Chapter 4
Evaluating Bit Wear

4.1 Current Evaluation

In the current evaluation process used by our industrial partner, bit wear is recorded photographically. After the Dixon rig has driven 250 screws, the bit is removed from the test rig and photographed. The bit is then returned to the rig, 250 more screws are driven, and the bit is photographed again. This process is repeated until the bit has driven 5000 screws. Once several bits are driven 5000 cycles and photographed, bit designers have 20 photographs of each bit type to compare. All damage assessment is done subjectively by experienced designers comparing photographs of various bits. Unfortunately this does not provide the designers with direct insight to why one bit is better than the other.

4.2 Shortcomings of Current Evaluation Methods

Comparing the photos in Fig. 4.1 and 4.2 a designer may conclude that bit A appears more worn that bit B, but there is no means to be sure that bit B actually performs better. Even if it could be determined that bit B did perform better, no direct information is obtained on how to design or manufacture a superior bit. The design process is an open loop.

Figure 4.1 Bit A
Grabber #2 Reduced Bit
after 2500 Cycles on Dixon Rig

Figure 4.2 Bit B
Black & Decker Scorpion Bit
after 5000 Cycles on Dixon Rig

To obtain information that will give insight into bit performance, the change in geometry needs to be evaluated. Geometry is critical because the regions of surface contact govern the force transfer between the bit and screw. The process of wear evaluation must consider specific information to geometric changes of the bit.

4.3 New Bit Evaluation Process

Section 1.6.2 concludes that, in order for any information to have an impact on improving a bit's design, that information must tangibly define the geometric changes due to the wear. Mapping bit geometry will quantify the geometrical changes in the bit.

The applied mapping method consisted of taking three-dimensional bits and dividing them into two-dimensional planes. Taking a complex three-dimensional object, which often is difficult to define in functional terms, and defining it as several two-dimensional planes, simplifies the process. A two-dimensional shape can be defined easily by lengths and radii, in comparison with a complex three-dimensional object that may have curvature in two planes. The collective data of the multiple two-dimensional surfaces combined will then define the three-dimensional bit.

In Fig. 4.3 it is easily seen from observing the photograph of the intact three-dimensional bit, the areas of the bit that are worn. What is not easily seen is how the geometry has changed due to that wear and how to define those changes. The two-dimensional section shown in Fig. 4.4 can more easily be defined using simple dimensions such as lengths and radii of curvature.

Figure 4.3 Intact Worn Bit

Figure 4.4 Section of Worn Bit

To breakdown the three-dimensional bit into two-dimensional layers, sectioning was proposed. The concept behind sectioning is starting with a whole bit as shown in Fig. 4.5 and physically exposing the planes as seen in Fig. 4.4. To do this, bit material must physically be removed. It can be seen in Fig. 4.6 that as the bit is sectioned, each plane is visible after the plane above it has been removed. Excluding the final two sections taken, the depth of material removed in each sectioning operation was 1/100 of an inch. As the planes are exposed, the geometric information of the plane can be captured.

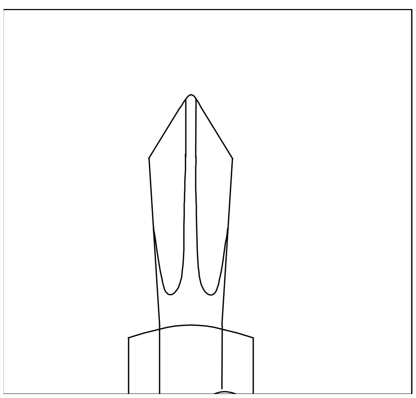

Figure 4.5 Intact Bit

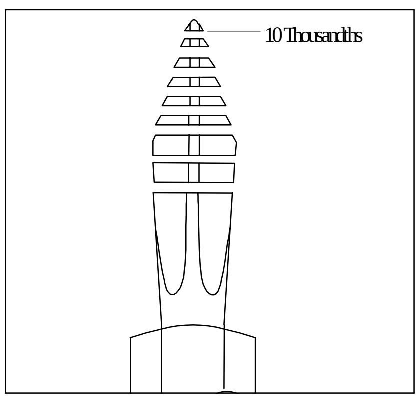

Figure 4.6 Sectioning of Bit

Traditional Coordinate measuring machines and other nondestructive methods for directly obtaining the three-dimensional information were considered, but were eliminated in favor of the sectioning method described above. Section 7.2.1.1 further discusses alternatives to the sectioning method.

4.4 Experimental Confirmation of New Bit Evaluation Process

To determine the effectiveness of the new bit evaluation process, a small study was undertaken. Four bits of the same manufacturer and type were taken and worn varying amounts and then examined by the process described in section 4.3.

