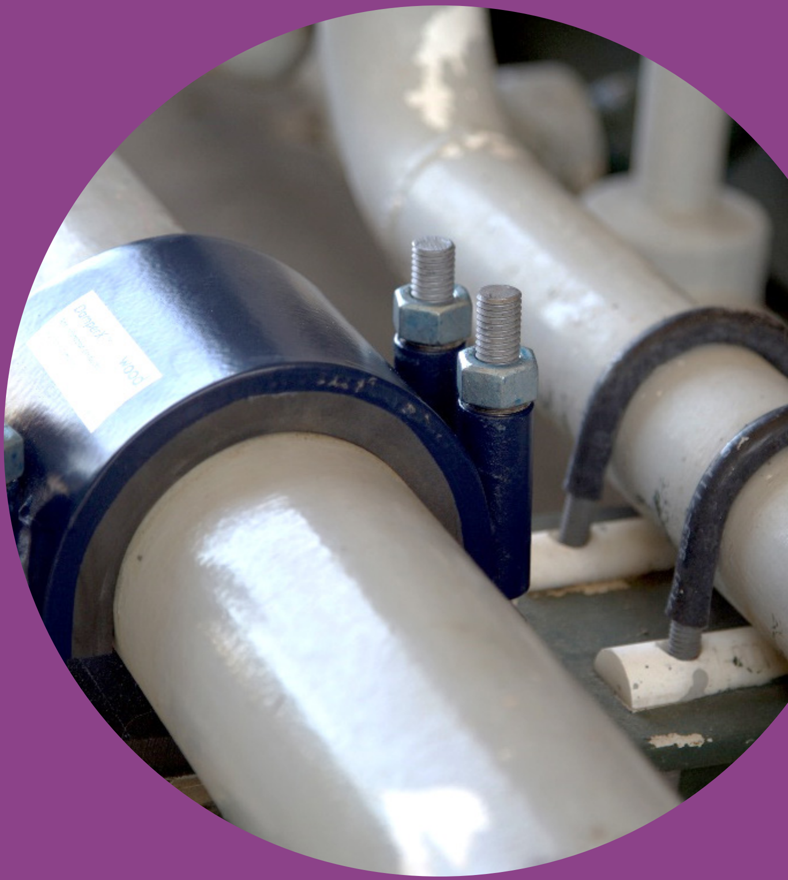
Technical report

Effects of various clamp liner materials on piping system vibration

Lab test results and field vibration measurements



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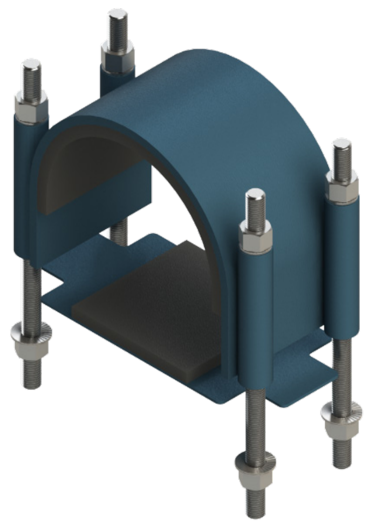
Executive summary

Experimental lab tests, both modal impact tests and shaker vibration tests, were conducted for a variety of pipe clamp liners to determine their ability to add damping to piping vibration modes and to quantify the corresponding reduction in vibration amplitude.

The tested liners included belting material (elastomeric with fiber reinforcement), silicone rubber, PTFE, Wood's DamperX™ clamps which include elastomeric material and a basic steel clamp as a baseline.

Results show that only the DamperX clamps added significant damping to the test piping span. Following successful lab tests, DamperX clamps were installed at a natural gas compressor station, where a significant reduction of piping vibration amplitudes was confirmed.



Introduction

Piping vibration and resulting fatigue failures are one of the most common causes of hydrocarbon releases (UK Health & Safety Executive). When vibration from machinery or flow conditions coincides with mechanical natural frequencies of the piping system, resonance occurs, which can cause excessive vibration leading to fatigue failures.

One approach to control vibration is to add damping to the system. Damping is widely used in the automotive and aerospace industries but has not commonly been applied in the oil and gas industry. Whether the source of vibration is from machinery forces, machinery generated pulsations, or flow-induced pulsations, additional damping from pipe clamp liners can significantly reduce mechanically resonant vibration.

Building on research with the Gas Machinery Research Council (GMRC), Wood has conducted vibration tests and field measurements to quantify the change in piping system response using various pipe clamp liner materials commonly found in industry.

