Reducing Noise In Hydraulic Systems

Dampening Chatter and Minimizing Vibration

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Reducing Noise In Hydraulic Systems

Specifically, audible and inaudible waves in the fluid.

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Article contributed Gregory J. Hayes, OEM Sales Manager for the Parflex Division Parker Hannifin

Noise is an Additive

Noise in hydraulic systems is generated primarily by the mechanical workings of the pump and fluid pulsations exiting the pump as it supplies the flow for the system. It can also be created by any element that causes turbulence or fluid velocity change. Noise is additive, so small amounts of noise from many components can be effectively amplified resulting in a significant noise problem. The transmission of the noise to the operators of the equipment can cause fatigue, nerve damage, and require operators to wear additional hearing protection.

About 30 million workers in the U.S. are exposed to hazardous noise levels making occupational hearing loss one of the most common occupational diseases[1]. The following list[2] provides the top industries where NIHL[3] is most prevalent:

- Agriculture
- Mining
- Construction
- Manufacturing
- Utilities
- Transportation

Ways To Eliminate Noise

Noise can be eliminated by adding attenuators which can be tuned to cancel the frequency out of the system. Attenuators are effective but relatively expensive and bulky units. In this article we will examine other methods of noise elimination that have been proven to be effective but are also less intrusive and inexpensive. Specifically hydraulic system development work that has utilized thermoplastic hydraulic hoses in place of conventional wire reinforced rubber product.

For this discussion we will use the term noise to refer to audible as well as inaudible waves in the fluid. Both can be troublesome for the fluid power system designer and end user so it will be our attempt to find ways to eliminate or at least minimize noise.

One cost effective and simple solution for reducing noise and/or adding damping and ramping characteristics to hydraulic functions is the use of hoses with varying rates of volumetric expansion (VE). Like accumulators, hoses have a capacitance characteristic but to a much lesser extent, that is, the higher the volumetric expansion the greater the accumulator effect.

Some examples are mobile OEM's using hoses with a high VE to reduce hydraulic shocks in steering applications while subsequently reducing hydraulic induced noise and vibration. High VE hoses can also be used in applications where sudden movement is not desired such as swing or rotation functions as well as ramping on load sense lines. Likewise, hoses with a low volumetric expansion can transfer energy from point to point quicker acting more as a hard line. This could be desirable where function response is critical.

Noise is undesirable because it can cause additional load on

1"Work-related hearing loss" NIOSH Publication No. 2001-103: 2001
2 NIOSH Publication No. 2001-103
3 Occupational Health and Safety Administration [OSHA], 2002
4 Katsuhiko Ogata (2004). System Dynamics (4th ed.). University of Minnesota.

hydraulic components leading to premature failure, additional system cost, operator fatigue, and potential hearing loss. The U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) states that exposure to 85 dB(A) of noise for more than eight hours per day can result in permanent noise induced hearing loss (NIHL).

Mechanical Noise

Noise is also known to cause many issues with components in hydraulic systems, but in particular, steel tube assemblies are known to be very susceptible to vibration failure.

Mechanical resonances occur within a system when it is able to store and easily transmit energy between two or more nodes. When the frequency of oscillations in a system approach the system's natural frequency, mechanical resonance in the form of vibrations occur. Each component in the system has a natural frequency and, when combined, will have a new set of natural frequencies depending on their damping and energy transmission properties[4].

Vibration can travel through the system via the fluid and/or metal components transmitting to all parts of the equipment. Noise travels easily though the metal components such as of pumps, valves, cylinders, steel tubes and elbow fittings but can also travel through the steel wire reinforcement in hose.

For example, let us say that a gear pump is being used in a typical mobile application. This gear pump operates at 2000 rpm during normal operation, with 8 teeth per gear resulting in sinusoidal waves at a frequency of 267 Hz. This means that any component or subset of components (from a single tube installation, implement, to entire piece of equipment) that have natural frequencies of or near 267 Hz, 534 Hz, 801 Hz, etc. will resonate due to harmonics.

