

DOWNHOLE VIBRATION MONITORING & CONTROL SYSTEM QUARTERLY PROGRESS REPORT #8

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ABSTRACT

The objective of this program is to develop a system to both monitor the vibration of a bottomhole assembly, and to adjust the properties of an active damper in response to these measured vibrations. Phase I of this program, which entailed modeling and design of the necessary subsystems and design, manufacture and test of a full laboratory prototype, was completed on May 31, 2004.

Phase II began on June 1, and the first month's effort were reported in the seventh quarterly report on the project.¹ The principal objectives of Phase II are: more extensive laboratory testing, including the evaluation of different feedback algorithms for control of the damper; design and manufacture of a field prototype system; and, testing of the field prototype in drilling laboratories and test wells.

The redesign and upgrade of the laboratory prototype was completed on schedule during this period, and assembly was complete at the end of this period. Testing will begin during the first week of October. This aspect of the project is thus approximately six weeks behind schedule. Design of the field prototype is progressing per schedule.

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Executive Summary

The objective of this program is to develop a system to both monitor the vibration of a bottomhole assembly, and to adjust the properties of an active damper in response to these measured vibrations. Phase I of this program, which entailed modeling and design of the necessary subsystems and design, manufacture and test of a full laboratory prototype, was completed on May 31, 2004.

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Design

Redesign of laboratory prototype

Complete. The laboratory prototype redesign was completed during this period. Among the features that were changed or added are the following:

- The Belleville springs were replaced with weaker one to enable a more extensive range of motion of the tamper under the ~10 klbs. WOB that can be applied by the test bed.
- A load cell was added to the end plate that represents the bit. This will enable measurement of the force being applied by the cam, rather than merely noting whether or not the 'bit' was bouncing off bottom.
- The electronics of the test system were upgraded to improve data acquisition and permit application of closed loop feedback.

Design of feedback system

The laboratory results of Phase I were analyzed to determine which particular feedback algorithms, and which input data, were likely to result in the most efficient control of the AVD. Two algorithms were identified for further study using the laboratory prototype:

- 'Minimum WOB variation.' In this algorithm, the relative motion of the two halves of the AVD is used as a proxy for the approximate WOB. The algorithm minimizes the change in AVD motion, thereby keeping WOB constant. A memo describing this algorithm and its implementation is attached as **Appendix A**.
- 'Hardening algorithm.' The first algorithm may have some difficulties near the extremes of motion. Under certain conditions, it might cause the AVD to 'lock up'

and effectively remove all damping from the system. To remedy this possible problem, a 'hardening algorithm' was developed, which uses a quadratic factor, also based on the relative motion of the AVD. This approach is described in **Appendix B**.

Both algorithms were installed in the test apparatus software for evaluation. In addition, a simple power sweep driver was installed, which will reproduce the Phase I testing in an automated manner. It is planned to use this sweep first to verify the performance of the AVD, and then apply the feedback.

Field prototype design

The design of the field prototype is progressing on schedule. Among the areas added or changed in the design are:

- Addition of a battery-powered, self-contained unit to record accelerations at the bit. (This is for evaluation purposes, and will likely not be a part of the commercial tool.)
- Addition of a battery to the AVD to preserve the absolute position when the tool is powered down.
- Elimination of the WOB sensor, as we will use the absolute deflection of the AVD as a proxy for this measurement.
- Development of a connector to transfer power and data between the turbine-alternator unit and the AVD sub.

Experimental

Retesting of DVMCS prototype

Assembly of the revised prototyped was completed at the end of September, approximately six weeks behind schedule; testing is now scheduled to begin during the first week of October. A revised test plan, which compares the different feedback algorithms, has been prepared.

Units

To be consistent with standard oilfield practice, English units have been used in this report. The conversion factors into SI units are given below.

