WHITE PAPER

HOW TO KEEP YOUR MUD SYSTEM VIBRATOR HOSE FROM GETTING HAMMERED TO DEATH

Introduction

A few decades ago, vibrator hoses on oilfield mud circulation systems lasted two years or more in service. Now they often fail within eight weeks to six months. Why?

Your first inclination may be to blame the hose manufacturer. But the hose may not be the culprit. New materials and construction methods have made vibrator/rotary hoses more durable than ever.

Instead, ask whether you're unknowingly turning your hose into a pulsation dampener—a task for which it was never designed.

Vibrator hose is built for static transfer applications, to transport mud from the discharge side of a mud pump to the standpipe on the derrick. It's not designed to handle the high pressure surges created by today's larger and more powerful mud pumps.

Because a failed vibrator hose is expensive to replace and disrupts operations, it behooves drilling operators to understand the relationship between vibrator hoses and conventional gas charged pulsation dampeners in their mud systems.

This understanding could result in vibrator hoses that last longer, and cause less downtime on the rig.

Mud Pumps Grow More Powerful

Mud pumps have been evolving to keep up with directional drilling and deeper wells. The typical mud pump used in oil and gas drilling today is a reciprocating triplex piston pump. It is capable of moving large volumes of mud at the high pressures required for deep hole, conventional and horizontal drilling.

Modern day triplex mud pumps range from 800 HP to 3,000 HP, with a maximum working pressure up to 7,500 psi. They have three piston liners that can range up to six inches in diameter with a twelve inch stroke length and are capable of discharging mud at a flow rate of up to 586 gallons per minute at 95% efficiency. For very deep wells, two or three triplex pumps are often connected in tandem, creating a mud pump system that can discharge mud at a flow rate of 1,328 to 1,992 gallons per minute.

Triplex pumps are replacing two-piston duplex pumps throughout the oilfield. Duplex pumps range in input horsepower from 190 to 1,790, with a maximum rated working pressure of 5,000 psi and piston liners that range up to six inches in diameter.

The evolution to more powerful mud pumps has a direct impact on the life of vibrator hose.

Damaging Effects of Pulsation

Pulsations and/or pressure surges are caused by the action of the reciprocating pistons in the mud pumps. In single-acting triplex pumps, each forward stroke of the piston displaces a certain amount of the fluid into the discharge cross based on the pump's filling efficiency (suction condition). This drilling mud surges through the discharge valve under high pressure (discharge condition), creating over shoot pressures (energy/wave) as a result of instantaneous changes in flow velocity caused by both fluid compression and valve opening delays. This pulsation energy (wave) travels at the speed of sound through the fluid mud until it first reaches the conventional gas charged dampener placed on the pump cross.

Assuming the pulsation dampener bladder is in good operating condition and pre-charged properly, it is designed to remove at least 85% of the pulsation energy from the system. However, all of this pulsation energy bypasses the dampener if the bladder has failed or the dampener is not pre-charged correctly. This remaining pulsation energy will then ultimately find its way to the vibrator hoses.

Within this mud system, the potential for further reflective (standing) waves can occur due to bends, valves and other restrictions in the mud system. These standing waves (surges) will seek the least path of resistance, causing premature failures in the vibrator hoses. Of course, the magnitude of these standing waves is defined by the output pulsation energies from the mud pumps and the effort placed in ensuring proper maintenance and pre-charge on the dampeners.

Over time, this cyclic loading on the vibrator hoses will contribute to early failures. The mean-time-between-failures (MTBF) on the vibrator hoses is defined by the amplitude of the repetitive pulsation energies downstream of the dampener. In a properly maintained and pre-charged dampener/ mud system, the potential for early vibrator hose failure is substantially reduced.

There is an additional and often overlooked issue where the instantaneous change in fluid flow (surge/hammering) in the mud system can cause substantial damage to the dampener bladder and vibrator hoses. This is often a result of the many sudden and hard pump starts/stops whilst MWD (Measurement while Drilling) signals are being processed on location. This is especially prevalent in shale drilling applications whilst operating in MPD (Managed Pressure Drilling) conditions on the "curve" and "horizontal" towards TD (Total Depth).

