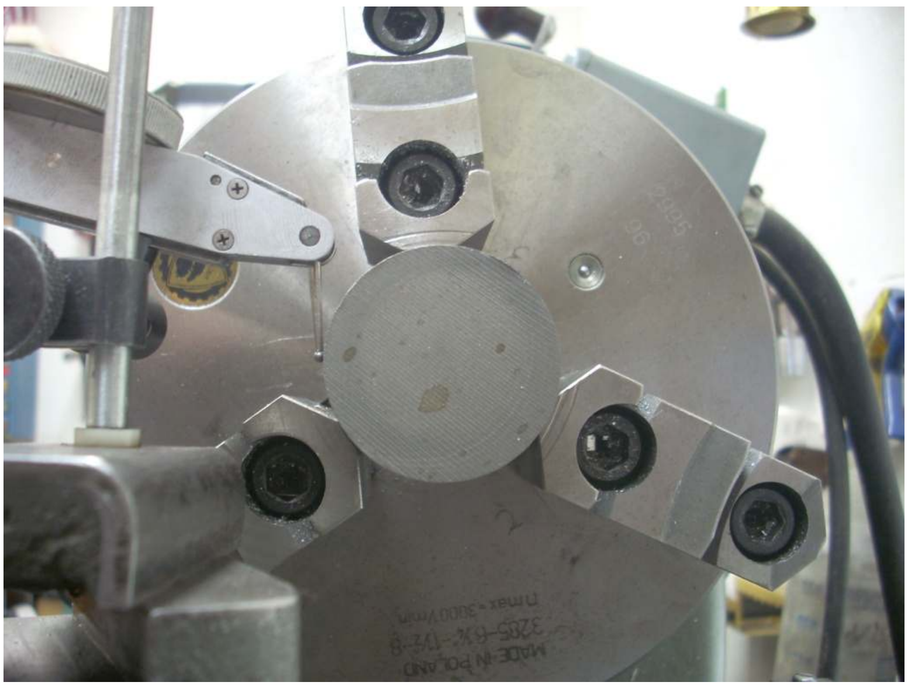
Reducing Total Indicated Runout on a 3 Jaw Chuck

By R. G. Sparber



There are times when I want to center a piece of round stock in my 3 jaw chuck. These cases are rare because I try to just start with an oversized piece and turn it down. This automatically places the center of rotation of the part at the center of the part within the limits of the lathe's run out.

This article along with a supplied Excel spreadsheet will enable you to take a few measurements and calculate the needed pair of shims to center the round stock.

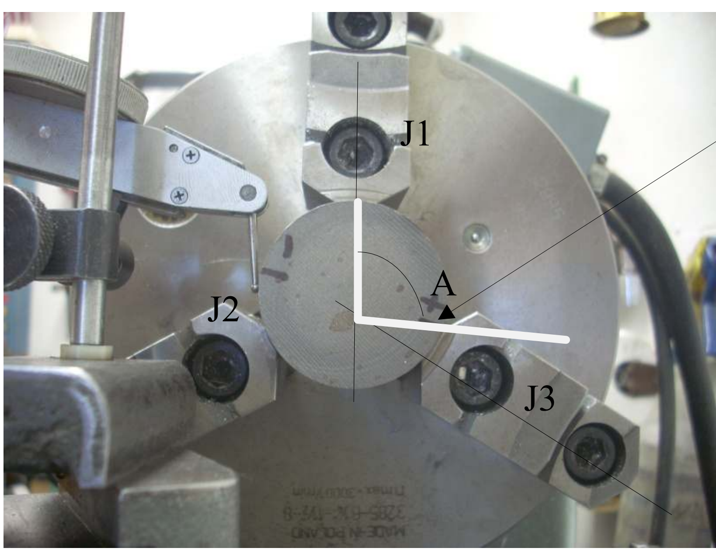
This article has two parts. The first part explains how to use the spreadsheet. The second part presents the math underlying the spreadsheet.

Centering Round Stock in a 3 Jaw Chuck

This procedure assumes that your round stock is smooth and perfectly round. If it is not smooth, then the Dial Test Indicator cannot give reliable readings. If it is not perfectly round, then the readings will define an erroneous center. It also assumes that the jaws all move in and out by the same amount as the key is turned. It does not assume that the jaws perfectly meet at the same distance from the center of rotation. If they did, this procedure would not be needed.

1. Measure the diameter of the stock. The spreadsheet handles imperial and metric.
2. Clean the outside of the stock as well as the jaws.
3. Chuck up the stock.

4. Mount your DTI so it is at the same height as the center of rotation.
5. Find the point on the circumference that is closest to the center of rotation and note the DTI reading. Call this value "min".
6. Find the point on the circumference that is the furthest from the center of rotation and note the DTI reading. It should be 180° from min. Call this value "max".



7. Turn the chuck so that the max point is no more than 120° from a jaw that is vertical. Call this vertical jaw J1. Jaw J2 will be counterclockwise from J1 and jaw J3 will be clockwise from J1.
8. Measure the angle, "A" defined between J1 and the max point.
9. Now plug in diameter, min, max, and angle "A" into the spreadsheet. It will tell you the thickness of two shims. One of the jaws will not need a shim.

Shop Testing

This is a demonstration, not a proof. I took some round stock and verified it read the same diameter at various points around its perimeter using my Harbor Freight® digital caliper. Then I used my digital caliper plus my spacer blocks to measure this diameter. The caliper has a resolution of 0.0005" and past experience has shown me that this is repeatable. A stack of spacer blocks 1.564" tall gave the same reading as the diameter of the round stock.

