Diminished Drillpipe Capacity Due to Slip Crushing

Drilling Engineering Association (DEA)
A Research Operations Forum
What We Know

- Reaching (Exceeding?) Limits
  - Materials
  - Equipment
DRILLING PROGRESS

Why does drill pipe fail in the slip area?

Proper pipe handling methods and understanding “crushing force” between pipe and slips can reduce drill pipe failures in the slip area.

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As drilling depths continually increase and hydraulic efficiency demands the use of 4½-inch or 5-inch O.D. drill pipe down to completion depth, greater hook loads encountered are drawing attention to drill pipe failures occurring in the slip area.

An analysis of these failures has revealed that they are caused by several factors and that in all cases such failures can be classified and minimized by use of proper equipment and handling techniques.

The following conclusions about drill pipe failures and theoretical calculations have been made:

1. Drill pipe failures in the slip area are caused by:
   - Highly concentrated stresses originating from axial and transverse loads that are not equally distributed over the full gripping surface of the slips.

2. Improper handling methods which result in abnormal marking and stressing in the slip area.
   - Drill pipe failures in the slip area can be prevented by maintaining rotary master bushings and slips to meet API specifications and by good handling techniques.
   - Transverse loading varies inversely with the coefficient of friction between the contact area of the slips and master bushings (see Figure 1). Therefore, it would be good practice to maintain a dry condition between slips and master bushings for optimum friction and minimum lateral loading.
   - Maximum axial and transverse loads do not act at the same cross section in the slip area. The critical section occurs at the area of maximum crushing pressure, and at this point the axial load is less than the hook load (see Figure 2).
   - Therefore, the calculated axial load versus the transverse load factor must always be considered when designing a drilling string where excessive hook loads are expected. As can be seen in the curve in Figure 3, it is vitally important to understand that the presence of transverse loading diminishes the total load, in pure tension, necessary to start yielding. Therefore, minimum properties based on tension yield only are not sufficient in the determination of adequate strength factors for drilling strings.
   - Oil and gas wells can be drilled successfully with 4½-inch, 16.6 pound per foot, Grade E drill pipe approaching hook loads somewhat greater than 200,000 pounds. Provided rotary slips and master bushings are maintained to API specifications and good handling techniques are used. When drilling conditions indicate axial loads approaching and in excess of 300,000 pounds, 4½-inch, 20.0 pounds per foot, Grade E drill pipe should be used above the conventional string.

Transverse loadings and crushing forces between the drill pipe and rotary slips, is generally overlooked. The transverse load, created by rotary slips working in combination with the master bushing, is always greater than the total vertical or hook load. This transverse load acts as a compressive force on drill pipe and, given adverse conditions of equipment or handling techniques, bottlenecking or crushing will occur.

FIGURE 1—Plot of $W$ vs. $h$ for an API taper.
Hydraulic Slips

- Hydraulic Controlled Slips
Conventional Slips

- Conventional Drop in 3 Man Slips
- Modified to enhance integrity at high loads
Strain Gage Placement

- Strain Gages Placed at Critical Load/Stress Points on Modified Conventional Slips
Wedding Cake

- ID Measuring System
- 3 sensors at 120° phase separation
1.6 MM Pound Load Frame

- Sample Loaded in Load Frame
Results

- Dimensional Locations
- Strain Gage Locations
- Evaluate Shape and Diameters Before and After Testing
Results

- Slip Die Bite Marks at Toe of Slips
## Landing Strings

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New 6 5/8 Drillpipe

- Hexagonal ID
- Mill Process
Neck down of OD

- OD Deformation
- Midway up the toe of the slips
Neckdown of Drillpipe

- As Weight is Hung Off Plastic Deformation Occurs
Change in Internal Diameter by Load Cycle

% Change in ID

Load Cycle Maximum (kips)
Cumulative Change in Internal Diameter

% Change in ID

Load (kips)

DRIFT
What We Think

- This problem should not be ignored.
- If the string needs to be held for a length of time, plastic deformation will cause the drillpipe to neckdown just below the slips.
- The reduction in area will eventually weaken the drillpipe causing the pipe to part just below the slips.
What Needs to be Done

- Comprehensive Studies to Better Define
  - Material Degradation
  - Material Limits
  - Equipment Operating Limits
- Test validity of Spiri-Reinhold Equation
- Possible solutions
  - Mitigate Risks
  - Improve Cost Effectiveness
How?

- Develop a study protocol that does not have the objective of qualifying a product
- Strain Gage OD and ID of Drill Pipe
  - ID Problematic
    - Precise, Repetitive, and Accurate Placement
      - Technically Difficult
Establish Control Values

- Limit Scope
  - Limit variables
  - Establish baseline values
- Determine generic damage to drill pipe
Limit Initial Study
6-12 Months

- 1 pipe vendor
  - Before tool joint
    - 10 foot lengths
      - 5"
      - 5 ½"
      - 6 5/8"
2 Slip Styles
- Narrow Column Inserts
- Wide Column Inserts
- New Solid Bowl inside new bushing
  - Establish control values
  - Split bowls more popular
    - Less consistent
    - More variance
Future Efforts – Phase II

- Determine correlation between laboratory conditions vs rig conditions
Future Efforts – Phase III

- 1 Drill Pipe vs Split Bowl vs Bushing
  - Split Bowl vs Bushing Condition Matrix
    - New x New
    - New x Mid API Spec
    - New x Max API Spec
    - Mid API Spec x New
    - Max API Spec x New
    - Mid API Spec x Mid API Spec
    - Mid API Spec x Max API Spec
    - Etc.
Future Efforts – Phase IV

- Establish Realistic Range
  - Coefficient of Friction
    - Water Base Mud vs Oil Base Mud
      - Insert Die and Slip Body
      - Slip Body and Bowl

- Define Critical Damage to Drill Pipe
  - Inspection Criteria

- Effect of Instantaneous Loading
## Projected Cost – Phase I

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<th>Item</th>
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Safe and Trouble-free Operations