The quality factor[5] or Q factor is a dimensionless parameter that describes how damped an oscillator or resonator is. Lower Q indicates a higher rate of energy loss relative to the stored energy of the oscillator; therefore the oscillations die out more quickly. So products and designs that reduce the Q factor in a system are beneficial in reducing noise transmission.

Designing for Noise

Special tuning chambers in pumps and hydraulic attenuators can reduce noise in hydraulic systems at or near where it starts but can be costly and may not completely eliminate the problems. Additionally there are many other sources of turbulence in the system plumbing such as elbow fittings and transitions from full bore hose to steel tubing making multiple attenuators unfeasible.

Resonance Theory

"The exact response of a resonance, especially for frequencies far from the resonant frequency, depends on the details of the physical system, and is usually not exactly symmetric about the resonant frequency. For a lightly damped linear oscillator with a resonant frequency Ω, the intensity of oscillations when the system is driven with a driving frequency ω typically approximated by a formula that is symmetric about the resonant frequency:

$$I(\omega) \propto \frac{\frac{\Gamma}{2}}{(\omega - \Omega)^2 + \frac{\Gamma}{2}}$$

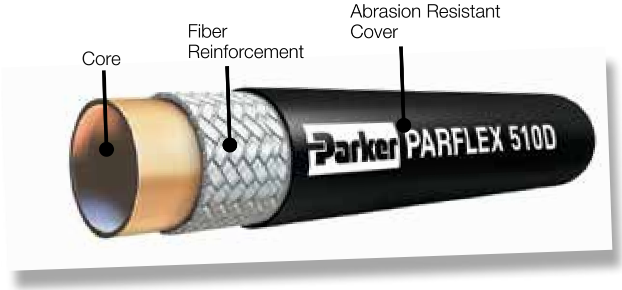
The intensity is defined as the square of the amplitude of the oscillations. This is a Lorentzian function, and this response is found in many physical situations involving resonant systems. Γ is a parameter dependent on the damping of the oscillator, and is known as the linewidth of the resonance. Heavily damped oscillators tend to have broad linewidths, and respond to a wider range of driving frequencies around the resonant frequency. The line width is inversely proportional to the Q factor, which is a measure of the sharpness of the resonance." A.E. Seigman, Author

5 James H. Harlow (2004). Electric power transformer engineering

Wire braided hose can replace steel tubing and relieve some amount of noise due to the full bore inside diameter and the additional volumetric expansion but the steel wire reinforcement still provides a good conduit of energy transfer in the form of vibrations through the system.

A quick and easy solution to eliminate noise is to install a thermoplastic fiber reinforced hose. These hoses are constructed using a variety of smooth bore polymer inner cores for a high degree of chemical compatibility, high strength fibers, and polymer jacket. Fiber braided thermoplastic hose is available in pressure ratings from 500 psi to 7500 psi. Also, fiber reinforced thermoplastic hose has an inherently higher volumetric expansion rate compared with that of an equivalent bore wire reinforced rubber hose, resulting in a total lower Q factor , thus improving noise damping. (see figure 1)

Parker's Parflex division has spent hours lab time invested in studying noise, as well as, working directly with customers to reduce the noise in their specific applications. Their wide offering of thermoplastic hoses use high strength fiber reinforcement using a variety of smooth bore polymer inner cores for a high degree of chemical compatibility, high strength fibers, and polymer jacket. Fiber braided thermoplastic hose is available in pressure ratings from 500 psi to 7500 psi. Also, fiber reinforced thermoplastic hose has an inherently higher volumetric expansion rate compared with that of an equivalent bore wire reinforced rubber hose, resulting in a total lower Q factor[6] , thus improving noise damping. (see figure 1)