4.4.1 Wearing the Bits

To reproduce worn bits, two test subjects were used to emulate drywallers. The subjects were each given a six-foot length of 4x4 pressure treated lumber, a DeWalt Quiet Clutch Drywall Screw Gun, four Grabber #2 Reduced bits and Grip-Rite 6 x 1¼ Coarse Threaded Phosphated Drywall Screws. The subjects then began to drive screws with the drywall guns until the first bit was, in the opinion of the user, no longer practical to use; so was determined the bit's life.

Once the first bit was worn to life, the number of screw driven was recorded and then classified as the user's bit life. The users then drove the second and third bits to 1/4 and 1/2 of the number of screws recorded above. Once the test was completed, there were four bits with varying wear patterns for each user. Of the 4 bits, there was one new bit and one bit for the 1/4, 1/2, and full lives of the bit. Table 4.1 shows the number of screws driven by each bit.

Table 4.1 Number of Screw Driven during Wear Test

Life	User	Bit	Screws Driven	User	Bit	Screws Driven
New	1	1A	0	2	2A	0
¼	1	1B	161	2	2B	154
½	1	1C	322	2	2C	309
Full	1	1D	643	2	2D	618

4.4.2 Sectioning the Bits

Once the bits were worn, they were taken to our industrial partner's metallurgy Lab, which is equipped to properly cut the bits and examine their geometric planes.

Since the majority of bit damage occurs in the first 0.1" of the bit, only this region was examined. It was important to reduce smearing of the metal when sectioning the bit. Smearing distorts the profile geometry. Fortunately the tool steel of the bits was hard enough to limit smearing. With the help of a tool and die maker, the bits were ground using a 120-grit boron cup. Visible smearing of the metal as observed through an optical video probe (75X magnification) was extremely limited.

As Fig. 4.7 indicates, eight section cuts were made. Six cuts at a depth of 0.01" were made, with final two cuts at a depth of 0.02". The motivation behind this pattern was a desire to closely study the area of most significant wear.

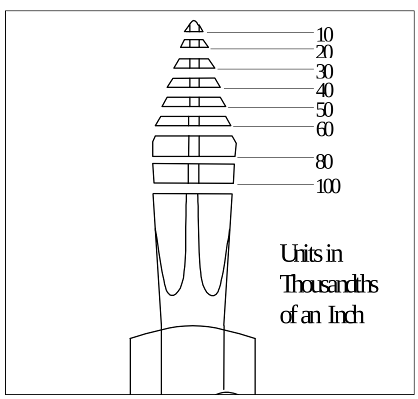

Figure 4.7 Sectioned Depths of the Bit

4.4.3 Recording Geometric Data

Since the surface plane of each section was destroyed once the following cut was made, it was important to preserve the information pertaining to each section. An optical video probe allowed the bit to be magnified, measured and photographed. The bit was magnified 22 times its original size with the probe to observe and photograph the exposed plane. Using the probe, measurements of the inner and outer radii were taken. The inner radius of the bit is the radius of the smallest circle that can be inscribed inside the bit. Likewise the outer radius is the radius of the largest circle that the bit can be inscribed in. The optical probe from four selected points calculated both the inner and outer radii. In the case of the inner diameter, the four points were in the valley of the flutes and in the case of the outer diameter the four points were at the tip of the wings.

The tip radius of each wing on the driving face and the radius of each flute were also measured. These radii were measured from the photographs using a professional circle template. Measurement locations are shown in Fig. 4.8.

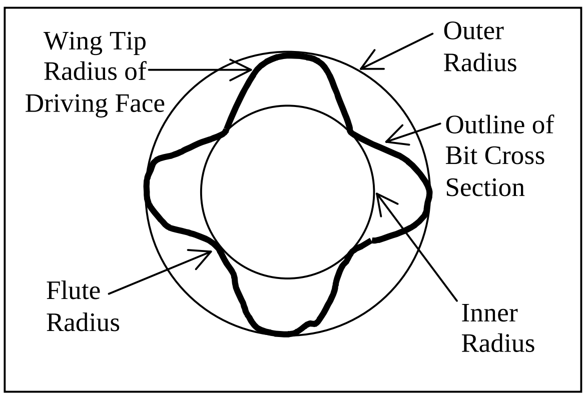

Figure 4.8 Captured Bit Dimensions

4.5 Does the Geometry Change?

By examining the images captured, an immediate and expected observation is made. The bit's geometry consistently changes over the life of the bit. Material is worn away on the wings, and the wing tips become rounded on both faces. For obvious reasons the driving face shows more wear than the opposite face. (Note that in the wearing process, screw were driven, but not removed.) The flute channel appears to round out as well.

