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# A standard conical point drill grinding machine

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**Abstract**

This paper describes a drill grinding machine that can produce conical twist drill points with very accurately specified point shapes. The machine is adjusted by precise orthogonal movements using shims and gages to make sure that the drill parameters are set precisely. The confidence in the point shape produced is high enough that inspection of the points produced is not necessary.

*Keywords:* Drill grinding; Drill sharpening; Cone model drill point; Twist drill grinding

## 1. Introduction

There are some problems in the adjustment of existing simple conical twist drill grinding machines. Many of these machines allow the operator to easily vary point parameters that are not very important as far as drilling performance is concerned, such as point angle, and at the same time do not allow straightforward adjustment of parameters that have a very powerful effect on performance, such as skew distance, $d$ parameter described by Tsai and Wu [1,2] and $\omega$ parameter described by Fugelso [3,4]. Most machines adjust $\omega$ in a trial-and-error manner until an acceptable but uncharacterized drill is produced. This leads to variations in batches of drill points produced.

After a conical drill point has been produced it is very difficult to measure the point and ascertain its model parameters. It is easy to find the sum of $\theta$ and $\phi$ because twice that sum is the easily measured point angle, but separating $\theta$ and $\phi$ is difficult. The measured chisel edge angle contains the $\omega$ parameter and $\omega$ cannot easily be separated from the chisel edge angle. While the $d$ parameter cannot be measured directly, Tsai and Wu [1] showed that it can be inferred

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**Nomenclature**

| | |
|---|---|
| $d$ | distance between tip of drill and tip of grinding cone measured parallel to cone axis |
| $D$ | drill diameter |
| $H_R$ | height of calibrating rod tip over the base |
| $H_S$ | height of contact point of square calibrating bar and grinding wheel over the base |
| $L$ | a calibration distance |
| $P$ | skew distance adjusting shim thickness |
| $P_0$ | thickness of shim P that causes the drill axis to intersect the cone axis AA′ |
| $Q$ | a parameter adjusting shim thickness |
| $Q_0$ | shim thickness required to produce $d$=0 on a drill of diameter $D$=0 |
| $Q_C$ | thickness of shim Q in place during $Q_0$ calibration, any thickness will do |
| $R$ | distance from base to top side of gage G |
| $R_0$ | distance from base to tip of calibrating rod |
| $S$ | skew distance between drill axis and grinding cone axis |
| $w$ | width of gage block to set $\omega$ parameter |
| $w_0$ | width of gage block that lines up with cone axis in side view, Fig. 2 |
| $W$ | drill web thickness |
| $\theta$ | grinding cone half angle |
| $\phi$ | angle between drill axis and grinding cone axis |
| $\omega$ | rotation of drill blank about its own axis before grinding |

from the chisel edge angle if the other parameters are known. This confounding of cone model parameters makes it difficult to inspect points, and it is therefore important to produce the points correctly in the first place.

This paper describes a twist drill grinding machine that allows the setting of all of the cone drill point parameters and makes sure that these parameters are well known and repeatable. This is because they are set directly from first principles using shims and gage blocks to position the drill blank precisely. And it can be calibrated with as little knowledge of grinder part dimensions as possible.

## 2. Description of grinder

Fig. 1 shows the cone model of a twist drill point with the parameters cone half angle ($\theta$), drill axis to cone axis angle ($\phi$), skew distance ($S$) and distance from cone tip to drill tip ($d$) as described by Tsai and Wu [1].

Fig. 2 shows the configuration of the standard conical drill grinder. The axis AA′ is the axis of the cone model. The angle $\theta$ is set at 30° as this gives a good distribution of relief angle along the cutting edge, but not too large a chisel edge angle, see Fugelso [4]; a chisel edge angle less than 120° sacrifices potential drill performance. The angle $\phi$ is fixed at 29° to give a standard