I then cleaned all mating surfaces and chucked up the round stock. My DTI was set to zero at the max point. The min point, 180 degrees from max, read -0.0032".

I then turned the chuck so the jaw counter clock wise from the max point was vertical. This is my Jaw 1. A level was used to set Jaw 1 vertical and a protractor level was used to measure the angle of 25°.

I then plugged into my spreadsheet:

Diameter	1.464
Max	0.0
Min	-0.0032
Angle	25

I read out:

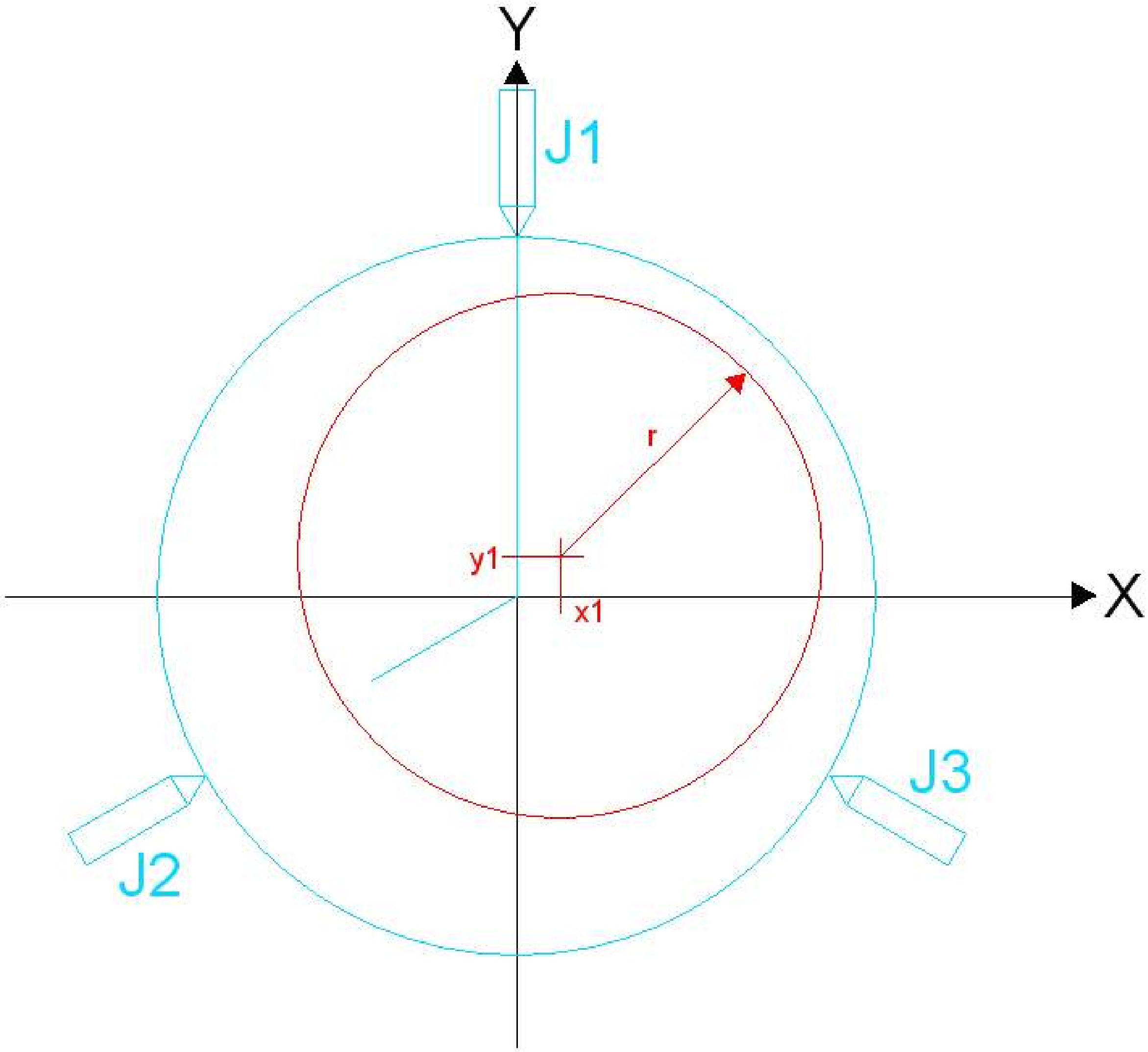
Jaw 1:	0.003
Jaw 2:	0.
Jaw 3:	0.001

I then found a 0.00315" and a 0.00125" shim and installed them without rotating the part with respect to the jaws.

My lathe bearings are not perfect and side pressure does move the chuck. So I ended up turning the chuck under power at 26 RPM. It was easy to follow the DTI needle which swung a total of 0.0005".

So I was able to reduce TIR from 0.0032" down to 0.0005" by using two shims.