Laboratory vibration testing

A simple piping system consisting of a span of pipe with two clamps was used to assess the damping effect of clamp liners, as shown in Figure 1. Wide-flange beams under the pipe clamps were anchored securely to a concrete foundation. An electromagnetic shaker was used to apply a dynamic force to the piping system at the center of the span and create vibration.

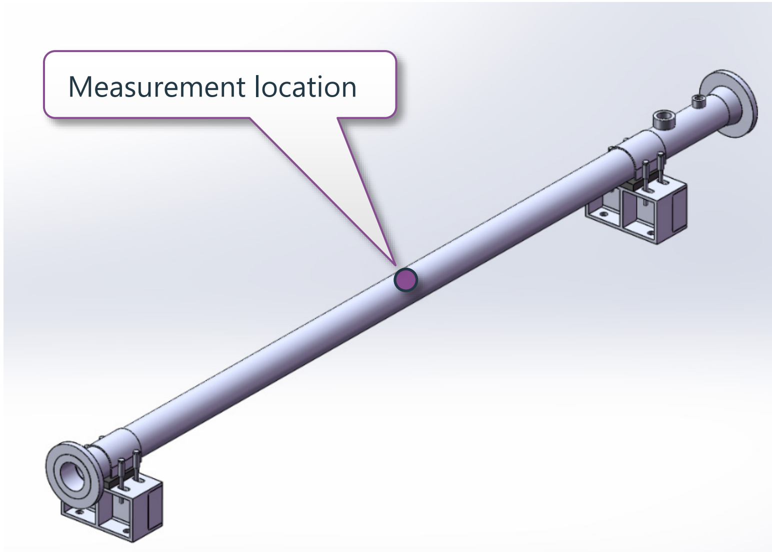


Figure 1 – Test piping span

Multiple pipe clamp liner materials were evaluated to determine their ability to add damping to the piping system. The tested materials are shown in Figure 2 and include a basic steel clamp along with liners of PTFE, belting material (elastomeric with fiber reinforcement), silicone rubber and Wood's elastomeric liners used in DamperX clamps.

Figure 2 – Test clamp configurations

In all cases, the hold-down bolts of the clamps were torqued to 250 in-lb, as is typical for this clamp size. The test pipe was a 4 in (10 cm) XS, and the flanges on the span were ANSI 150# rated. The distance between clamps was 96 in (244 cm). This arrangement has the benefits of being easily reproducible for future testing and simple to model and compare in any piping analysis software.

Two types of tests and measurements were completed to quantify the damping benefits of the various liner materials. An impact modal test, also referred to as bump test, was conducted first. The results of this test included a frequency response function (FRF), which shows the response of the pipe to excitation in the frequency spectrum.

The tabulated results of the impact tests with the various clamp liners are shown in Figure 3. For the test data presented, the span of pipe was impacted and the vibration response recorded at the center of the span. The vibration reduction was calculated by taking the magnitude of the response peak of the lined clamp and comparing it to the magnitude response of the unlined steel clamp. Vibration reduction values are listed for both the horizontal (H) and vertical (V) mode directions.

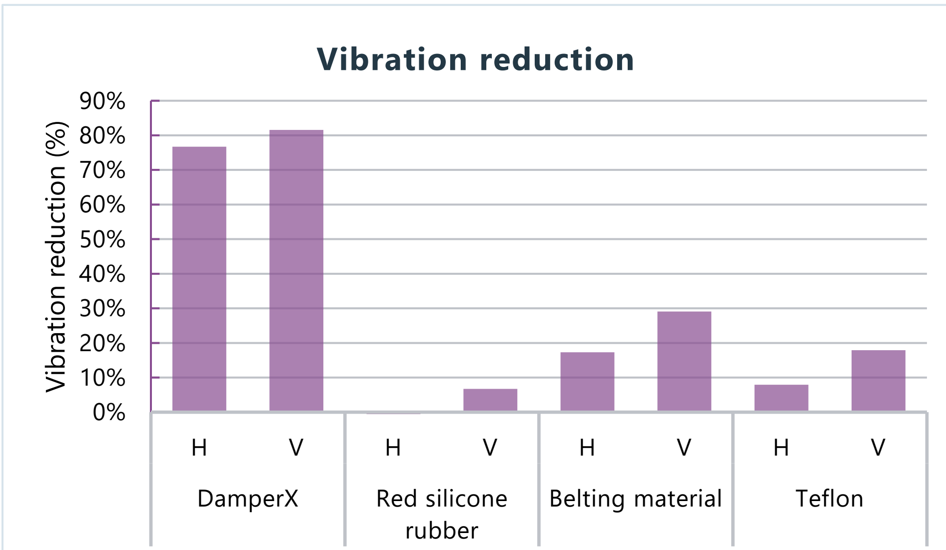


Figure 3 – Vibration reduction by lining, as a percentage of an unlined steel clamp

