Anatomy of the Mud Pump Pulse

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Pulsation analysis and dampeners can help minimize damage to sensitive drilling equipment.

Mud Pumps with pulse reducing pulsation dampeners have been in existence for more than half a century. Until now, the market has been dominated with 40-year-old triplex pump designs that have rough discharges and excessive vibration. During the last four decades, the drilling industry has accepted the difficulties of mud pump pulses and the problems they cause. Some of these problems are poor telemetry for direction drilling and rig vibration/ harmonics in offshore environments. Mud pump pulses can be minimized using pulsation dampeners or syncing the pumps when more than one electric drive pump is used in parallel. Syncing pumps is a process in which multiple pumps' strokes are controlled to synchronize their pulses and reduce the combined effect of the pulse's by dispatching a peak in the other pumps' trough. However, syncing the pumps still leaves a tremendous amount of pulse in the mud flow and vibration offshore. Traditional triplex mud pumps have proven ineffective in adequately delivering a smooth flow, despite counter measures. To reduce the many causes of pulses in single acting reciprocating triplex pumps, one needs to first consider the source or sources of the these pulsations before they can truly be minimized in any significant way.

Pulsation at the Mud Inlet

One of the first places that pulse can occur is at the suction or mud inlet to the pump. The mud enters the suction manifold and fills the liners.It is critical that the inlet valve open and close quickly to allow the liner to fully fill up during the suction stroke. The term suction can be misleading because the pump would be supercharged by an impeller pump, so as the piston moves back, the charge pump pushes the mud into the cylinder cavity. As the cylinder retreats on the back stroke and the mud flows in,

the piston moves back at a nonlinear speed, starting at zero velocity, building up to maximum velocity near the middle of the stroke and back down to zero at the end of the stroke when the liner is filled with mud.

This sine wave velocity profile means that the flow rate of a single cylinder in a typical 1,600 hp triplex pump varies from zero at the beginning of the backstroke to more than three times the average flow rate of that same cylinder. The charge pump should deliver more than the flow rate pumped, but it should not be so oversized that it lifts the suction valve prematurely. High charge volume with low pressure is optimal.

Suction desurgers should be deployed on the suction manifold to assist the charge pump with supplying additional volume to the cylinder cavity at the highest piston speed. Assuming that the fill up stroke is achieved almost to perfection, only a short, but significant, pair of pulses will be generated as the suction valve opens and snaps closed.

Pulse Due to Rotation of the Crankshaft

The next, and probably the most significant, source of pulsation is due to the characteristic of a rotating crankshaft. The motion of a rotating crank at constant rpm when converted to linear movement of the piston always creates a changing flow rate as the piston accelerates and de-accelerates. The nature of a crankshaft driven cylinder is to start slow then speed up through the midpoint of the stroke and then slow down until full stop at the end of the stroke. For example, the stroke starts at 0 feet per min (fpm) and accelerates to 380 fpm in the middle of the stroke and then back to zero fpm, resulting in an average of 275 gpm flow rate.

