UNDERSTANDING FORCE AND RELATED TERMINOLOGY FOR SEISMIC VIBRATORS

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The purpose of a seismic vibroseis is to reproduce a designed sweep with sufficient force required to stimulate a predictable, repeatable seismic response from the earth. When the earth response is lacking, the initial reaction by stakeholders is to increase the force setting on vibrators. This is not always the best corrective measure. The amount of force a vibroseis can exert into the ground is a complicated issue that involves the maintenance condition of the vibrator, the condition of the ground, and other factors. Depending on these factors, increasing the force levels may cause undesirable results.

Further complicating the force drive level quandary is the use of terms that describe vibroseis specifications related to force and terms that describe vibroseis force output in the field. A few of the key terms are defined here as a starting point to aid understanding of the comparisons and examples that follow.

TERMS AND DEFINITIONS

Vibroseis terms can be confusing. This is exacerbated by the fact that, in some instances, the same term is used with a different meaning depending on the context it is being applied. The terms and definitions that follow are broken into two general categories or contexts; Vibroseis Vehicle Terms and Vibroseis Operational Terms.

VIBROSEIS VEHICLE TERMS

Gross Vehicle Weight (GVW) is the total physical weight of the entire vibroseis vehicle.

Hold-down Weight (HDW) is the weight of only the vehicle components that play a role in keeping the baseplate coupled to the ground and the force exerted by hold-down cylinder pressure. HDW is the sum of the weight of the reaction mass, the weight of the baseplate driven structure and the force supplied by the hold-down cylinders based on the hold-down pressure setting. HDW is smaller than GVW.

Peak Force is the highest force level the vibrator hydraulic system can produce. It is equal to the product of supply pressure and the area of the piston.

Max Force is the maximum total force the vibrator can produce and is the smaller of Peak Force and HDW.

VIBROSEIS OPERATIONAL TERMS

Drive Level or Force Drive Level is a force level setting entered into the vibroseis source controller. The value is typically entered as a percent and is used to limit Max Force to the prescribed percent level.

Fundamental Ground Force or simply Fundamental Force is the force exerted by the vibroseis less distortion. This is the desirable energy produced by the vibroseis and ultimately transferred into the ground.

Peak Ground Force is the contact force between the baseplate and the ground and is a summation of Fundamental Force (desirable) and distortion (undesirable), representing all force transferred into the ground from the vibroseis. Peak Ground Force is sometimes truncated to simply Peak Force but in this context has a different meaning than Peak Force used in vibroseis specifications, above. Peak Ground Force cannot be measured reliably so it is estimated using accelerometer measurements placed on the vibrator reaction mass and baseplate.

Estimated Weighted Sum Ground Force is calculated using the mass of the reaction mass times its measured acceleration plus the mass of the baseplate times its measured acceleration. Estimated Weighted Sum Ground Force or Weighted Sum Ground Force is synonymous with Peak Ground Force.

FUNDAMENTAL GROUND FORCE VS. PEAK GROUND FORCE

Modern vibroseis control electronics govern the fundamental ground force output of a vibroseis and not the peak ground force output. A common example of this is when operators set the drive level to 70% on a 60000lb vibroseis. This will cause the control electronics to attempt to achieve 42000lbs of fundamental ground force while sweeping. Depending on the vibrator's condition and the near surface, a distortion level of 25% is common. A 25% distortion level is equivalent to 15000lbs. of force. The peak ground force that the vibroseis achieves is the summation of the fundamental ground force and the distortion and for this example it is equivalent to 57000lbs.

HOLD-DOWN WEIGHT VS. PEAK GROUND FORCE

When the peak ground force of a vibrator exceeds the hold-down weight of a vibroseis, partial decoupling of the baseplate from the earth occurs. Decoupling causes cavitations in the hydraulic system of the vibroseis. When cavitations occur, many of the mechanical parts of the vibroseis undergo accelerated wear and tear with the greatest potential for damage coming to the servo valve and the inline piston accumulators. Repeated decoupling

events also cause degradation of the feedback loop accelerometers further impacting the control of the vibroseis. This degradation causes large amounts of distortion to occur and results in the vibroseis control electronics reducing the drive levels and adjusting phase in order to compensate for the measured baseplate motion.

There has been a great deal of research and testing in our industry around the topic of drive levels. The general consensus of this research is that increasing Force Drive Level does not improve the signal-to-noise ratio of the desired ground force signal and the increase in distortion introduced by increasing the drive level actually reduces the percentage of Fundamental Force output rather than increase it.

Peak Ground Force vs. Peak Force

Another common mistake when using terms is to assume that the Peak Force capability of the vibroseis is the same as the Peak Ground Force. From an engineering perspective, Peak Force is defined as the product of the piston head area and the high side hydraulic pressure minus the product of the piston head area and the low side pressure. This value defines the true maximum force the vibroseis can output and vibrators are generally engineered to deliver Peak Force values that are very near the Hold-down Weight of the vehicle. For example, in the instance were Peak Force is equal to Hold-down Weight, Max Force is equal to that value per the definition presented earlier.

Correct Drive Level Settings

Millions of hours of vibroseis sweeping on nearly every continent have shown that Drive Levels set in the range of 70%-75% of the available Hold-down Weight will reliably prevent the vibrator from decoupling and improve the quality and level of the force signal driven into the earth. Another benefit of these recommended Drive Levels is that the vibroseis signature repeats more reliably when near surface ground conditions are changing.

Further reading on this topic.

Sallas, J.J. "Seismic vibrator control and the down going P-wave." Geophysics Vol. 49, No. 6 (June 1984)

Reust, Dennis K. "Vibrator force control: How simple can it get?" The Leading Edge, Nov. 1995

Cooper, Norman M. 2002 "Vibroseis- a Counter-Intuitive Tool." Presented at the CSEG Geophysics Convention, Calgary Alberta Canada.