DamperX clamps showed a significant benefit over other linings in terms of response reduction for the first bending mode shape of the piping span. For the liner material to add damping to this mode, the material must undergo deformation at the clamp location. A finite element analysis indicated that, since the piping span is nodal (has zero deflection) in the three translational directions, the liner material would only add damping to the piping mode if the material was deformed rotationally at the clamp locations and if the rotation had a significant damping participation. This test showed that the DamperX material, when used as a lining, is able to reduce vibration by up to 80% compared to an unlined clamp.

The next test performed was a running vibration test, where the electromagnetic shaker was used to create vibration in the piping span. The shaker was installed on the piping span at the halfway point, right next to the measurement location. Vibration was created and measured in two planes, vertical (V) and horizontal (H). The tabulated results of the running tests with the various clamp liners are shown in Figure 4.

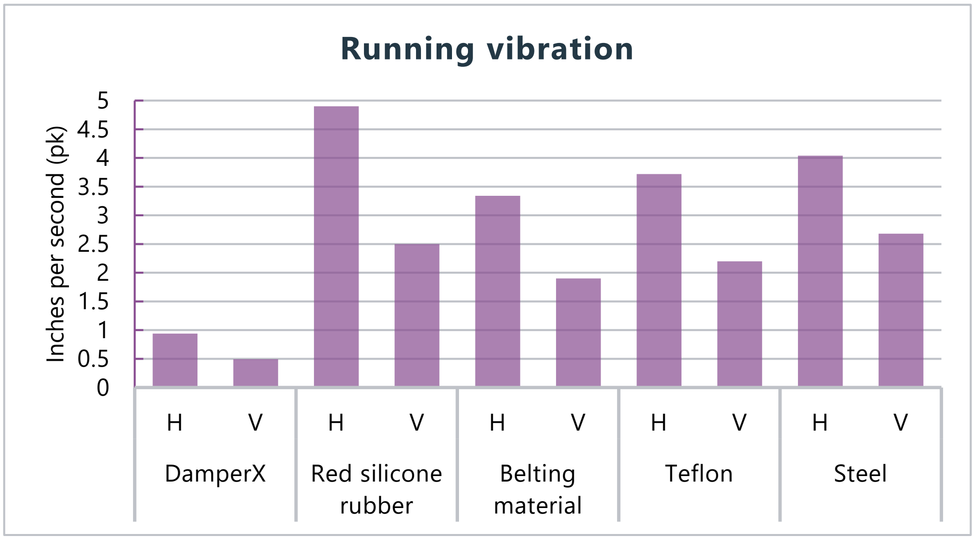


Figure 4 – Running vibration by lining

The DamperX clamps produced a 70% percent vibration reduction in the horizontal direction and an 80% reduction in the vertical direction, considering the running test and the steel clamps as a baseline.

The resulting vibration with the various clamp liners is a function of liner stiffness, material damping loss factor, coefficient of friction and geometry of the pipe clamp relative to the direction of vibration. The silicone rubber liner, for example, has a higher damping loss factor than steel. However, the reduction in stiffness results in a higher vibration amplitude. This stiffness loss was not observed in any significant sense with the DamperX material, and the running vibration test has good coherence with the impact testing results.

Field vibration testing

Following the laboratory tests, Wood's DamperX clamps were installed on the discharge line of a reciprocating compressor at a natural gas compressor station in Texas, USA. The compressor was a two-throw single-stage unit, operating from 1350-1650 RPM. The discharge line was selected to be re-fitted with DamperX clamps:

- The piping between the cylinder and the cooler had been previously secured with a single flatbar clamp style hold-down support. This support was removed, and a new support pedestal was modified to accommodate the DamperX clamp (bolt hole spacing). The DamperX clamp was installed right next to the old support location. The temperature of the discharge line required the use of a clamp lined with DamperX HT (high temperature) material suitable for the higher temperatures.
- The piping downstream of the cooler was initially secured with coated double-U-bolts at five locations. These u-bolts were removed, and DamperX clamps were installed as direct substitutes.

The temperature of the after-cooler line was low enough to allow using a clamp lined with DamperX HD (high damping) material.

Impact and running vibration tests were carried out for both the original support arrangement and the DamperX arrangement. The vibration test points are shown in Figure 5.