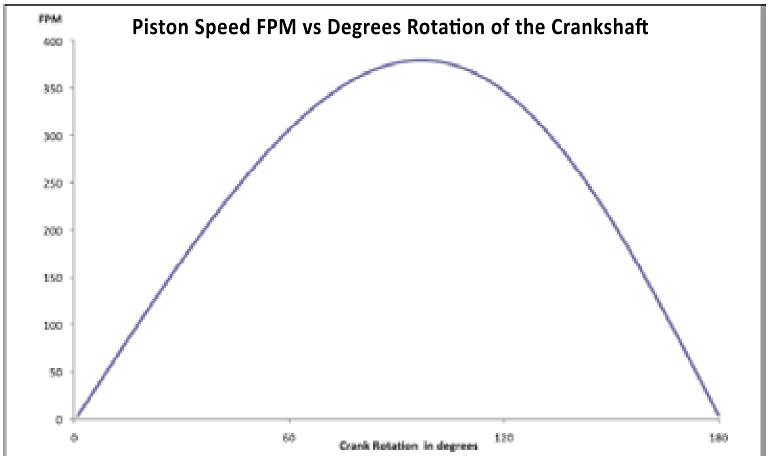
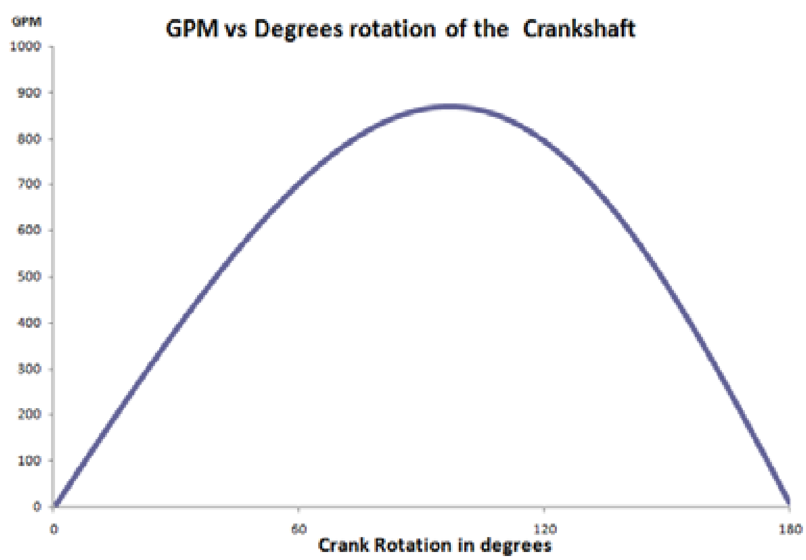
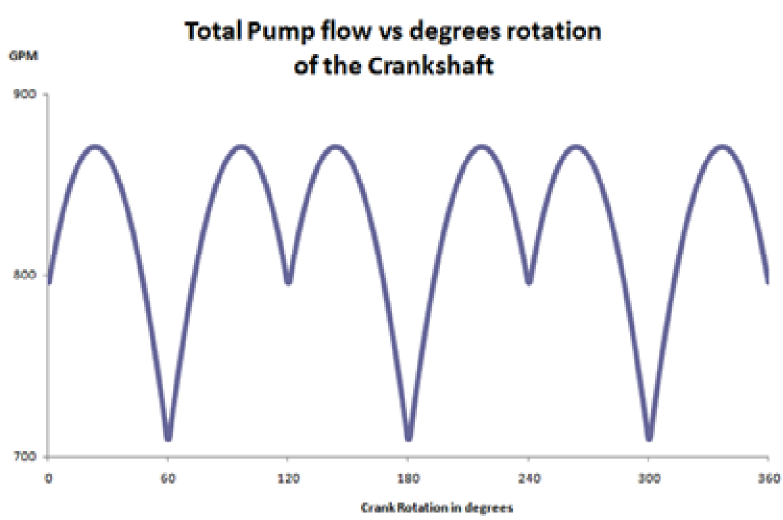


Figure 2. The Crank Speed at Continuous rpm to the Piston Speed Sine Wave





However, the maximum flow in the cylinder at the peak speed of 380 fpm is 871 gpm, more than three times the cylinder average flow rate.

Figure 2 shows the constant speed of a theoretical crankshaft rotating and the resultant speed of a piston being driven by the crank. The longer the stroke the higher the maximum piston speed will be at the middle of the stroke. This speed increase during the middle of the stroke is why pumps with longer pistons will have a lower maximum rpm, to stay below the industry standard of 381 fpm for piston wear reduction. Only a few pump companies claim a piston speed higher than 381 fpm at the maximum rpm of the pump.

Figures 3A and 3B show the discharge flow rate has a significant variance for each cylinder and even after overlapping the three cylinders, the resulting flow has major pulses.

The pulses caused by a 120-degree phased pump, such as the triplex pump, are irregular (as shown in Figure 3B) with regard to their peaks or maximum amplitudes. This creates some confusion in the pressure of the discharge as exemplified by the apparent twin peaks followed by a single dip, then peaks again, and so on. As a result of this irregular pulse, any dampening system will be cycled at alternate amplitudes, an undesirable situation as the pulsation dampeners have two different-sized pulses that they must reduce.

Pulsation Dampeners

At this point, the resulting pulses have been created and will have to be absorbed in part by some system, such as a pulsation dampener. A pulsation dampener as commonly deployed relies on differential pressure and moving parts to absorb the instantaneous changes in the flow rate resulting from changing piston speed. (It works much like a shock absorber in a car). Because of the flow rate change during one piston stroke and the exponential pressure that results, pulsation dampeners are generally large, heavy, difficult to handle and time consuming to service.