1 ft.	=	0.30480 m
1 g	=	9.82 m/s
1 in.	=	0.02540 m
1 klb.	=	4448.2 N
1 lb.	=	4.4482 N
1 rpm	=	0.01667 Hz
1 psi	=	6984.76 Pa

References

¹ Downhole Vibration Monitoring & Control System: Quarterly Technical Report #7," Report 41664R07, September, 2004

Appendix A: Minimum WOB Variation



TECHNOLOGY

MEMORANDUM

TO: Marty, Dan, Bill, Doug, Carl
FROM: Mark Wassell
DATE: August 17, 2004
SUBJECT: AVD Sensor Algorithm
CC:

Scope

I ran through a number of analyses to get some data for the AVD sensor algorithm. These analyses look at the vibration data that can be easily measure during operation downhole.

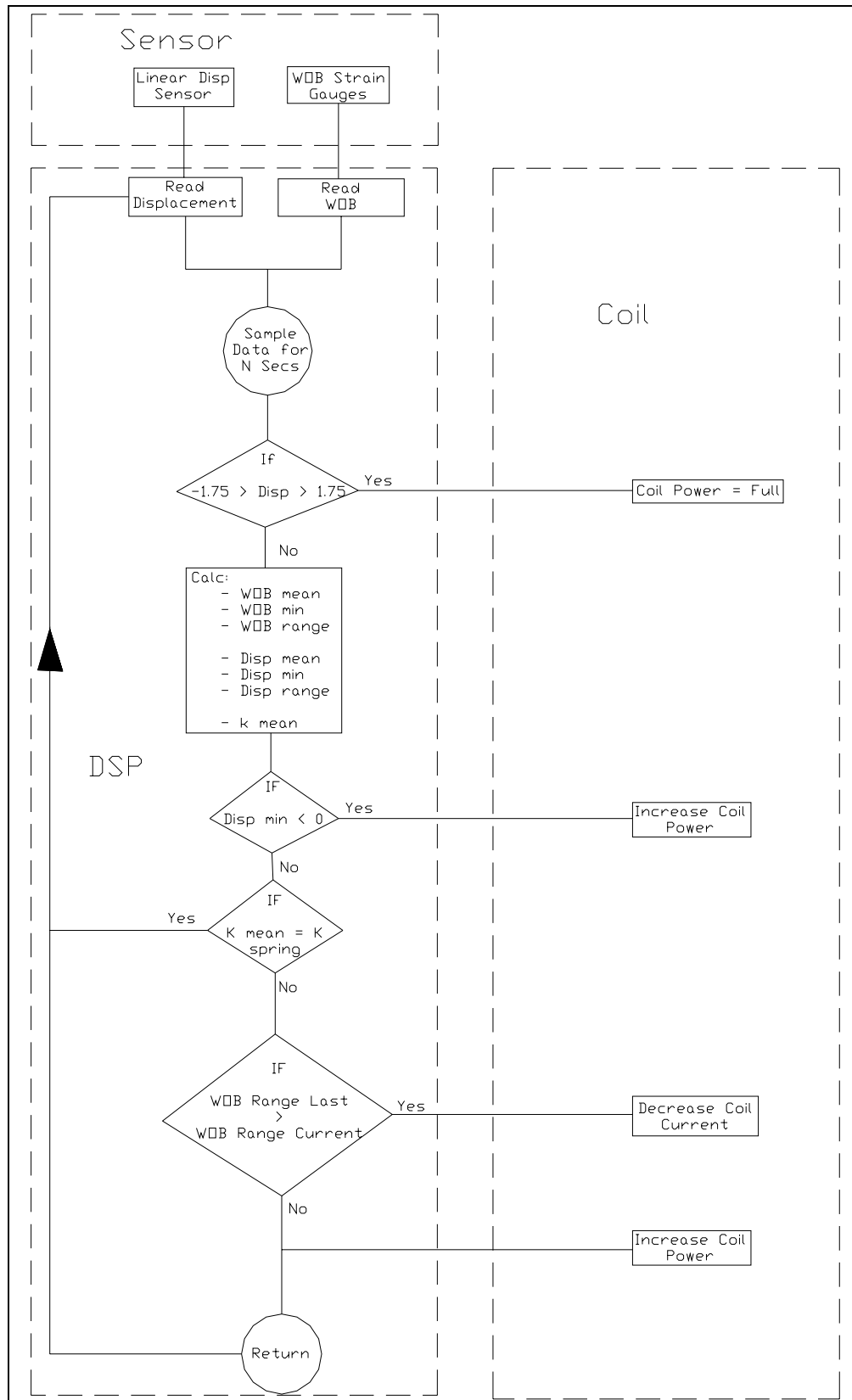
Summary

1. It is easy to determine whether the system damping is optimal because the WOB range and the displacement range are minimized. However, when the system does not have optimum damping it is difficult to determine whether there is too much or too little damping.
2. This method uses the absolute linear displacement between the upper and lower housings and the fluctuating WOB to determine whether the damping needs to be adjusted.
