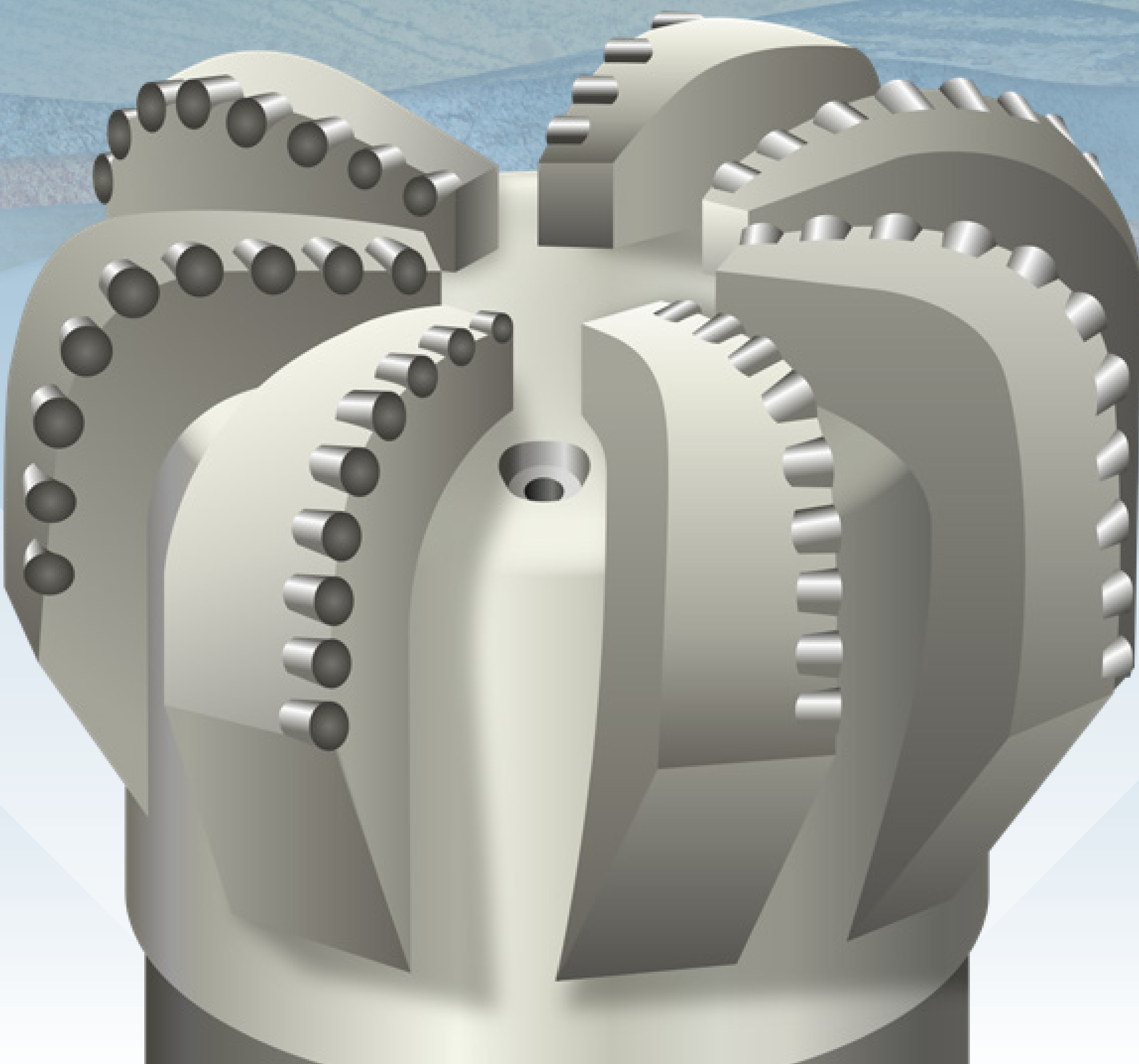
Pegasus Vertex, Inc.

Drilling Software | Sophisticated Yet Simple

Armed to the Teeth: Common Drill Bit Problems and Solutions

WHITE PAPER



CONTENTS

1. Introduction

A drill bit is a crucial drilling tool used to produce a wellbore in the earth's crust through the rotary drilling method. It is a drilling engineer's hope to complete a target section in a single trip, without tripping in and out, to replace the drill bit. However, critical issues such as teeth/bearing/cutter wear impact the entire drilling operation and can result in significant financial and time losses.

