turret size and the dwell time is a normalization of the turret size and punch head flat. It is important to understand the turret velocity before we can discuss dwell time.

TURRET VELOCITY

When comparing press speed, the tangential velocity (TV) expressed in mm/sec allows for a true comparison. The TV is a function of the turret RPM and pitch circle diameter (PCD), which is the measurement of the turret from center of the die to the opposite die center (Figure 1). The PCD is critical as this is where the compression event occurs.

Figure 2. Examples of Different Pitch Circle Diameters



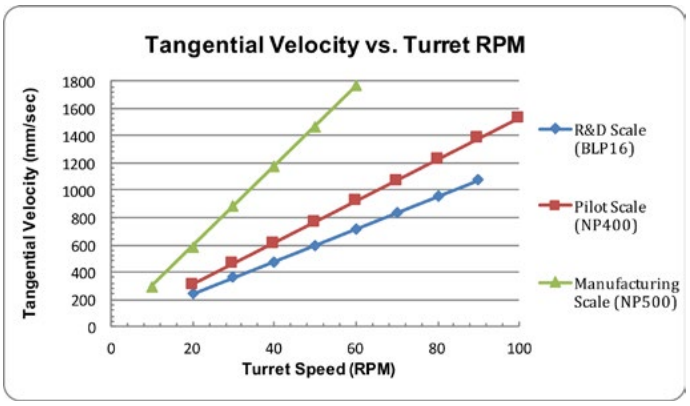


Figure 3. Tangential Velocity for Different Sized Presses

At a particular turret RPM the TV is dependent on the PCD, which varies depending on the number of stations on a turret. Figure 3 depicts examples of different sized machines and the relationship between turret RPM and TV. As the turret PCD increases, the required turret RPM is reduced to match a particular TV. A representable manufacturing velocity is above 1,000 mm/sec. At 1,000 mm/sec, the larger-scale NP-500 press will operate at a turret speed of 34 RPM, where the medium-scale NP-400 operates at 65 RPM and the smaller-scale BLP-16 at 84 RPM. Running at 84 RPM turret speed can pose some challenges with powder flow into the die cavity, inhibiting the ability to evaluate tablet attributes. In fact, some small-scale industry tablet presses are not able to generate manufacturing velocities due to their smaller PCD or limited turret RPM. This is where the punch head flat can be designed to provide this gap for scale-up matching.

HEAD FLAT AND DWELL TIME

Compression tooling heads are designed with a flat, providing a constant strain to the powder bed while under the compression rollers. The longer the head flat the longer the dwell time and depending on your powder deformation characteristics and strain rate sensitivity, a longer dwell time may be needed to produce a robust tablet. Slowing the turret speed can increase the dwell time, but slowing the turret speed also will decrease production rates.

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Many different types of tools used in the industry have different head configurations. Some are designed specifically to increase dwell time, while others are designed to reduce premature wear. The two most recognized tool configurations are the European ISO standard and the American TSM. These standards are provided to allow tablet press tool interchangeability, consistent quality between tooling vendors, and simplified inspection processes and inventory. Within both configurations, the B and D type tools are the most common. B tooling is designed with a smaller body allowing a higher population of punches in a turret ,which is favorable for high tablet output, while the D tooling is designed with a larger body, allowing for larger tablets approaching up to one inch. As a D tool is larger, the head profile and flat for a standard configuration is also larger, providing a longer dwell time. Figures 4 and 5 show different head designs and their respective dwell times for a given TV. Notice that the TSM Domed Std. and EU 19 Std. are almost identical as their head profiles are very similar. Also notice that the dwell time is less sensitive at the higher turret rates.

Dwell time can be calculated by taking the punch head flat dimension divided by the turret tangential velocity. This simple calculation is helpful when transferring product to a different size press. And in the case of the large gap between TV as discussed previously with smaller R&D machines and larger scale machines, the tooling head flat can be designed by your tool manufacturer to match, or closely match, dwell