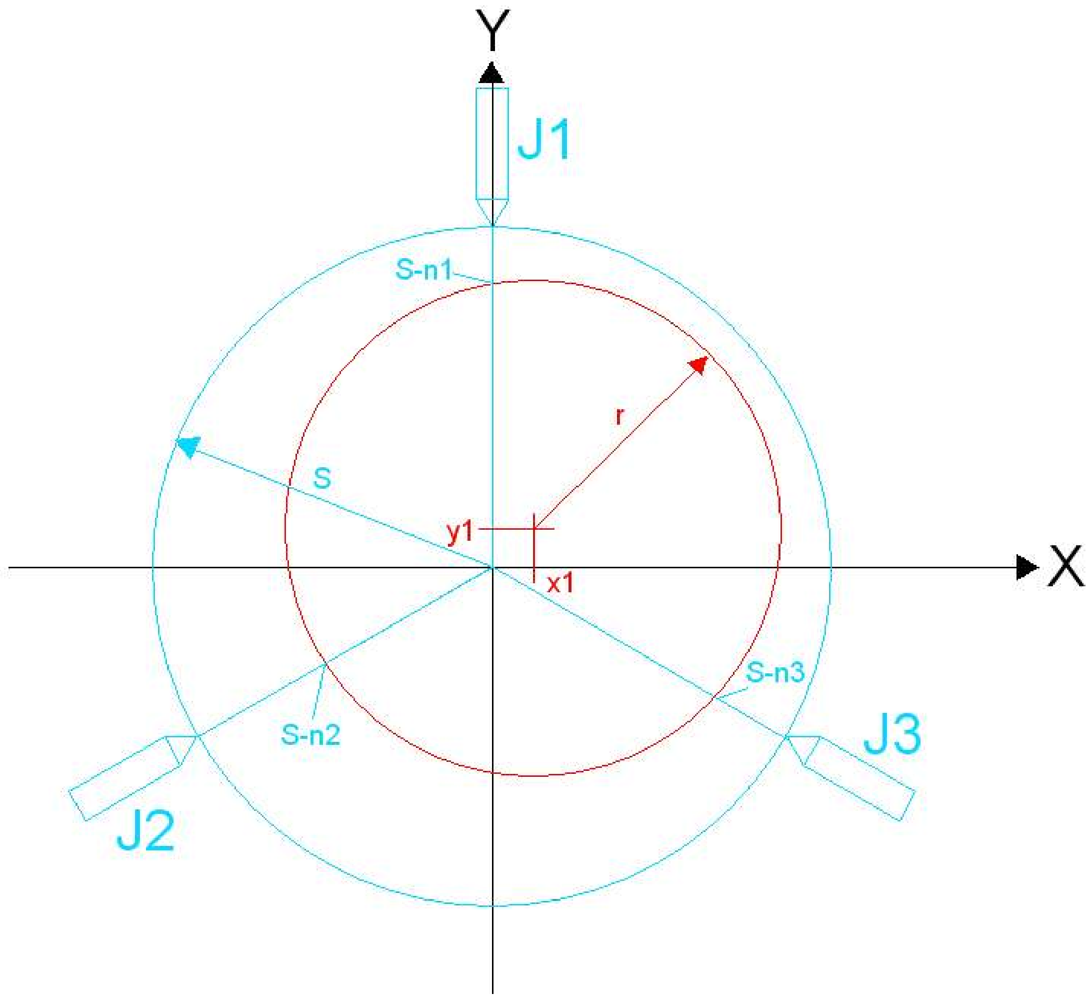
Behind the Spreadsheet



Looking into the face of the 3 jaw chuck we see jaws J1, J2, and J3. I will assume that they are the same distance from the center of rotation (COR) in order to simplify the math. But in fact, any error is absorbed in the shim calculations.

Held in the chuck is a piece of round stock of radius r. The center of this piece of stock is at the point (x_1,y_1).

The distance along the axis followed by each jaw from the tip of the jaw to the surface of the stock is the needed shim. One of these shims can be set to zero but at this point we don't know which one. So I will carry all 3 variables through the derivation.



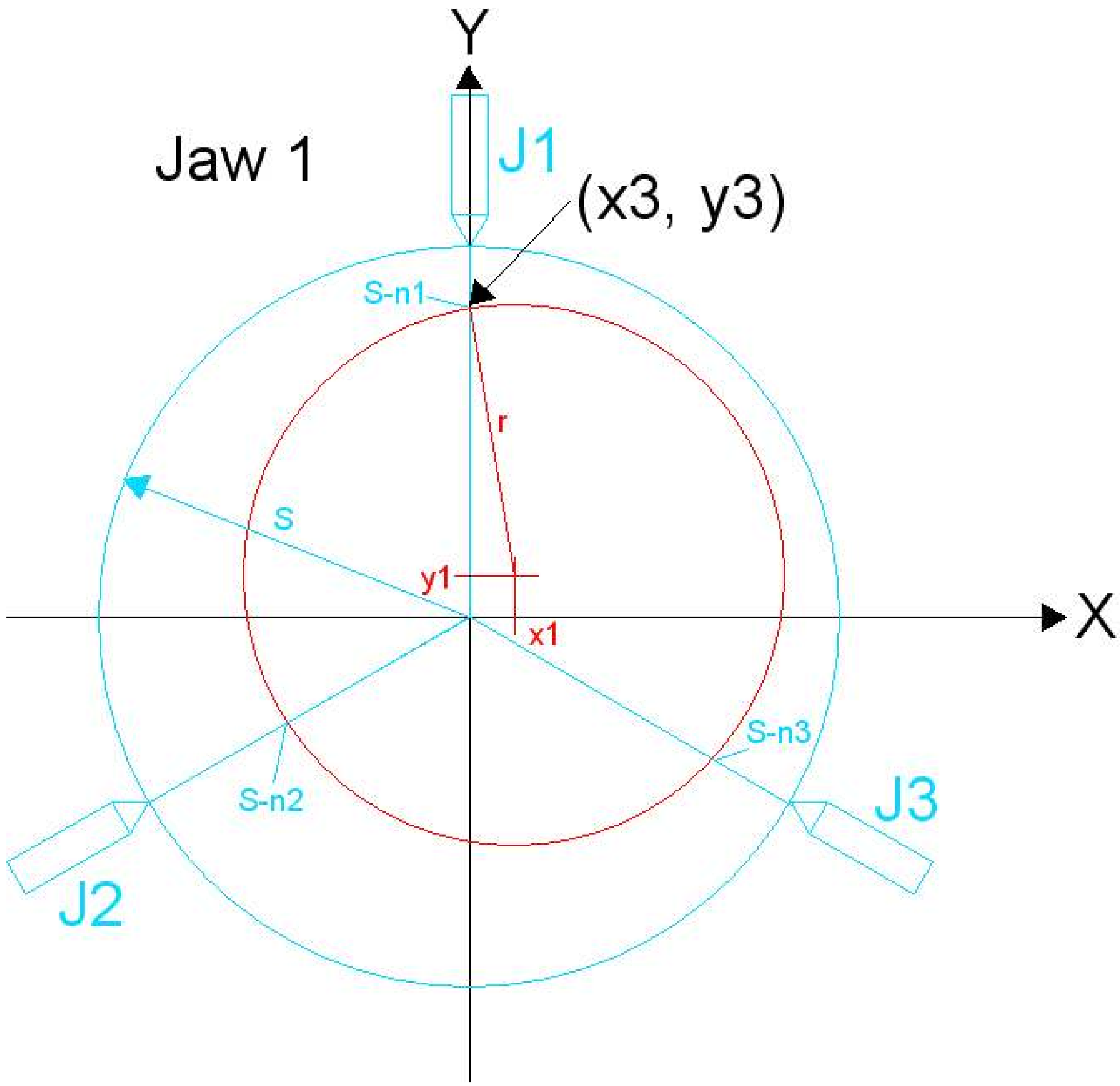
The distance from the COR to the circle defined by the jaws has a radius of "S". Each jaw has a shim of thickness "n_i". Measuring from the COR, we have a distance S-n_i, i=1,2,or 3. Measuring from the positive X axis, I have S-n_1 at 90°, S-n_2 at 120°, and S-n_3 at 330°.