This rounding is easily seen when comparing Fig. 4.9 and Fig. 4.10. These images are of a new bit (Fig. 4.9) and one that was driven to life with 618 screws (Fig. 4.10). Both of these images are taken from the plane after 30-thousands of material was removed.

Figure 4.9 New Bit, Sectioned to 30-Thousands

Figure 4.10 Fully Worn Bit, Sectioned to 30-Thousandths

Appendix B is a collection of the images from the 10-thousandth layer through the 60-thousandth. Observing these images it is clear that there is a pattern; the more screws a bit drives, the more the corners become rounded. The further away from the tip, the less wear is seen. Comparing the images from the 60/1000 and 10/1000 section clearly show this. The bit from 1/4 life is only slightly rounded, the bit from 1/2 is a bit more rounded and the full life bit has a large radius. How this wear pattern affects the surface mating is further explained in section 5.4.2.

4.6 How the Geometry Changes

It has been determined that bit geometry changes with wear, however these changes have not been quantified. The initial thought was that the geometry change resulted in decreasing inner and outer bit diameters over the life of the bits. However the inner and outer diameter measurements taken from the sectioned bits imply that there is little change in either of these dimensions over the bit's life. Figure 4.11 and 4.12 are graphical representations of the outer and inner radii for all four bits at each plane observed.

Figure 4.11 suggest that there is no significant variation in the outer radius of the bit over its life.

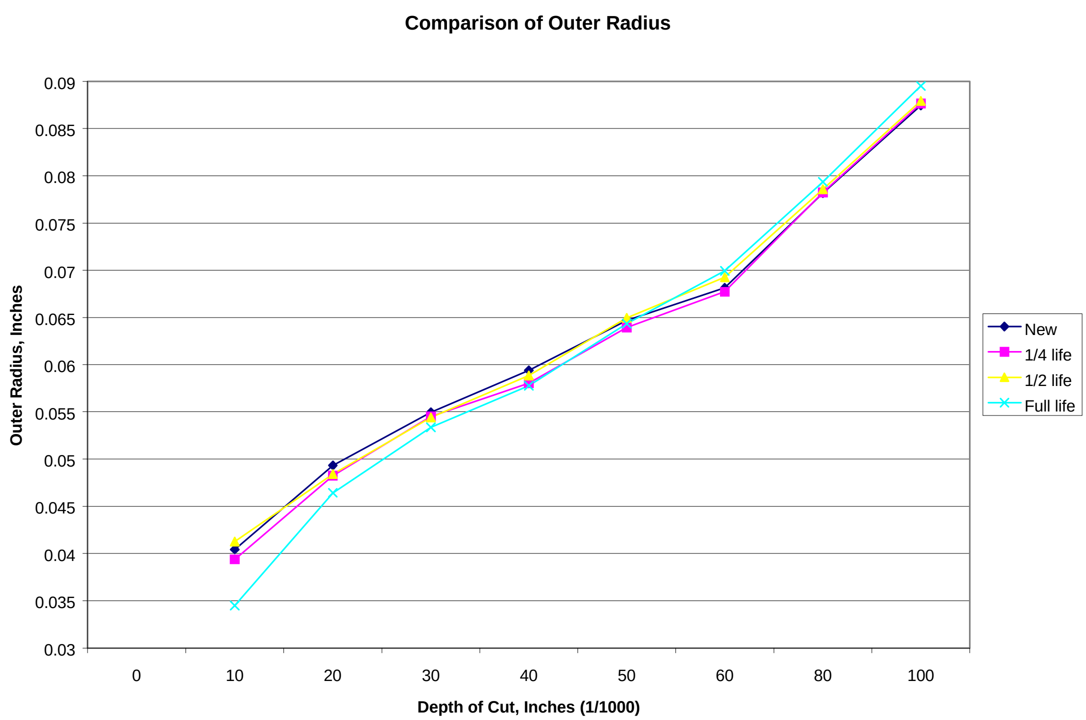

Figure 4.11 Comparison of Outer Radius

Figure 4.12 also suggests that there is no significant variation in the inner radius. Note the difference in scale between the two figures.

