"More Parts, Less Maintenance Through Continuous Cycle"

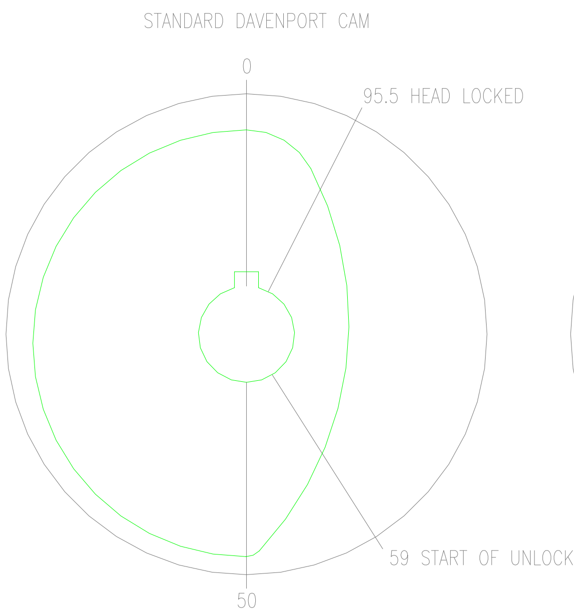
Continuous cycle is not revolutionary. If fact, it was probably the predecessor to the high speed indexing automatic bar machines we know today. Due to the advancements in tooling, specifically carbide, the possibility of new opportunities using old tricks is emerging. The changing dynamics are allowing a shift in the methodology wherein layouts or processes are developed. This shift can open the door for *today's machines* to run with more efficiency and less downtime than current constructs allow. How is this possible? The following is a detailed and somewhat technical discussion of continuous cycle and its application. Let us begin with the basics.

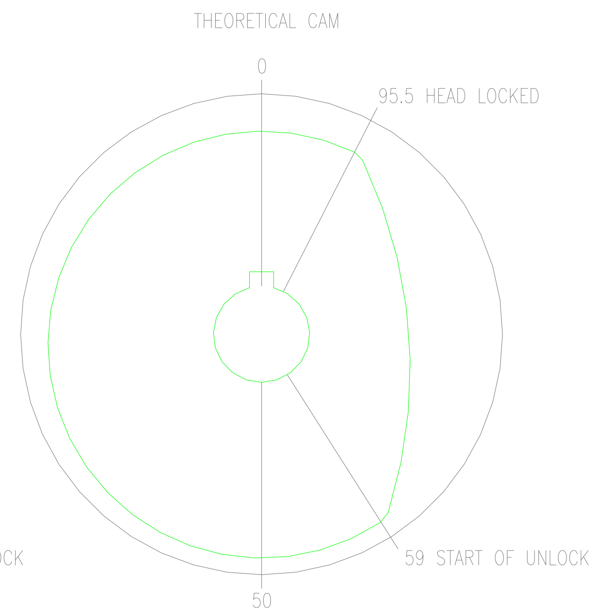
The typical multiple spindle screw machine has two distinct portions of a cycle, the cutting time and the non-cutting time. The cutting time is determined by the part and tooling required to produce it. Required tool travels are divided by feed rates to determine effective revolutions (Travel / Feed = Rev's). Five revolutions of dwell should be added for the sake of dimensional stability (Effective Rev's + 5 = Total Rev's required). Spindle speeds are calculated by dividing the toolings' surface feet per minute (SFM) restrictions by $\pi \div 12" \approx (.262")$ and the diameter to be cut, resulting in revolutions per minute (RPM) (SFM / .262 * OD = RPM). The longest required effective revolutions in a process multiplied by sixty seconds and divided by RPM consequentially are seconds of cutting time (Total Rev's * 60 / RPM = Cutting Seconds). Feed gears set this time by regulating the cams' drum rotation during the cutting time or low segment of the cycle.

