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FLUX DRIVE WHITEPAPER

IDENTIFYING AND CORRECTING MISALIGNMENT WITH THE FLUX DRIVE *Smart*COUPLING™

For more than 25 years, Flux Drive has been delivering vibration monitoring and mitigation services – combining expert rotating equipment analysis with simple and effective corrective measures. However, as anyone familiar with vibration monitoring knows, determining the source and underlying cause of vibration problems is no easy task – especially when multiple pieces of equipment are combined in complex industrial processes.

Fortunately, Flux Drive's new Inline SmartCOUPLING provides both diagnostic assistance and a means to correct severe misalignment. The following paper describes the ways in which the SmartCOUPLING addresses these issues.

Why worry about vibration?

Maintenance managers understand that vibration is the root cause of a wide array of costly rotating equipment problems - from failed bearings to broken shafts and leaky pump seals.

Indeed, as shown in the following equation, bearing life (L_{10}) is related to the cube of ratio of rate to load - where 'Rate' is the *rated* load capcity of the bearing and 'Load' is the *actual* load on the bearing: $L_{10} = (16{,}666/RPM)\ X\ (RATE/LOAD)^3$

Load itself is comprised of two components, the static load (i.e. the actual weight carried by the bearing) and the dynamic load, which results for misalignment or unbalanced – which in turn show up as vibration. Since there is a cubic relationship, a doubling of the total load on the bearing will result in an *8-fold* decrease in bearing life! While vibration may not account for such a large portion of the overall load in comparision with the static force of the application, it's easy to understand how even small amounts of vibration from misalignment can lead to very large decreases in bearing and seal life.

Understanding the true sources of vibration

One of the most common challenges for vibration specialists is identifying which elements within a vibration spectrum should be attributed to each piece of connected equipment. When motor and load are physically coupled (including via "soft" or "flexible" couplings) vibration from one piece of equipment is easily registered in another. Vibration can also travel through the motor/pump base. Clearly, if the motor and load could be fully isolated during analysis, a much clearer picture would emerge of exactly where the vibration is originating.

Unlike any other coupling, the Flux Drive SmartCOUPLING fully isolates the motor from the driven load. Torque is transmitted magnetically across an air gap, with no physically touching parts to convey vibration from one source to another.

Further, the SmartCOUPLING's underlying technology creates a very slight speed differential between the motor and load. When the coupling is configured for full speed operation, the speed differential is less than 2%. This typically has no impact on system's overall performance, but is signifant enough to allow differentiation between vibration frequencies – and therfore the sources of those frequencies.

Another unique feature of the SmartCOUPLING is the ability to further reduce load speed through the addition of air gap spacer shims. By allowing the load to run at any speed between approximately 50% and 98+% of motor speed, the coupling allows for fine tuning of energy consumption based on process requirements.

Vibration analysis example – 40hp pump @ 1800rpm

To provide an example of the vibration analysis benefits of the SmartCOUPLING, a test was performed to compare vibration readings between a grid-style coupling and the Flux Drive SmartCOUPLING. To begin, a grid coupling was installed on a 40hp pump skid and laser aligned to the coupling manufacturer's tolerances. A chart showing the final alignment values is provided below.

