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Design Development Testing and analysis of resonator baffle and rubber bladder type hydraulic silencer and study effect of variation in charging pressure on noise and vibration reduction ability

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ABSTRACT

Many industrialized countries have regulations restricting noise levels in the workplace. The high-power density and corresponding high noise emission of hydraulic components cause industrial hydraulic systems to be the target of efforts to reduce mean noise levels. The pump is the dominant source of noise in hydraulic systems. It transmits structure-borne and fluid-borne noise into the system and radiates air-borne noise. All positive-displacement hydraulic pumps have a specific number of pumping chambers, which operate in a continuous cycle of opening to be filled (inlet), closing to prevent back flow, opening to expel contents (outlet) and closing to prevent back flow. These separate but superimposed flows result in a pulsating delivery, resulting in a corresponding sequence of pressure pulsations. These pulsations create fluid-borne noise, which cause downstream components to vibrate. The pump also creates structure-borne noise by producing vibration in any component it is mechanically linked to, for example, the tank lid. The transfer of fluid- and structure-induced vibration to the adjacent air mass results in air-borne noise.

Keywords— **Hydraulic system; Vibration; Noise; Pulsation**.

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I. INTRODUCTION

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Pump pressure and pump sizes have about equal effects on hydraulic noise levels. However the pump speed has about 300% greater affect on pump noise than either pressure or pump size. This is the reason some pump manufacturers recommend slower electric motor speeds. Fixed pumps are usually quieter then variable displacement pumps. It is almost impossible to forecast how much additional sound the hydraulic lines and surrounding structure will radiate. This is why many power units are enclosed after they have been manufactured and installed. Slight adjustments to the nitrogen precharge of the Suppressor will vary the noise control. This is easier than wrapping the piping in sound absorbing tape, or enclosing the entirepower unit as an afterthought.Lab tests show that pump noise levels are increased by 2 to 3 dB(A) just by adding 12 feet of outlet and return lines. The lines do not generate noise; instead they radiate noise when they respond to pulsations or vibrations. The pump usually generates the pulsations and the vibrations are radiated by large flat machine surfaces. So not only do hydraulic lines radiate noise but also they frequently provide the primary path for propagating noise from the pump to components. This helps explain why many pump manufacturers have a very low dB(A) pump

rating, but when the pump is installed on a power unit the sound rating is much higher

II.PRESENT THEORIES AND PRACTICES

A.ReducingFluid-borneNoise

While fluid-borne noise caused by pressure pulsation can be minimized through hydraulic pump design, it cannot be completely eliminated. In large hydraulic systems or noise-sensitive applications, the propagation of fluid-borne noise can be reduced by the installation of a silencer. The simplest type of silencer is the reflection silencer, which eliminates sound waves by superimposing a second sound wave of the same amplitude and frequency at a 180-degree phase angle to the first.

B.ReducingStructure-borneNoise

Structure-borne noise created by the vibrating mass of the power unit (the hydraulic pump and its prime mover) can be minimized through the elimination of sound bridges between the power unit and tank, and the power unit and valves. This is normally achieved with the use of flexible connections, such as rubber mounting blocks and hoses. However, it is necessary to introduce additional mass in certain situations, where the inertia reduces the transmission of vibration at bridging points.

C.ReducingAir-borneNoise

The magnitude of noise radiating from an object is proportional to its area and inversely proportional to its mass. Reducing an object's surface area or increasing its mass can therefore reduce its noise radiation. For example, constructing the hydraulic reservoir from thicker plates, which increases its mass, will reduce its noise radiation.Air-borne noise can be reduced by mounting the hydraulic pump inside the tank. For full effectiveness, a clearance of half a meter between the pump and the sides of tank is required. The mounting arrangement must also incorporate decoupling between the power unit and tank to insulate against structure-borne noise. The obvious disadvantage to this is the access for maintenance and adjustment is restricted.

III. ENERGY STORAGE IN HYDRAULIC FLUID

Another source of noise in hydraulic systems derives from the storage and subsequent release of energy in the hydraulic fluid. Hydraulic fluid is not perfectly rigid, and the compression of the fluid results in energy storage, similar to the potential energy stored in a compressed spring. Like a compressed spring, compressed fluid has the ability to perform beneficial work. If decompression is not controlled, the stored energy dissipates instantaneously. This sudden release of energy accelerates the fluid, which affects anything in its path. Uncontrolled decompression creates noise and stresses conductors, and can cause pressure transients that damage system components

IV.BULK MODULUS AND DECOMPRESSION

The ratio of a fluid's decrease in volume as a result of a pressure increase is given by its bulk modulus of elasticity. The bulk modulus for hydrocarbon-based hydraulic fluids is approximately 250,000 PSI, (17,240 bar) which results in a volume change of around 0.4 percent per 1,000 PSI (70 bar).As a general rule, when the change in volume exceeds 10 cubic inches (160 cubic centimeters), decompression must be controlled. Decompression control is essential in presses or other applications that have large volume cylinders operating at high pressures. Although hydrocarbon-based hydraulic fluids compress 0.4 to 0.5 percent by volume per 1,000 PSI, in an actual applications compression should be calculated at 1 percent per 1,000 PSI. This compensates for the elasticity of the cylinder and conductors and variations in the volume of air entrained in the fluid.If, for example, the combined captive volume of the cylinder and conductors on a press were 10 gallons and operating pressure was 5,000 PSI, the volume of compressed fluid would be half a gallon (10 x 0.01 x 5 = 0.5). This equates to a potential energy of around 33,000 watt-seconds. If the release of this amount of energy is not controlled, a big bang will be heard throughout the plant! Decompression is controlled by converting the potential energy of the compressed fluid into heat. This is achieved by metering the compressed volume of fluid across an orifice.