During the non-cutting portion of a cycle tools: advance and clear, heads: unlock, index and relock, and the stock is feed out. This happens at an accelerated rate due to a separate drive train referred to as high speed. The cams' rotations are controlled by this second drive throughout this high part of the cycle. Clutching and braking in and out of high (indexing) and low (cutting) set the parameters for each component of the cycle. The time required for indexing varies between machine types and models, but it is a fraction of the cut time. The addition of the cut and the index time determines the cycle time per part (Cutting Time + Indexing Time = Cycle Time per Part).

This has served the parts manufacturing industry well over years. Standard cams could be changed to suit a variety of applications. The cycle time losses due to canned set ups were minuscule compared the engineering required to develop customized processes that are part specific. The cost of wear and tear on the machines due to the acceleration and deceleration of the drive trains has been considered normal.

So what is continuous cycle and what is its benefit? Basically if you maximize the cutting portion of the cycle by increasing the normal lengths of cams you minimize the non cutting time. At certain fixed drum rotations there may be a cycle time advantages. Without the constant shifting from high to low there is reduced wear on the machine therefore less downtime. This can also result in higher levels of quality since there is less vibration and wear on moving parts consequential providing a more stable platform on which to run precision parts. As the industry turns to running smaller lot sizes achieved by grouping parts in families the dynamics of how part processes are developed is changing opening the door for more highly tuned processes.





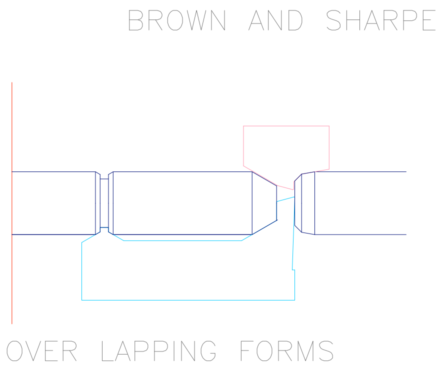
To illustrate the continuous principle think of a Davenport locked in high running a small aluminum part at .8 seconds (.4 seconds cutting, .4 seconds indexing). The Davenport typically uses cams that are 50 hundredths long or 180° out of 360°. We could therefore say that the machine is 50% efficient per cycle when locked in high. Indexing, tool retreats and advances, and stock feed all occur in the non machining 50% of the index portion of the cycle.

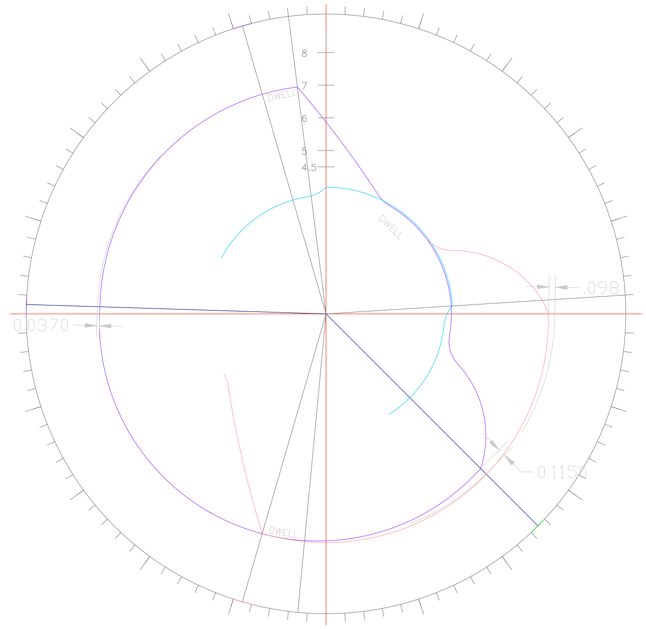
Theoretically, while the head is unlocked (59-95.5 hundredths) is only time that cutting can not happen. If the cams were able to be elongated gaining back the lost 13.5 hundredths (non head lock time during index) we would improve the efficiency of the cutting part of the cycle.