The dampener, in good operating condition and with the correct pre-charge, is designed to reduce this "fluid hammering" to some extent, the balance of which will ultimately find its way into the mud system and vibrator hoses. Contractors are encouraged to use soft starts/stops on mud pumps at all times. If not, the dampener bladder will fail first, allowing for an un-dampened mud system that will ultimately wreak havoc on the vibrator hoses that are not designed to take up these pulsation energies.

These pulsation energies over time cause significant flexures in the layers of tightly wound fabric and rubber, the outer steel reinforcement, and the steel coupling ends, causing premature vibrator hose failures. The more sudden and severe the pressure impulse, the greater the wear inside the hose, until the vibrator hose eventually gives out.

Vibrator hose is built and tested to withstand 15,000 impulse cycles. Compare that to high pressure hydraulic hose, which is tested to withstand up to 1,000,000 impulse cycles. This underscores the point that vibrator hose is designed for fluid transfer under constant pressure, and not for withstanding pressure spikes, as are hydraulic hoses or dampener bladders!

Maintaining as near to constant a pressure as possible in a mud system is achieved by a properly functioning and maintained pulsation dampener.

The Role of Pulsation Dampeners

The role of pulsation dampeners is to absorb the mud pump's pressure surges (changes in flow velocity), creating a steady-state (non-surging) flow of mud under more-or-less constant pressure, which lessens wear on the hose (and other mud system components).

Mud pumps are usually equipped with pulsation dampeners on both the discharge line and the intake suction line. On the discharge side, the pulsation dampener sits on the cross between the pump and the vibrator hose, which carries mud from the pump to the standpipe on the drilling mast. A rotary hose is attached to the top of the standpipe to transport the mud to the drilling equipment.

Pulsation dampeners (red and yellow cylinders) connected to the discharge manifolds of triplex mud pumps, with vibrator hoses attached.

The pulsation dampener in the discharge line is typically a conventional N2 (nitrogen) gas charged bladder-type dampener. Its basic elements consist of a metal shape (forged design preferred) containing a synthetic rubber diaphragm, or bladder, which separates the N2 gas (pre-charge) from the mud. The effectiveness of the dampener (pulsation control) is defined by the amount of pre-charge (set initially) and how that residual (working) gas volume functions at downhole (system) pressures. The amount of pre-charge is defined by the type and make of dampener employed.

Most cast offshore (Chinese) dampeners follow the old CE PD55 design that has a maximum pre-charge of 450 psig. In today's drilling operations, we often see downhole pressures ranging from 4200 psig to over 5000 psig, and utilizing dampeners with maximum pre-charge pressures of 450 psig is woefully inadequate.

The remaining working gas volume and response to system changes defines dampener performance!

Contractors *must* seek standardization in the dampeners employed and especially use ones that can be pre-charged to at least 2500 psig. These are typically available in all forged (not cast) designs. They should also insist on ASME Section VIII Code Stamped dampeners as this provides them with an independent certifying authority and a standard to which the assets can be inspected and recertified if need be. Risk mitigation, long term service life and minimized rig down time are key to rig profitability!

The nitrogen gas pre-charge is often prescribed as up to 75 percent of the system's minimum operating pressure, not to exceed the dampener's maximum pre-charge level (450 psig in the case of the woefully inadequate cast PD55s seen in the field today). Manufacturers place pre-charge limits on their dampeners and contractors must adhere to the dampener manufacturer's recommendations in all cases. To err on the side of caution is always best.

Again, the efficiency of the dampener is defined by the level of pre-charge first established against zero operating pressure. Once the mud system is brought up to pressure, the remaining gas volume defines the dampener performance. The gas over liquid volume ratio (the Pre-charge Ratio) must range from 0.25 to 0.75. Operating outside these limits will impact bladder service life to be sure. Also, the higher the ratio, the better the dampener performance and response to system changes.

The purpose of the bladder is to act as a barrier medium between the N2 gas and drilling mud. Any N2 gas pre-charge in dampener systems where there is no barrier medium results in the N2 gas being quickly absorbed into the drilling mud, providing no effective dampening at all.