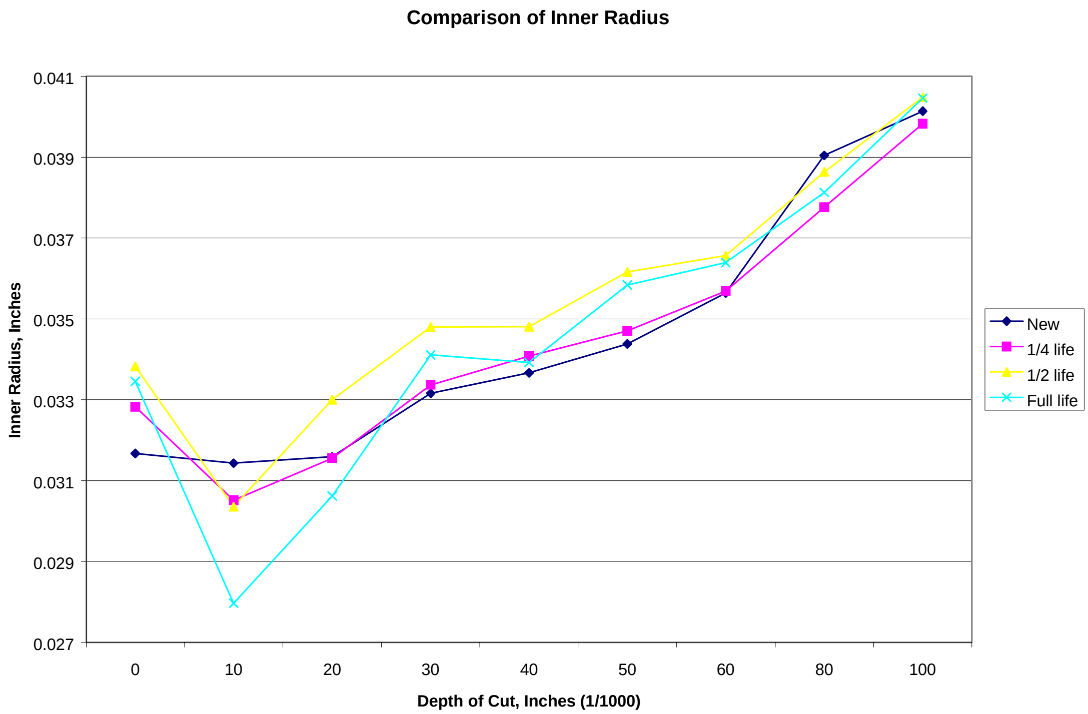

Figure 4.12 Comparison of Inner Radius

Figures 4.13 and 4.14 are comparisons of the average radius of curvature of the flute and wing tip. Both of these charts only represent the bits that were worn to 1/4, 1/2 and full life. The new bit was not included because, prior to wear, the flute and wing tips have nearly sharp corners that are difficult to measure. It also should be noted that the radii shown are average radii representing the four radii found in each section observed.

Figure 4.13 shows that there is, indeed, a tendency for the flute radius to increase over the life of the bit. Although there are some slight discrepancies in the data, it is clear that there is a trend.

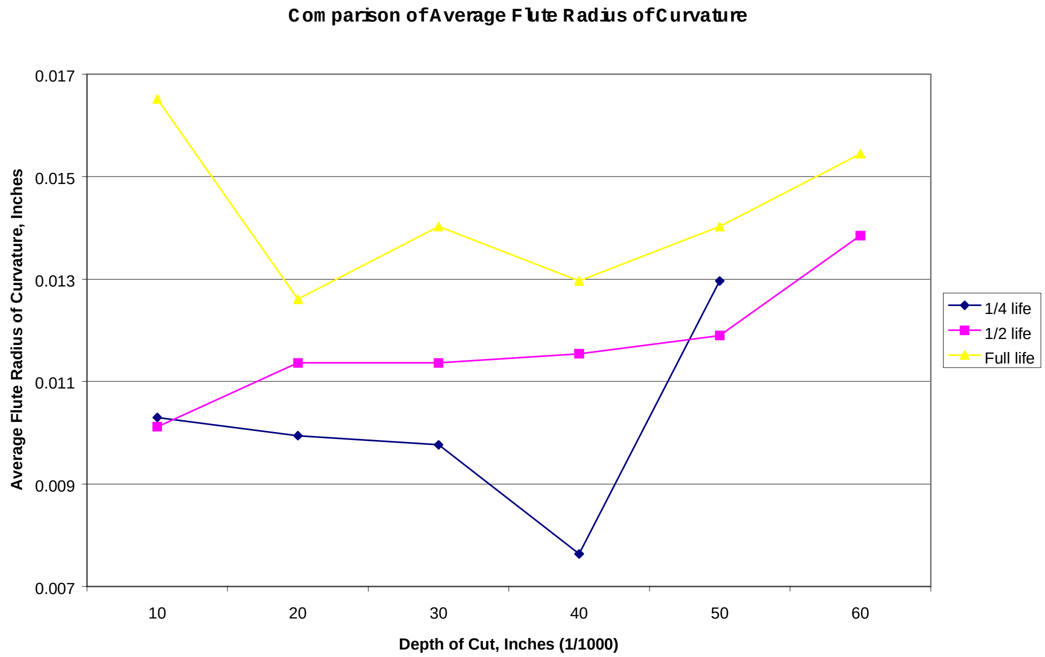

Figure 4.13 Comparison of Flute Radius

Figure 4.14 like the previous figure also shows a trend of the radius increasing.