If you look at the feed gear chart for a 45 cycle Davenport machine there are 15 effective revolutions available at 2500 RPM. At that RPM if the cams were able to be stretched to rise from 95.5-59 hundredths (verses 0-50 hundredths) for a net of 63.5 hundredth we would gain 4.3 revolutions for cutting for a total of 19.3 cutting revolutions. (Note: 5 hundredths reserved for dwell.) Since more revolutions are available additional parts that need more Rev's could be run at this cycle time. In terms of the .8 second cycle time: cutting would take place for .51 seconds, while lost indexing time would be reduced to .29 seconds. It is not recommended that cams should be developed like this without a careful study of clearance issues but for discussion purposes this is a valid premise.

The Davenport machine has the least amount of cycle time improvement possible as compared with other multiple spindle machines when applying continuous cycle. First of all the index times on the Davenport are the fastest within the industry. Secondly the drum rotation ratios of low to high are among the least of any machine since the feed out overlaps indexing. In other machines such as Acme or New Britains feed does not overlap indexing but occurs outside of carrier movement (After or before respectively). This is reflected in the working lengths (Cutting + Dwell) of the different screw machines' standard camming. (Acme 1" RA-6 = 112°, New Britain #51 = 134° and Davenport Model B 50 hundredths ≈ 180°)

Careful study of the motions and timings of the various actions of the multi spindle as high speed indexing occurs permits the extension of the cams which increases their working lengths. Time must be allotted for interference issues. This is similar to the clearance allowances that have been developed for Brown and Sharpe single spindle machine layouts. In Brown and Sharpe sequencing time must be given for: feed outs, the advancement and retreat of tools, and turret indexing. If conditions allow, some operations can be overlapped achieving greater efficiencies (I.e.: Indexing while forming).





Similar gains are achieved when CNC programs are developed so that movements are minimized (Clearing work just enough to index) and rapid travel is maximized (Stopping narrowly ahead of the actual cut). One example of how multiple operations can improve cycle time improvements on the CNC is to simply incorporate a plunge form verses single point turning. This finishes the profile with one cut verses several passes provided that there is enough available horsepower for the cut.

With the onset of carbide technology higher SFM have become available and are being employed throughout the metal cutting industry. Custom carbide form inserts have overcome the older limitations of solid high speed steel tooling. Powered metal taps, cobalt and carbide drills have also helped to remove historic limitations. This changing paradigm has breathed new life into the vintage machines that have been the work horses of the manufacturing sector.

The old Scotty exhortation from Star Trek, "Captain, she'll never take it…" has been proven hollow time after time through countless successful applications. Due in part to robustness of the machine themselves (Hats off to the original designers). If a machine is production ready, new adaptations are possible within the limits of the machines' constraints. *This change in the toolings' SFM confines has opened the door for continuous cycle possibilities.*

In order to examine this further let's look at a scenario on a 1 ¼" RB-8 National Acme.

<u>Original</u>: If the older process was based on ninety seven effective revolutions (Rev's) and ran at twelve hundred RPM than with an index time of two seconds the cycle time would be

seven seconds. (Note: If 97.1 Rev's at 100.67° Cutting = 101.6 Rev's at 105.31° Cutting plus dwell, then (101.6 Rev's * 60 seconds / 1200 RPM) + 2.0 seconds indexing = 7.08 seconds per part)

Higher SFM: If a revised higher RPM process was still based on ninety seven effective revolutions (Rev's) and ran at two thousand RPM then with an index time of two seconds the cycle time would be five seconds. (Note: If 97.1 Rev's at 100.67° Cutting, = 101.6 Rev's at 105.31° Cutting plus dwell, then (101.6 Rev's * 60 seconds / 2000 RPM) + 2.0 seconds indexing = 5.05 seconds per part)

