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January 2020

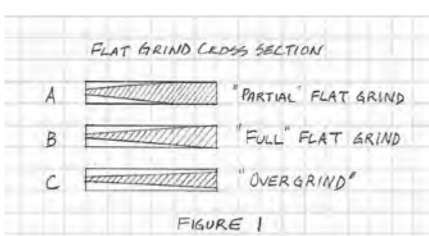
Calculating Flat Grinds – Part 1

Michael Faber

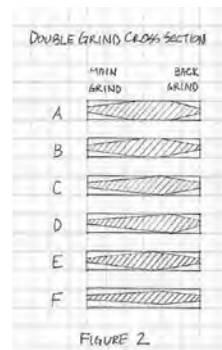
Please note: this article is the first in a series of three.

Flat grinds have their place in both the functional and aesthetic worlds and are typically done by holding the workpiece against a grinding belt that passes over a flat surface, or platen. For those of you who are pretty good at eyeballing and free-handing your flat grinds and get results you are happy with, this article may have limited value. I like to work things out on paper before moving metal around in the shop (I've found that paper experiments are often quicker and always cheaper than metal experiments) and control my grind angles by mounting my blade to a block that holds it square to the work rest and adjusting the angle between the platen and the work rest. Call me a rookie; I'm just not that good at free-hand grinding, and I'm after specific and reproducible results. The concepts presented here are intended to help you define and control your flat grinds to achieve the results you are looking for. The approaches given here may most benefit those who make stock-removal blades, but some of the concepts are still applicable to clean-up grinding of forged blades. Now, about the math…if you are one of those who bear lifelong scars from math classes where it was a struggle just to stay awake, let alone pass – don't panic! You don't have to understand math to be able to use it to accomplish something you want to do, just like you don't have to understand how and why all the parts of a car work together to be able to drive to the store to buy groceries.

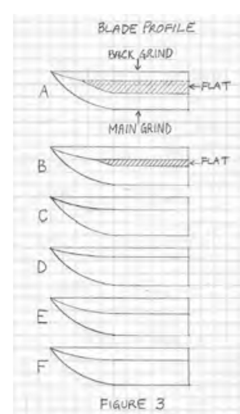
Let's start by taking a qualitative look at some examples where grind angle matters, and what can happen when the grind angle changes. First, let's examine the case of a single, simple flat grind. Figure 1 shows three examples of the cross section of a piece of bar stock that has been ground into a blade. Example "A" shows what I refer to as a partial flat grind, where the width of the grind is less than the full width, leaving a flat. In example "B" the grind angle has been reduced, and the width of the grind extends exactly from the edge to the backbone. I refer to this as a full-width flat grind. In example "C" the grind angle is further reduced, resulting in what I refer to as an "overgrind." In profile appearance, example "C" is still a full width flat grind, but in cross section the thickness of the backbone is reduced. When you compare examples "A", "B" and "C" in Figure 1, it's easy to see that as you decrease the grind angle you increase the grind width until you reach the backbone. Further reduction in the grind angle from that point can't increase the grind width but does reduce the thickness of the backbone.



Now let's consider the case of a double grind. By this I mean a blade that has two flat grinds – what I refer to as the main grind that tapers down to the cutting edge that will be sharpened, and what I refer to as the back grind that thins down the backbone. The back grind may be sharpened or left as a false edge and may or may not extend the full length of the main grind. The main grind is usually wider than the back grind. When the main grind and the back grind meet, they form what I refer to as the common grind line and when either the main grind meet a flat, they form just a grind line.