At the rig site, a drilling engineer typically faces the following challenges:

- Selecting a suitable drill bit for a particular well section
- Identifying the main factors that cause drill bit failures
- Performing accurate drill bit post-job analysis after a bit is pulled out of the hole

This white paper gives an overview of bit selection, a list of common drill bit issues, and solutions that help people understand bit performance.

2. Drill Bit Selection

Drill bits are classified into two main types: roller cone bits and fixed cutter bits. Roller cone bits drill by crushing the formation with tooth-shaped cutting elements on two or three cone-shaped components that roll across the bottom hole as the bit rotates. Fixed cutter bits use Polycrystalline Diamond Compact (PDC) cutters to shear rock with a continuous scraping motion.

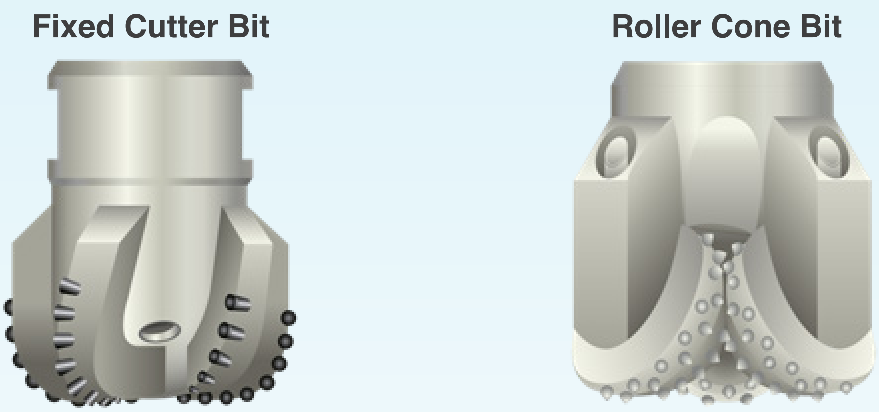


Figure 1: Comparison of Fixed Cutter Bit and Roller Cone Bit

Each drill bit has its own cutting mechanics for different formations.

	Roller Cone Bits		Fixed Cutter Bits	
Bit Type	Steel Tooth	TCI*	PDC**	Diamond
Formation	Soft to Hard	Soft to Very Hard	Soft to Hard	Very Hard
Cutting Actions	Crushing and Gouging	Chipping and Breaking	Shearing or Plowing	Grinding
Bit Size	2-7/8” to 36”		3-1/4” to 26”	

*TCI: Tungsten Carbide Insert
** PDC: Polycrystalline Diamond Compact

Proper bit selection is based on the study of logging data as well as the properties of each bit. The projected rate of penetration, as well as formation strength and hardness, are the primary considerations. Drilling software also assists in the selection of a suitable drill bit.

3. Drill Bit Common Problems and Solutions

Roller cone bits were once trendy due to their low cost and effectiveness in a wide range of formations. However, as unconventional wells became increasingly common, driven by new technological developments, as well as economic considerations, and at greater depths, the rocks encountered tend to be harder; the invention of the PDC cutter propelled the fixed cutter bits to the forefront of the drilling industry. In this paper, we will primarily examine the performance of the PDC bit.

Drill bits are routinely tripped out of the hole, inspected, and evaluated to determine their usability for land and offshore drilling operations. This information enhances the bit design, product operating efficiency, and future bit selection. International Association of Drilling Contractors (IADC) established an eight-point dull grading system to enable drillers and bit manufacturers to evaluate the performance of a drill bit.