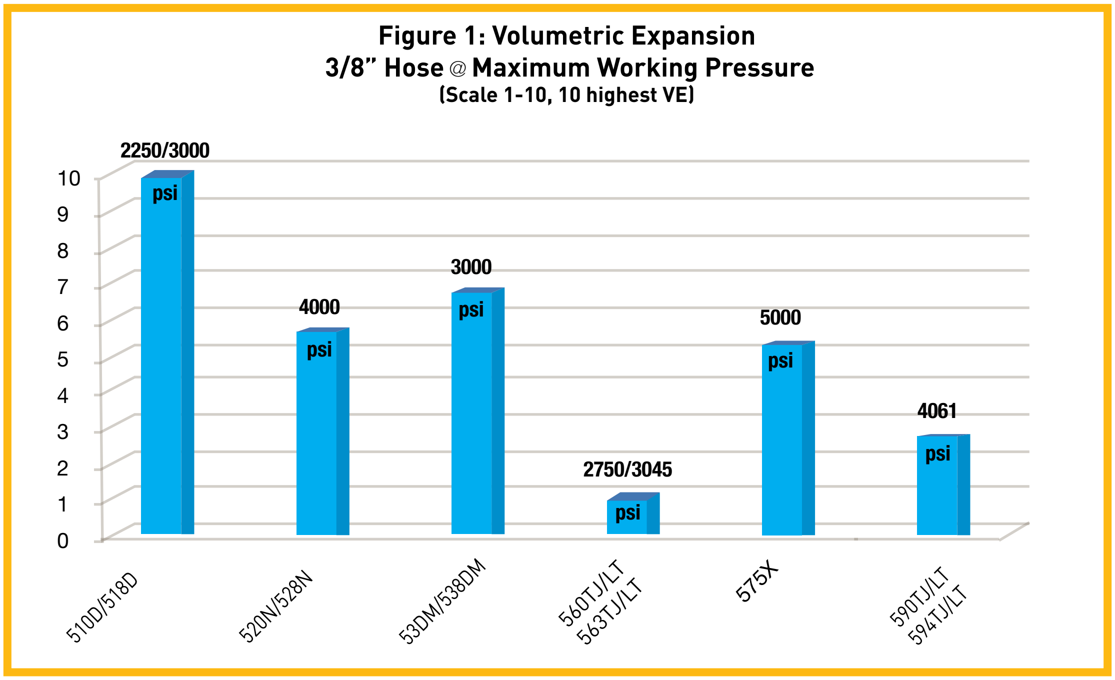


Figure 1 gives an example of the broad range of 3/8" bore thermoplastic hoses and their comparable volumetric expansion rates. These particular hoses are available from Parker Parflex. They have a proven, high degree of dampening effect and working pressures ranging from 1500 to 5000 psi at a 4:1 design factor.