Looking at Figure 2, we see a number of examples of double grinds in cross section that illustrate how the blade geometry can be changed just by changing the grind angles. In example "A" the main grind angle and the back grind angle are large enough that the two grinds don't meet, leaving a full thickness flat between them. In example "B" the grinds still don't meet, but both the main grind angle and the back grind angle have been reduced so both of the grind widths have increased, resulting in a narrower flat between the two grinds. If we reduce both of the grind angles further so that the main grind and the back grind just meet at the surface of the stock, we get the cross section shown in example "C". (Note that all of the cross section examples in Figure 2 are shown in profile in Figure 3 with the corresponding letters.) In example "D" we have kept the same back grind



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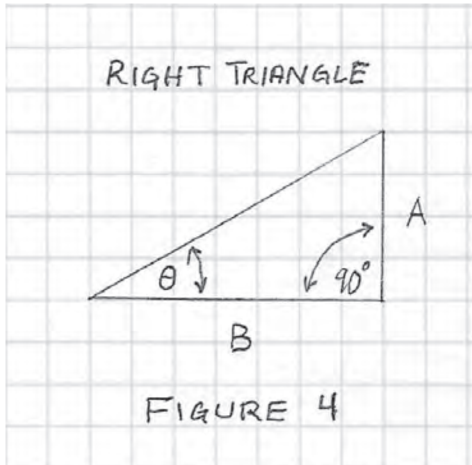
angle as in example "B", but we have decreased the main grind angle so that the two grinds meet at the surface of the stock. By doing this we have eliminated the flat that exists in example "B", and we have moved the compound grind line that exists in example "C" closer to the backbone. In example "E" we do just the reverse – we keep the same main grind angle as in example "B", but we decrease the back grind angle until the two grinds just meet at the surface of the stock. Now we've increased the width of the back grind relative to the main grind, and the compound grind line moves closer to the cutting edge. Finally, in example "F" we have further reduced both of the grind angles relative to example "C" while keeping the grind widths the same, resulting in the same profile but with reduced blade thickness. This is like a double overgrind case of example "C" in Figure 1. By looking at and comparing all of these examples you can see that by changing your grind angles, you can change your flat size, move the common grind line around and change the maximum thickness of your blade. Putting a subtle spin on it, working with a specific stock thickness and blade profile, in order to change your flat size, move the common grind line around or change the maximum thickness of your blade, you have to change your grind angles.

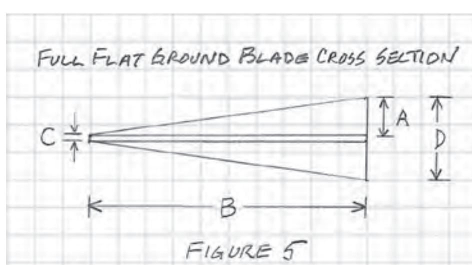
OK, enough general, qualitative rambling – let's move on to accomplishing specific things by applying numbers to them. Before we can do this, we have to deal with just a little bit of math, namely algebra and trigonometry. For the algebra, we only need to know two things – first, if we have an algebraic equation with three variables in it, such as "A = B X C", if we know the numerical value of any two of the three variables, "A", "B" and "C", we can determine the numerical value of the third variable. Second, when we have an algebraical equation, if we perform the same algebraical operation to everything on both sides of the "=" sign, we can manipulate the equation to make it easy to solve it for our unknown variable. Without going through all of the steps, our equation "A = B X C" can then become "B = A ÷ C" or "C = A ÷ B". Pretty painless so far. Now for the trigonometry.

Let's look at a right triangle (that's a triangle that has a 90° angle in it) with the two sides forming the right angle labeled "A" and "B", as in Figure 4.



The angle opposite side "A" is labeled "θ". Now, here's the trigonometry part: the length of side "A" (also referred to as "rise") divided by the length of side "B" (also referred to as "run") is equal to the tangent of the angle "θ" (designated as TAN (θ)). That's it! For our purposes here, that's all the trigonometry we need to use.

"Yeah, yeah," you say. So what's this have to do with knifemaking? Let's take that triangle and flatten it out a bit, take another identical triangle, flip it upside down and put it underneath, and then sandwich in a thin rectangle between them, as in Figure 5.