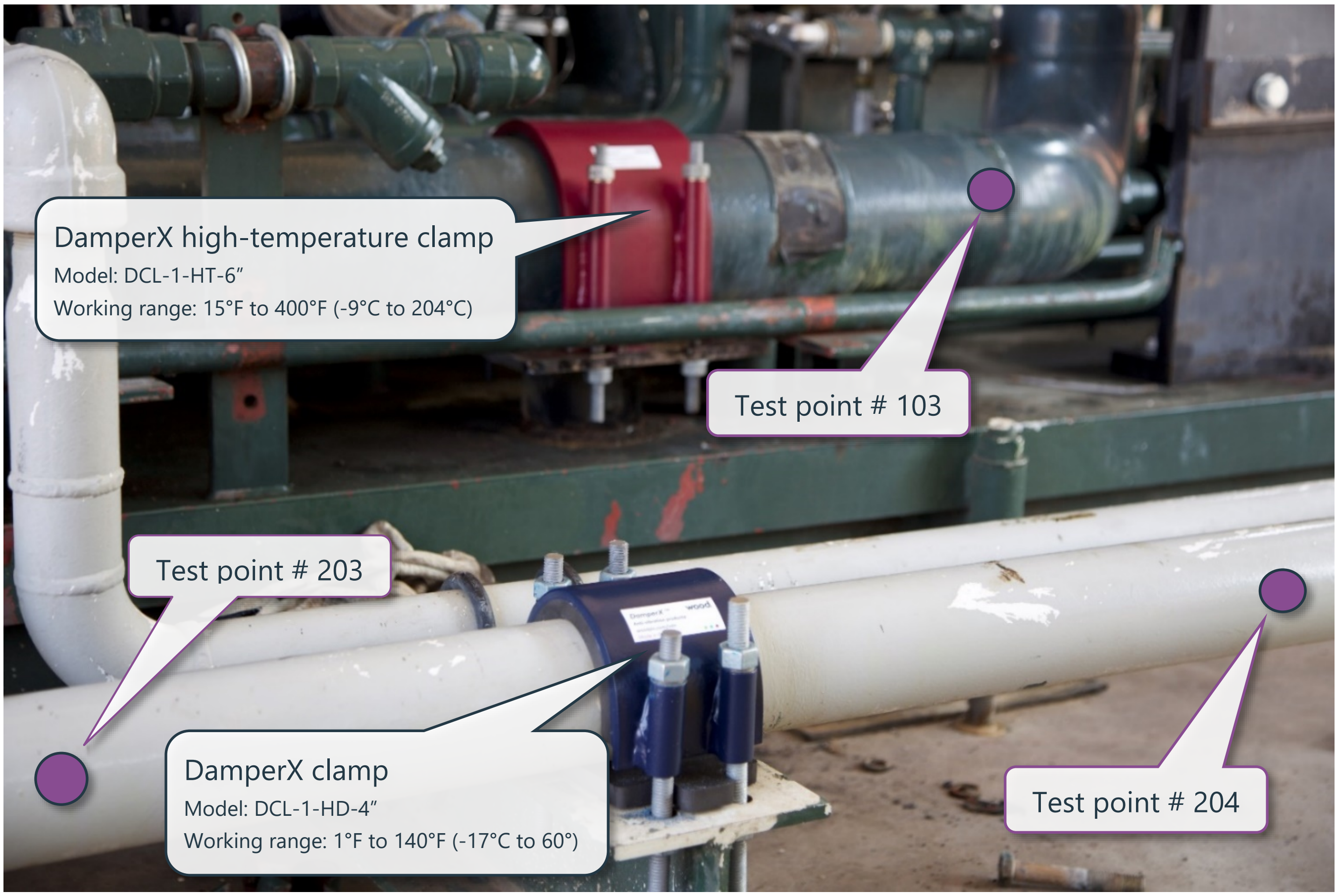


Figure 5 – Main discharge pipe with DamperX clamps installed (TPs #203 and #204)

Results from the impact test at point #103 are shown in Figure 6 and Figure 7. Results from the running vibration tests at points #203 and #204 are summarized in Table 1. The individual speed-sweep vibration plots are provided in Figures 8 to Figure 11.

Conclusions

The results show significant reductions in vibration with the substitution of unlined hold-down clamps and u-bolts for DamperX clamps. Vibration was reduced between 40 and 90% at the main resonant peaks. Additionally, many reductions were also observed across the frequency spectrum. DamperX clamps provide a significant vibration reduction benefit when applied to resonant piping vibration issues and can be used as a potential solution to challenging vibration problems.