IADC Bit Dull Grading Code

Cutting Structure				B	G	Remarks	
Inner Rows	Outer Rows	Dull Char.	Location	Bearings/Seals	Gauge 1/16”	Other Char.	Reason Pulled

Fixed Cutter Bits

BF — Bond Failure
BT — Broken Cutters
BU — Balled Up
CT — Chipped Cutters
ER — Erosion
HC — Heat Checking
JD — Junk Damage
LN — Lost Nozzle
LT — Lost Cutter
NR — Not Rerunable
PN — Plugged Nozzle
RG — Rounded Gauge
RO — Rong Out
RR — Rerunable
SS — Self Sharpening Wear
TR — Tracking
WO — Washed Out Bit
WT — Worn Cutters
NO — No Dull Characteristics

Roller Cone Bits

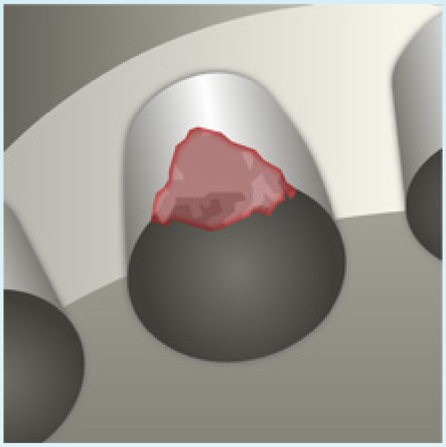
BC — Broken Cone
BF — Bond Failure
BT — Broken Teeth/Cutters
BU — Balled Up Bit
CC — Cracked Cone
CD — Cone Dragged
CI — Cone Interference
CR — Cored
CT — Chipped Teeth/Cutters
ER — Erosion
FC — Flat Crested Wear
HC — Heat Checking
JD — Junk Damage
LC — Lost Cone
LN — Lost Nozzle
LT — Lost Teeth/Cutters
OC — Off-Center Wear
PB — Pinched Bit
PN — Plugged Nozzle/Flow Passage
RG — Rounded Gauge
RO — Ring Out
SD — Shirttail Damage
SS — Self Sharpening Wear
TR — Tracking
WO — Washed Out Bit
WT — Worn Teeth/Cutters
NO — No Dull Characteristics

Table 1: IADC Guidelines for Dull Drill Bit Features

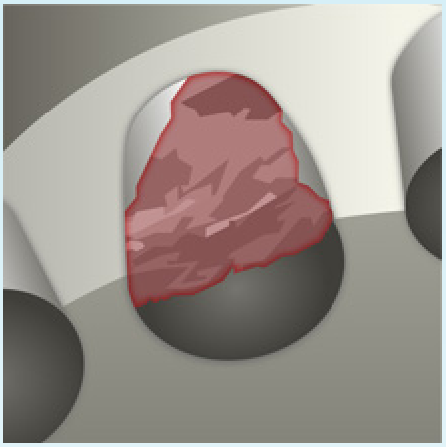
3.1 The Side-Force and Dynamic Impact on the Gauge Cutters

In drilling operations, gauge cutter wear is quite prevalent. Broken teeth (BT) and chipped teeth (CT) are often indicators of the cutter's worn condition. During drilling operations, components of the bottom hole assembly (BHA) are subjected to a combination of lateral and circumferential loads (Stick-Slip), resulting in numerous lateral impact loads on the drill bits. In drilling operations, side force and dynamic impact on gauge cutters (those on the side of the bit to keep the hole with the correct ID) are common. Teeth wear on gauge cutters is classified into two types of wear: chipped teeth (CT) and broken teeth (BT).

Problem 1: Teeth Wear — Chipped Teeth (CT) and Broken Teeth (BT)



CT - Chipped Teeth
Less than 1/3 of Cutting Element Lost



BT - Broken Teeth
More than 1/3 of Cutting Element Lost

Figures 2 and 3: Comparison Between a Chipped Teeth and Broken Teeth

We can use high abrasive and anti-concussion cutters to lessen the drill bit CT or BT. However, adjusting BHA to reduce the side force or lateral impact loads on bits is a more practical approach. As a result, prior to running BHA down the hole, calculation under complex downhole conditions is recommended for stressors on BHA components.

If a bit failure occurs, and the bit can be pulled out of the hole, a post-job analysis can determine the cause of the BT and CT. Pegasus Vertex, Inc. (PVI)'s [BHA Mechanics Software (BHAPRO)] calculates contact points of BHA components on the wellbore wall, as well as crucial rotational speed, to avoid harmful vibration frequencies. Users can use BHAPRO to optimize BHA design, enhance BHA perfor-mance, and reduce the risks of drill bit failure.