3. The WOB measurement needs only to be a relative measurement and therefore does not require the accuracy of the typical WOB tool. Drift, pressure and temperature effects do not need to be included into the measurement, only the range and the average need to be measured.
4. The linear displacement sensor must measure absolute position for this method.
5. One indication that the damping is optimized is that the WOB range is minimal. However, the high the applied weight on bit the greater the WOB range. Therefore without knowing the desired or actual WOB it is difficult to tell whether the system has been optimized.
6. The analysis also shows that when the dynamic spring rate of the system equals the static spring rate the system has been optimized. In general if the dynamic spring rate is greater than the static spring rate, then damping level is to low. If

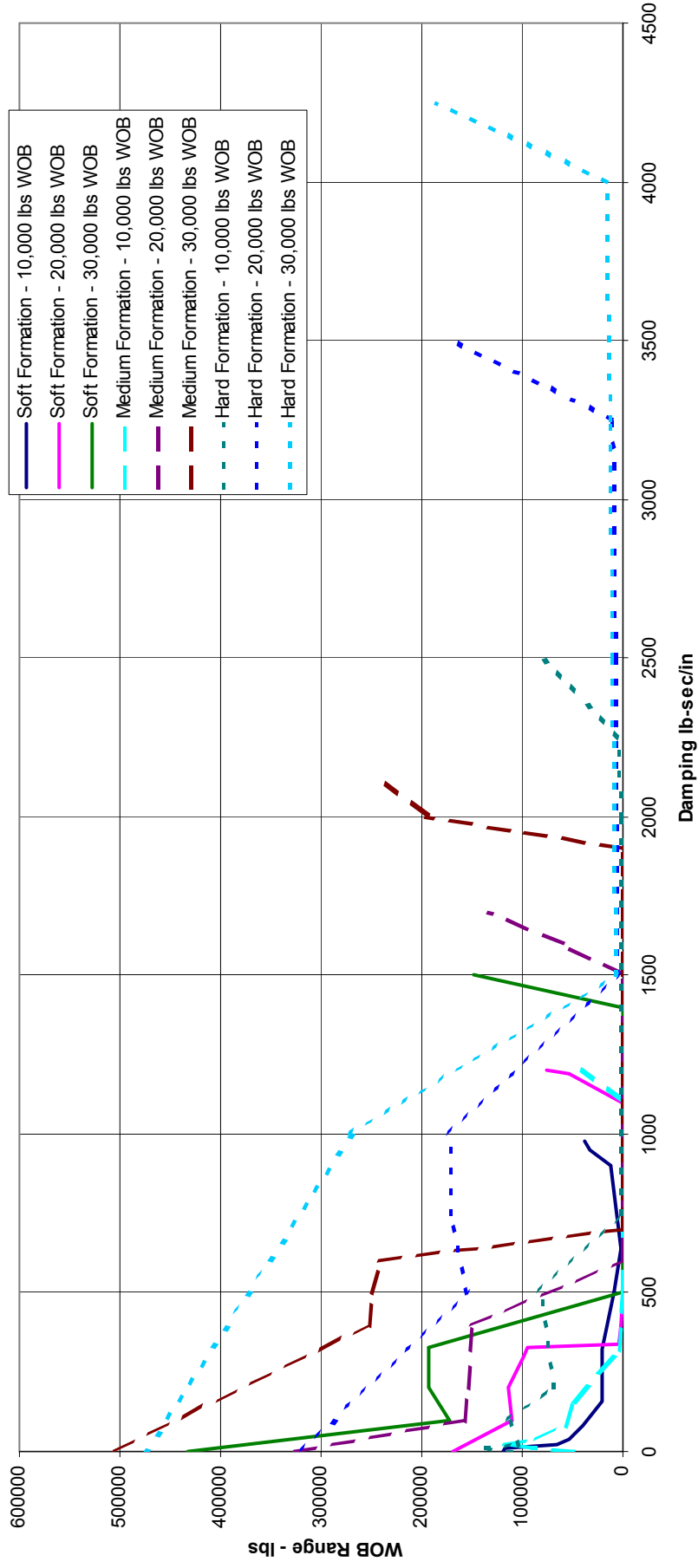
the dynamic spring rate is less than the static spring rate then the damping is too high.