Continuous Cycle and Higher SFM: If 250° cams were possible the Rev's required would be one hundred and two to include five Rev's for dwell (97 Cutting Rev's + 5 Dwell Rev's = 102 Total Revs required). If there are 102 Rev's at 250°, then in 360° there are 146.8 Rev's. At two thousand RPM and no index time since indexing will occur in low, the cycle time would be 4.4 seconds. (Note: 148.6 Rev's * 60 seconds / 2000 RPM = 4.40 seconds per part)

In the above scenario it would be possible to drop into high for 110° (360° - 250° = 110°) instead of continuing in low for a cycle time of 3.92 seconds per part. (Indexing time note: If 360° - 105.31° Cutting plus dwell = 254.69° are reserved for indexing which happens in 2 seconds, then 110° in high would take .86 seconds. (102 Rev's * 60 seconds / 2000 RPM + .86 seconds indexing = 3.92 seconds per part.) However, the abrupt stops and starts of high speed indexing with the constrained approaches of the 250° camming leaves one little room for clutching/braking errors.

One hallmark of continuous cycle is fluidity of motion. This reduces the whipping of the stock reel and the abrupt jumps of slides. Granted, tooling just clear indexing parts and tools start cutting the moment heads locks but once the cams have been developed they never falter. Without the harsh momentum shifts, the internal mechanics of the machine tend to last indefinitely. Think of it akin to city verses highway driving. How long would brakes and transmissions last if there was no stop and go?

One fitting company running New Britains decided to forgo running conventionally in high/low with increased RPM. In this particular case high/low was quicker than continuous cycle for their specific parts. They opted for the unconventional; in their minds the reductions of maintenance issues and therefore improved efficiency out weighted the cycle time advantage they may have realized. *More part through efficiency than cycle time reductions, novel concept isn't it?*

In subsequent years that process won corporate wide awards for downtime reduction and exceedingly high levels of quality. It has run inexorably on various parts for over a decade. The minuscule amount (None - Believe it or not) of service calls required for the machine shocked old diehard repairmen who had been skeptics at the project's onset. They subsequently became the biggest supporters and promoters of continuous cycle much to their chagrin.

In camming a machine for continuous cycle various strategies can be utilized. Not all cams need to be elongated. In some positions where the required revolutions allow, standard cams may be used. There is no requirement that all positions have the same high point. Only the longest operations have to be scrutinized, remaining cams can vary in length to suit specific operations. This will minimized the engineering involved in calculating clearance issues.

It must be noted that families of parts run using the same sequence of operations are possible as long as the continuous process is designed for the worst case scenario. Due to the nature of continuous camming elongated drum cams require segments for the full 360° of the drum. This adds to their cost and the time it takes to install full drum sets. Standard disc cams are typically supplied for 360° and therefore are not as much of an impediment. Machines can be reconverted to high/low by simply replacing the old cams and reconnecting the high speed drive.

Feed outs in Acmes normally occur in the 6th position on a 6 spindle machine or the 8th position on an 8 spindle machine *after* indexing. Special considerations must be employed while developing these positions. If an Acrofeed bar loader is used these considerations are mitigated. New Britains' feed in the 6th position on a six spindle or in the 8th position on an eight, after the cutoff retreats and right *before* indexing. If the required revolutions for cutting off the part allows (I.e.: Parts with thru holes, small parts or if high feed parting inserts are an option) standard cams can be used, which then requires no changes to the normal feed out.