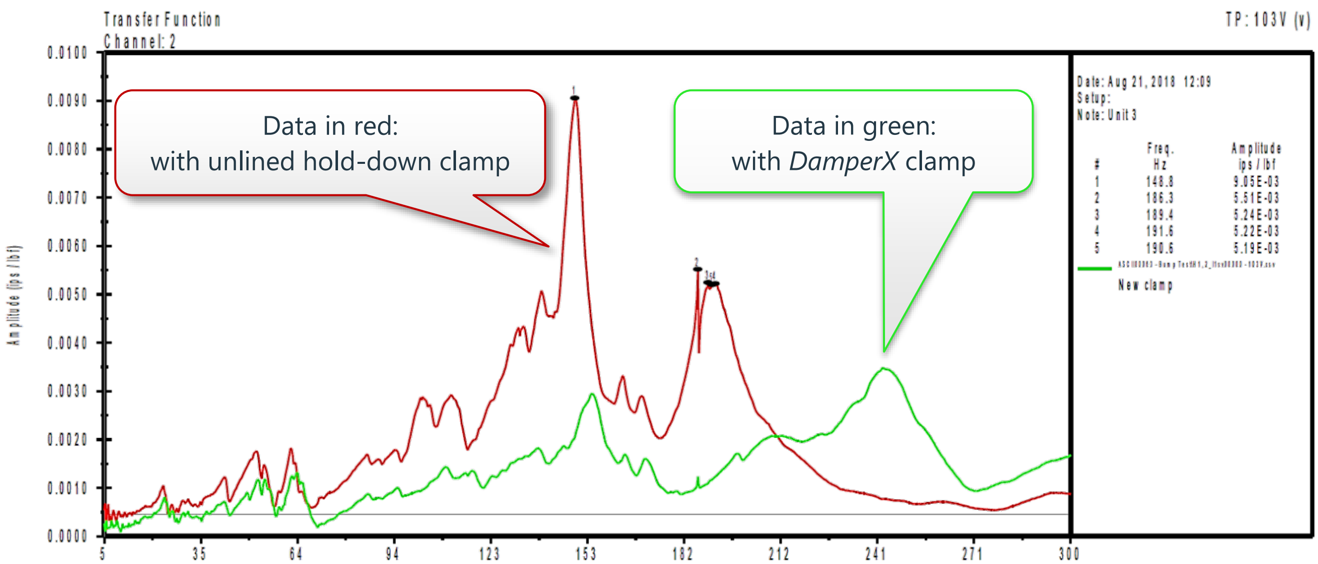


Figure 6 – Impact test of main discharge pipe vertical direction (before and after TP #103)

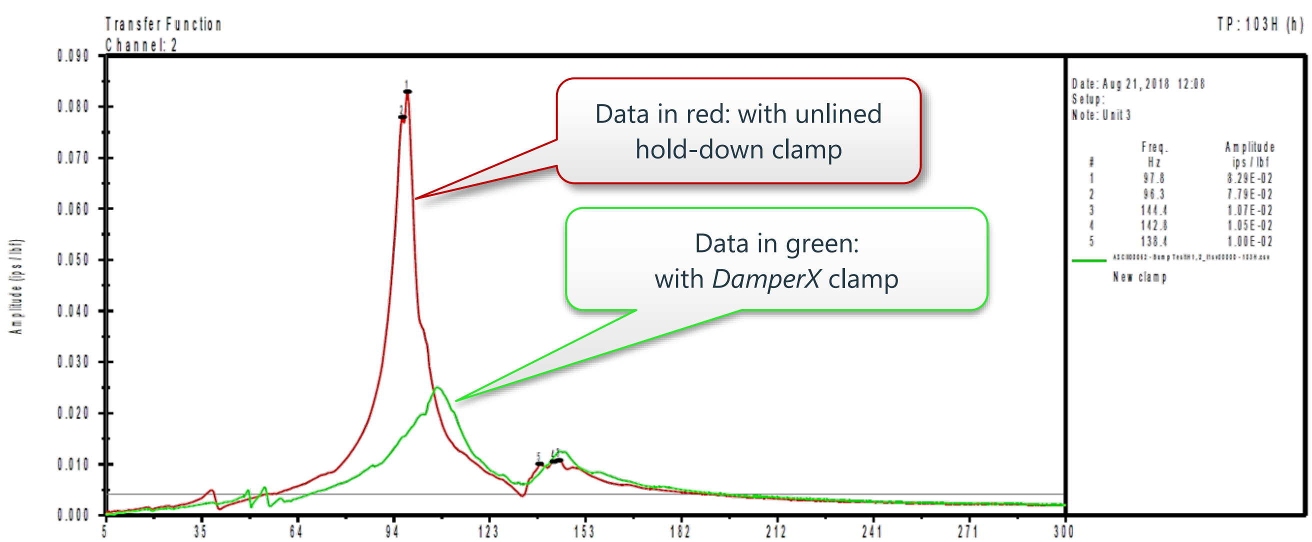


Figure 7 – Impact test of main discharge pipe horizontal direction (before and after TP #103)