7. If the minimum displacement is negative then the damping level is too low. However, for high WOB the minimum displacement is positive. Therefore this is only useful at low WOB.

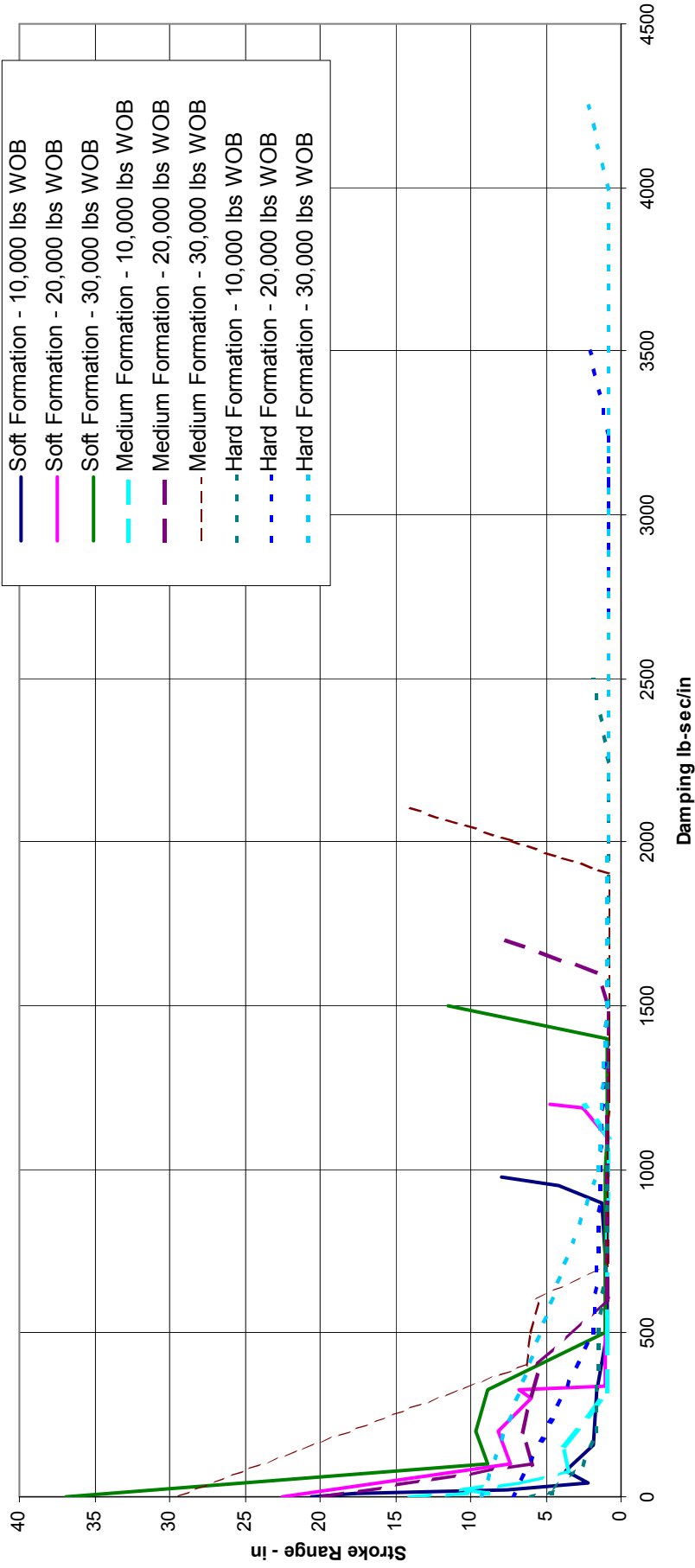
Figure 1 - Damping Control Schematic



6 3/4 AVD WOB Range Variation



6 3/4 AVD Stroke Range



Appendix B: Hardening Algorithm

AVD – Hardening Damper Scheme

Scope

This scheme uses the relative position of the AVD inner housing to the outer housing to set the MR damping. Analysis shows that the greater the travel of the damper the higher the required damping level. Analysis shows that lighter WOB requires less damping than higher WOB. The analysis also shows that the greater the stroke the greater the required damping. The analysis below shows that this concept works for varying amounts of WOB and ROP.

