Variable Speed Three-Phase Knife Grinder

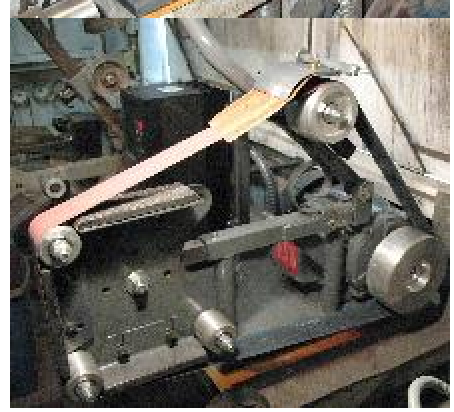
The grinder pictured here grew out of a gift - a 3-phase 5-HP motor and a single-phase 5-HP motor. While I already have three knife grinders, those free motor were effectively burning a hole in my proverbial pocket.

The first question was single or multiple speeds? Either motor unit could be used as a direct drive single speed unit but I already have a Bader B2, so this option really didn't make much sense.

A variable speed system could use either motor. The single-phase motor could talk through a jack shaft, a drive shaft, and 10 pulleys to get 4 speeds encompassing the full range of speeds typical of the Bader units using 1.5", 4" and 6" drive wheels. The 3-phase motor could use a variable frequency drive to generate an infinite range of speeds from effectively zero to 1740 rpm (the maximum speed of the motor and assuming no over-clocking). The single phase option would be the less costly (about $150 for pillow blocks, pulleys, etc) but the most involved in fabrication.

The variable frequency drive option was the opposite - the greatest cost but the least hassle in terms of fabrication. It turns out that a VFD for a 5-HP motor needs to have a 10-HP capacity (the shift from single to triple phase requires twice the nominal capacity of the motor) and it is an expensive item - $600 or more. Given that it is to be used in a grinding room, a decent enclosure must be used to prevent frying the electronics. That adds another $100. That free motor was beginning not to look so wonderful. A bit of shopping turned up an alterative - a 3-HP VFD with a NEMA 12 enclosure and a 1.5 HP motor (3420 rpm) for under $350. That's the route I went.

I have built a variable speed DC unit (2 HP DC motor and controller from the Surplus Center - about $300) that has a ternary grinding head (slack belt, soft- back flat platen and hard-back flat platen). Imagine an equilateral triangle, 10" on a side with a 2"x2" idler wheel in each apex. Back out the lock bolt, spin the unit, and relock the system and you're ready to go again. The tracking and belt tensioning mechanisms, however, left a lot to be desired, so I wanted to retain the quick-change feature while correcting the deficiencies in the new grinder.



The grinder started with an 18.5" x 18.5" 10-gage base plate. It already had a rolled over edge front and back, so a 1" strip welded on left and right sides completed the base. The grinder has the VFD on the left front corner bolted to an upright of angle iron. The motor is to the rear with a 6" drive wheel and rests on a temporary motor mount (more on this later). There is an elevated socket on the right extending from the motor forward to the edge of the base plate. The socket is 12" of 1.25" square tubing (internal measurement is a touch over 1"). It is supported on two legs made from 1" black pipe and are long enough to allow an arm in the socket to slide over the motor. There is a 1" x 0.5" x 3" tab welded to the right rear with a 0.5" hole to accommodate the idler arm. Extending forward from the tab, there are a pair of 1" x 1/14" x 6" long strips welded on the sides of the socket. The strips were drilled and tapped for 3/8x16 bolts 3" from the rear edges to provide attachment points for the belt-tensioning spring. The left strip was drilled and tapped 1" from the front edge of that strip to provide the arm-locking point.

The arms are made from 1"x1" stainless steel, are designed to slide into the socket, and bear either a grinding head or contact wheels. The grinding head is a quaternary unit - (slack belt, soft- back flat platen, hard-back flat platen with soft edges, and hard-back flat platen with sharp edges). It uses four 2"x2" idler wheels and allows for a 6" platen on three of the four sides. The grinding head actually drove the location of the motor. The center of the idler wheel to the nearest side of the arm was 2.20". The motor was then moved left-to-right to place the center of the drive wheel exactly 2.20'" from the arm. The motor was then rotated in place to insure that the side of the drive wheel was parallel to the side of the idler wheels. Once I was happy with the alignment, the temporary mount was tack welded to the base and the motor removed from the mount. The holes corresponding to the motor base holes were then drilled through the base plate and the motor reinstalled.