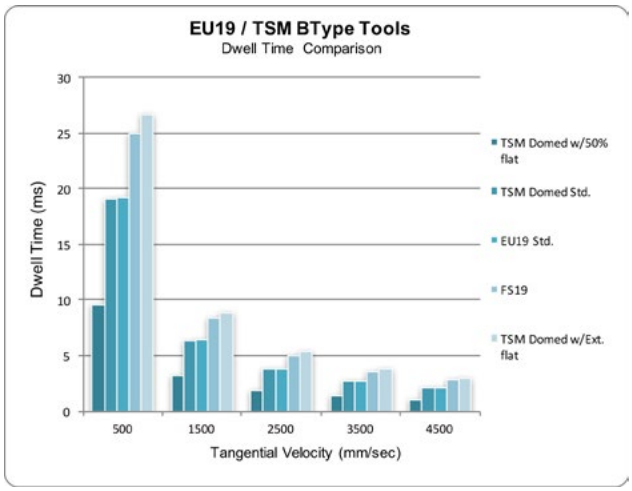


Figure 4. "B" Type Tooling Dwell Time Comparison

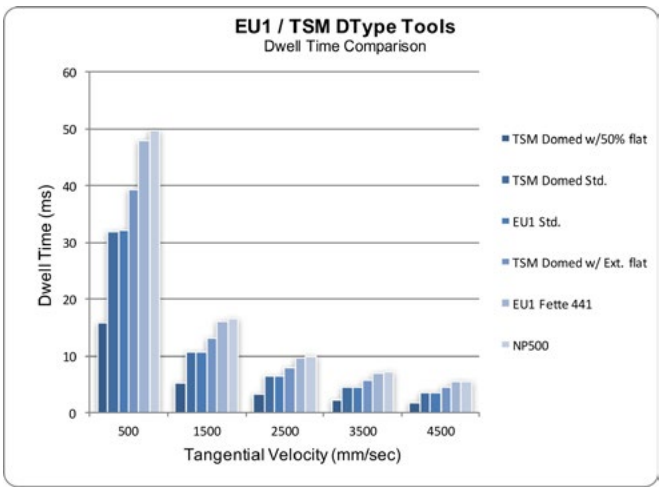


Figure 5. "D" Type Tooling Dwell Time

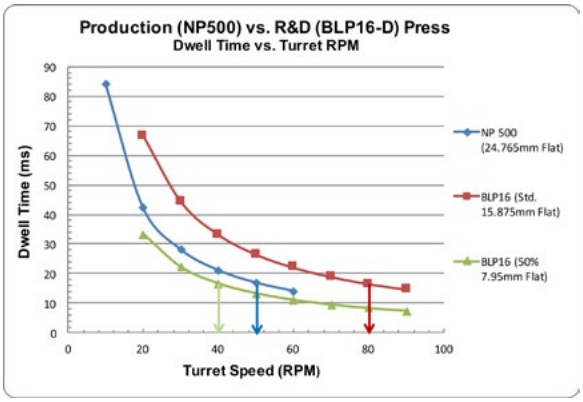


Figure 6. Production Press vs. R&D "D" Tablet Presses

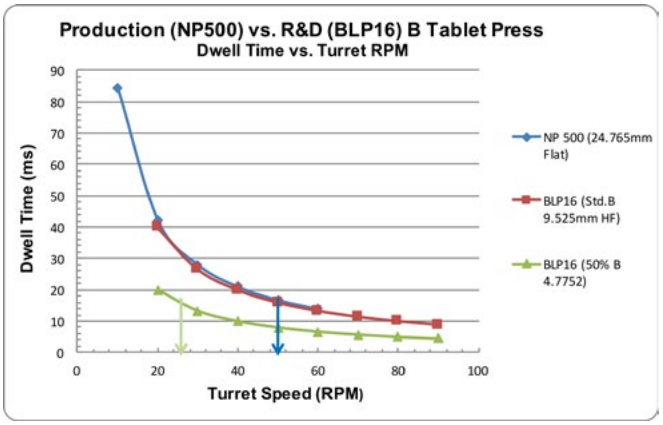
times. The flexibility of the flat dimension is dependent on the punch neck diameter. To ensure the robustness and integrity of the punch, the neck diameter should be larger than the head flat and with some safety margin.

Figure 6 is an example of comparing the dwell time of a production press (NP-500) and an R&D tablet press (BLP16-D). The NP-500 is a high-speed, 45-station, double-sided production tablet press with extended head flat tooling, and the BLP16-D is a 16-station, D tooled development press. The NP-500 running at 80 percent of its maximum speed reaches 50 RPM and 17 ms of dwell time. With standard TSM domed heads the BLP16-D must reach 80 RPM turret speed to match 17 ms. It can be challenging to maintain consistent tablet weights at such a high speed. When using the reduced head flat of 7.95 mm on the BLP16-D, the required turret speed is now only 40 RPM, which is a more manageable speed for tablet weight consistency and helps reduce powder wastes.

Another challenge that can be resolved with head flat designs is transferring product from a B tooled machine to a D tooled machine or vice versa.

Figure 7 is an example of matching dwell time from an NP-500 to a BLP-16 utilizing B tooling. The standard B tooling matches dwell time of the NP-500 at similar turret speeds. When using the 50 percent of standard B head, the turret speed is reduced to 25 RPM, which again, at slower speeds, helps reduce powder wastes.

Figure 7. Production Press vs. R&D "B" Tablet Presses



As previously discussed the European ISO standard and American TSM are the references for tooling specifications. They provide the acceptable tolerances to ensure proper installation, alignment, and tablet consistency. The punch head flat also specifies an acceptable tolerance of ±0.2mm for the European standard and +0.00 /-0.76 mm for the TSM standard. At common production rates the extreme difference is less than 1 ms and as low as 0.2 ms at higher production rates. Figure 8 depicts the small dwell time differences for the European tolerances. To accurately measure your punch head dimension a horizontal optical comparator can be used.

CONCLUSION

Tooling designs and dwell time are one of many important parameters that play a role in tablet quality. Tooling head flats can be designed to achieve your desired dwell to assist in product transfer scalability processes or tablet robustness issues. Normalizing for turret size, speeds, and tooling allows for a clearer understanding and comparison of different size tablet presses.

Figure 8. European Punch Head Tolerances & Impact to Dwell Time