These same 3 points can be defined by looking at the round stock. If (x_1,y_1) was (0,0), it is easier to see. In this case, we know the radius, r. The angle would be the same as the jaws. Not terribly useful since this is just the case of zero TIR. I will show how to find coordinates for the general case of non-zero (x_1,y_1).

The strategy is therefore to define each of the 3 contact points with respect to a jaw and the corresponding point on the surface of the stock. This gives me values for the three (S-n_i). I then center the part which means that the distance from the COR out towards each jaw is simply r. The needed shim is then (S-ni) – r. Recalling that the assumption that the jaws move in and out together, I can add a constant to all three shims such that they are equal to or greater than zero.

Jaw 1

This set of equations is unique because I have defined the axis that Jaw 1 moves along to be coincident with the Y axis.

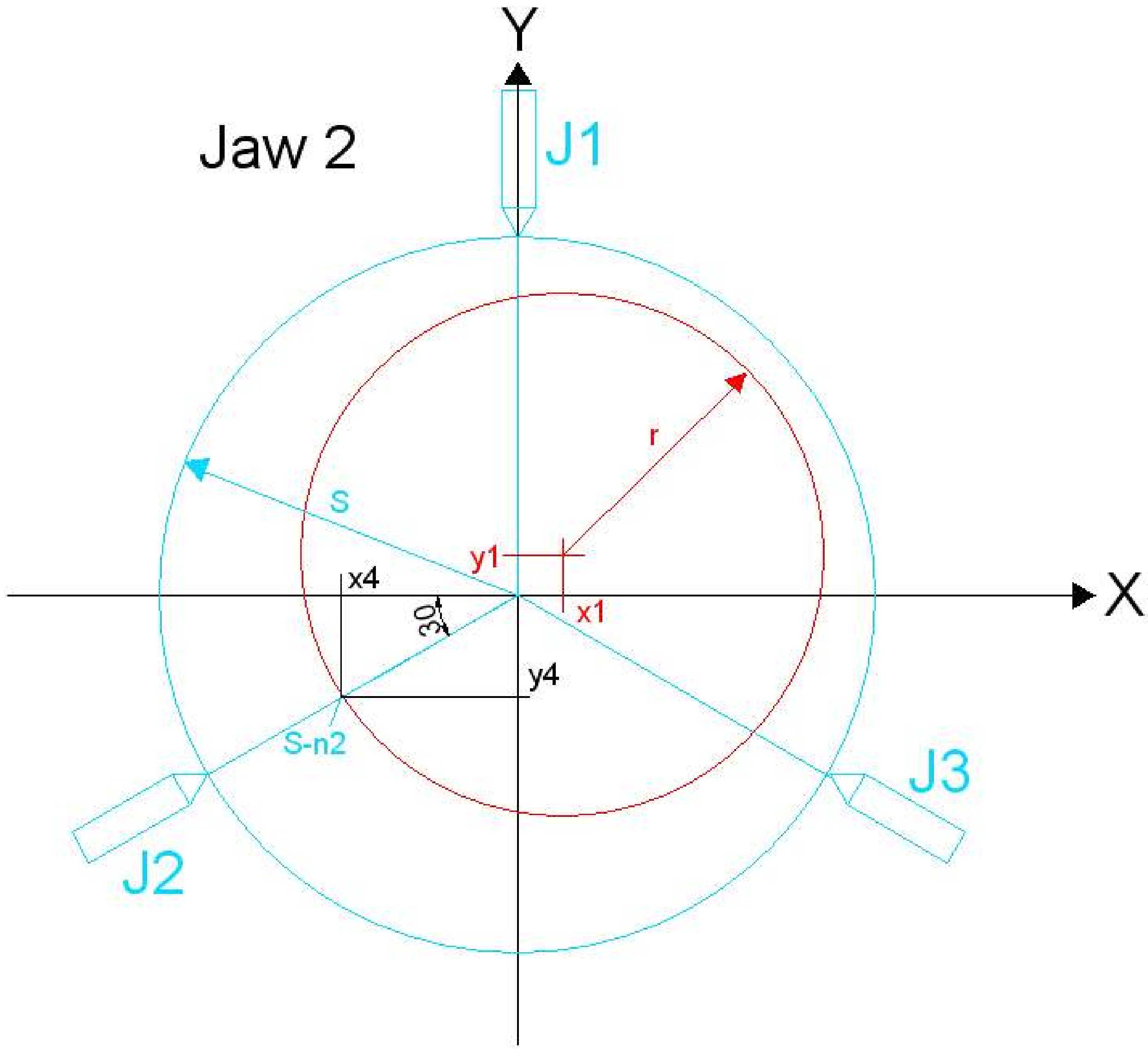


My point of contact is (x_3,y_3) but $x_3 = 0$. From Jaw 1's viewpoint, it is at y_3=S-n_1.

From the viewpoint of the round stock I can find y3 because I have a right triangle with known base and hypotenuse. The vertical distance from the contact point down to y_1 is $\sqrt{r^2 - x_1{}^2}$. I can then say that $y_3 = y_1 + \sqrt{r^2 - x_1{}^2}$. Matching up the two equations I can say that S-n_1 = $y_1 + \sqrt{r^2 - x_1{}^2}$ (equation 1).

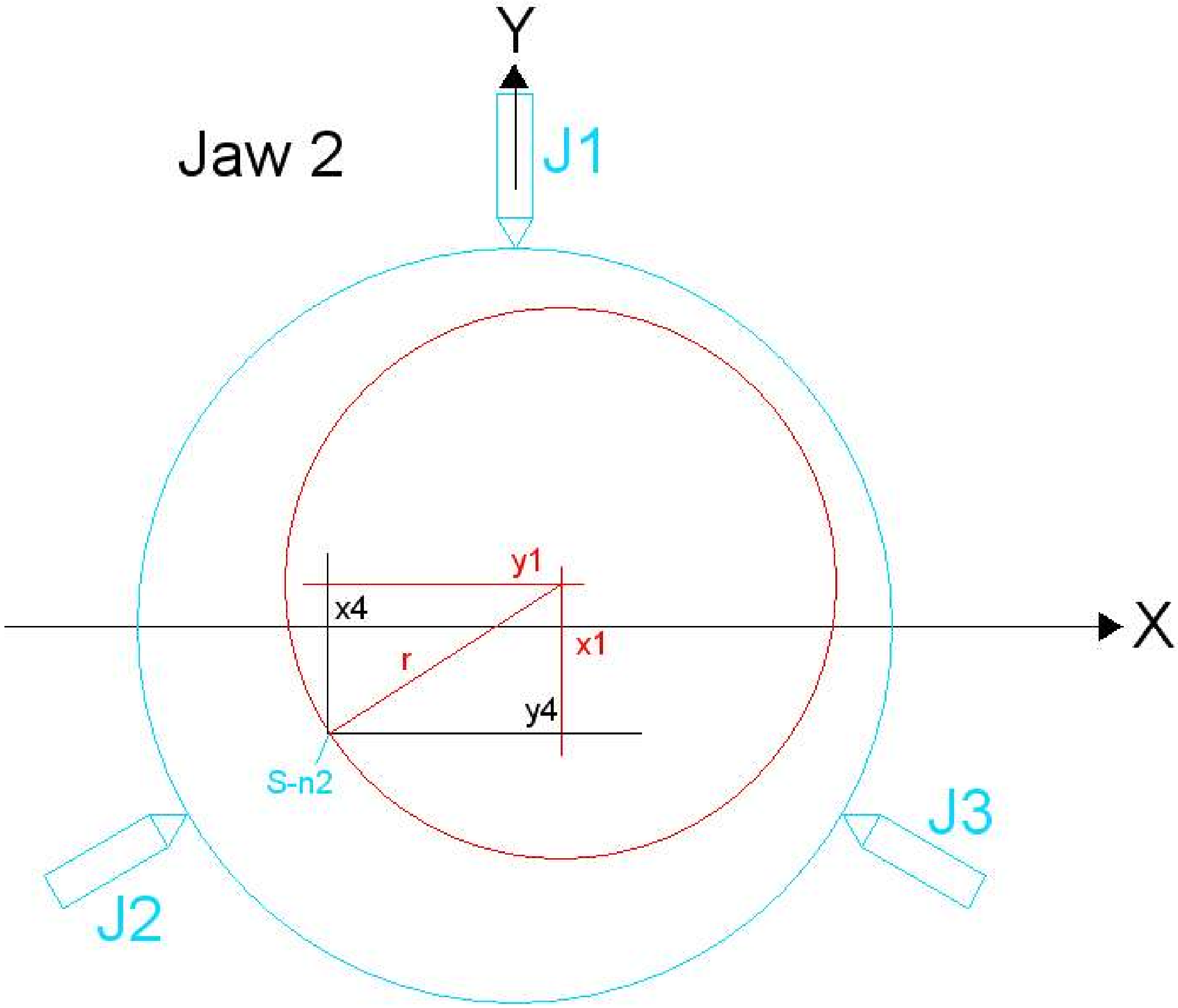
Jaw 2

Things get messy now but at least the approach for Jaw 2 is the same for Jaw 3.