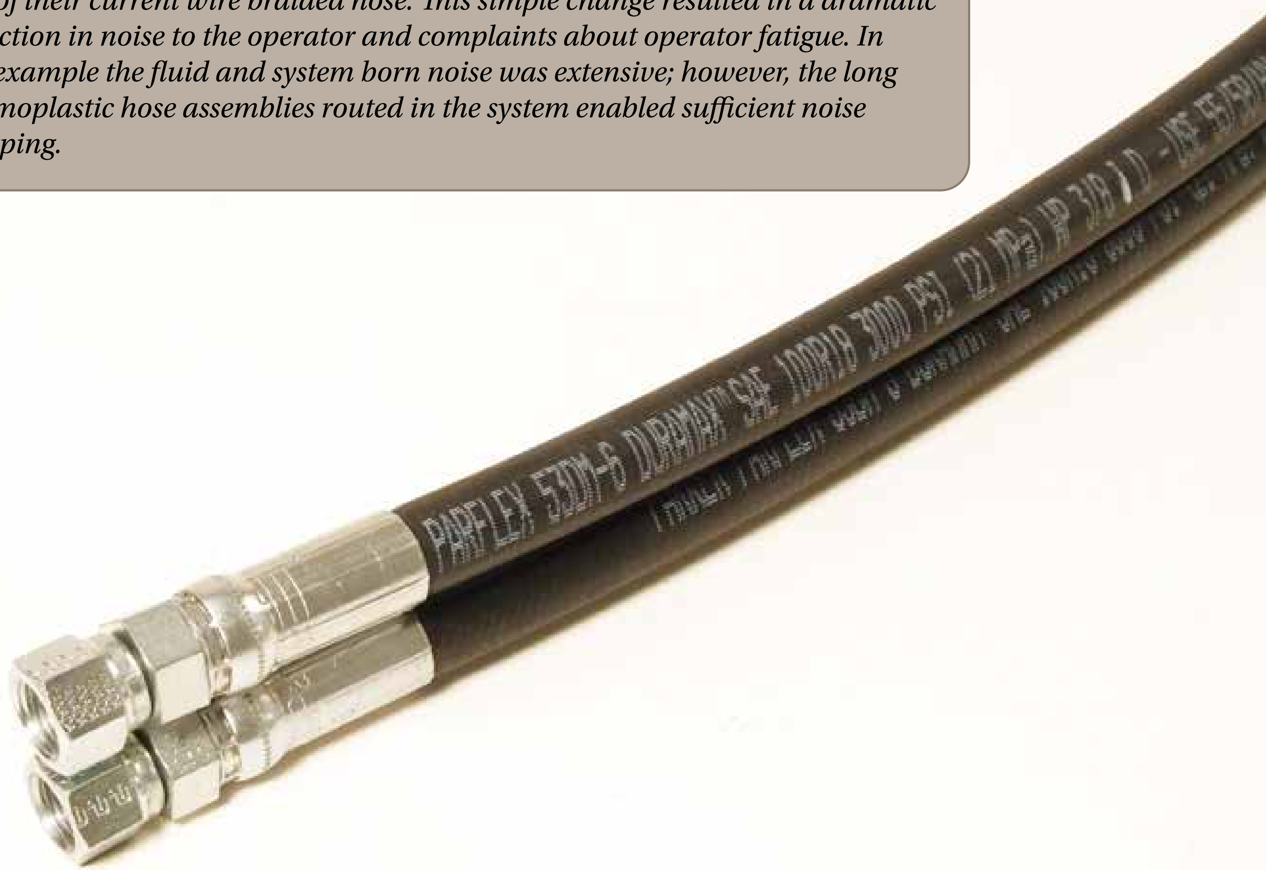
6 A.E. Seigman, 1986 Lasers

Parker's Parflex division has hours of lab time invested in studying noise, as well as, working directly with customers to reduce the noise in their specific applications. A wide offering of these thermoplastic hoses use high strength fiber reinforcement in place of steel and therefore, do not as readily transmit hydraulic vibrations from component to component. This can eliminate the additive effects of noise and potential of resonant frequencies propagating through a system by isolating the components. This, combined with a higher volumetric expansion, can act as an attenuator, driving fluid born noise from the system. Below are actual hose solutions developed by Parflex engineers to reduce and/or eliminate noise.

In each case, by working with Parflex, they were able to realize less operator fatigue and reduce overall application noise.

Case 1:

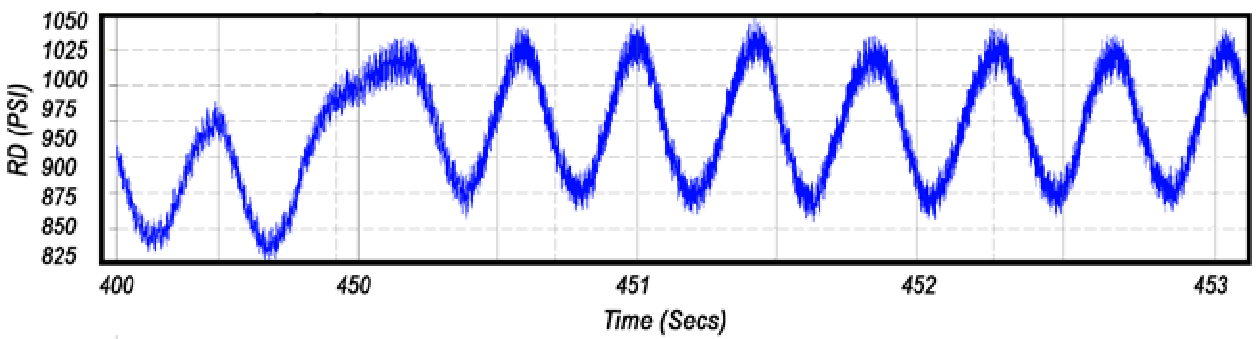
In 2001 a major manufacture of motor homes with rear engines was looking to solve a noise problem in their power steering system. The engine was 35 feet from the steering gear and the wire braided rubber hose routed between the pump and motor picked up multi-source noise from other mechanical system components along with additional road noise transmitting through the steering column. The manufacturer contacted Parker who suggested that they utilize 53DM hose in lieu of their current wire braided hose. This simple change resulted in a dramatic reduction in noise to the operator and complaints about operator fatigue. In this example the fluid and system born noise was extensive; however, the long thermoplastic hose assemblies routed in the system enabled sufficient noise damping.



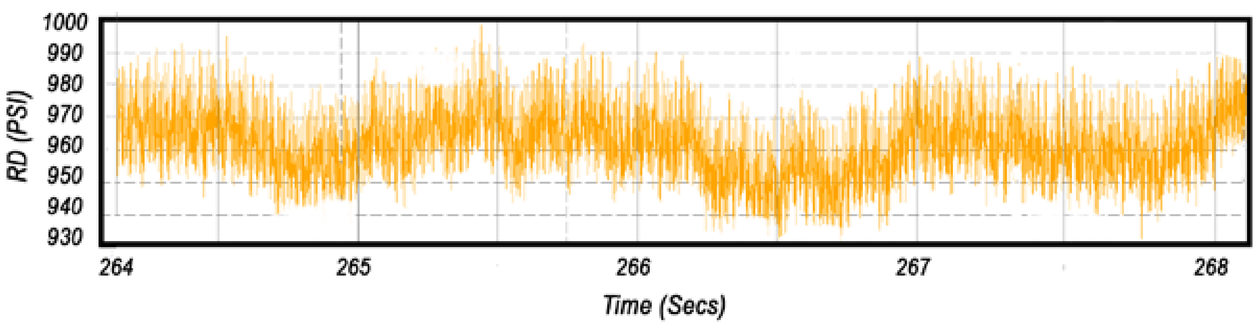
Case 2:

A major manufacturer of turf maintenance equipment was experiencing an annoying mechanical noise from its steering valve. End users complained of a pulse in the steering column resulting in a "popping" noise. The engineering team experimented with different types of hoses and settled on Parflex 510D hose. The high volumetric expansion rate naturally damped the pressure surge, eliminated the pulse in the steering column, thus eliminating the objectionable noise.

Typical Rubber Hose with Wire Reinforcement



Thermoplastic Hose with Fiber Reinforcement



re-created graph representative of data from an OEM

Case 3:

A truck manufacture was working on a steering system temperature reduction project. They were getting temperatures in excess of 280°F and needed to bring them down below 250°F. Parflex worked with the customer and determined that the temperature increase was due to the small reservoir size which did not allow for enough dwell time for cooling. Reconfiguring the new plastic reservoir and the millions of dollars in tooling was not an option.

The Parflex team suggested sizing up the pressure lines. The original -8 went to -10 and the suction/return went from -12 and -16 respectively. This added enough fluid to the system to reduce the temperature to manageable levels. Lowering the temperatures to manageable levels also lowered the noise levels. Review the Volumetric Expansion graphs on the next page to view data for the 520N/528N hoses.

Hydraulic hoses expand under pressure. On some applications, customers can use the differences in expansion between hoses to tune systems for better performance or even noise reduction. Parflex has tested a select list of hoses and determined the rate of expansion in cubic centimeters per foot of hose (cc/ft).

