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WHITEPAPER

EXTENDED HEAD FLATS INCREASE DWELL TIME

A variety of options are available for punches and dies to help compress difficult formulations. One commonly overlooked punch modification, the extended head flat, increases the diameter of the flat area atop the punch head. Typically, this option doesn't require any modifications to the press, and you can use it with cam tracks that meet Tableting Specification Manual (TSM) or European Union (EU) standards.

The extended head flat offers multiple benefits, including a longer dwell time—the time the head flat spends in contact with the pressure roll—at a given press speed to better compact poorly compressible products. The longer dwell time may also reduce the amount of force required to attain a specific tablet hardness. Although extending the head flat is beneficial in many situations, it is important to note that extended head flats and the resulting extended dwell time are not always the ideal way to mitigate common tableting issues such as capping for all products. Studies, sponsored by Natoli Engineering, have shown that for some products reducing the head flat can be beneficial in some circumstances.

Extended head flat
vs. standard head flat

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Dwell time is dependent on press speed, the pitch circle diameter of the turret, and the head flat's diameter (Figure 1).

Increasing the diameter of the head flat is the easiest way to prolong dwell time without switching to a press with a smaller turret pitch circle and generally with fewer stations, or without decreasing the turret speed, both of which would decrease production. For example, a Fette 2090 press has a pitch-circle diameter of 410 mm, and assuming an operating speed of 50 rpm, a standard B-type punch, TSM domed head flat of 9.525mm (0.375 in) would have a dwell time of 8.87 milliseconds. Meanwhile, on that same press, a B-type punch with TSM domed head with extended head flat (13.59mm, 0.535in) would have a dwell time of 12.66 milliseconds (Figure 2). Figure 3 illustrates the differences in dimensions between a standard B-type TSM domed head and TSM extended domed head. The larger head flat increases dwell time by more than 43% without reducing the turret speed.

Dwell time (ms)

$$dt = \frac{Dhf}{Dpc\ x\ \pi\ x\ rpm}(60)(1000)$$

Where:

dt=dwell time (milliseconds)

Dhf=head flat diameter (millimeters)

Dpc=pitch circle diameter of turret (millimeters)

rpm=revolutions per minute (turret speed)

FIGURE 1.

The extended head flat punch also can reduce the amount of compression force needed to form a tablet at a given breaking force, also known as hardness. Tablet hardness and density are related to both compression force and dwell time. If the amount of time spent under compression increases, the amount of force necessary to maintain the same tablet hardness may decrease. The reduction in required compression force depends on the characteristics of the granulation being compressed.

Figure 2.

Fette 2090 with Pitch-Circle Diameter of 410mm		
B-TYPE TOOLING	**ROTATION SPEED**	**DWELL TIME**
TSM Domed Head Flat 9.525mm (0.375")	50 RPM	8.87ms
TSM Extended Head Flat 13.59mm (0.535")	50 RPM	12.66ms

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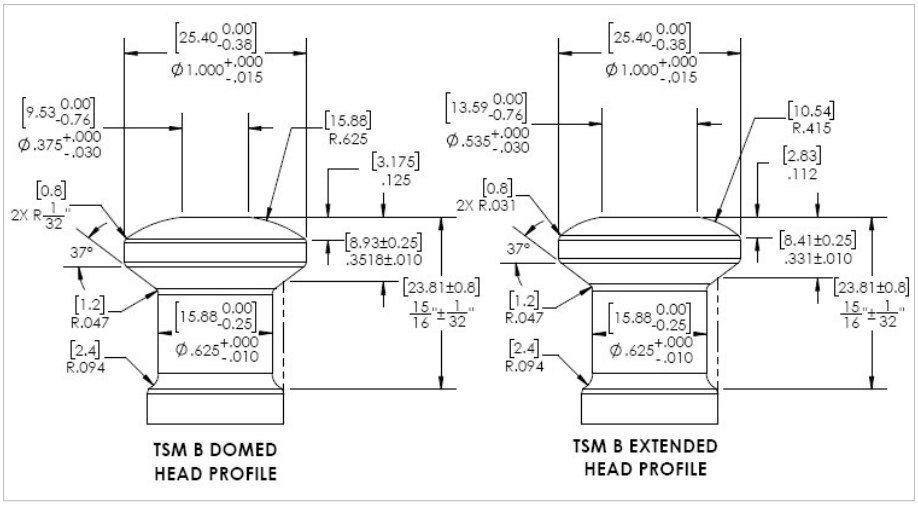

Figure 3.

Since the required compression force is dependent on the product being compressed, it's impossible to predict accurately how much an increase in dwell time will decrease compression force. The effect of dwell time on compression force can best be quantified during the research and development stage, and understanding the relationship of dwell time to compression force can mitigate issues that commonly arise during scale-up to large production presses.

Geometrically, the design of the extended head flat differs only slightly from a TSM domed head or an EU head. Other than the increased head flat, one notable difference is a reduction in the head's thickness to allow the larger flat to fit through the same cam profile as that of a standard TSM domed or EU head. It's this slightly thinner head that allows extended head flats to traverse the standard cams without modifications to the cam tracks or press. The head flat can even be customized to achieve a specific dwell time on a given press.