From Jaw 2's standpoint, I can say

$$x_4 = -(S - n_2)\cos 30° \quad \text{(equation a)}$$
$$y_4 = -(S - n_2)\sin 30° \quad \text{(equation b)}$$



From the round stock's viewpoint, I can define a right triangle with a rise of $y_1 - y_4$ and a base of $x_1 - x_4$. My hypotenuse is "r" so I can write

$$r^2 = (x_1 - x_4)^2 + (y_1 - y_4)^2 \quad \text{(equation c)}$$

Next I feed equations a and b into equation c

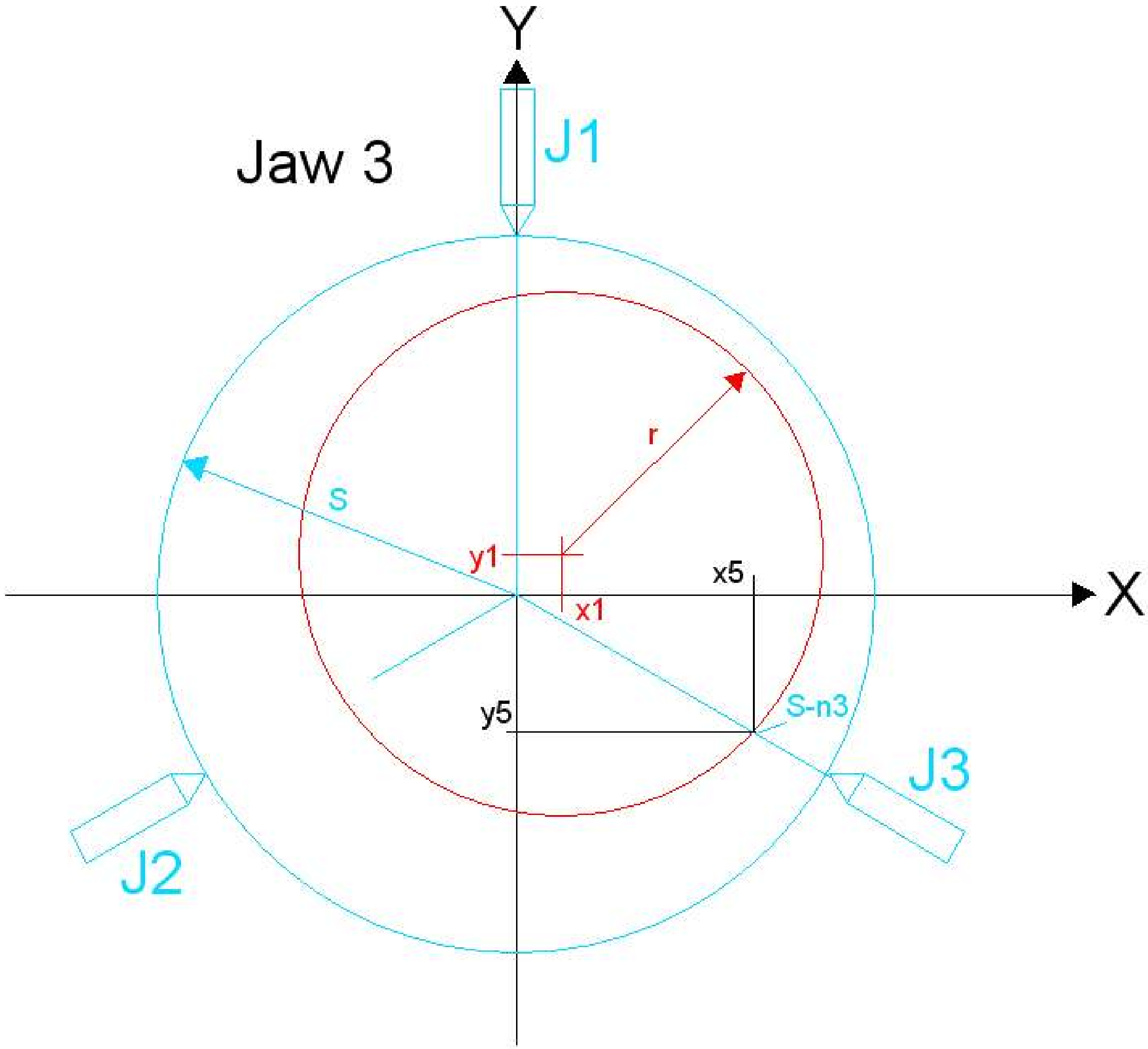
$$r^2 = (x_1 + (S - n_2)\cos 30°)^2 + (y_1 + (S - n_2)\sin 30°)^2 \quad \text{(equation d)}$$

Multiplying this all out and grouping like terms I get a polynomial of the form

$$0 = A(S - n_2)^2 + B(S - n_2) + C$$

Where A = 1, $B = 2x_1 \cos 30° + 2y_1 \sin 30°$, and $C = x_1^2 + y_1^2 - r^2$. I then solved for the positive root using $\frac{-B+\sqrt{B^2-4AC}}{2A}$ to get (equation 2).