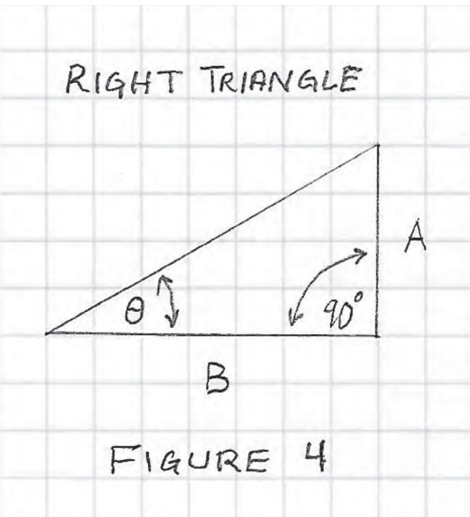
Now we're looking at the cross section of a full width flat ground knife blade that hasn't been sharpened yet. In Figure 5 "B" is the blade width at the widest point, "C" is the grind-to edge thickness, "D" is the blade thickness and "A" is the height from the top of the grind-to edge thickness to the top surface of the stock. Now let's put some numbers to this and work through a sample calculation. Let's say we have a piece of 5/32" x 1 1/2" stock that we want to do a full width flat grind on. Referring again to Figure 5, we know that "B", our blade width is 1.5". We also know that "D", our blade thickness is .156". Let's say that we want to set "C", our grind-to edge thickness to .020" (you can go thicker or thinner, but if you go too thin the edge can warp during heat treat, and if you go much thicker you will spend more time sharpening and also increase the width of the sharpening bevel). So, to create this blade, what do we need to set our grind angle to? From our triangle in Figure 4 we know that the tangent of the angle we want to find is "A" ÷ "B". We have a number to use for "B" (1.5"), but we have to figure out a number to use for "A". To do this, we take the blade thickness, "D", subtract the edge thickness "C" and divide by 2 (we're only working with one triangle or one side of the blade at a time). Now we have "A" = (.156 - .020) ÷ 2, so "A" = .068". Now that we have a value for "A", we can solve our equation, TAN(θ) = A ÷ B. Now, TAN(θ) = .068" ÷ 1.5", so TAN(θ) = .04533. Now, if you're a dinosaur like me, you could blow the dust off an old book of mathematical tables, go to the trigonometry tables and look up what angle corresponds to a tangent of .04533, but it's quicker and easier to just enter .04533 into your calculator and press the TAN^{-1} button (or ARCTAN, or ATAN or however they've labeled the inverse tangent function). Either way, you'll find that the grind angle, θ, is 2.596°.

OK, so all you have to do is set your grind angle to 2.596° and grind away – your friends will be amazed! Actually, it's time to bring up a couple of questions – What happens if you don't hit that angle exactly? How accurately do you have to set your grind angle? We'll address these questions next time. In the next article we will be referring back to this one, so if you are really interested in following this article series, you may want to save your *Knewsletter*.

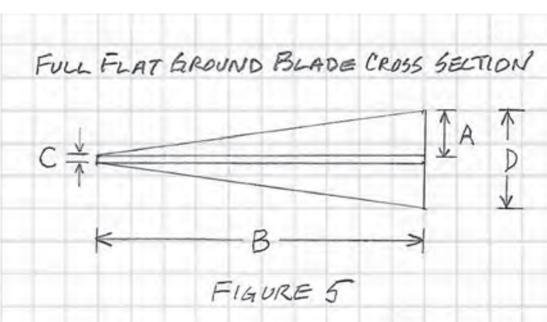
Calculating Flat Grinds – Part 2

Michael Faber

This article is a continuation of an article that appeared in the last issue of the *Knewslettter*. We will be referring to that article, so you may find it helpful to have that issue of the *Knewslettter* in hand. (You do save your *Knewslettters*, don't you? If not, well, maybe you can pull it out of the bottom of the bird cage and brush it off a bit, or go to the Club website and pull it up.)



In review, last time we invoked the properties of a right triangle (see Figure 4) to come up with the trigonometric relationship between the height of the triangle, "A", the base of the triangle, "B" and the angle, "θ" : TAN (θ) = A ÷ B. We also invoked algebra so that if we know numerical values for any two of the three variables, "A", "B" and "θ", we can manipulate the equation to easily calculate the numerical value of the third variable. We used a drawing of a couple of stacked triangles and a rectangle (see Figure 5) to represent the cross section of a full-width flat ground knife blade and explored qualitatively how we could create or eliminate a flat on the blade, or reduce the thickness of the backbone of the blade by changing the grind angle. We then qualitatively explored the case of a double grind (see Figures 2 and 3 in Part 1) and saw that by changing the grind angles we could create or eliminate a flat, move the common grind line around or reduce the thickness of the blade. Finally, we got quantitative and performed a sample calculation to determine the grind angle (θ) required to produce a full-width flat grind on a piece of .156" x 1.5" flat stock, and found our grind angle, θ, needs to be 2.596°. We concluded by raising a couple of questions: "What happens when you don't hit that angle exactly?" and "How accurately do you need to set your grind angle?"