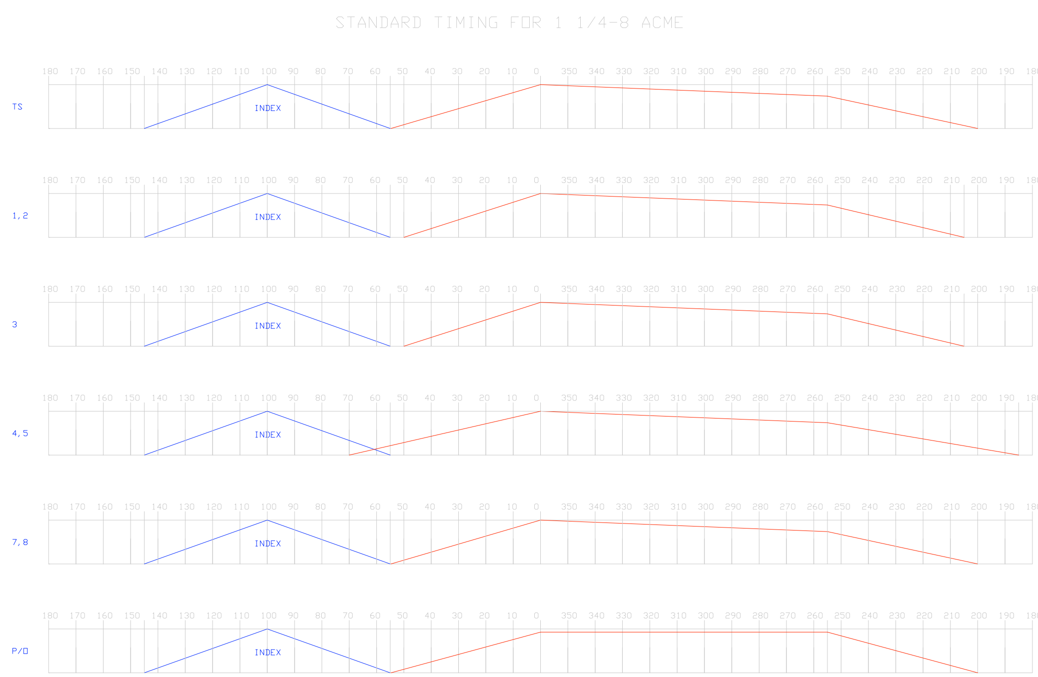
The only other advice as it concerns normal machine functioning is to shorten the collet opening/closing cams. Due to the slow motion of the low speed drum rotation, the rubbing of the shoes against the collet spools for a longer than normal period of time will cause heat. Shortening these cams with quicker approaches and drops helps to simulate the normal high speed condition which solves this problem.

Since we have a “tabula rasa” (blank slate) for cam development, shorting the back position of the slides is possible. This carefully planned improvement will help prolong the life of these sliding mechanisms. While this is not a requirement it can be a serendipitous enhancement. All cams should maintain there standard full forward position otherwise tooling may not reach the part. While the ink is wet, this is also an opportune time to glean revolutions essential for cutting by developing cams with double or even triple rise. Chip breaking segments can also be added to help manage nuisance issues. Cam manufactures are more than happy to assist with design ideas. (http://www.moderncam.com)

In the search to find ways to lengthen cams, some scrunching of the standard degrees reserved for approaches and drops is possible. *This must be done with discretion!* If too aggressive and angle is pursued, binding and excessive loads on machine components may result. The easiest and safest way to find areas to extend cams is in the advancement and in the retardation of tooling beyond traditional zones.