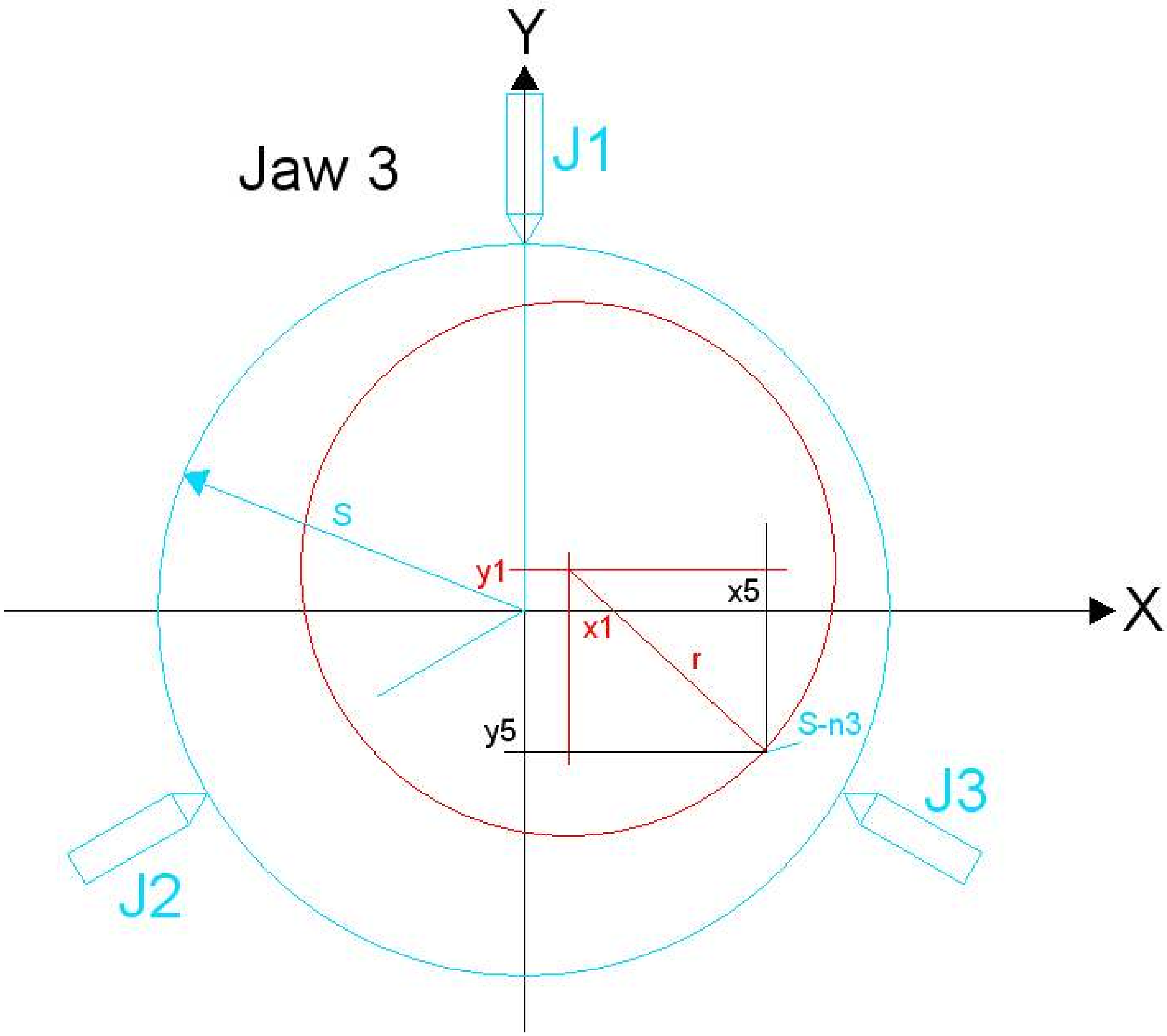
Jaw 3



Similar to Jaw 2, I can say

$$x_5 = (S - n_3)\cos 30° \qquad \text{(equation e)}$$
$$y_5 = -(S - n_3)\sin 30° \qquad \text{(equation f)}$$

from the jaw's standpoint. Recall that Jaw 3 is 120° from Jaw 1 so must be 30° from the X axis.