V..SOLUTION TO THE PROBLEM OF HYDRAULIC NOISE

In any hydraulic system, the pump is the main source of pulsations and vibrations. While pump manufacturers have made noise reduction a design goal, every pump still produces some ripple - the pump manufacturers' term for pulsations. Ripple produces the line vibrations which cause additional noise. System designers cannot change how much ripple the pump produces, so they must find ways to control the propagation of that ripple out through the rest of the system. One of the first areas that should be reviewed when attempting to reduce power-unit noise is the hydraulic conductors. Somewhat surprisingly, one factor that can contribute much to the noise level is improper use of hydraulic hose. Recent research at a large pump manufacturer showed that they could take an average of 5 dB(A) out of a standard power unit merely by changing the configuration of the hydraulic hose. Frequently, a 90° curved hose is used when a horizontal line has to be connected to a vertical line, and 180° hose curves also are quite common. Experiments show that both of these configurations actually increase system noise level. The solution: don't bend hydraulic hose; instead, substitute bent metal tubing. Only use hose in a relatively straight line. It is well known that introducing a compressible medium such as nitrogen into the relatively incompressible medium of hydraulic fluid will help reduce pulsations. The challenge is to get the fluid to interact with the nitrogen so the nitrogen compresses and the fluid merely loses its pulsation. Over the years, nitrogen-charged accumulators have been installed in many hydraulic circuits to absorb pulsations. At first, accumulators were used as appendage devices - teed off the hydraulic line. The designer hoped that the pulsations would wander into the accumulator. However, experience showed that the majority of the pulsations bypassed the line leading to the accumulator. Different designs then evolved in which the full flow was diverted into the accumulator. Correctly sizing this type of accumulator is complicated and the circuit that directs flow into the accumulator is very expensive. Also, pressure drop through these accumulators may be unacceptably high.Another method of using compliant nitrogen to deal with noise-causing pulsations is to mount an in-line nitrogen-charged noise suppressor right at the outlet of the pump. (This suppressor is described in detail in the box at right.) This design is more efficient than a large conventional accumulator because the fluid flow-path to the bladder is short and unrestricted, and the fluid contacts a much greater bladder area.

VI.SOLUTION DESCRIPTION

The suppressor consists of three concentric, cylindrical metal noise baffles or diffusers inside a air -charged tubular rubber bladder. The inner baffle has 1Ú2-in. diameter holes cut into it; the second layer is a coil spring that helps support the thin outer baffle; and the outer baffle is perforated by more than 4000 1Ú32-in. diameter holes. (These holes are small enough that the surrounding bladder cannot extrude into them.) Pulsations enter the suppressor and then pass through the three baffles - a total radial distance of only 1Ú4 in. - and strike the bladder which typically is charged at 50 to 60% of the hydraulic-system operating pressure. The bladder deflects each time it is hit by a pulsation, and this slight deflection absorbs and reduces noise - and as a bonus, any shock waves. The bladder's large area, its ability to oscillate at high frequency, and short travel distance combine to absorb pulsations with frequencies above 600 Hz. The size of the suppressor is determined simply by the size of the hydraulic line in which it will be installed. Models are available for pipe and tube sizes from 3Ú8 to 3 in., with NPT pipe, SAE tube, and split-flange port connections. Sizing older-style, accumulator-type hydraulic pulsation dampeners was a long and complicated process. With this design, the size of the line becomes the size of the suppressor. The installation of in-line noise suppressors directly at the outlet of the pumps will be done .The suppressors is expected to bring the noise level down to 78 dB (A), and the cost will be considerably less than building noise enclosures around the power units.

The hydraulic noise enters the Suppressor and goes through three different noise baffles or diffusers. These metal baffles are designed to convert D/2 diameter holes to D/32 diameter holes. The total radial distance through these baffles is only 1/4D. After passing through these holes the noise then strikes the nitrogen charged rubber tube, or bladder. The bladder is usually charged with air to 50% to 60% of the hydraulic operating pressure. The D/32 diameter holes are so small that the bladder cannot extrude into them. The bladder deflects each time it is hit by a pulsation. This slight deflection of the bladder reduces the shock and noise. The large bladder area and the short travel distance combine to absorb high frequency pulsations over 600