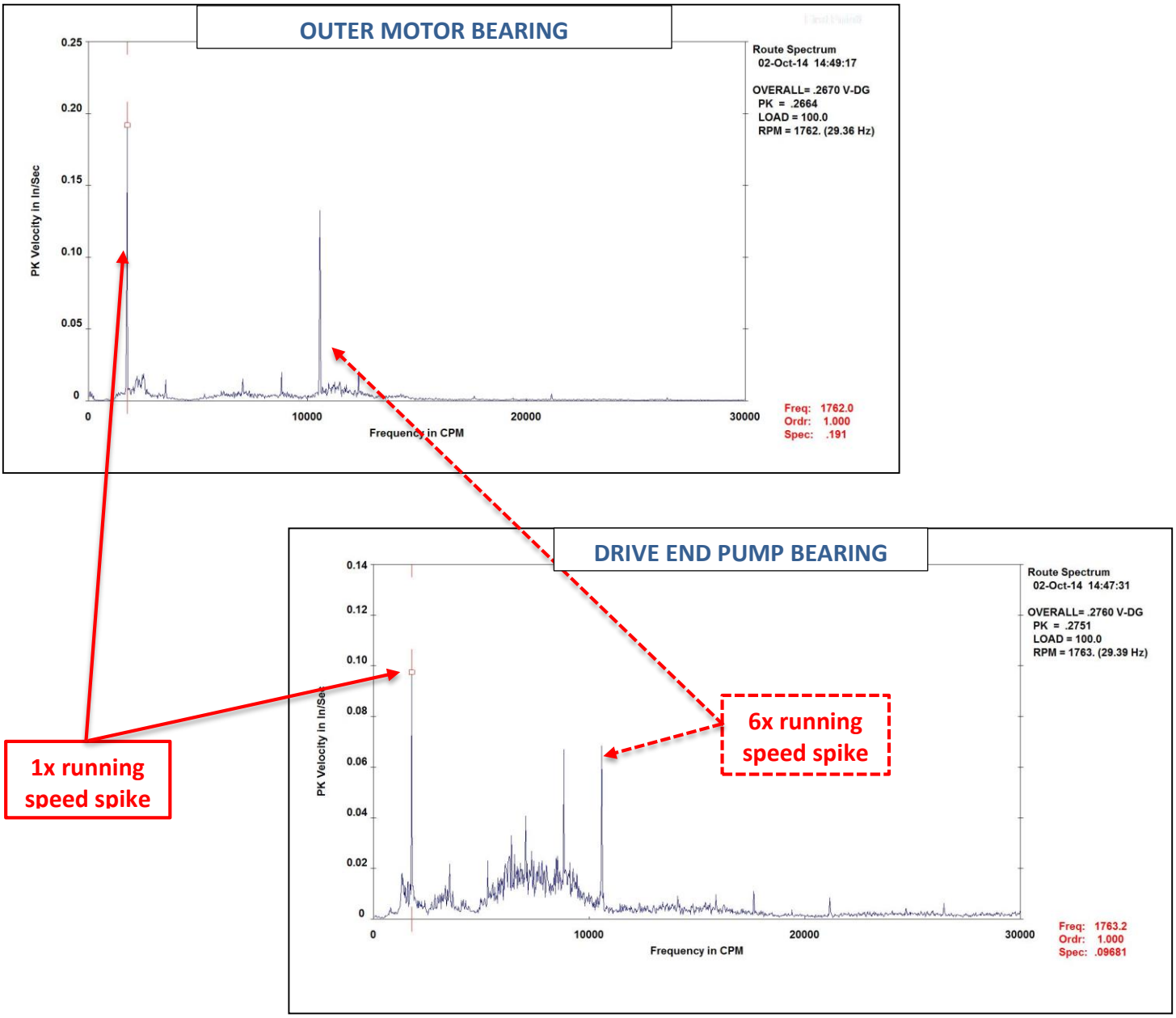
Grid Coupling Laser Alignment				
Parameter	Vertical Offset (mils)	Horiz. Offset (mils)	Vertical Angle (mils/10in)	Horiz. Angle (mils/10in)
Target	<3.0	<3.0	<5.0	<5.0
Measured	-2.1	2.4	-2.0	1.0

Since the grid coupling has no ability to change the load speed, vertical, horizontal, and axial vibration data was recorded with the motor and pump running at full motor speed under load (1762 rpm). The horiontal direction provided the highest amplitude vibration for comparison purposes between the grid coupling and Flux Drive and is therefore shown throughout this paper. The changes in vertical and axial vibration levels, however, followed the horizontal vibrations very closely.

The images below represent the horizontal vibration spectrum at the Rear motor bearing (left) and at the drive end pump bearing (right). Note the peak value of 0.191 in/sec at 1x running speed on the motor. Again, because the pump is running at full motor speed, the peak appears at the same frequency on the pump spectrum – but with a lower amplitude of 0.096 in/sec. Because the pump and motor vibrations occur at exactly the same frequency, it is impossible to determine the level at which each device is contributing to the overall vibration within either spectrum. For instance, because there are so many potential factors involved, it is impossible to know if an imbalance in the motor rotor is causing the majority of the 0.191in/sec peak, or if perhaps an impeller imbalance is causing a vibration that is being transmitted down the shaft and into the motor.