Before we tackle these questions, we need to begin the discussion about what tools you use to set the grind angle with. There are a couple of more or less affordable options. For less than $200.00 you can buy a sine bar and an adequate set of "import" gage blocks that will practically give you any angle you need; but the sine bar/gage block set up can be a bit cumbersome, stacking and balancing all the pieces while you adjust your platen angle. Plus, you will have to do an initial calculation to determine which gage blocks you need to use. For less than $40.00 you can buy an adequate set of "import" angle blocks which are a little easier to use and don't require any real calculation to set up. Angle blocks have a drawback – an affordable set will generally come with only a 1/4° increment, and this can cause some issues. We'll address the question of what happens if you don't hit your calculated grind angle exactly by working some sample calculations using angle blocks.

We know from Part 1 that for a piece of .156" x 1.5" stock with a .020" grind-to edge thickness our target grind angle for a full-width flat grind is 2.596°. If we're using angle blocks to set our grind angle, our choices are 2.50° or 2.75°, since the angle blocks come in .25° increments. We could make an a priori judgement that 2.50° will be a better choice than 2.75°; since 2.50° is closer to 2.596° than 2.75° is, but let's run both calculations and see. Referring to Figure 1 in Part 1, we know if we choose 2.50°, we'll be reducing the grind angle, or "overgrinding," and reducing the thickness of the backbone. To find out by how much, we need to solve our equation: TAN (θ) = A ÷ B, for A (element "A" in Figure 5); so our equation becomes A = B x TAN (θ). Plugging in numbers, we get A = 1.5" x TAN (2.5°), so A = .0655". To get our new backbone thickness (element "E" in Figure 5), we just multiply A by 2 and add .020", our grind-to edge thickness (element "C" in Figure 5) to get a backbone thickness of .151". This means the backbone is .005" thinner, so when you're looking down at the backbone, you'll see a step down of .0025" from the ricasso on each side – about the thickness of a human hair. Maybe not noticeable, maybe it is – if you want to split hairs.

Now let's see what happens when we increase the grind angle to 2.75°. Since we're increasing the grind angle, we know we're decreasing the grind width, B; and we'll be left with a flat next to the backbone. To find out how wide that flat is, we'll set up our equation to solve for B (our new grind width) and our equation becomes B = A ÷ TAN (θ). Plugging in our known numbers we get B = .068" ÷ TAN (2.75°), or B = .068" ÷ .048, so our new grind width, B = 1.416". Taking the blade width of 1.500" and subtracting 1.416", we're left with a flat that is .084" wide. Definitely noticeable and not likely to disappear with finish sanding.

So now we have a choice – live with a barely noticeable step down on the backbone thickness or live with a noticeable flat when the blade is viewed in profile. If you're not happy with either of these choices, there is a third option – reduce the blade width. You can scribe a line .084" in from the edge of your stock and grind the width down to that line. Or, if you have access to a milling machine, you can quickly and easily (and perfectly, too) mill the stock width down to .416”. Either way, with a grind angle of 2.75° you’ll get a full-width flat grind with no flat on the blade and no thinning of the backbone.

Now let’s address the question, “How accurately do you need to set your grind angle?” Again using our example of .156” x 1.5” stock with a .020” grind-to edge thickness, let’s see what happens if we change our grind angle by 0.1° and then by 0.01°. These calculations will be left as an exercise for the reader (you know how to do this now). If we increase the grind angle (2.596°) by 0.1°, we will be left with a flat .056” wide, which will be noticeable. If we decrease the grind angle by 0.1°, we will make the backbone .0052” thinner, which may be noticeable. So, 0.1° accuracy in the grind angle setting may not be good enough. Now, if we increase the grind angle by 0.01°, we will be left with a flat .006” wide, which will probably disappear during finish sanding. If we decrease the grind angle by 0.01°, we will decrease the backbone thickness by 0.0005”, which won’t be noticeable at all. So, we might or might not be OK with 0.1° accuracy and will definitely be OK with 0.01° accuracy in setting our grind angle.