Head wear and the propensity of surface origin fatigue (i.e. head pitting) are affected by the head profile design. The smaller the outside head radius, the higher the contact stress and likelihood of accelerated wear. The difference in stress can be calculated analytically using Hertzian contact stress equations.

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For example, using the cylinder-on-cylinder Hertzian stress equation to approximate a comparison between TSM Std, TSM Domed, and TSM Extended head profiles assuming a 10" (254mm) diameter pressure roll:

Pressure Roller (AISI D2)
Diameter 254mm
Poisson ratio: 0.29
Elastic modulus: 190 GPa

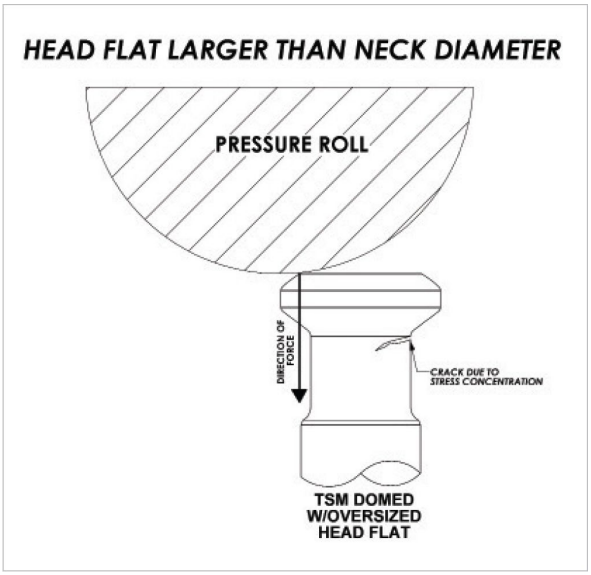
Punch Head (AISI S7)
Punch Head Outside Diameter:
- Domed: 31.75mm
- Extended: 21.08mm
- TSM Standard: 15.88mm

Poisson ratio: 0.28
Elastic modulus: 190 GPa
Force applied: 40KN

Results	Domed	Extended	TSM Standard
Maximum Hertzian contact stress:	248,626psi	299,378psi	341,653psi

Note that contact stresses are reduced with larger pressure rollers and are higher with smaller pressure rollers.

Figure 4.



For this reason, the old TSM standard head design with a small 5/16" radius between the outside head angle and the head flat was replaced with the domed head design. Punches with extended heads will be less resistant to head wear than domed punches, so care in selection is advised when high compression forces are needed.

The limiting factor in the head flat's size is the neck diameter of the punch. The neck transfers the force from the head to the barrel and tip and then to the granulation. As you can see in Figure 4, if the head flat gets larger than the neck's diameter, it won't have the support required to transfer the force generated when it contacts the pressure roll, which can cause the head or neck to fail.

For mini-tablet production, the size of the head flat affects the side loads being applied to the punch tips during compression and the likelihood of punch tips bending or buckling.

Larger head flats increase side loads. Therefore, a reduced head flat (i.e. ¼" or 6.35mm) may be advised.

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Extended head flats can also be oval or elliptically shaped. Although this design extends the dwell time exactly as a round extended head flat does, it has some drawbacks. The primary drawback is that the oval head flat can pass under the pressure rolls only in one direction along the major axis of the oval or ellipse to extend dwell time. For that reason, punches with an oval head flat must be keyed on the upper AND lower punches, even when round, to prevent them from rotating as they pass under or over the pressure rolls. With upper and lower punches requiring keys for oval or elliptical head flats, punch heads can experience accelerated wear because of repeated contact between the punch head and the compression roller at the same spot and no punch rotation.

Additionally, if a turret doesn't have lower key slots, then round tooling with an oval head cannot be used because the benefit of the extended head flat will be lost if the lower punch rotates. Another limitation is that if two presses have turrets with key slots of different angles, the oval head flat's punches cannot be interchanged because the different angle will alter the orientation of the head flat with respect to the pressure rolls.

Punch head profiles and the resulting dwell time play an important role in the compaction characteristics of many drug products. Using extended head flat punches can provide a quick and reliable way to increase dwell times and, in some cases, reduce compression force without the need to modify the tablet press or cam tracks. Round, extended head flat punches don't require keyed tooling for round shapes, as oval ones do, and that allows them on many makes and models of tablet presses interchangeably. Furthermore, Natoli Engineering exclusively offers a unique set of tooling that allows you to maintain turret RPM, punch velocity, and powder flow while easily changing out head flats from no head flat to an extended head flat with no required tools.

Don't be deceived by sales tactics that lack data representing head flats. Working with a knowledgeable tool vendor like Natoli Engineering early in the development process to examine the role of dwell time and head flats can eliminate any misconceptions. Examining the role of dwell time in the R&D stages of product development will allow for the determination of which head flat (standard, extended, or even reduced/eliminated) is ideal for specific products. That early work can help minimize compression-related issues that could ultimately limit production.