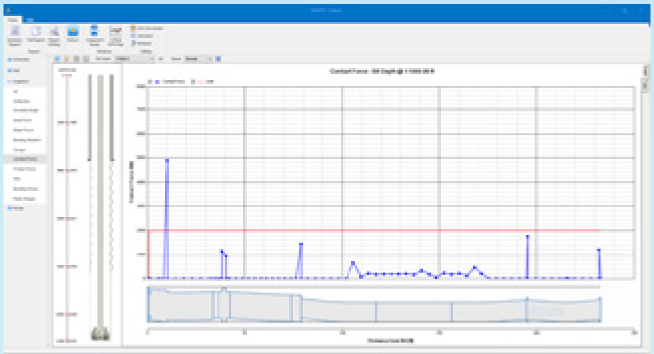


Figure 4: BHA Contact Force

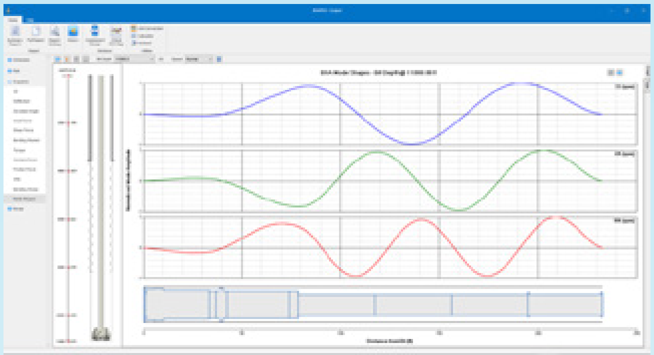


Figure 5: BHA Mode Shapes

In addition, the following also cause CT:

- Too high WOB
- Low-quality cutters
- Unsuitable bit structure
- Uneven oscillation during drilling in the cracked or interbedded formation

3.2 Drilling Hydraulics on Drill Bit

During drilling operations, a drilling fluid transports hydraulic energy from rig pumps to the drill bit as it circulates through pipes from the mud tank to the bottom of the hole and then back to the surface. Many drill bit problems are the result of poorly designed hydraulics.

Problem 2: Bit Balled Up (BU)

BU occurs while drilling soft, sticky formations with water-based mud (WBM). Swollen and sticky cuttings can adhere to the bit, clogging up waterways, junk slots, individual blades, and possibly the entire bit.

Severe balling results in the cutting structure clogging up, severely reducing the penetration rate. It results in less rotary torque and more stand pipe pressure (SPP). In addition, a reduction in the amount of cuttings transported from the bit and annulus to the surface happens.

When bit balling occurs, experts recommend the following steps:

- Increase the flow rate to the maximum for at least 5 minutes. High flow rates provide better bit cleaning through greater hydraulic energy at the bit. However, high flow rates can cause formation damage, especially in highly fractured formations. As a result, excessive flow rates must be avoided. (Pay attention to the equivalent circulating density [ECD] to keep the formation safe).
- Lift and drop the string rapidly to ‘shake’ the compacted material off. Make sure not to surge the hole and break down the formation. This may result in dropping the bit on the bottom and damaging the cutting structure.

- Spin the bit as fast as possible to ‘fling’ the compacted material off.
- Pump a pill (e.g., Nut Plug) to wash the compacted material off.

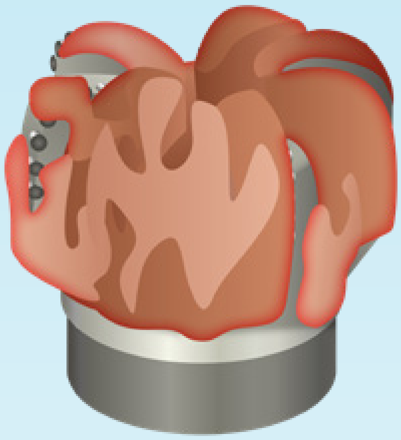


Figure 6: Balled Up (BU)

Problem 3: Bit Erosion (ER)

ER is a result of poor hydraulics design with high-velocity mud and entrained cuttings or high solid content.