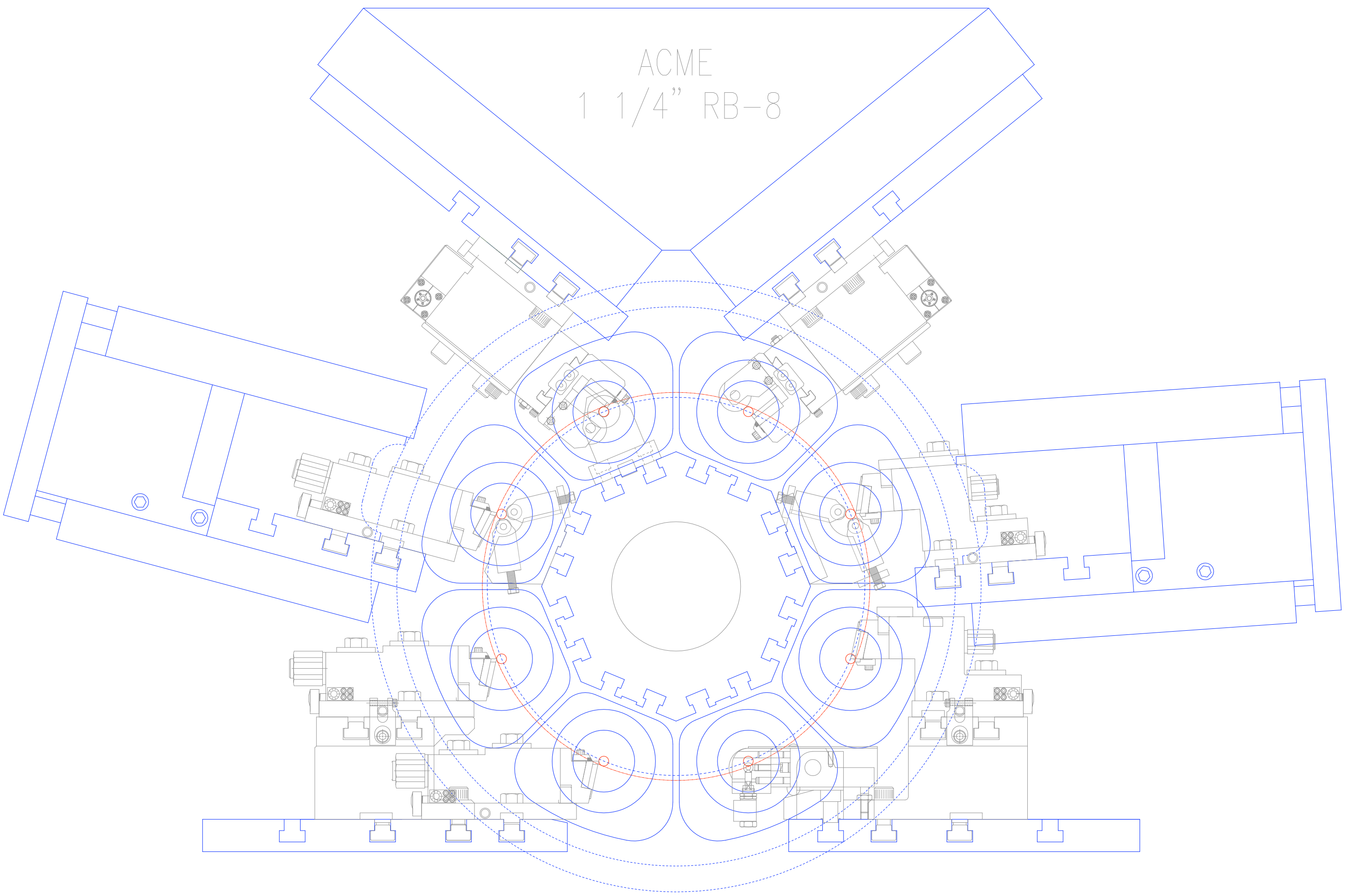
The only constraints are: 1) Cutting can not occur unless the head is locked.

2) Stating the obvious, two things can’t be in the same place at the same time.



Machine timing diagrams are essential in developing a continuous process. OEM’s, re-builders, original documentation or manuals may be the only places were these may be found.

