Chapter 3
Old and New Test Machines

3.1 Motivation for New Rig

As mentioned in section 1.2, measuring fracture and bit torque transfer efficiency are concerns when evaluating a bit. Bit wear, however, is the dominant worry. The current screwdriver bit life test rig shown in Fig. 3.1, must drive up to 5000 screws to wear a bit to the end of its useful life. Most end users wear a bit to life driving as few as 500 screws. To accurately test the bits, a more realistic testing approach was needed.

Figure 3.1 Dixon Test Rig

3.2 Current Rig

The current bit life test rig from Fig. 3.1, was developed by Dixon Automatic Tool Inc. The rig is a partially automated system that simplifies a technician's job of driving screws. The rig automates both the tasks of feeding and driving of the screws, leaving the operator only to be concerned with triggering the drive cycle and indexing the work piece into which the screws are driven.

3.2.1 Components of Current Rig

The Dixon rig uses the vibrating bowl feeder, shown in Fig. 3.2, to sort and orient screws. This method of sorting uses vibration to move the parts along a path with a series of varying geometries.

Figure 3.2 Vibrating Bowl Feeder

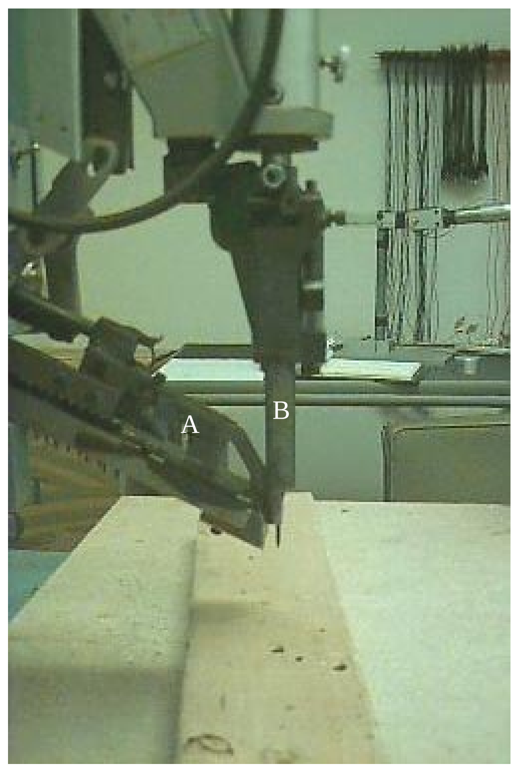


Figure 3.3 Feeding Mechanism and Driving Head

These geometries separate the screws from one another and eventually align them all in an identical orientation. The screws are held in a downward sloped pair of rails until the feeding mechanism (A), shown in Fig. 3.3, feeds the screws individually into the driving head (B). Once a screw is positioned into the driving head, the operator can actuate the machine with the foot switch and the driving head will drive the screw into the work piece. As the screw is being driven into the work piece the driving head separates, releasing the screw and allowing it to be fully driven into the work piece. Figure 3.4, shows the rig working during the drive stroke.

Figure 3.4 Stroke of Driving Head

Figure 3.5 Pneumatic Actuators

When the driver is traveling through the drive stroke, the feeding mechanism simultaneously grabs another screw and places it into the driving head. Once the drive stroke is complete, a new screw is already positioned in the drive head and ready for the operator to manually advance the work piece and actuate the machine to drive the next screw.

Pneumatic actuators, shown in Fig. 3.5, produce the force for the drive stroke and the torque to drive the screw. The pneumatic cylinder (C) shown toward the bottom of the picture produces the force and the air motor (D) shown at the top of the picture provides the torque.

The principle that governs pneumatic actuators is that the force produced is dependant on air pressure and the area of the actuator on which the air acts. The area of the force actuator does not change, so any variation in force must arise from fluctuations in air pressure. Therefore, assuming nearly constant supply pressure the force actuator provides nearly constant driving force.

3.3 Problems with Current Rig

The Dixon rig does a good job of partially automating the process of driving screws. Unfortunately that does not qualify it as an acceptable test rig for screwdriver bits. The Dixon rig was designed to drive screws efficiently, not to test screwdriver bits. The angular misalignment and force variations typical of a human user are absent in the Dixon rig. Absent as well are peculiarities of the power drivers, mainly torque variations and impacts resulting from the clutch. In order for a machine to test bits in a realistic way, that machine must reproduce the imperfect driving motion of a user.