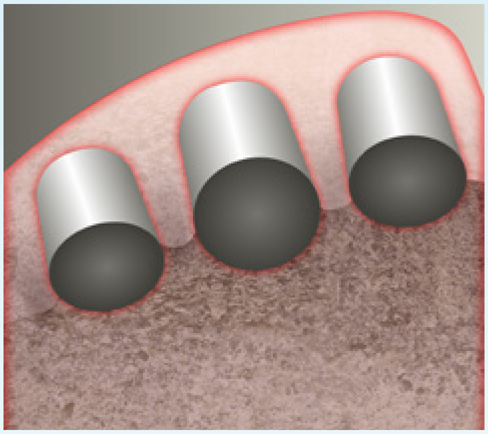


Figure 7: Erosion (ER)

Problem 4: Plugged Nozzle (PN)

PN results in increased SPP. To solve the problem, increase the flow rate or quickly lift and lower the drilling strings.

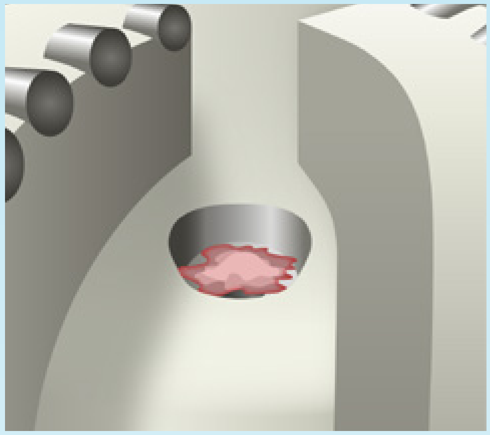


Figure 8: Plugged Nozzle (PN)

Accurate modeling of downhole hydraulics can identify and prevent potential problems, including drill bit failure, prior to field execution. The [Drilling Hydraulics Software (HYDPRO)] from PVI is a comprehensive drilling hydraulics model that covers all aspects of hydraulics, including; downhole circulating pressures, surge and swab, ECD, bit optimization, hole cleaning, and volumetric displacements.

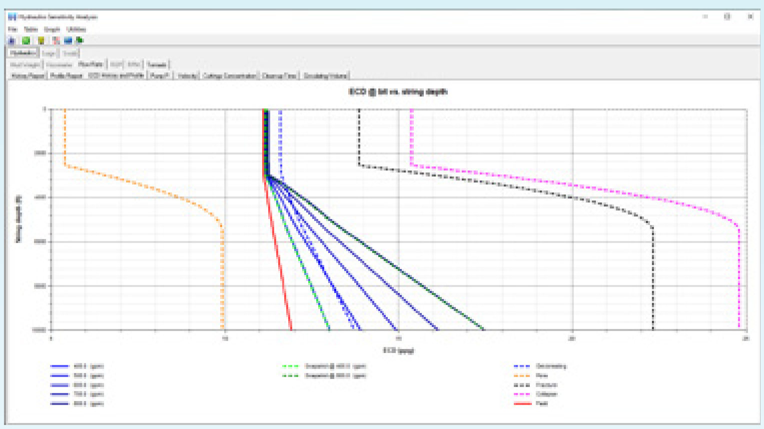


Figure 9: Hydraulics Sensitivity Analysis

Drilling hydraulics can be optimized using two criteria: hydraulic horsepower and jet impact force.

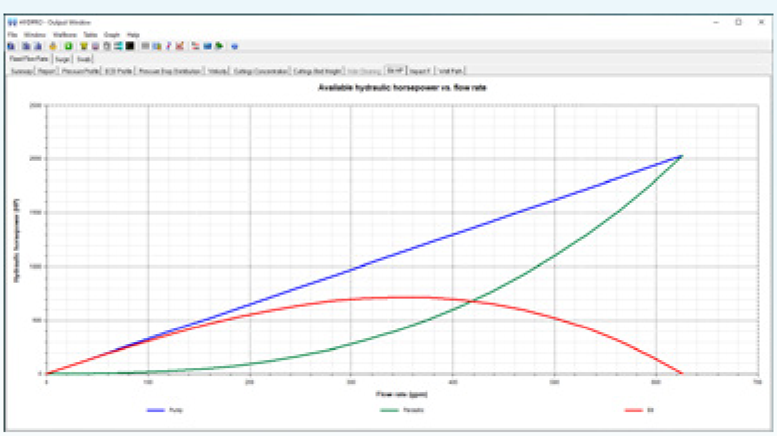


Figure 10: Hydraulic Horsepower

3.3 Drill Bit Problems Related to Drilling Parameters

Drilling parameters include weight on bit (WOB), torque on bit (TOB), rotation per minute (RPM), flow rates, etc. In general, weight should be applied so that the cutting structure maintains a substantial cutter depth that supports the bit and reliably cuts the formation. Torque varies when the bit digs in and out of formation beds with varying rock strength. In most circumstances, a high RPM leads to a high rate of penetration (ROP). However, rotational speeds need to be controlled to avoid slip-stick and other destructive vibrations of BHA, which can occur with decreased WOB and increased RPM.