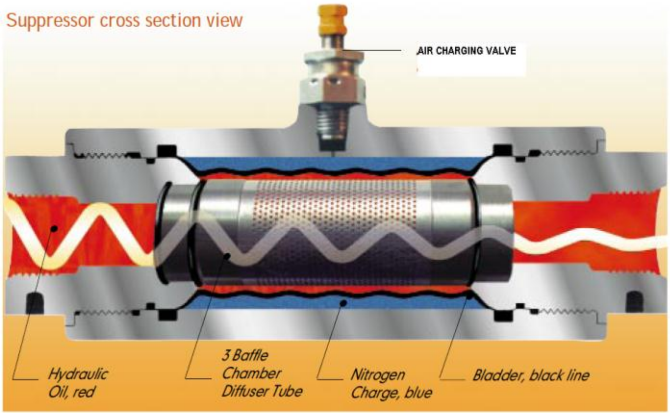

Fig 1.suppressor cross section

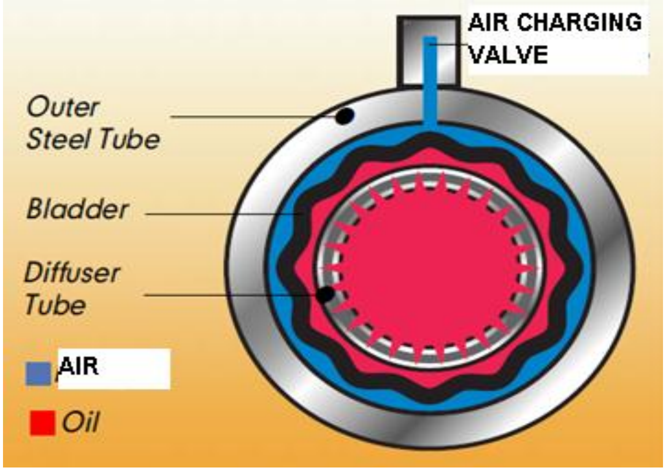

Fig2.Modification proposed in the formed resonator chamber before the bladder section

Sound is a **pressure wave** formed from pulses of alternating high and low air pressure. These pulses makes their way through the air at — you guessed it — the speed of sound.In an hydraulic line, pulses are created when pump delivery valve opens and a burst of high-pressure oil suddenly enters the system. The molecules in this oil collide with the lower-pressure molecules in the pipe, causing them to stack up on each other. They in turn stack up on the molecules a little further down the pipe, leaving an area of low pressure behind. In this way, the sound wave makes its way down the pipe much faster than the actual gases do. When these pressure pulses reach ear, the eardrum vibrates back and forth. Brain interprets this motion as sound. Two main characteristics of the wave determine how we perceive the sound:

1. ***Sound wave frequency*** – A higher wave frequency simply means that the oil pressure fluctuates faster. The faster an pump runs, the higher the pitch we hear. Slower fluctuations sound like a lower pitch.
2. ***Oil pressure level*** – The wave's amplitude determines how loud the sound is. Sound waves with greater amplitudes move our eardrums more, and we register this sensation as a higher volume.

VII. CANCELLATION OF SOUND WAVE USING RESONATOR

It is possible to produce a sound wave that is exactly the opposite of another wave. If the waves are exactly out of phase, they add up to zero. This is called **destructive interference**. At the time when the first wave is at its maximum pressure, the second wave is at its minimum. If both of these waves hit ear drum at the same time, you would not hear anything because the two waves always add up to zero. When a wave hits the resonator baffle , part of it continues into the chamber and part of it is reflected. The wave travels through the chamber, hits the back wall of the silencer and bounces back out of the chamber. The length of this chamber is calculated so that this wave leaves the resonator chamber just after the next wave reflects off the outside of the chamber. Ideally, the high-pressure part of the wave that came from the chamber will line up with the low-pressure part of the wave that was reflected off the outside of the chamber wall, and the two waves will cancel each other out

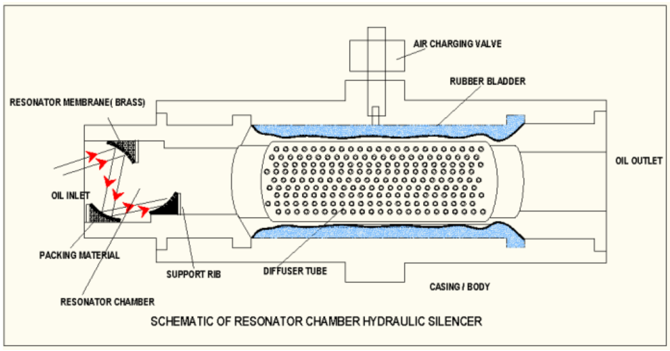

Fig.3. Schematic of resonator chamber hydraulic silencer

Design validation of the stress produced in the parts like resonator , resonator membrane bracket ,diffuser tube , air bladder chamber at different percentage of charging (30 % , 50 % and 60 % respectively using ANSYS software.

VII.CONCLUSION

Noise level of the device in decibel at various charging levels will be less. Discharge abilities of the silencer at various charging levels will be less. Observe Pressure characteristics of(theoretical) analysis as to space and power requirements of the device as compared to conventional noise reduction arrangements the silencer at various charging levels. Comparative

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