What this tells us is that when using angle blocks with 0.25° increments, if our calculated grind angle is within 0.01° of an angle block (or combination of angle blocks), then we will be fine. If the calculated grind angle is within 0.1° of an angle block (or combination of blocks), then we might or might not be OK, depending on what we’re willing to live with. With a 3” sine bar and a set of gage blocks with only 0.001” increments, we can adjust our grind angle in 0.02° increments (again, this calculation is left as an exercise for the reader), which will cause some small but observable issues either with leaving a flat or thinning the backbone. Using a 5” sine bar and a set of gage blocks with only .001” increments, we will be able to adjust or grind angle in approximately 0.01° increments and should be OK. If we use a set of gage blocks with 0.0001” increments, we are golden and won’t have any problems with angle accuracy no matter what sine bar we use.

What this all boils down to is if you are willing to spend the money and time using a sine bar and gage blocks to set your grind angle, you can achieve a full-width flat grind without having to live with a potentially objectionable flat or reduction in backbone thickness or be forced to reduce your blade width. And, if you choose to use angle blocks to set your grind angle (whether because of cost or convenience), you can calculate your deviations from perfection and decide which option works best for you before removing any metal.

Next time, we’ll quantitatively examine the case of double grinds and go through some more calculations to see exactly how to change aspects of the blade by changing grind angles. If you’re really interested in following this article series, you may want to save your *Knewslettters* since we will be referring back to this article as well as the previous one.

Calculating Flat Grinds – Part 3

Michael Faber

This article is a continuation of two articles that appeared in the last two issues of the *Knewslettter*. We will be referring to those articles, so you may find it helpful to have the January and February issues in hand. (Of course you saved them, but if you can't find them you can go to the Club website and pull them up.)

Last time we examined the case of a full-width flat grind and calculated what happens if we aren't able to set the target grind angle exactly, as when using angle blocks, and saw exactly how much the backbone thickness is reduced with a lower than target grind angle, and exactly how much of a flat is left with a higher than target grind angle. We also saw how we can set the grind angle with all the accuracy we need by using a sine bar and gage blocks.

This time we'll explore how to calculate grind angles to obtain a couple of different double grinds. It's similar to calculating a single flat grind; you just have to calculate twice – once for the main grind and once for the back grind. First we'll look at the case of a double grind with a flat between the main grind and the back grind, shown in cross section as example B in Figure 2 and in profile as example B in Figure 3 (see January Knewslettter, p.1). Let's say we're using .156" x 1.5" stock, and we want a 3/4" grind width for the main grind, a 1/2" grind width for the back grind and a flat between the two grinds that is 1/4" wide. For the main grind, our grind-to edge thickness will be .020". The back grind will be left as a false edge, and the grind-to edge thickness will be .040" (you could also sharpen the back grind, in which case the grind-to edge thickness would be .020" instead). Returning to our familiar old triangles in Figure 5 (see February Knewslettter, p.4), we can start assigning numbers to the variables we will use in our equation to find the grind angles.

Let's deal with the main grind first. To find the grind angle, θ, we'll use the equation, TAN (θ) = A ÷ B; but first we need to find what A and B are. That's easy – looking at Figure 5, A is the height from the grind-to edge to the top of the stock (in cross section), B is the grind width, C is the grind-to edge thickness and D is the stock thickness. To find A, we just subtract the grind-to edge thickness from the stock thickness and divide by 2. So, A = (D – C) ÷ 2 or A = (.156 - .020) ÷ 2, thus A = .068". We already know that B is .750". Now we can plug numerical values into our equation, TAN (θ) = A ÷ B, and we get TAN (θ) = .068" ÷ .750", or TAN (θ) = .0907. Now we just push the "TAN^{-1}" button on the calculator; we find that the main grind angle, θ = 5.181°. Now we do the same thing for the other side of the blade, the back grind. To find A, we have A = (D – C) ÷ 2, or A = (.156 - .040) ÷ 2, thus A = .158". We already know that B, the grind width of the back grind, is .500". Now our grind angle equation, TAN (θ) = A ÷ B, becomes TAN (θ) = .058" ÷ .500", or TAN (θ) = .116. Again, press the magic "TAN^{-1}" button; and we find our back grind angle, θ = 6.617°. Easy!