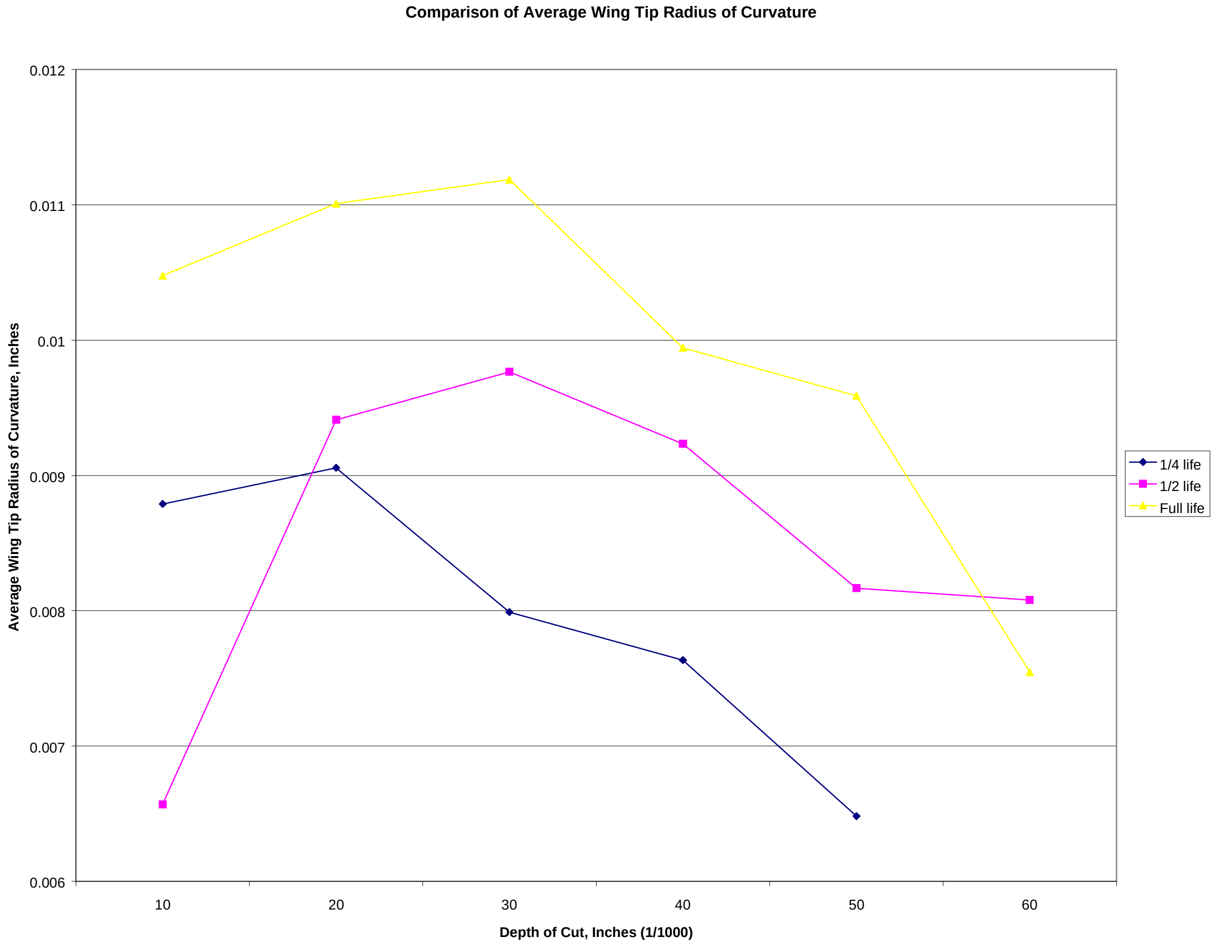

Figure 4.14 Comparison of Average Wing Tip Radius

The inconsistencies in both figures may be due to measurement errors or natural variation in manufactured bits.