Analysis

The hardening equation:

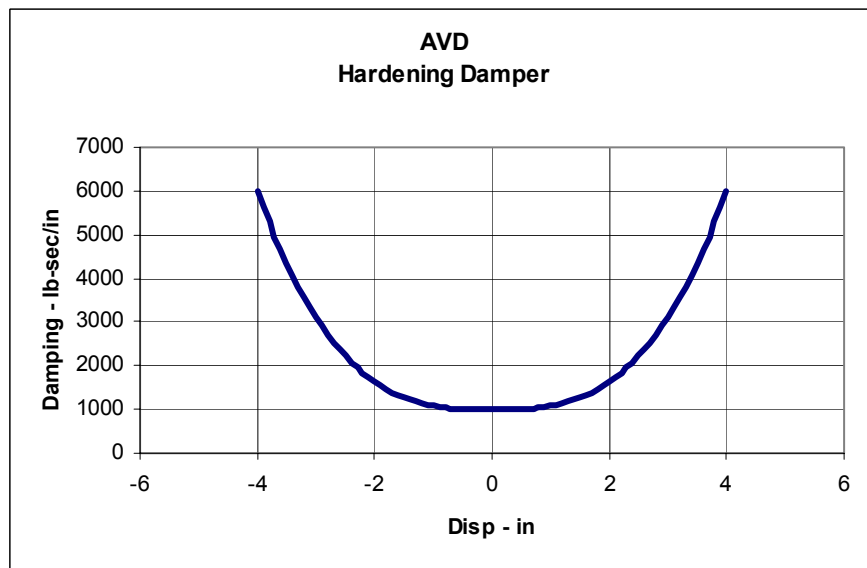
$$c = A \times d^n + B$$

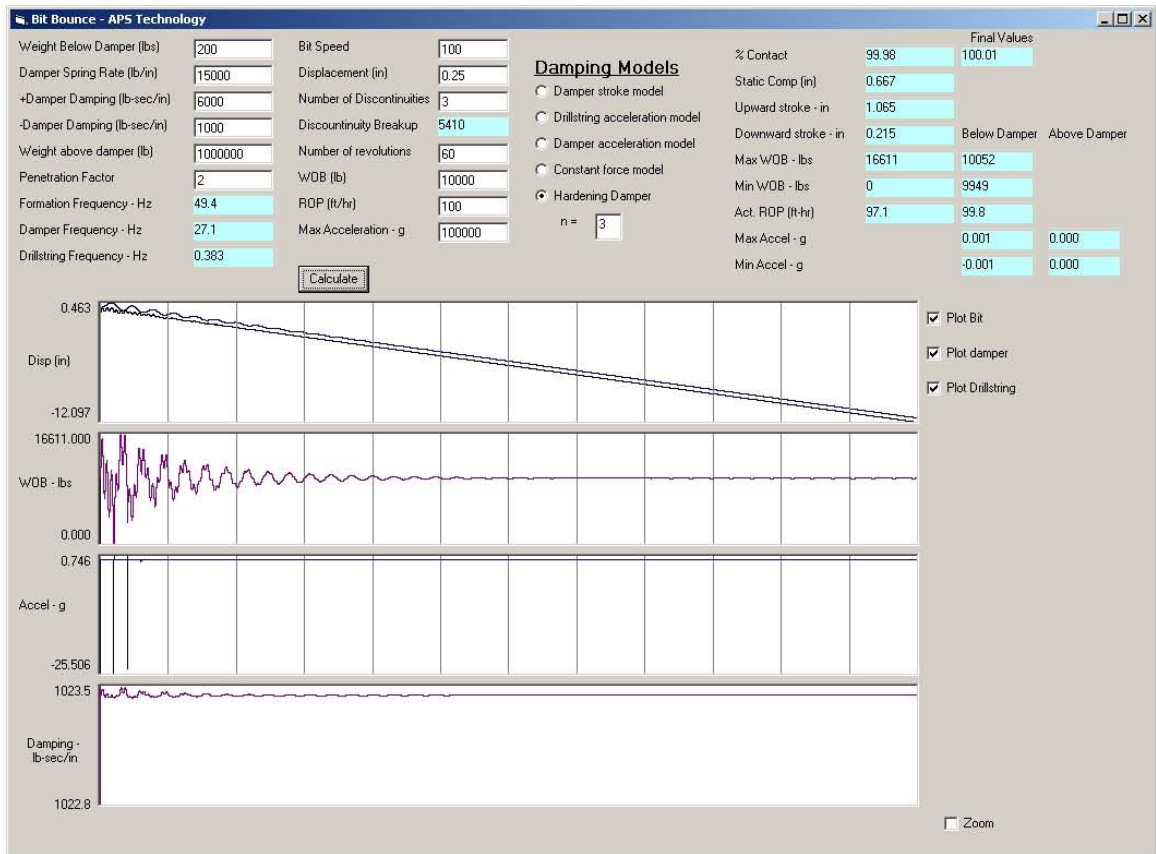
where:

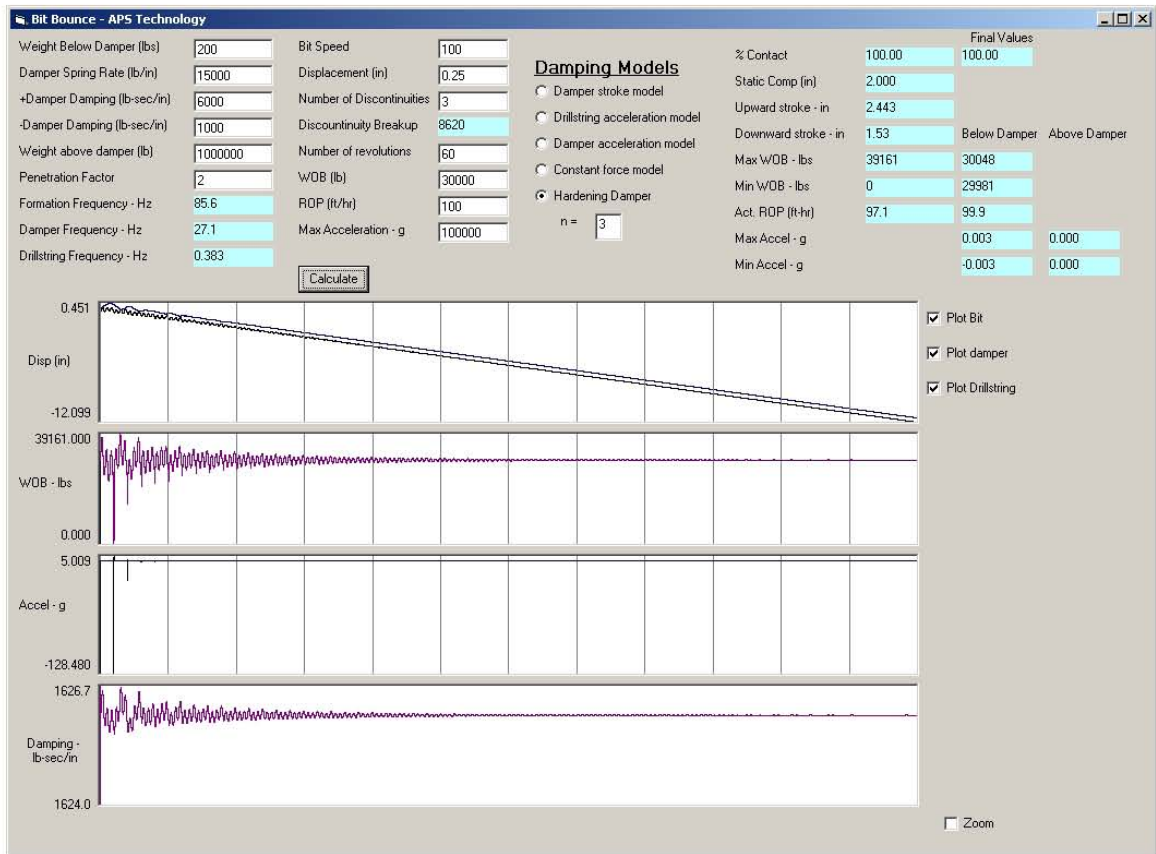
c = damping (lb-sec/in)