To calculate the volumetric expansion of a hose, substitute the desired pressure into the "X" values in the appropriate equation. For other hoses, please contact the division.

If you or your company could benefit from hydraulic noise reduction, please contact Parker representative :

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The actual volumetric expansion achieved is influenced by multiple variables including fluid properties, hose routing and application temperature. The volumetric expansion calculation is only a general guideline and must be verified by actual testing in the end-use application. No performance warranty in design is expressed or implied by this calculation. Parker recommends that the user review and understand all the precautions listed in the Parker Safety Guide for Selecting and Using Hose, Fittings and Accessories, bulletin BUL. 4400-b.1.

Volumetric Expansion of Hose

Hose Part Number	Volumetric Expansion at Maximum Working Pressure		Equation for Volumetric Expansion
	(psi)	(cc/ft)	Y=(cc/ft) X=(psi)
520N-3/528N-3	5000	1.13	Y = 0.0002x + 0.16
520N-4/528N-4	5000	2.05	Y = 0.00031x + 0.48
520N-5/528N-5	4500	2.63	Y = 0.00048x + 0.48
520N-6/528N-6	4000	2.87	Y = 0.00053x + 0.75
520N-8/528N-8	3500	3.64	Y = 0.00086x + 0.65
53DM-4	3000	1.90	Y = 0.00062x + 0.02
53DM-6/538DM-6	3000	3.19	Y = 0.0010x + 0.06
53DM-8	3000	4.68	Y = 0.0016x + 0.04
53DM-10	3000	9.82	Y = 0.0033x - 0.23
560TJ-4	3263	.757	Y = 0.0002x + 0.12
560TJ-6	2750	1.33	Y = 0.0004x + 0.19
560TJ-8	2500	1.98	Y = 0.0007x + 0.21
560TJ-10	2000	3.04	Y = 0.0012x + 0.57
560TJ-8	2500	1.98	Y = 0.0007x + 0.21
560TJ-10	2000	3.04	Y = 0.0012x + 0.57
575X-3	5000	1.69	Y = 0.0003x + 0.21
575X-5	5000	2.05	Y = 0.0003x + 0.56
575X-6	5000	2.71	Y = 0.0004x + 0.84
575XN-6	5000	4.59	Y = 0.00064x + 1.42
590TJ-6	4061	1.87	Y = 0.00038x + 0.32
590TJ-8	3553	2.17	Y = 0.00049x + 0.44
590TJ-12	2500	4.20	Y = 0.0013x + 0.82
510D-3/518D-3	3250	2.34	Y = 0.0007x + 0.06
510D-4/518D-4	3000	2.71	Y = 0.0009x + 0.01
510D-5/518D-5	2500	3.41	Y = 0.0013x + 0.16
510D-6/518D-6	2250	4.33	Y = 0.0019x + 0.05
510D-8/518D-8	2250	7.36	Y = 0.0032x + 0.16
510D-6/518D-10	2750	14.19	Y = 0.0053x - 0.39
510D-8/518D-12	1250	11.71	Y = 0.0087x + 0.83
510D-8/518D-16	1000	17.19	Y = 0.0157x + 1.47
563TJ/LT-6	3045	1.48	Y = 0.00038x + 0.32
563TJ/LT-8	3045	1.93	Y = .00049x + 0.44
563TJ/LT-10	3045	2.09	Y = .00061x + 0.23
594TJ/LT-4	4061	0.93	Y = 0.0002x + 0.12
594TJ/LT-6	4061	1.87	Y = 0.00038x + 0.32
594TJ/LT-8	4061	4.26	Y = .00049x + 0.44

Noise Facts

– **Noise in hydraulic systems is generated primarily by the mechanical workings of the pump and fluid pulsations exiting the pump as it sup plies the flow for the system**

– **Noise is additive**

– **Noise is audible as well as inaudible waves in the fluid**

– **Noise causes additional load on hydraulic components**

– **Noise is often caused by steel tube assemblies because they are known to be very susceptible to vibration failure**

– **Noise travels easily through metal**

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