Although a pulsation dampener can absorb much of the pump's pulse, its effectiveness depends upon the following factors:

- Location
- Distance from the source of the pulse
- Not being compromised by flow barriers
- Not being dampened by the strainer cross; with the dampener on top of the strainer cross some

of the pulse will escape down hole rather than being removed by the dampener

- Regularity of pulses, to assist with proper dampener calibration.
- Proper calibration

There has been little evolution in triplex pumps and their pulsation dampeners for many years but one thing that seems to be constant with conventional triplex pumps, is that a pulse and vibration will be noticed.

The Quadraplex Solution

Some issues can be addressed with the use of two pulsation dampeners on a quadraplex pump instead of using conventional triplex pumps. A pump with an even number of cylinders, where the sine wave is overlapped at the peaks and the troughs, will provide a constant amplitude pulse, which is repetitive and may be eradicated by well-placed pulsation dampeners. This is demonstrated by the live recording of the quadraplex output pressure curve (Figure 3C), which is probably the best currently available for a reciprocating, single acting pump.

Each dampener is:

- Close to the fluid modules
- Upstream of the strainer, so the strainer cannot dampen or block the flow to the dampener
- Handling a consistent pulse generated from a pair of cylinders

The remaining pulse or spikes in the pressure that have not been removed by the dampener are created by the flow rate change mentioned earlier, and unfortunately any remaining pulse will exhibit much more severe results than would be expected. For example, the pressure increase or pulse is protional to the flow rate squared. As the flow rate changes, the drill system pressure changes due to the added surge down the drill string and through the down hole tools and drill bit. The resulting pressure change is much greater than the flow rate change.

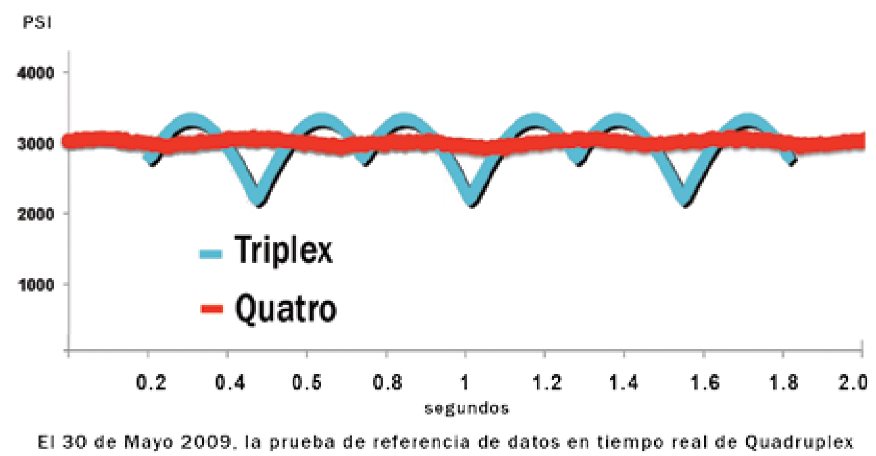


Figure 3C. Live recording of the quadraplex mud pump output pressure curve

As the pressure changes in the pump liner, the crankshaft experiences higher torque during the middle of the stroke when the piston is moving fastest, and that means the driving engines,whether diesel or electric, feel the torque change. This results in a constant whirring.

This whirring is a different and distinct vibration, felt more intensely through the steel structures in an offshore environment. The constant transient overload of the crankshaft by constant and repetitive torque peaks will create a jerking motion due to the uneven load and will, ultimately, cause a crank to fail.

Another effect of this repeated slowing of the crankshaft on every rotationof a triplex pump is that, while one cylinder is at the peak of its stroke, the crankshaft slows down slightly and slows the stroke of the other two pistons that are filling on their return stroke. So, the added torque created by one piston stroke results in speed-variations in the remaining pistons.

Future mud pump designs must ensure that a signature pulse is notcreated and that no pulsation dampeners are required. When mud pumps are pulse free, they will dramatically reduce unwanted vibration in drilling equipment, which will benefit the entire industry.

Shaun White's experience in the field of offshore drilling and production spans nearly four decades. White is currently the engineering and product development director for the Texasbased White Star Pump company, a manufacturer and global exporter of triplex and quadraplex mud pumps for the mining and the oil & gas drilling industries. For more information go to www.whitestarpump.com.