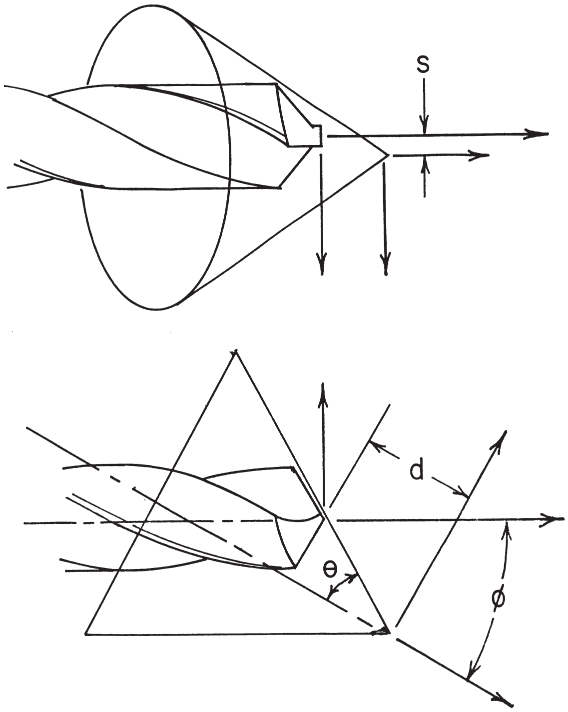


Fig. 1. Cone model of a twist drill point.

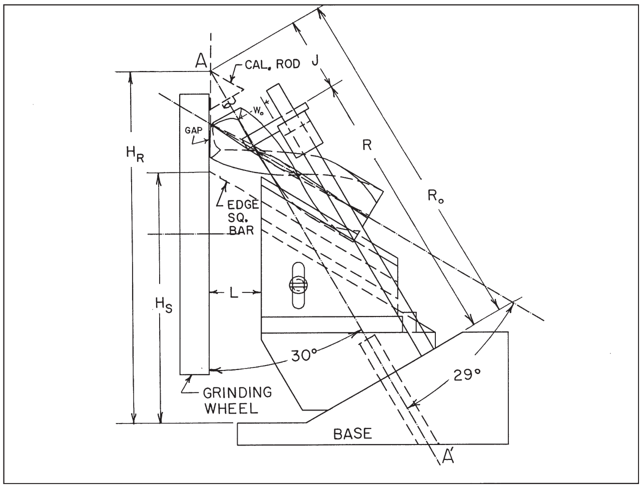


Fig. 2. Side view of the standard conical twist drill grinder.

point angle of 118°, the point angle being double the sum of $\phi$ and $\theta$. If desired $\theta$ and $\phi$ could be different, but the above values should be adequate for a wide range of applications.

Skew distance has a great effect on drill geometry. A small change in skew distance changes the relief angles as defined in [5] a great deal. An increase in skew distance results in a uniform increase in relief angle over the entire length of the cutting edge of the drill. Typically the skew distance is about equal to the web thickness. The skew distance $S$ can be accurately adjusted by varying the thickness of shim P, Fig. 3. The value of skew distance is equal to a machine constant $P_0$ determined after construction minus the shim thickness $P$.

The $d$ parameter can be adjusted with shim Q, Fig. 3. The shim Q causes displacements at right angles to the displacements caused by shim P, raising and lowering the drill blank. The shim thickness $Q$ is given by the following equation that is a function of drill diameter $D$ and the $d$ parameter:

$$Q=Q_0-\frac{D}{2\sin 45°\sin(\theta+\phi)}-\frac{d}{\cos\theta}. \tag{1}$$

The $d$ parameter is a function of the drill diameter because the drill is held in a 'V' groove. If the drill were held in a chuck, $d$ would not be a function of drill diameter. The value of $d$ should be equal to 60–90% of the drill diameter, as small as possible without making the chisel edge angle too large, i.e., greater than 133°. This results in the relief angle increasing as much as possible along the cutting edge traveling toward the drill axis. Most existing drill grinders do not allow adjustment of this parameter and have a built-in fixed $d$ value that is marginally acceptable for large drills and much too large for smaller drills.

The top side of gage G must be at a distance $J$ from the cone tip to properly align $\omega$, Fig. 2. $J$ is given by:

$$J=d+\frac{d\cos\theta}{2\sin(\theta+\phi)}. \tag{2}$$

Then distance $R$ would be:

$$R=R_0-J. \tag{3}$$

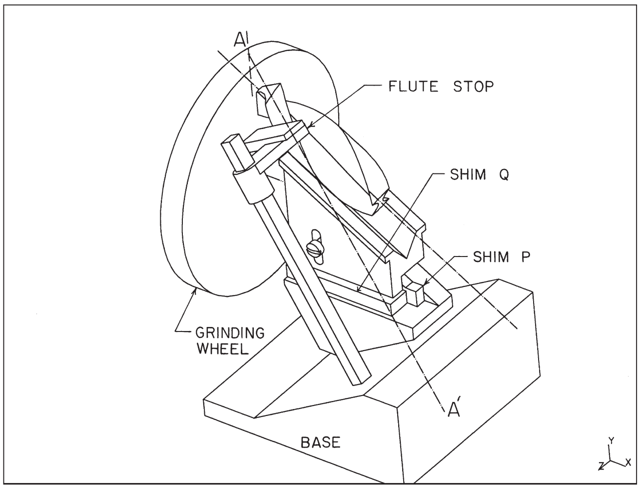


Fig. 3. Isometric view of the standard conical twist drill grinder.