If you're using a sine bar and gage blocks to set your platen angle you can hit these angles pretty exactly. If you're using angle blocks with 1/4° increments, there will be some issues with the width and location of the flat. Last time (Calculating Flat Grinds – Part 2, O.K.C.A. Knewslettter, February 2020), we calculated what can happen using angle blocks that don't match the target angle perfectly. Let's see what happens in this instance. For the main grind angle of 5.181°, our choices using angle blocks are 5.00° or 5.25°, so let's see what happens to the grind width, knowing that reducing the grind angle increases the grind width, and vice versa. Choosing the angle of 5° will give us a main grind width of .777". This calculation will be left as an exercise for the reader. (If you've been following this article series, by now you can do these calculations in your sleep – in fact, you may already be asleep… If you're just now jumping in, look at the last article to see how it's done.) This means the flat is now .027" narrower, or .223" in width. Now, if we use the 5.25° angle blocks, we get a main grind width of .740". This means the flat is now .010" wider, or .260" in width.

Now let's go to the other side of the blade and see what happens with the back grind. Our choices for angles using the angle blocks are 6.50° or 6.75°. If we choose 6.50°, we get a back grind width of .509", which will reduce the flat width by .009". Not too much. If we choose 6.75° for the back grind angle, we get a back grind width of .490", which will increase the flat width by .010".

By now you can see that different combinations of angle blocks can increase or decrease the width of the flat and/or push the flat toward the cutting edge or toward the false edge. If you run the calculations, you will find that the combination of 5.00° on the main grind and 6.5° on the back grind gives a flat width of .214", shifted by .018" toward the cutting edge. A 5.25° main grind and 6.5° back grind gives a flat width of .251", shifted .001" toward the cutting edge – practically identical to the target! A 5.00° main grind and a 6.75° back grind increase the flat width to .270", but don't shift the flat position at all. In this example, the worst case changes the flat width a little more than 1/32" and shifts its position by less than .020" – not very much difference. How much change you get all depends on your target configuration – you just have to run the numbers and see.

Now let's look at the case of a double grind where the main grind and the back grind meet to form a common grind, shown in cross section as example C in Figure 2 and in profile as example C in Figure 3. Again, let's use a piece of .156" x 1.5" stock and target a main grind width of 1.000" and a back grind width of .500". We'll set the grind-to-edge thickness of the cutting edge to .020"; but this time we'll use a fairly hefty grind-to edge thickness of .070" for the false edge of the back grind. You do the grind angle calculations the same way we did for the example with the flat (you can do them yourself now, so I won't take up the space). Running the numbers, we find the main grind angle is 3.890° and the back grind angle is 4.915°.

Again, if you're using a sine bar and gage blocks you'll be fine hitting your target grind angles; but if you're using angle blocks, this is where things can get a little bit touchy. When we have a common grind line, a slight shift in the position of the grind line won't significantly effect the functionality of the blade; but it can really effect the appearance. In the case of a double grind with a flat between the grinds, the flat can help "absorb" the visual impact of a small change to the ratio of the two grind widths. In the case of a common grind line, shifting the position of the common grind line by as little as .020" can change the overall appearance of the blade and make things look not quite right.

So now let's look at what happens when we set our grind angles using angle blocks. Looking at the target main grind angle of 3.890° first, our choices for angle blocks are 3.75° and 4.00°. A main grind angle of 3.75° will give us a main grind width of 1.038", and a main grind angle of 4.00° will give us a main grind width of .972". Looking at the target back grind angle of 4.915°, our choices for angle blocks are 4.75° and 5.00°. A back grind angle of 4.75° will give us a back grind width of .518", and a back grind angle of 5.00° will give us a back grind width of .492". If we construct a table that has the calculated values for main grind width, back grind width, the sum of the main grind width, and the back grind width, as well as the difference between the total grind width and the stock width (1.5") for each of the four possible angle block combinations (see Figure 6); several things become apparent. Two of the combinations (B and D) result in a flat, because the grinds don't meet; and two of the combinations (A and C) result in a grind overlap that shifts the common grind line away from the target position, away from the cutting edge by approximately .020" and .030", respectively.

