The Use of Link Motion on Mechanical Presses
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What is link motion?
Conventional mechanical presses have long been equipped with a crankshaft or eccentric gear drive where the slide velocity was symmetrical between the bottom and top halves of the press stroke (see Figure #1). With this simple system, press working was limited to those operations where the crank motion slide velocity would produce an acceptable part. However, the need for improved plastic flow of metal during a stamping operation often cannot be achieved by use of a standard crank motion press because of the excessive slide velocity through the working portion of the press stroke. To meet the requirement for improved metal flow, modern press builders have designed drive modifications that alter the slide motion as the press goes through the working portion of the stroke. The modified slide motions improve stamping operations such as deep drawing, forming, coining, embossing, flow control forming, cold forging, blanking and conventional progressive or transfer die operations.

Modifying slide motion for specific applications.
Link motion is a general category that includes a variety of modified slide motions. It must be understood that a single modified slide motion is not the ideal for performing all types of stamping operations. A given type of modified slide motion must be matched with the stamping operation that is to be performed in the press. The incorrect application of a modified slide motion in the stamping operation can result in poor press and tooling performance as well as unsatisfactory part quality. Following is a list of the types of modified slide motions and the applications for which they were designed.

**Figure # 2**

**Draw link** – This is the motion that generally comes to mind when link motion is being discussed. The draw link motion is used to perform deep drawing operations (see Figure #2) and allows the metal to be stretched and formed without tearing by reducing the slide velocity through the working portion of the press stroke. Another feature of the draw link design is the maintenance of constant slide velocity while the drawing operation is performed. This constant velocity improves part quality and strength by reducing side wall thinning. This constant velocity is illustrated in Figure #3 by the straight portion of the velocity curve as the slide approaches the bottom of...
the press stroke. What must be understood is that the draw link motion is not good for blanking, coining, flow control forming or progressive die operations because of the small amount of time that the slide is near or bottom of the stroke.

**Progressive die link** - As the name indicates, this modified slide motion is designed to enhance the performance of progressive die operations. Drag link or slider link are also terms that might be applied to this motion. The progressive die link is used to reduce the slide velocity through the working portion of the press stroke by 25% to 40%. When pressure is applied to metal it becomes plastic and can be formed into nearly any desired shape. This plasticity is enhanced by extending the period of time that pressure is maintained on the metal. The benefits of this enhanced plasticity include but are not limited to the following:

- Forming operations that have less spring back.
- Coining stations that achieve the desired shape without re-striking the part.
- Pierce and extrude operations are completed with less material cracking.
- In-die tapping operations can be performed at higher strokes per minute.
- Shallow draws can be produced at very high strokes per minute.

Figure #4 illustrates the reduced slide velocity of the progressive die link as compared to a standard crank motion. To reclaim the lost time created by the slide velocity reduction in the lower portion of the press stroke, the velocity is increased through the upper portion of the stroke so that strokes per minute are not sacrificed. In many cases, the progressive die link will allow the press user to increase the operating speed of the press by 25% or more because the forming operations are performed with slower slide velocity. This increased speed can mean the difference between making or losing money.

**Vertical link** – The vertical link motion is a modified slide motion that more than doubles the time that the punch is engaged with the metal being formed (see Figure #5). This motion is most commonly used in coil fed progressive dies where flow control forming is used to produce net shape parts. This flow control forming process forces the metal to plastically flow under the pressure provided by the press and produces parts with the metal re-distributed to desired areas.
In Figure #6 the varying metal thickness in this part produced from coil in a progressive die illustrates the metal flow that is achieved in the flow control forming process. The vertical link motion provides the additional time to allow the plastic flow of the material and is essential in the production of net shape parts where secondary machining operations have been eliminated. The vertical link motion also provides the same benefits as the progressive link motion described previously only to an even greater degree because of the increased slow down of the slide velocity.

**Figure # 7**

**Knuckle joint** – Although the knuckle joint motion is not a link motion, it is a modified slide motion. This drive design is illustrated in Figure #7 and is used in presses where a very high degree of metal flow is required to produce the finished part. The knuckle joint design provides infinite pressure at the bottom of the press stroke and actually produces a dwell there. Knuckle joint drives are primarily used in heavy coining or cold forging operations for net shape or near net shape parts (see Figure #8) where secondary machining is eliminated.

**Figure # 8**

**Are link motion presses good for blanking?**

Not all link motions are good for heavy blanking operations, however, the progressive die and vertical link motions provide significant advantages over the standard crank motion where heavy blanking is required. Because these two link motions significantly reduce slide velocity in the working portion of the press stroke, the shock and vibration that plagues normal blanking operations is reduced by 30% to 70% depending on the velocity reduction. This reduction in shock and vibration reduces the noise level, which makes the working environment substantially better. Also, the improved shock and vibration characteristics reduce wear and tear on the press and any auxiliary equipment attached to the press.
Feeds or transfers applied to link motion presses

Using feeds or transfers on modified slide motion presses requires an understanding of the reduced time available in the upper portion of the slide stroke. Traditionally feed timing has been based on degrees of crankshaft rotation, however, because the slide velocity on link motion presses is increased through the upper portion of the press stroke, there is less time available to complete the feed cycle. Figure #9 is a timing chart for a standard crank motion press operating at 60 strokes per minute. With a crank motion drive, the crank rotation from 270 degrees to 90 degrees (top half of the press stroke) takes 500 milliseconds, which is the same as the time consumed as the crank rotates from 90 degrees to 270 degrees (bottom half of the press stroke). Compare this to Figure #10, which is a timing chart for a typical link motion, drive operating at 60 strokes per minute. Because the slide velocity is reduced through the working portion of the press stroke, more time is consumed there.