It was also desired to fully automate the new test rig. The Dixon rig is a partially automated system, which makes testing easier for the technician but does not increase productivity. A fully automated rig will allow a technician to be significantly more productive by allowing a machine to perform the repetitive cycles independently. This would allow the technician to focus on data analysis and other tests.

3.4 User Emulation

The key to successfully designing a rig to test screwdriver bits is to emulate the forces and motions produced by a person using an actual power driver. Any test rig must have provisions for engaging the driver and screw and for supplying axial motion and driving torque. In addition, the new rig will be designed to vary the driving angle and force as well as using an actual power driver to supply torque.

3.4.1 Angular Displacement

It is clear that, in practical use, the bit and screw will not always stay in collinear alignment, meaning the angle (θ in Fig. 3.6) between the axis of the bit and the axis of the screw will vary from zero degrees.

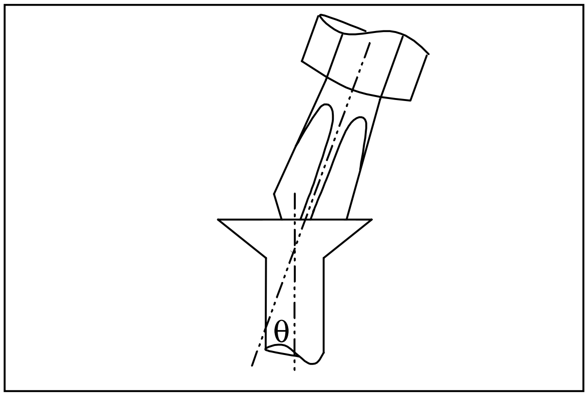


Figure 3.6 Bit/Screw Alignment

To determine the magnitude of this variation, a laser pointer was mounted to both a drywallgun and a cordless screwgun. The angular displacement of the driver and bit were measured by projecting the laser on a bull's eye target, where the center of the target marked perfect alignment and each ring of the target represented one degree of misalignment (Fig. 3.7).

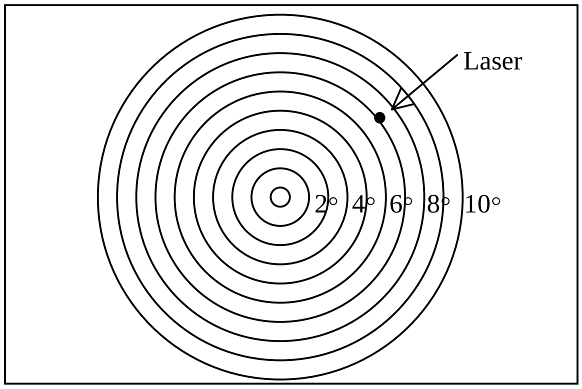


Figure 3.7 Bulls Eye Target for Laser

Figure 3.8 shows the basic setup of the test, where the driver bit is the center of rotation. Any variance from 0° of the angle θ (defined in Fig. 3.6) during a driving cycle can be observed by the movement of the laser projected on the target.

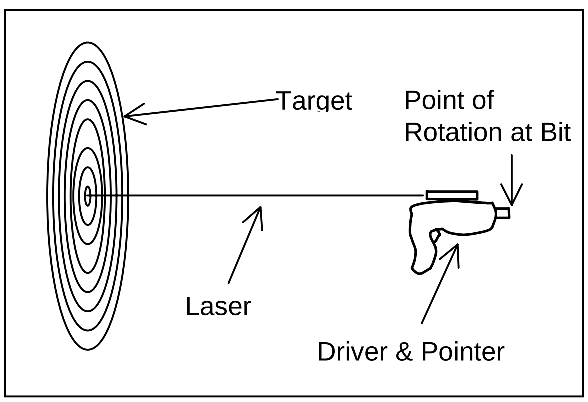


Figure 3.8 Angular Off-Set Test Setup

Twenty test cycles were run with two users and both a DeWalt Heavy Duty Drywall Screwdriver and a DeWalt 12 Volt Adjustable Clutch Cordless Driver/Drill. To analyze the data, the target was videotaped for each cycle. The tape was later reviewed in slow motion and the angular variation of the bit was recorded. The results of the test are tabulated in table 3.1. Recorded are the maximum variations of θ from zero for each cycle.