Table 1 – Summary of vibration for final discharge pipe (TP # 203 and #204)

TP #	TP Description	Dir'n	% of Guideline		Vibration peak (in/s) @ Frequency (Hz) & % above Guideline (%)	
			BEFORE	AFTER	BEFORE	AFTER
203	Main Discharge Pipe	H	120	68	1.2 in/s pk @ 55.6 Hz (120%)	0.677 in/s pk @ 99.7 Hz (68%)
		V	149	94	1.49 in/s pk @ 99.1 Hz (149%)	0.942 in/s pk @ 103.1 Hz (94%)
204	Main Discharge Pipe	H	256	35	2.56 in/s pk @ 55.6 Hz (256%)	0.35 in/s pk @ 82.2 Hz (35%)
		V	76	44	0.76 in/s pk @ 55 Hz (76%)	0.438 in/s pk @ 51.9 Hz (44%)

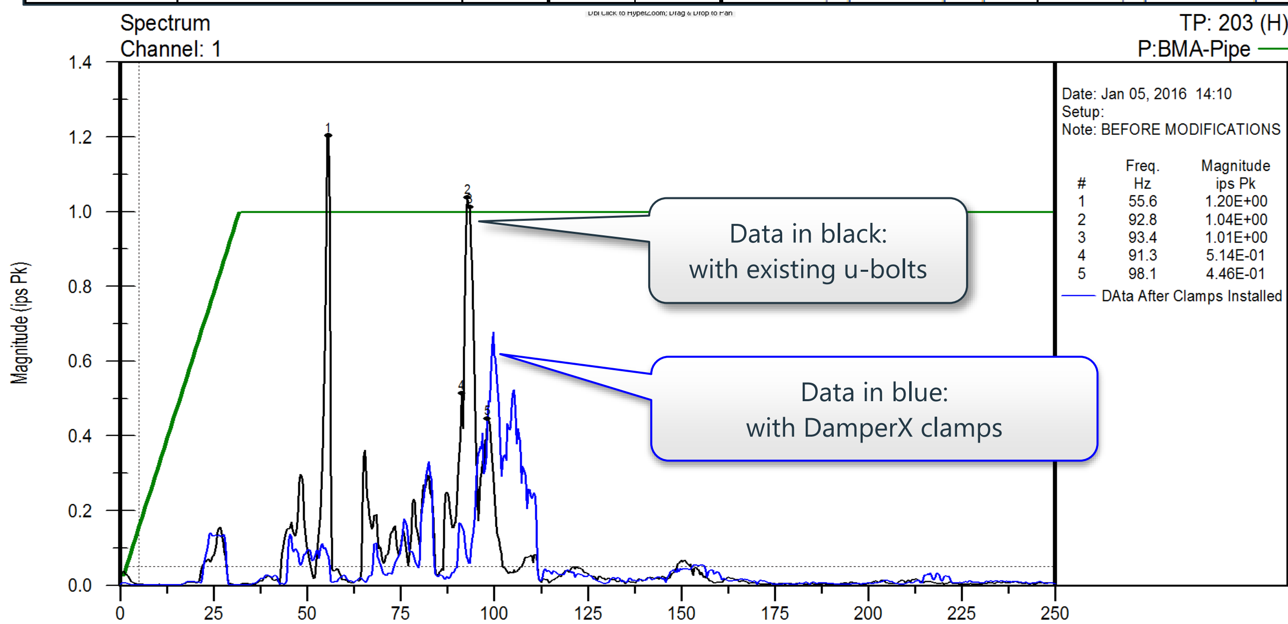


Figure 8 – Operating vibration of main discharge pipe horizontal direction (before and after TP #203)