To maintain the press cycle rate, (SPM) the velocity is increased as the slide travels through the top portion of the press stroke. In this illustration, the bottom one third of the press stroke consumes 50% of the cycle time while the remaining two thirds consumes the remaining 50% of the cycle time. Feed systems are activated in this upper two thirds of the stroke and with link motion drives, a significant reduction in time available to accomplish the task of moving material through the die space is experienced. With servo driven feeds or transfers, degrees of crankshaft rotation should no longer be used to set the feed cycle. In a link motion drive press the number of milliseconds to complete material feeding must be compared to the press timing diagram for proper setting of the feed cycle. From a practical perspective, using milliseconds to determine the feed cycle is no more difficult than using degrees of crankshaft rotation, it just requires a different set of timing diagrams. Mechanical press feed systems that are driven from a power take-off on the crankshaft will see higher acceleration characteristics with a link motion drive when compared to the standard crank motion.
This increased acceleration may require that the press speed be reduced. However, this is not the case with servo driven feed systems because there is no mechanical tie to the press crankshaft.

Does link motion improve die life?
The answer to this question is a resounding “yes”. By modifying the slide motion and slowing it down through the working portion of the stroke, the high shock and vibration levels normally experienced in crank motion presses are significantly reduced. The shock and highest vibration levels occur while the punch is engaged with the material and lower die section and wears away the die materials. The lower shock and vibration significantly reduces the wear factor of the die components, which improves the die life. Some metal stamping companies have actually doubled their die life when they converted to a link motion press from a standard crank motion machine.

Dynamic balancing of inertia forces
Inertia forces in a press are the result of a mass (the slide and upper die) moving at a certain velocity. The reciprocating motion of the press slide and the upper die creates an inertia force that alternately tends to lift the press (the up-stroke) or push it toward the floor (the down-stroke). Because the link motion press increases the slide velocity during the upstroke higher lifting forces are generated, especially on progressive die presses where the cycle rate can be as much as 100 strokes per minute or more. In these high-speed presses with link motion drives, the inertia forces can affect the stability and performance of the press and die system. To prevent the negative effects of the inertia forces, high quality presses with link motion drives incorporate a dynamic balancing method. Figure #11 illustrates a link motion press with the dynamic balancing feature.

Two large weights located at the ends of the press crankshaft act in the opposite direction of the slide and upper die, which cancels the inertia forces. With the dynamic balancing system, the floor and press mounting system only experience the static weight of the press and die and therefore the system performance is substantially improved.

Link motion and spring loaded strippers
Because progressive die and vertical link motions significantly reduce slide velocity through the working portion of the press stroke, the velocity must be increased through the upper part of the press stroke to reclaim the time lost so that cycle rates can be maintained. If this increased velocity were to begin immediately after the slide passed through the bottom of the press stroke, then the spring-loaded stripper velocity would also increase which could have a negative effect on the stripper bolts. This would be the case if a draw link motion drive were used for progressive die operations. By referring back to Figure #3 we can see that the slide velocity increase starts immediately after the bottom of the press stroke with a draw link. However, if we look at Figure #4 and Figure #5 we can see that the progressive die link and vertical link motions do not increase slide velocity until the stripper has lifted off of the material. These two motions actually reduce the stripper velocity when compared to the standard crank motion. Therefore, the load on the stripper bolts is actually reduced.
Are there other benefits achieved by using link motion?
Although increased die life and improved part quality are prominent benefits achieved through the use of link motion press drives there are many other areas that are improved by this technology. Noise levels are reduced by 50% or more, which improves the environment for operators. The reduced shock and vibration lowers press maintenance costs and nearly eliminates nuisance failures: related guards shaking loose, wiring in press controls coming loose at the terminal points, fatigue cracks developing in sheet metal components, etc. Money is saved on die lubrication because lower cost lubricants still produce acceptable parts as a result of the lower working velocities. Special operations such as in die tapping can be performed at 30% to 60% increase in strokes per minute depending on the type of link motion being used. Foundation and installation costs are reduced because of the dynamic balancing system.

Summary:
Link motion will improve almost any metal stamping operation, however, what must be remembered is that as one size does not fit all, also one link motion does not work for everything. Selecting the correct modified slide motion for each specific application will enhance press and die performance and produce parts of the ultimate quality while reducing cost. If only everything were this good.