Table 3.1 Angular Misalignment Test Results
Average Maximum Misalignment: 6.4°
Absolute Maximum Misalignment: 10°

Cycle	User	Tool	Max. Angle
1	#7	Drywall	8°
2	#7	Drywall	-
3	#7	Drywall	8°
4	#7	Drywall	6°
5	#7	Drywall	10°
6	#7	Drywall	9°
7	#7	Drywall	4°
8	#7	Drywall	4°
9	#8	Cordless	-
10	#8	Cordless	7°

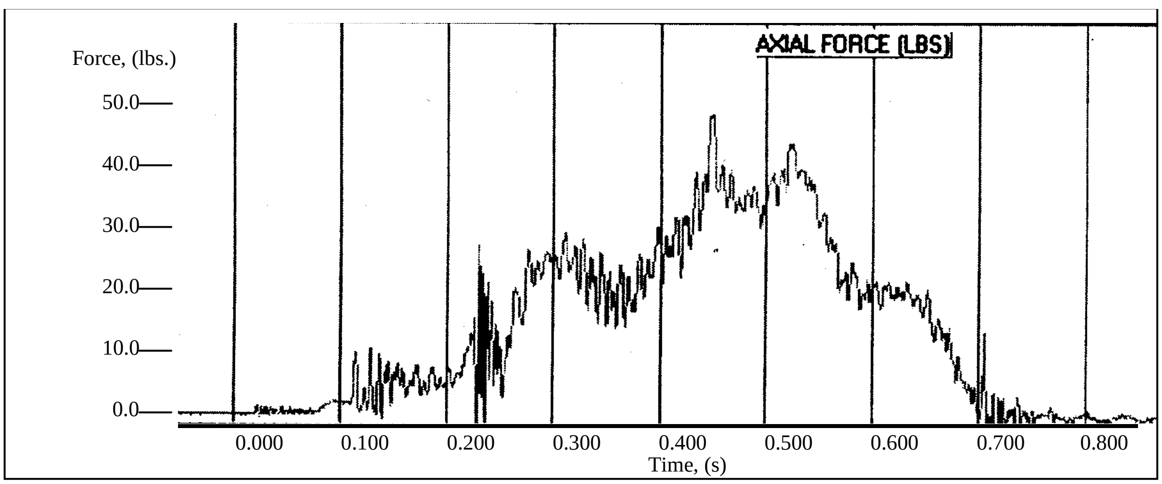
Cycle	User	Tool	Max. Angle
11	#8	Cordless	9°
12	#8	Cordless	7°
13	#8	Cordless	5°
14	#7	Cordless	5°
15	#7	Cordless	3°
16	#7	Cordless	9°
17	#7	Cordless	5°
18	#7	Cordless	4°
19	#7	Cordless	6°
20	#7	Cordless	6°

Test cycles 2 and 9 were inconclusive due to the user blocking the laser beam with their body. The other 18 cycles, however, did return useful information. The test cycles yielded an average maximum angle of 6.4° and an absolute maximum angle of 10°.

3.4.2 LINEAR FORCE VARIATION

Unlike the Dixon rig, an actual user does not drive a screw with constant force applied to the driver. With the assistance of our industrial partner's ergonomics lab, data pertaining to axial force of professional drywallers was obtained. The results both confirmed that the actual user's axial force was not constant and gave insight into the length of time users needed to drive a screw.

Figure 3.9 plots axial force of a user with respect to time. The plot shows that after 0.100 seconds axial force is applied. The force increases until the 0.450 - second mark where it peaks at approximately 48 lbs. and then drops and hits a secondary peak of approximately 43 lbs. The entire cycle concludes with the force decreasing to zero just short of the 0.750-second mark. Throughout the 0.650-second duration of the cycle the force is clearly not constant. In addition to the two clear peaks between the 0.4 and 0.6-second marks there are several additional minor peaks throughout both the ascent and decent of the axial force magnitude.



(User #3)

Figure 3.9 Axial Force on Driver during Drive Cycle

In entirety, data was collected for four professional drywallers. Peak axial driving force and driving cycle duration are listed below in table 3.2.