Alternatives to the traditional gas charged dampeners are the discharge reactive spherical maintenance-free (bladderless) type dampeners. These pulsation dampeners are spherical in shape and are about four feet in diameter built into the pump's discharge line. The sphere has no bladder or internal moving parts. The large chamber is filled with mud, which absorbs the pressure surges leaving the pump. This style of pulsation dampener is commonly known as a "Maintenance Free Discharge Reactive" dampener.

Mitigating Pressure Surges

In a triplex mud pump, each piston reaches the end of its stroke at a different point in time, which tends to even out the pressure highs and lows and reduce the damaging effects of pulsation. This is one reason triplex pumps are gaining ground over duplex (two-piston) pumps in the oilfield. The more pistons, the lower the pulsation energies created by the pump.

Even with triplex pumps, however, pulsation or pressure surge poses a problem, because the fluid volume at the discharge port can vary significantly above and below the average flow. (This variation is called the K-factor.) The magnitude of these pressure surges and the resulting compression waves depend on the size and power (bore and stroke) of the pump.

At times, the problem is compounded when two or three mud pumps are connected (common system) in order to deliver a greater volume of mud. Now as many as six or nine pistons are pushing mud through a common discharge manifold, which can create overlapping pressure surges and harmonic distortion.

The solution to stabilizing this multi-pump system and achieve a relatively constant flow is to install a pulsation dampener on the discharge line of each mud pump and phase control into the mud pump control system. It is not recommended to use a "common" dampener irrespective of phase control in multiple mud pump systems. Every mud pump must have its own pulsation dampener. Pulsation dampeners even the flow of mud and mitigate the pressure surges/pulsations from occurring; however, not all pulsation dampeners are of sufficient quality, sized properly, or well maintained in the field.

Pulsation Dampener Challenges

Sizing and Installation

A properly sized and installed pulsation dampener can eliminate 85 percent or more of the flow and pressure variations in a mud system, protecting not just the life of your vibrator hose, but other system components as well.

Sizing a pulsation dampener involves a calculation that includes the number of pistons, the area of the pump piston's plunger face, the length of the piston stroke, the K-factor (how much the fluid volume at the discharge port varies above and below the average flow), and the pressure factor. This calculation will determine the dampener volume required to achieve certain and expected performance levels.

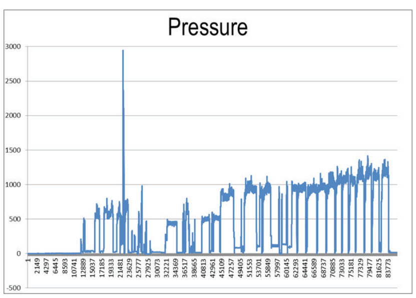
Dampener installation is also very important. The dampener should be placed as near to the discharge port as possible, ideally on the cross or within 10 pipe diameters from the pump discharge flange. Depending on the type, it can either sit in line (flow through maintenance-free) or to the side (conventional gas charged).

Drilling Operations

In the normal course of drilling a well, a number of events can occur that will overwhelm a pulsation dampener or render it useless, including the following:

- Frequent and rapid pump start-up and shut-down (during the curve and horizontal operations)
- Wellbore "kicks"
- Establishing an incorrect pulsation dampener pre-charge (insufficient by dampener design employed is most often the case)
- Not adjusting or changing the dampener pre-charge level based on wellbore pressures. (One size does not fit all!)

Repeated pressure spikes that exceed 50 percent of the rated working pressure of the vibrator hose can quickly damage the tube and reinforcement layers, shortening its service life.



This graph depicts actual data from a pressure transducer in the discharge line. It shows a mud pump starting up at zero psi, and spiking immediately to 3,000 psi (a "hard" start). The effect is akin to a hammer blow to the inside of the vibrator hose. The subsequent pressure trace shows peaks and valleys with differences as great as 1,500 psi. This could indicate a damaged or improperly charged pressure dampener. These pressure differentials cause the wire reinforcement in the hose to flex repeatedly, leading to flex fatigue and ultimately to hose failure.