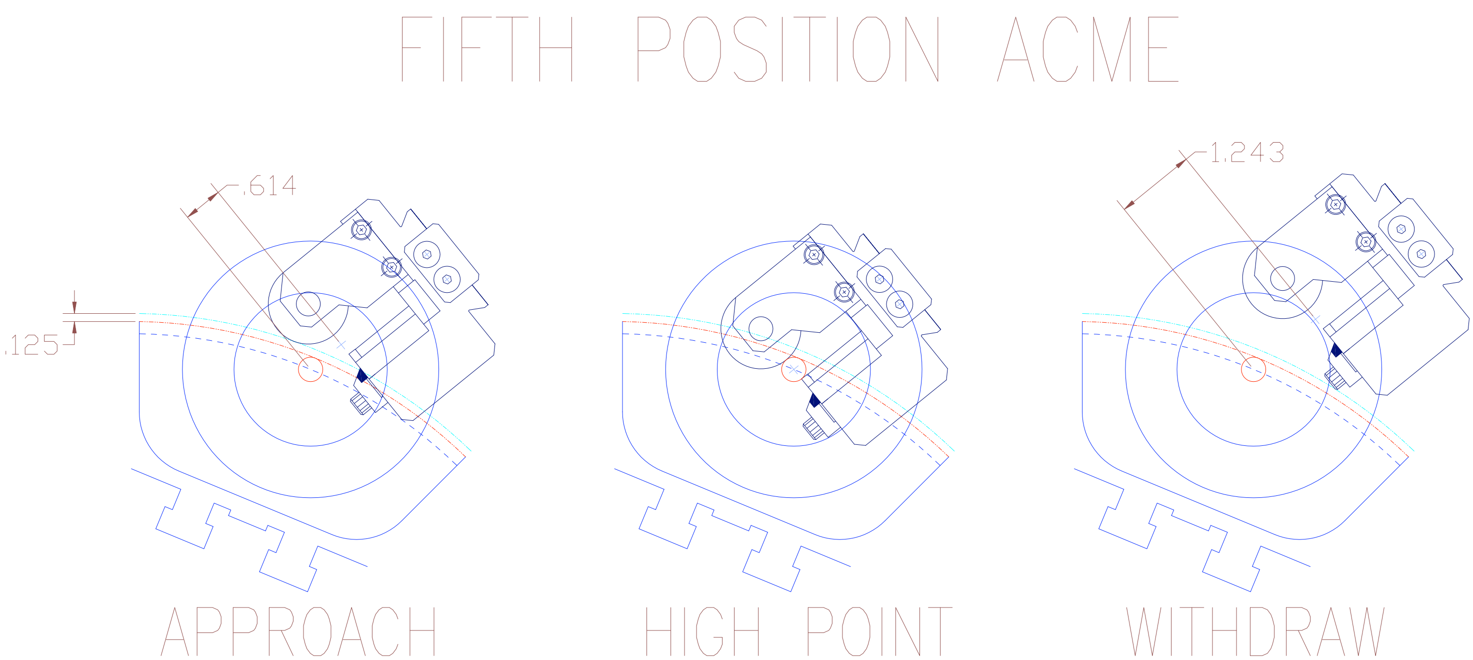
Even so and depending on how much you sharpen the pencil, measurements at the actual machine are beneficial. Many machines in the field today have updated older relay logic and timing drums with PCL's and encoders. Encoders can give precisely readings in degrees when significant moments happen. Within a half of a degree is possible to pin point the exact time a roller comes in contact with the lever that initiates the head unlocking sequence or the moment it falls away from the lever verifying that is safe to cut. It will also be ascertainable to know when indexing parts swing past advancing tools.