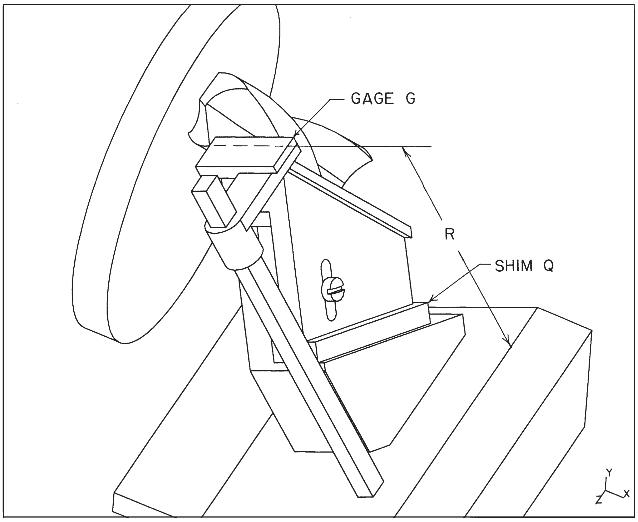


Fig. 4. Setting distance *R*, with drill rotated 90° about cone axis.

Fig. 4 shows the distance *R* from gage G to the base. The gage G must be positioned along the *Z* axis of the flute stop, Fig. 5, so that it engages the flute of the drill, but this is not a precision adjustment because of the concave shape of the flute. The $\omega$ parameter is adjusted by the width ($w$) of gage G. The drill holder rotates 90° about the cone axis AA′. Then the gage contacts the point on the drill where the cutting edge will reach the outside diameter after grinding has taken place, Figs. 4 and 5. This results in setting $\omega$ from first principles, $w$ is given by the following equation:

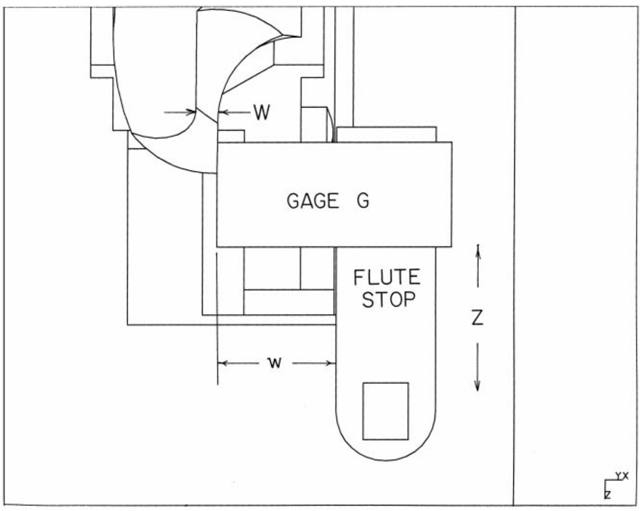


Fig. 5. Setting drill point $\omega$ parameter.

$$w=w_0-\frac{W}{2}-\frac{D}{2}\tan\omega. \quad (4)$$

The $\omega$ parameter ranges from zero to a small positive angle, not more than +15°. Increasing $\omega$ by 1° increases the chisel edge angle by 1°. Increasing $\omega$ has a beneficial effect on the distribution of relief angle along the cutting edge, see Fugelso [3,4]. But doing this increases chisel edge angle. The chisel edge angle must be less than about 133° or the chisel edge will be too long. Often the $\omega$ parameter is increased to compensate for a built-in $d$ parameter that is too large, as demonstrated by Fugelso [3].

After touching off the drill flute on the gage G as shown in Fig. 4, the drill is clamped in the 'V' groove drill holder and the drill holder is rotated backward by 90° on the cone axis, encountering the grinding wheel and forming half the point. The drill is then loosened and rotated about 180°, and the drill holder is rotated forward 90°. The second flute is touched off on gage G to line up the second half of the point and the drill is reclamped. Then the drill holder is rotated back again, forming the second half of the point. For clarity the clamps and AA′ axis rotation stops are not shown on the figures.