Further, note that there is a second significant vibration registering at approximately 6x running speed (~10,570rpm) on both spectra. In this case, the pump has a six-bladed impeller, leading to a vane pass vibration at that frequency. Because there is a physical connection between the motor and pump via the grid coupling, the vane pass vibration from the pump is clearly registered in the motor. As will be seen later, the majority of this vibration from the pump is travelling down the shaft and into the motor through the grid coupling, although a smaller portion is also travelling through the motor base.

The other smaller anomalies between 1762 and 10,570 rpm largely appear only on the pump spectrum, and can therefore clearly be identified as cavitation or other pump-related phenomena.



In the second phase of the test, the grid coupling was replaced with a SmartCOUPLING. The SmartCOUPLING was also laser aligned to provide the most direct comparison between the two technologies - but it should be noted that laser alignment is not normally required when installing the SmartCOUPLING. Because a 0.100" minimum air gap exists between the permanent-magnet rotor and induction rotor portions of the coupling, motor and load shafts can be misaligned up to that amount with no negative effects on vibration or the coupling's ability to transmit torque. Nonetheless, for this test the SmartCOUPLING was laser aligned to the values shown.

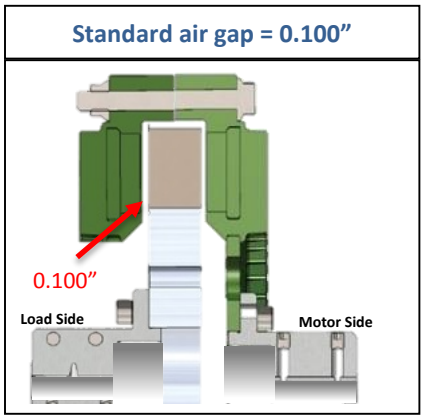
SmartCOUPLING™ Laser Alignment				
Parameter	Vertical Offset (mils)	Horiz. Offset (mils)	Vertical Angle (mils/10in)	Horiz. Angle (mils/10in)
Target	<3.0	<3.0	<5.0	<5.0
Measured	-2.1	2.4	-2.0	1.0

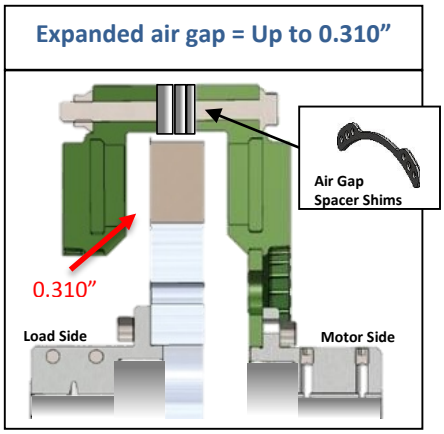
A truly unique feature of the SmartCOUPLING is the ability to adjust the air gap between the induction rotor plates (connected to the motor shaft) and the magnet rotor (connected to the load shaft). Doing so provides three separate but related benefits:

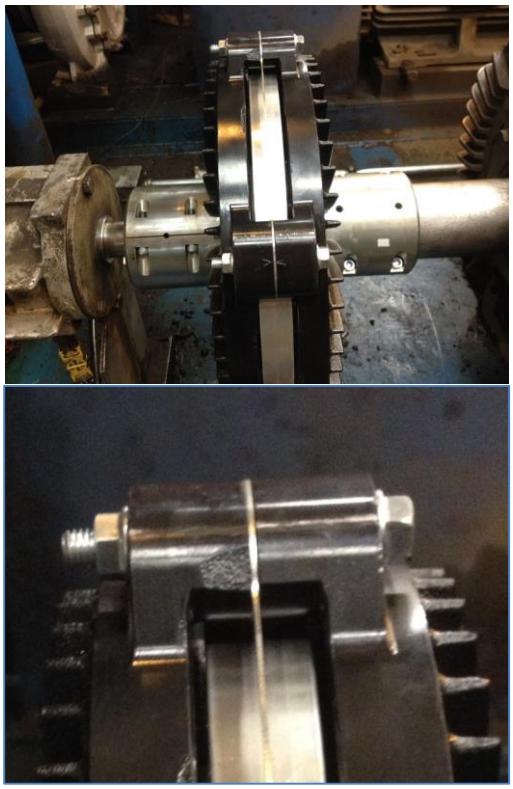
1) The increased air gap decreases the magnetic coupling effect between the motor and load, allowing the load to operate at a lower speed. On centrifugal loads such as most pumps and fans, a reduction in load speed results in an exponential reduction in energy consumption - providing substantial cost savings on oversize systems. As an example, a 20% reduction in speed using the SmartCOUPLING will provide a 40+% energy savings.