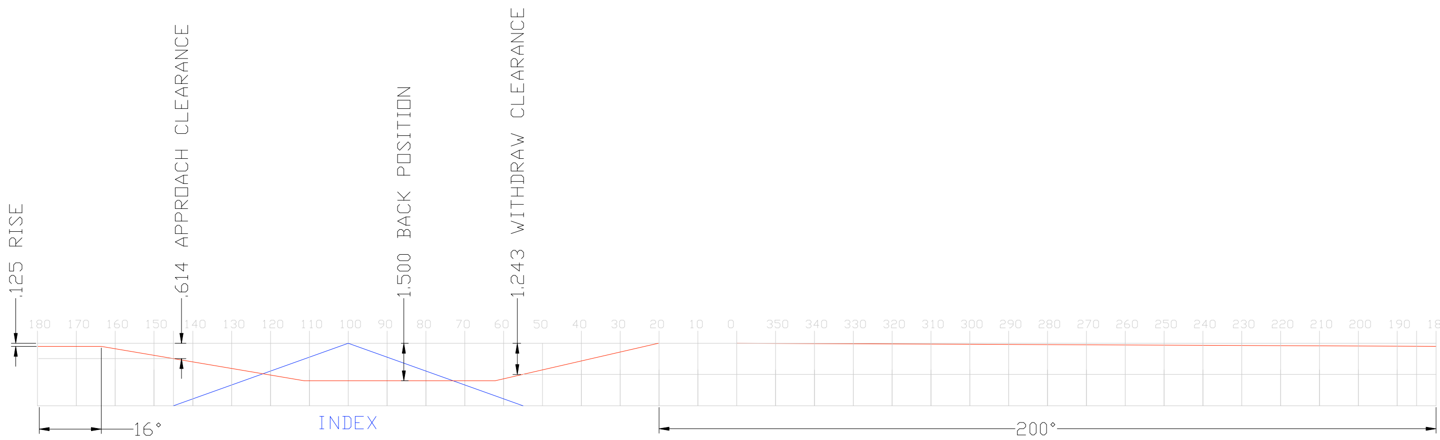
The next piece of the puzzle required is the dimensions of the tooling zone. Machine manuals supply this information readily. Catalogs or suppliers may provide data for holders and fixtures. When all else fails measuring and sketches may be your only option. Due to the angles of approach different positions are easier or harder to clear. Sequencing the operations to suit clearance issues may massage away impediments. This may permit the cut, requiring the greatest number of Rev's, to have the longest working length thereby optimizing the layout.

Special allowances are critical with anything that captures or enters the part. These items must be unobstructed as they come in and out of contact with the work. Drills and supports cannot deflect parts that are still moving though space. Thread rolls and shave tools, like turtles in their shells, must be retracted back enough so that clipping the part is impossible.

Traditionally when layouts are developed and/or drawn the side view is the point of reference. This is still the first step in developing any process. However, since we are now dealing with objects traveling through space and time, it is imperative that we understand end view, in other words the view into the collet face. These two vistas are sufficient to accomplish our task.



A two dimensional drawing of the tools mounted on their slides and the orbit of the part as it transitions around the center of the carrier, is a requisite. From this vantage point we can now calculate the thresholds that tools can advance to and draw back from for safe passage. An eighth of an inch is sufficient for clearance; any closer than that and your knees may shake. The last recommended drawing is a scaled representation of the timing diagram for the machine per operation.



FIFTH POSITION ELONGATED 216° CAM

Our final undertaking is bringing all this information together analogous to standing up a bundle of sticks one piece at a time. The data of distance is now to be transposed onto time. From standard high points the required clearance and rise distances are now to be scribed though the scaled timing chart. Next, simply slide the standard approaches and drops along the base toward the indexing and rotational limits. When the sliding approach/drop intersects the hatch mark of the required clearance distance and the critical time, fix the location. Truncate the approach and the rise, measure the overall length of the cutting portion of the cam and voilà we are done! Repeat this position by position.

At this final phase it is helpful to enter the rises and lengths of the cams into a spreadsheet. Here we can use standard low speed gearing options to form ratios of Rev's to degrees to calculate feed rates. If the standard charts do not fit the application, different worm and bevel gears may be used to change the low speed range. When determining the actual cutting lengths of the cam, be sure to make allowances for dwell.

To facilitate communicating with the cam manufacture, note on the specifications, that all degrees and rises you are calling out are in reference from standard locations such as traditional high point. Also note, on critical moments, the degrees and distances that must be held on approaches or drops.

Not all parts are suitable for your company's needs and continuous cycle. If you would like assistance in examining this or other process options please feel free to contact us at Peterson Tool Company.