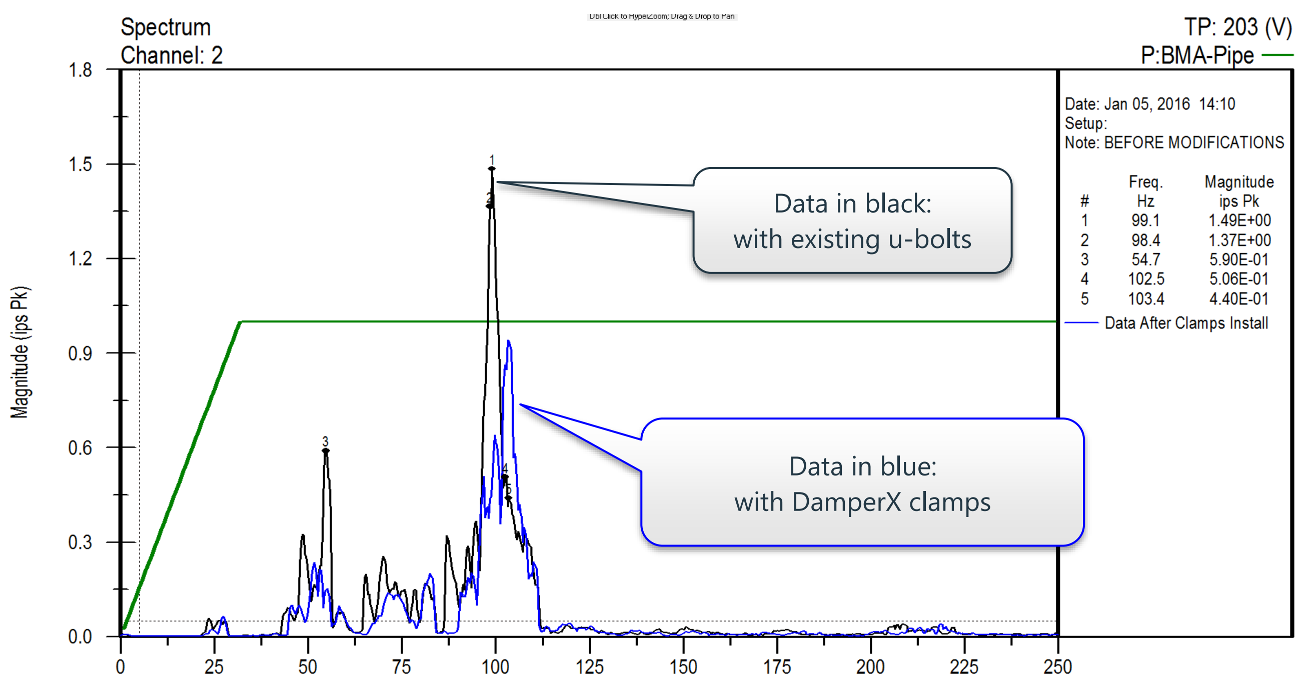


Figure 9 – Operating vibration of main discharge pipe vertical direction (before and after TP #203)