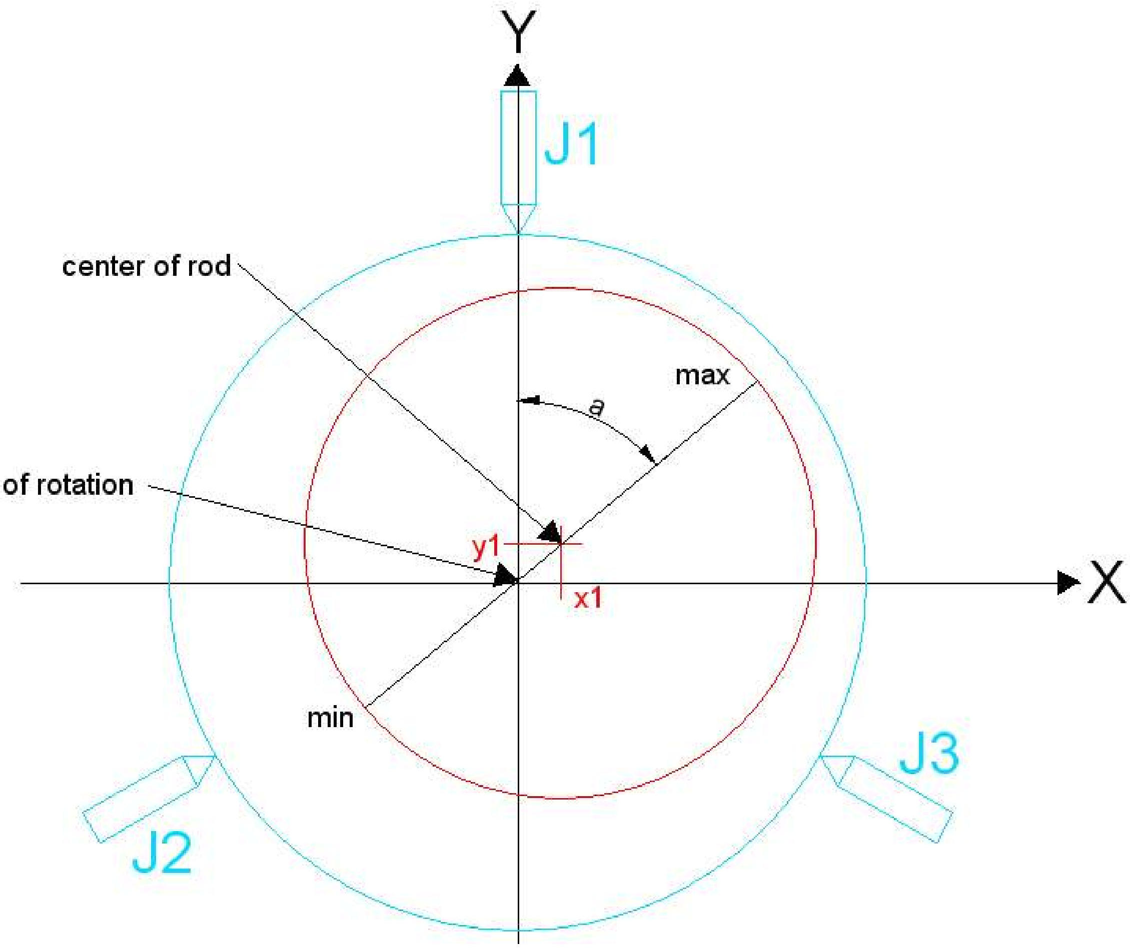


As viewed from the round stock, I can again define a right triangle with a base of $x_5 - x_1$ and height of $y_1 - y_5$. Since I know the hypotenuse is r, I can write

$$r^2 = (x_1 - x_5)^2 + (y_1 - y_5)^2 \quad \text{(equation g)}$$

I again combine the two equations, e and f, from the jaw with the one from the round stock, g, and get a polynomial. The terms are A = 1, $B = -2x_1 \cos 30° + 2y_1 \sin 30°$, and $C = -r^2 + x_1^2 + y_1^2$. The positive root is used. This is (equation 3).

Total Indicated Run-Out

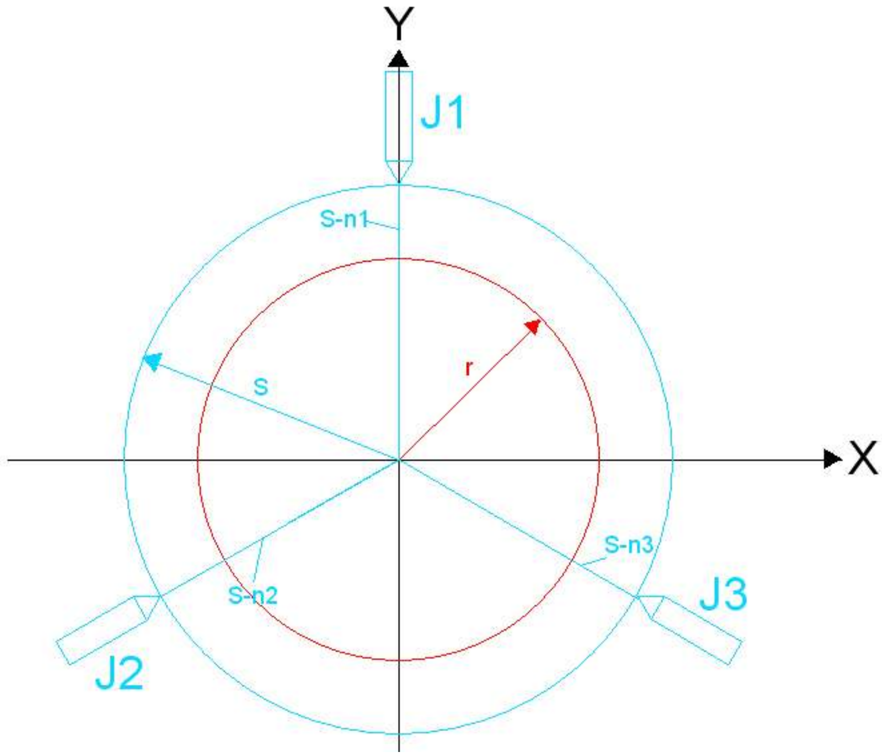


The last piece of the puzzle is to translate the TIR readings into (x_1,y_1).

By definition, $TIR = \frac{max - min}{2}$. The TIR is the hypotenuse of my right triangle. The angle "a" was measured. I can then say

$$x_1 = TIR \sin A \quad \text{(equation h)}$$
$$y_1 = TIR \cos A \quad \text{(equation i)}$$

I end up with a set of equations, 1,2, and 3 of the form $S - n_i = k_i$, for i=1,2,3. These values represent the positions of the three jaws when the part has a non-zero TIR. What I want is the correction to drive the TIR to zero.



The shim needed on Jaw 1 is $(S\text{-}n_1) - r$. Note that the angle does not enter into the equation because we are only talking about the motion along the axis traversed by the jaw.

Similarly, I can say that the shim needed for Jaw 2 is $(S\text{-}n_2) - r$ and for jaw 3 is $(S\text{-}n_3) - r$. We end up with shims that can have a positive or negative value. Since the jaws all move in and out by the same amount, I will not change the part's position as long as I add the same value to each shim. I therefore choose to select the smallest shim (most negative) and subtract that from all three shims. This will cause one shim to be zero while the other two are positive.

I welcome your comments and questions.

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