The grinding head require a bit of carefully layout such that the distance between the idler wheels was the same and that the center of the 10" x 10" x 0.4" thick plate was, in fact, dead center. 0.5" holes were drilled at the five locations (on a mill). A template was created to standardize the location for the 3/8" holes needed for the platens. Those 6 holes were then drilled and tapped for 3/8x16 bolts. A stiffening plate (6" x 6") was welded on the back side of the 10x10 plate and an additional 0.5" boss was welded at the center. The 0.5" hole at the center was then extended through the boss. A 5" diameter ring was forged from 1/2x1/2 square stock, centered around the boss and welded to the stiffening plate. The assembly was then dropped onto the mill and the ring and central boss were milled to the same thickness. The result is a plate 1.15" thick - add a washer and the idler wheel center will be 2.20" from the arm.

The head needs to lock in place, so a line running from the center of the plate and perpendicular to a side was scribed. A hole just inside the ring and on the line was drilled with a "Q" bit (the size needed for tapping a 3/8x16 hole). The arm was positioned so that the end was just inside the slack belt cutout on the main plate. The center hole was then located on the arm and a 0.5" hole drilled. A tapped 3/8x 16 hole was created near the forward end of the arm to allow the use of a steady rest. The arm was bolted to the head and carefully rotated to center the "Q" sized hole on the arm. A transfer punch was then used to mark the arm and a 3/8" hole was drilled in the arm for the lock bolt. The locations of the other three lock points were determined by rotating the arm, verifying that it was perpendicular to the side, and marking the plate through the lock hole in the arm. Those locations were then drilled and tapped.

Once the basic geometry is locked, all that is needed for the other arms is to make sure that spacers between the contact wheels and the arm replicated the 2.20" standard. For the 10" and 4" contact wheels from my Bader, this required a 1" block to be welded to the arm. A 3/8" hole was drilled through the arm and the block and a 0.9" deep hole (5/8" diameter) was drilled into block. A tapped 3/8x16 holes was created a few inches back from the front of the arm to allow for the use of a steady rest. The 0.5" contact wheel (the 'forked' wheel of the Bader) required a bit more construction and I added an adapter for a collection of small contact wheel on the flip side of that arm (it's in the storage position in the picture here).

The steady rest is composed to a slotted arm with a 1.25" cubic terminal block with a 3/8x16 lock bolt. The arm allows rotation in the plane of the belt and controls the location of the terminal block with respect to the belt. The terminal block is penetrated by a horizontal 3/4" round bar which also has an identical terminal block. The combination of the 1st block and the 3/4" bar allows for rotation at 90 degrees to the arm and also controls the location of the 2nd block in front of the belt. The 2nd block holes a 3/4" shaft supporting the actual rest. Just look at the picture if this verbage is as opaque as I suspect it is.


(click an image for high-res version)

The idler arm (1" square stock) is attached to the tab at the rear of the socket with a 1/2" bolt. It bears a boss near the front and on the right through which a 3/8" bolt passes. That bolt is the pivot point for another section of 1" square stock, the tracking arm. The tracking arm has a lateral hole (on the left) to hold the end of a compression spring and there is a tab with a similar hole welded to the left side of the idler arm such that the spring runs from hole to hole. The idler wheel (2.5" x 3.5") is attached to tracking arm near the front of the arm. A tab with a 3/8" Acme nut is located on the left side of the idler arm such that an Acme bolt running through that nut will contact the tracking arm. The top of the Acme tab continues upwards and bears a 3/8" carriage bolt that extends over the idler wheel. The bolt supports a spark arrestor that keeps those sparks from whipping around with belt and whacking the user in the face.

The belt tensioning is created by a spring made from a strip of 5160 and locked to the socket with the 3/8x16 holes near the end of the socket. The tool steel was bent into a scroll and then heat-treated to become a spring (650 F temper). The actual tension was adjusted by grinding away some of the spring's thickness until it felt right (how's that for exact descriptions, huh?). You can see the spring in the top two pictures. All of the accessory material nicely stores in a single file cabinet drawer.

Total cost for the unit is somewhere in the $800 range ($400 for the VFD and motor, $300 for the wheels, and $100 for steel and beer. Time-wise, it ate maybe three days, some of which was spent at the drawing board figuring out what I needed to do. The tracking is wonderful - better than my Bader when it was new. The infinite variable speed is cool as is the quaternary head. Overall, it was a fun project and now I better start making some knives to pay for it.