Angle Block Combo	Main Grind Angle	Back Grind Angle	Main Grind Width	Back Grind Width	Total Grind Width	Total Grind Width Difference From 1.500"	Common Grind Line Position Shift
A	3.75°	4.75°	1.038"	.518"	1.556"	+ .056"	≈ .020"
B	4.00°	4.75°	.972"	.518"	1.490"	- .010"	Flat
C	3.75°	5.00°	1.038"	.492"	1.530"	+ .030"	≈ .030"
D	4.00°	5.00°	.972"	.492"	1.464"	- .036"	Flat

FIGURE 6

So, how do we choose which angle block combination to use? Well, we can immediately eliminate combinations B and D; because they both result in a flat between the two grinds, and we wanted a common grind line. Both of the remaining combinations, A and C, result in a common grind line that is shifted away from the target position; but combination A is shifted less than combination C, so A is the best choice. But it's still .020" away from where we wanted it to be…

If we aren't completely happy with these choices, there is still one adjustment we can make to try and improve things – change the grind-to edge thickness while keeping the grind angles the same. Looking at it qualitatively, we know that we have to move the common grind line toward the cutting edge. If we reduce the grind-to thickness of the false edge, that increases the grind width of the back grind and pushes the common grind line toward the cutting edge. If we increase the grind-to thickness of the cutting edge, that decreases the grind width of the main grind and pulls the common grind line toward the cutting edge.

Let's put some numbers to this and calculate how much we need to reduce the grind-to edge thickness of the false edge to move the common grind line to where we wanted it to be. Looking at the table in Figure 6, we see that for combination A the main grind and the back grind meet at a point 1.020" from the cutting edge. This means we need to increase the width of the back grind by .020". (Note: Determining the position of the common grind line by subtracting the grind width "overlap," as we have done here, is only an approximation – it is not exact because the grind angles are different; but it is close enough for our purposes here. It is possible to calculate the exact position of the common grind line of overlapping grinds, but that is beyond the scope of this article. If you really want to know how it's done, shoot me an e-mail.) Dusting off our trusty equation, TAN (θ) = A ÷ B, we need to rearrange it solve for A, and we get A = B x TAN (θ). To find our new grind width, B, we take the old grind width, .518" and add .020", to get B = .538". The back grind angle, θ, remains unchanged at 4.75°; so our equation becomes A = .538 x TAN (4.75°), thus A = .0447. To find our new grind-to edge thickness, we subtract 2 x A from the stock thickness and get .156 – (2 x .0447), or .067". So, we only need to reduce the false edge thickness by .003" to get the grinds to meet where we want them to. If we do this same calculation adjusting the grind-to edge thickness for the main grind, we get a new grind-to-edge thickness for the cutting edge of .023", or an increase of .003". On the false edge a decrease in thickness of .003" won't be visibly noticeable; but on the cutting edge you'll likely notice the extra .003" when you're sharpening it.

In summary, you've seen how using just

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Calculating Flat Grinds – Part 3
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simple math you can calculate grind angles to get what you want in terms of blade geometry and profile appearance. You've seen that if there are limitations that prevent you from getting exactly what you want, you can calculate what you can achieve with what you have available to you and select the best option before you move metal around. A key point is that this isn't so much about achieving perfection (although that can be your goal), as it is about quickly determining your best option. Once you've done these kinds of calculations a few times, you will rapidly develop a sense for where your best approach lies without even going through all of the calculations. Perhaps, through experience, you already know how to make eyeball adjustments to get exactly what you want. If not, and you really don't like taking measurements and doing calculations, now you know how to make qualitative adjustments to take you in the right direction. And, if you're most comfortable doing things by the numbers, now you can do that, too.