2) Increasing the air gap provides additional misalignment accomodation. While the standard 0.100" air gap is typically more than enough to accommodate even the most severly misaligned systems, the air gap spacer shims can add up to an *additional* .210" of axial misalignment capacity to each side of the coupling.

3) Specificially related to the topic of this paper, separating the motor and load operating speed allows for independent analysis of the vibration spectrum by allowing the motor and load to run at different speeds.





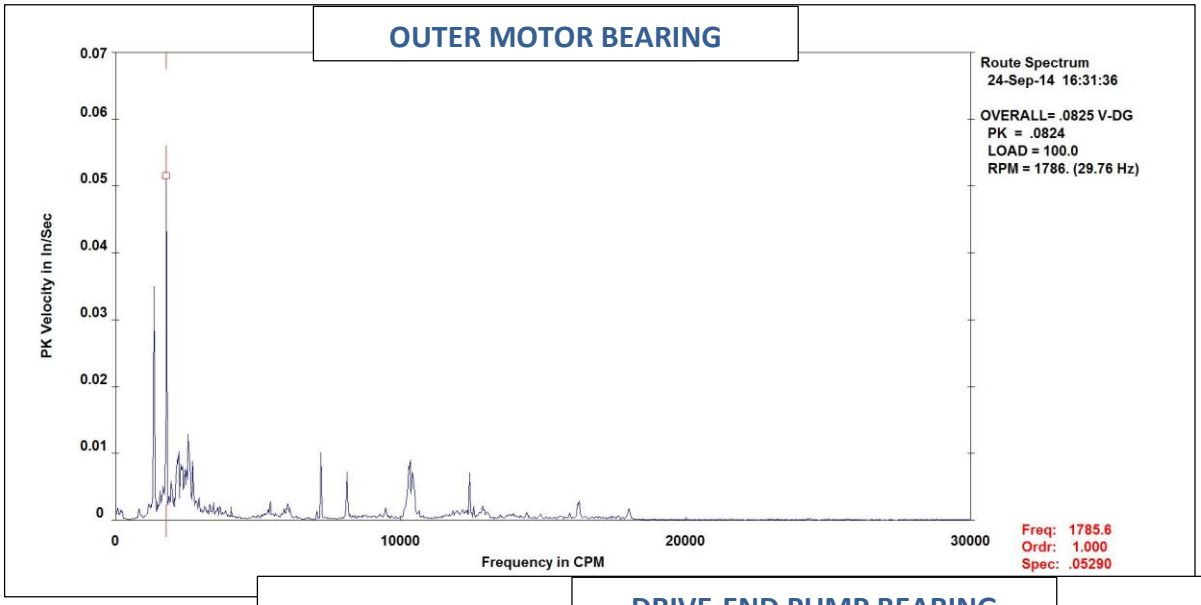


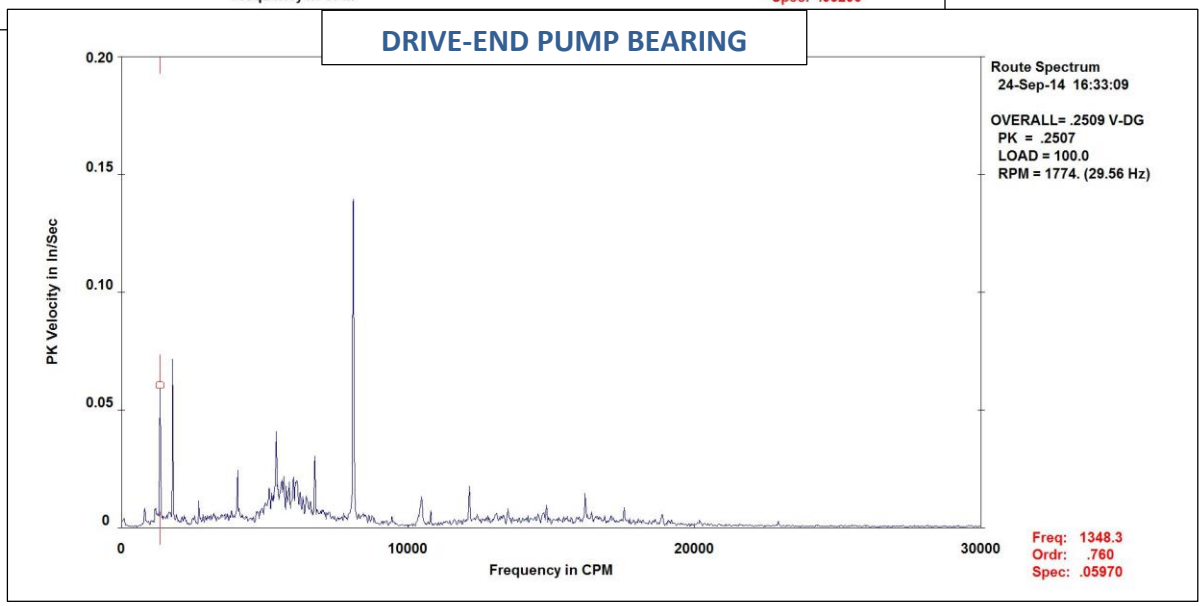
A single air gap spacer shim installed on an FSC