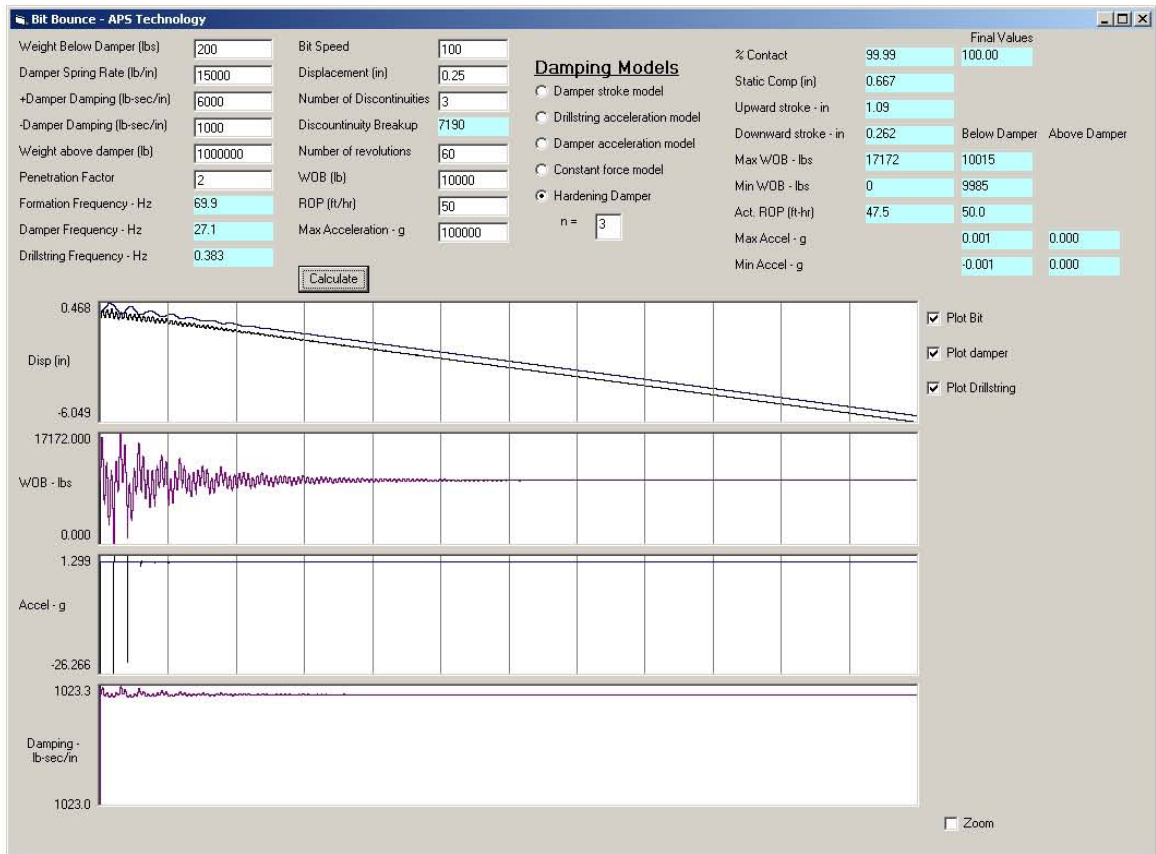
$A = (\text{damp}_{\text{max}} - \text{damping}_{\text{min}}) / \text{disp}^n$