Rapid Pump Start-Up

Starting up a mud pump and taking it almost instantly to 2,500 – 3,000 psi operating pressure sends a pressure surge through the discharge line. This impulse spike may be too large for the dampener, allowing a compression wave to hammer away at the vibrator hose. To prevent this kind of impulse spike, a mud pump should undergo a "soft" start-up, gradually reaching its full operating pressure.

Wellbore kicks

When gas, oil, or salt water from the formation being drilled enters the wellbore and overcomes the pressure of the drilling mud, the resulting pressure kick travels back up the column of mud until it meets resistance. This point of resistance is typically within the rotary or vibrator hose. The area just behind the hose coupling is especially vulnerable, because the rigid coupling prevents volumetric expansion, intensifying the hammering effect of the compression wave at that point.

Manipulating the Pulsation Dampener

Service companies steering a downhole motor during directional drilling (or performing other work over tasks) may charge a pulsation dampener up to 75 percent of the system's minimum operating pressure, to a maximum set by the dampener manufacturer (follow dampener manufacturer's guidelines in their IOM in all cases!). This may allow transmission of a clearer signal through the mud flowing down the wellbore to help steer the drill motor.

Having the pulsation dampener off-line for a short period of time is not a serious problem. What becomes a problem, however, is neglecting to adjust the dampener pre-charge to optimum levels. An overcharged or under charged dampener cannot absorb the pressure surges from the mud pump efficiently (Pre-charge Ratio must be greater than 0.25 and less than 0.75). The diaphragm will rupture, rendering the dampener useless and subjecting the vibrator hose to the full impact of repeated full pulsation energies.

An added concern during directional drilling is the effect of pulsation energies emitted from the downhole mud motor. These waves travel up the mud column and collide with waves from the mud pump. The resulting standing wave will affect the vibrator hose and also the interior of the rotary hose that connects the standpipe to the top drive.

The rotary hose is constructed exactly like the vibrator hose, but damage to the rotary hose carries much greater consequences. For one thing, the hose costs more to replace due to its length. Also, ordering a new hose may take weeks of delivery time. And even if a replacement hose is readily available, drilling activity comes to a halt for hours at a time while the hose is being replaced.

Insufficient Dampener Charge

Another problem occurs when a pulsation dampener is insufficiently charged. Without sufficient pre-charge, there's not enough nitrogen gas volume over liquid volume (the Pre-charge Ratio) calculated at operating (downhole) pressure. In surge conditions, having a large dampener gas volume available is key to mitigation. Reducing these surge conditions is key to achieving longer vibrator hose service life.

Costs and Consequences

In drilling operations, some problems are simply taken for granted. Such may be the case with mud system vibrator hoses. Many a drilling crew may accept a few months of working life from a vibrator hose, thinking that is the norm.

However, when a mud system is set up with appropriately sized, properly installed, and well maintained pulsation dampeners of high quality (forged ASME Stamped Dampeners), one could expect up to two years of life from a vibrator hose. The same applies to the rotary hose. Additional service life should also be expected for the wash pipe packing employed on the top drive.

Operating a mud system with improperly sized or non-functional pulsation dampeners can be not only expensive, but dangerous. Pulsation dampeners on the discharge side of mud pumps that are not up to the task have been known to literally explode, sending metal shards from their cast housings in all directions. Again, forged is better. ASME Code Stamped Made in the USA is *best*!

Evaluation and Remedy

If your vibrator hoses are repeatedly failing, look beyond the hoses. Evaluate your mud pump system. Have newer, more powerful pumps been installed recently? Has a well servicing company changed any settings on the pulsation dampeners? Are the dampeners charged properly? Are you running pumps in tandem to increase the flow for deeper drilling? Are you engaged in directional drilling? Are you using soft starts on mud pumps?

The answers to these questions may indicate whether you are asking your vibrator hose to perform the job of a pulsation dampener, thereby placing demands on the hose that it was not designed to endure. If that's the case, you may be shortening the life of your vibrator hose, incurring unnecessary cost and downtime, and posing a safety risk to your crew.

The remedy is regular and frequent inspections by an engineering service company that understands the complex interactions between pulsation dampeners and rotary/vibrator drilling hose.