Table 3.2 Results of Axial Force Test

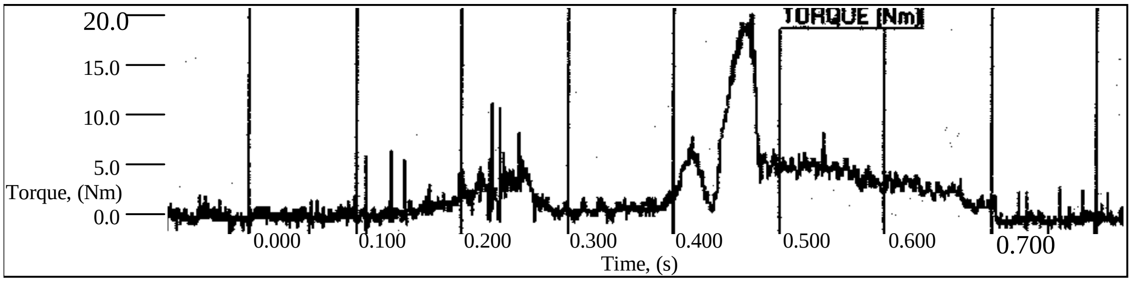
User	Peak Force (lbs.)	Duration of Cycle (seconds)
#3	48	0.650
#4	63	0.500
#5	75	0.300
#6	50	0.700

From Fig. 3.9 and table 3.2 several things are evident, one is that the force applied by a user will not be constant. Conclusions drawn by observing the four drywallers are that a driving cycle will take 0.3 to 0.7 seconds and the maximum force in a cycle will be 48 to 75 lbs. It appears that the shorter the cycle time, the greater peak force.

3.4.3 Using the Actual Power Drivers

Sections 3.4.1 and 3.4.2 focused on defining behavior of the user. In this section the focus is on the actual tool that the user is using to supply the power to drive the screw. We have assumed the Dixon's air motor provides near constant torque to drive screws. The power drivers, however, are driven by electric motors. The ergonomics lab also captured torque information from the same four professional drywallers mentioned section 3.4.2.

Figure 3.10 shows the torque provided by the motor is not constant. At the 0.100-second mark the cycle begins, immediately three spikes are seen. The torque fluctuates through the 0.400-second mark and immediately thereafter it hits two peaks and then slowly decreases as the cycle ends at the 0.750-mark.



(User #3)

Figure 3.10 Torque Provided by Motor during Drive Cycle

The drywall drivers also have a clutch coupling the electric motor and drive shaft, which the Dixon rig does not have. This clutch allows the users to continuously run the electric motor while permitting the drive shaft to turn only when the clutch is engaged through the driving process. The presence of this clutch is noteworthy because during its engaging and disengaging there are significant impact forces seen by the bit and screw. During the interval when the clutch is neither fully seated nor disengaged, the clutch skips transferring sudden torque spikes from the motor to the drive shaft and bit. Naturally the torque spikes seen by the bit will result in repeated impact of the bit into the screw. These impacts will occur at the bit’s driving surface, which after repeated exposure will change the bit's geometry at the point of contact.

3.5 New Rig

In conclusion to the findings of user emulation, incorporating angular variability, axial force variability and actual drivers on a test rig is critical to reproduce the wear that will occur in the field.

Figure 3.11 shows the concept for a new test rig.