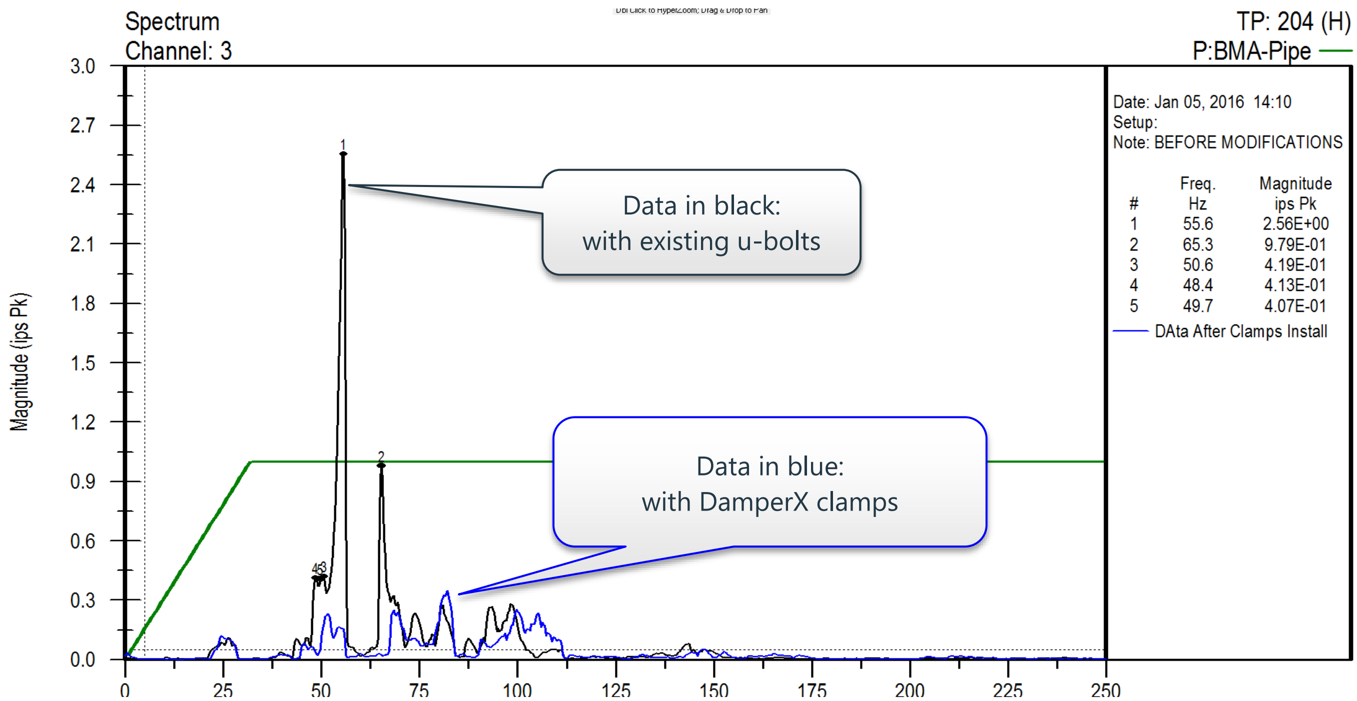


Figure 10 – Operating vibration of main discharge pipe horizontal direction (before and after TP #204)

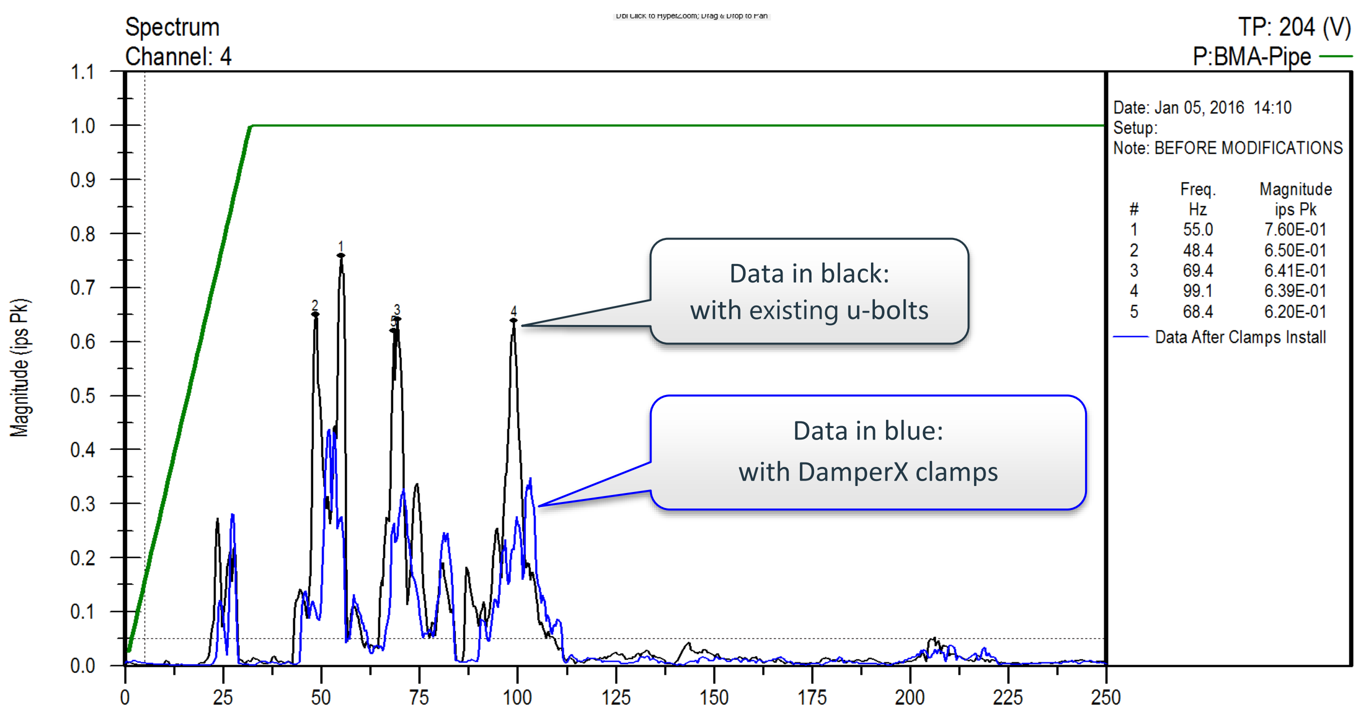


Figure 11 – Operating vibration of main discharge pipe vertical direction (before and after TP #204)

Contact us at info.vdn@woodplc.com or visit our dedicated vibration, dynamics and noise pages at woodplc.com/vdn for more information.