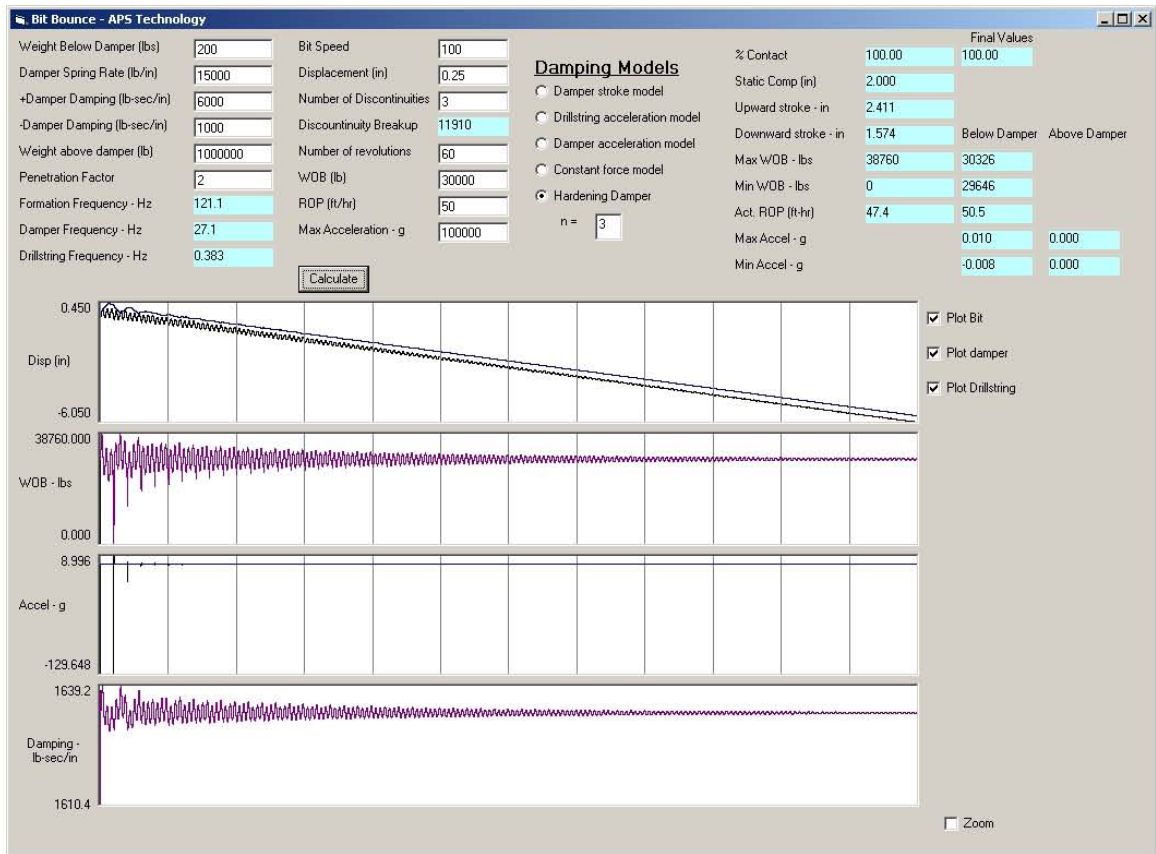
B = Min damping











AVD Damping Equation

$$W_O := 0 \cdot \text{watt}$$

Power at the neutral position

$$W_f := 150 \cdot \text{watt}$$

Power at full stroke +/-

$$\delta_O := 0 \cdot \text{in}$$

Neutral position

$$\delta_f := 4 \cdot \text{in}$$

Full Stroke

$$a_1 := \frac{W_f}{\delta_f}$$

Linear constant

$$a_1 = 37.5 \frac{\text{watt}}{\text{in}}$$

$$a_2 := \frac{W_f}{\delta_f^2}$$

Squared constant

$$a_2 = 9.375 \frac{\text{watt}}{\text{in}^2}$$

$$a_3 := \frac{W_f}{\delta_f^3}$$

Cubed constant

$$a_3 = 2.344 \frac{\text{watt}}{\text{in}^3}$$

$$W_1(x) := |a_1 \cdot x|$$

Linear equation

$$W_2(x) := a_2 \cdot x^2$$

Squared equation

$$W_3(x) := |a_3 \cdot x^3|$$

Cubed equation