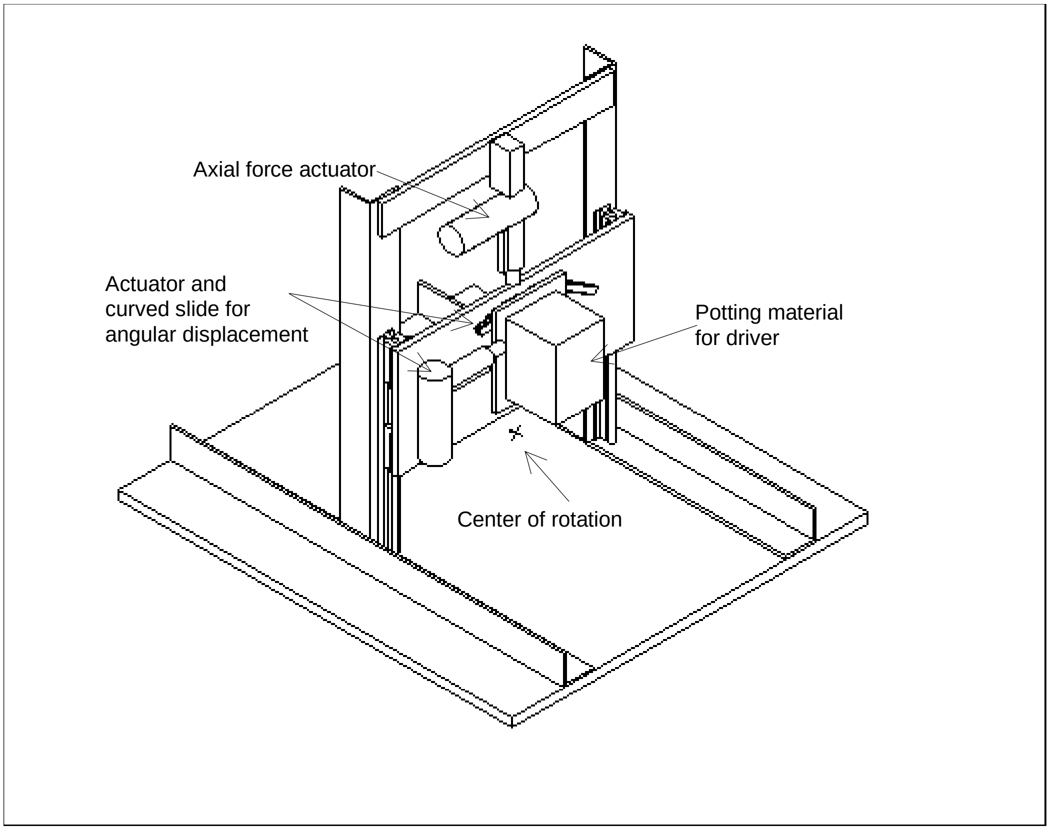


Figure 3.11 New Test Rig Concept

To reproduce the angular displacement discussed in section 3.4.1, a kinematic restraint governing the driver's angular motion and a method of actuating that motion is need. The curved slide shown in the figure restrains the motion so that rotation occurs about the point marked X. A linear actuator, which can move the driver through the varying angular misalignments, is shown. The actuator produce up to a 15° angular misalignment.

The figure also shows a linear actuator that provides the axial force to drive the screws. Section 3.4.2 concluded that the actuator would need to supply a significant amount of force in a very short period of time. The actuator would also need to vary force within that short time period. A linear motor is used to provide this axial force. The linear motor selected, has the capability to deliver

100 lbs. in 0.200 seconds. The motor also has excellent response time, which may allow the force to be varied within a cycle.

The rig will use actual power drivers to provide the torque need to drive the screws. Using the drivers on the test rig will allow the rig to better reproduce the wear that occurs in the bits. The drivers will be molded in a potting material similar to the arrangement shown in Fig. 3.12. Once the driver has been potted, the entire piece can be mounted onto the rig as shown in Fig. 3.11.

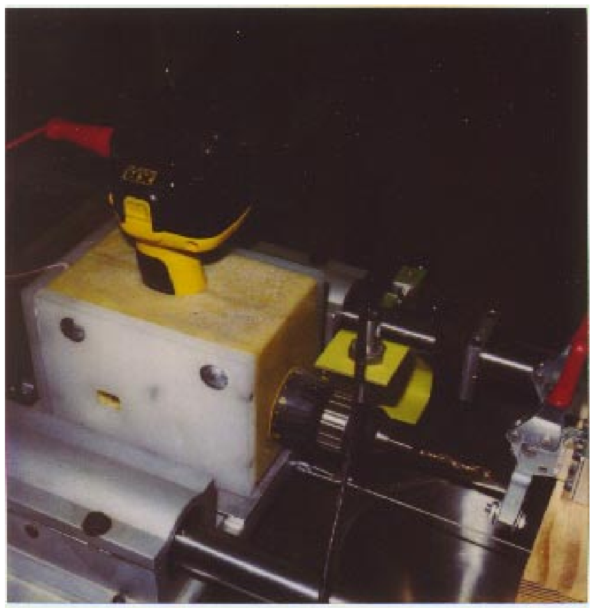


Figure 3.12 Potting Material and Driver

Appendix A is an overview of the new machine and its sub-systems.