## 3. Calibration

It is desirable to calibrate the machine without explicitly knowing the dimensions of the grinder because then the calibration is not affected by inaccurately formed or measured parts. While there is no easy way to get around measuring the angular dimensions, it is possible to calibrate without knowing many of the linear dimensions. But, finding $P_0$ is very simple and may be found utilizing ordinary measuring tools.

The calibration of $Q_0$ and $R_0$ assumes that the grinding wheel can be moved along its axis of rotation and returned to a previous axial position accurately. $R_0$ may be found by replacing the rotating part of the grinder with a conical pointed calibrating rod, dashed lines in Fig. 2. $R_0$ is the distance from the base to the tip of the rod when the side of the cone touches the grinding wheel. The height $H_R$ from the tip of the rod to the base must be recorded to use in the calibration of $Q_0$. $H_R$ only needs to measured once because it has a constant ratio with $R_0$.

$Q_0$ may be found by placing a square calibrating bar on the 'V' groove and measuring the height $H_S$ from the base to the point of contact of the square bar and the grinding wheel, dashed lines in Fig. 2. Also, the distance $L$ should be measured at this point for future recalibrations. Then:

$$Q_0=H_R-H_S+Q_C. \quad (5)$$

In a grinding machine intended to produce a wide range of drill diameters, the range of shim Q thicknesses required may be inconveniently large. The grinding wheel may be translated to the left increasing $L$, Fig. 2. Increasing $L$ from its originally measured value will increase $d$ and three of the calibration constants according to the following relations:

$$\Delta d=[\Delta L/\tan\theta-\Delta L\tan(90-\theta-\phi)]\cos\theta,\quad \Delta R_0=\Delta L/\sin\theta,\quad \Delta H_R=\Delta L/\tan\theta,\quad \Delta H_S \quad (6)$$

$$=\Delta L\tan(90-\theta-\phi).$$

Eq. (6) also may be used to recalibrate the machine after dressing the side of the grinding wheel. The effect of wheel dressing is to create a small $\Delta L$.

## 4. Accuracy

When the ‘V’ groove drill holder is in the position shown in Fig. 2, there is a very small gap between the drill point and the grinding wheel. The gap width is given by:

$$\text{Gap width}=\frac{[S-(W/2)]^2}{D}. \tag{7}$$

The gap width approaches 0.0 as the skew distance approaches its lower limit of $W/2$. This gap increases with increasing skew distance. Neglecting this gap produces a small error in of the second term of Eq. (2) of about 1%. This could result in a fraction of a degree error in the $\omega$ parameter. This is acceptable because $\omega$ is normally specified in whole degrees, not fractions.

## 5. Discussion

The drill points created by this standard drill grinder can be compared with drills produced by other grinders in a number of ways. The surface of the drill flank and its edges could be measured with a coordinate-measuring machine (CMM) to compare the point produced by a production grinder with a standard point. This would tell if the two points were the same. However, it would be good for the comparison if the drill parameters of the point could be extracted from the flank surface points measured by the CMM. Then the production drill grinder could be adjusted in a rational way so that it produces points the same as the standard drill grinder.

Another comparison would be to conduct tool life tests of the standard point and the production point, but the problem is that the cutting performance could be quite similar for points that had different shapes. The drills produced by the standard grinder are intended to provide a geometric benchmark for tests of new drill point shapes.

A third comparison would be to check the relief angle of the two drill points at the outer diameter (OD) and at a point near the end of the chisel edge. These angles are critical to drill performance. The relief angle near the chisel edge should be larger than at the OD. This approach would yield good drilling performance but still leave the shape of the production drill incompletely specified.

## 6. Conclusions

While cam-driven mechanical grinding machines and computer-controlled grinders can produce a wide variety of points with programmed changeover from one point shape to another, the drill grinder proposed in this paper, although somewhat tedious to set up, can produce large batches of identical cone points with high confidence in the point shape being produced. This is especially important for very small diameter drills because they are difficult to inspect. These drills can be used for benchmark tests of common conical drill point performance for comparison with more complex points produced for research. Future work would include designing measuring techniques for production drill flank shapes, with this grinder providing the first step toward rational comparisons of drilling performance.

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