Here are some of the common drill bit problems and their causes associated with drilling parameters:

Problem 5: Ring Out (RO)

The following cause RO:

- Too high RPM
- Worn cutters
- Hard formation

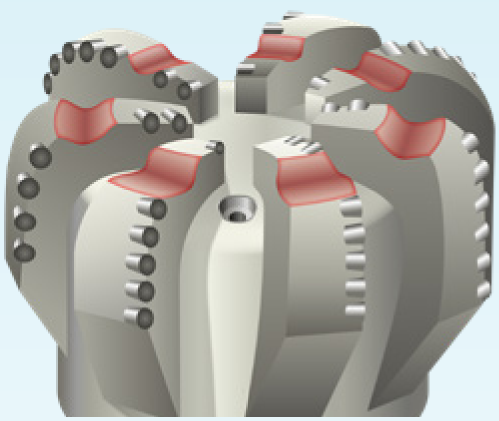


Figure 11: Ring Out (RO)

Problem 6: Lost Cutters (LT)

The following cause LT:

- Too high WOB
- Manufacturing default
- Poor bit design and cutter arrangement

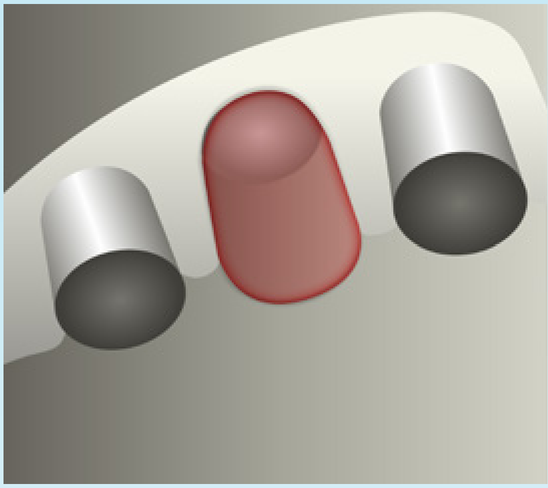


Figure 12: Lost Cutters (LT)

We can read surface torque and hook loads from the rig floor, but we usually cannot measure the downhole torque and drag along the pipes. What are the relationships among surface torque, hook load, TOB, and WOB? Drilling software such as TADPRO (PVI's torque and drag model) will enable you to see the invisible, and obtain a complete picture of the drilling string and drill bit.

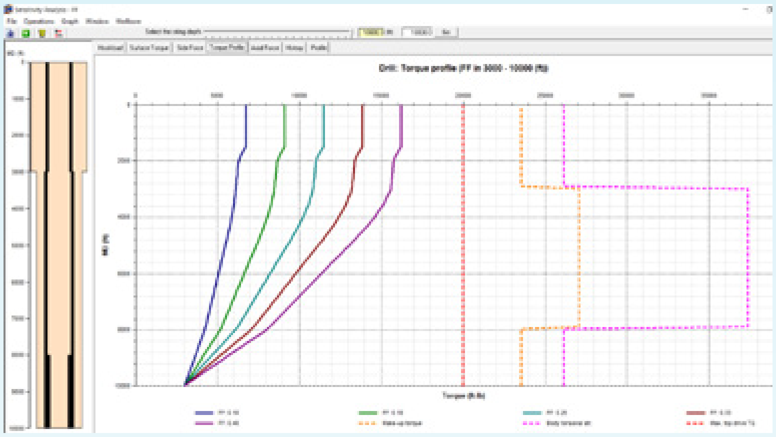


Figure 13: Friction Factor Sensitivity Analysis

4. Conclusion

Due to the high daily cost of drilling operations, drilling engineers do their best to avoid pulling a bit out of a hole unless necessary. Fit-for-purpose software models will assist drilling engineers in anticipating and resolving bit issues before tripping a bit into the hole.

For more information on software models, please contact PVI at:
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