In this comparison, the SmartCOUPLING was configured with an additional air gap spacer shim to demonstrate load speed reduction capabilities. With a single 0.100" shim installed, the air gap was increased from 0.100" on each side of the magnet rotor to .150". This resulted in a pump speed of 1348rpm – or about 24% below motor speed.

Analyzing the same horizontal spectra for the rear motor bearing and drive-end pump bearing on the following page, we can now see the benefits of the SmartCOUPLING even more clearly.

First, the amplitude of the 1x running speed vibration on the motor is instantly reduced from .191 in/sec to 0.052 in/sec – a nearly 4x reduction. Second, the 6x vane pass vibration that originates in the pump, but was clearly visible in the motor spectrum, is nearly eliminated from the motor. Finally, the overall amplitude of vibration from cavitation in the pump (the "chatter" found between the 1x and 6x running speeds in the original pump spectrum) is also considerably dampened.





Note that a small amount of vibration is still transferred between the two devices via the motor/pump base. This is unavoidable, but reveals another critical benefit of the SmartCOUPLING's speed reduction capabilities: *For the first time, vibration analysts can use a coupling to isolate motor related vibration from pump-related vibration by running the two devices at different speeds. This is not possible with any other form of "flexible" coupling since those couplings maintain a synchronous speed between motor and pump.*

As seen in both images above, two separate peaks occur on the left side of the spectra images. These peaks signify the now different 1x operating speeds of the motor and pump (1785 and 1348rpm respectively). The motor speed has actually increased slightly due to the fact that reduced speed operation of the pump has unloaded the motor – causing less internal slip in the motor itself. It is this reduction in speed and the resulting reduction in torque requirement that results in the energy savings previously mentioned.

When considering the amplitude of the peaks, it can be seen that the amplitude of both the motor and pump running speed spikes are considerably reduced compared to the combined amplitude in the grid coupling charts shown earlier. Both measure approximately 0.05 in/sec or below, compared to the 0.191 in/sec single peak shown in the grid coupling test.

Because the speed reduction on the pump clearly separates motor-caused vibration from load-caused vibration, the analyst can more easily determine the underlying source of those vibrations (i.e. imbalance, misalignment, resonance) using common spectrum analysis techniques.

As an example, if imbalance in the pump impeller was the root cause of vibration, the analyst would expect to see a relatively high value at 1x the pump running speed – but not at 1x the motor running speed. If imbalance in the motor rotor was the culprit, the opposite would be true.

With a solid-coupled system where load speed matches motor speed, breaking out the root causes of the vibration, and ultimately identifying solutions, is a much more difficult task.

Maintaining equipment performance and longevity with misalignment

While establishing proper alignment is obviously critical at the time of initial installation, it is also a reality that equipment becomes misaligned over time – sometimes severely. Another benefit of the SmartCOUPLING is its ability to accommodate increasing misalignment due to thermal growth, vibration, or other factors without a resulting increase in system vibration.

In addition to the comparison of the laser-aligned SmartCOUPLING and Grid Coupling discussed above, further tests were performed to determine the vibration dampening capabilities of the SmartCOUPLING as offset/misalignment between the shafts was intentionally, and dramatically, increased.

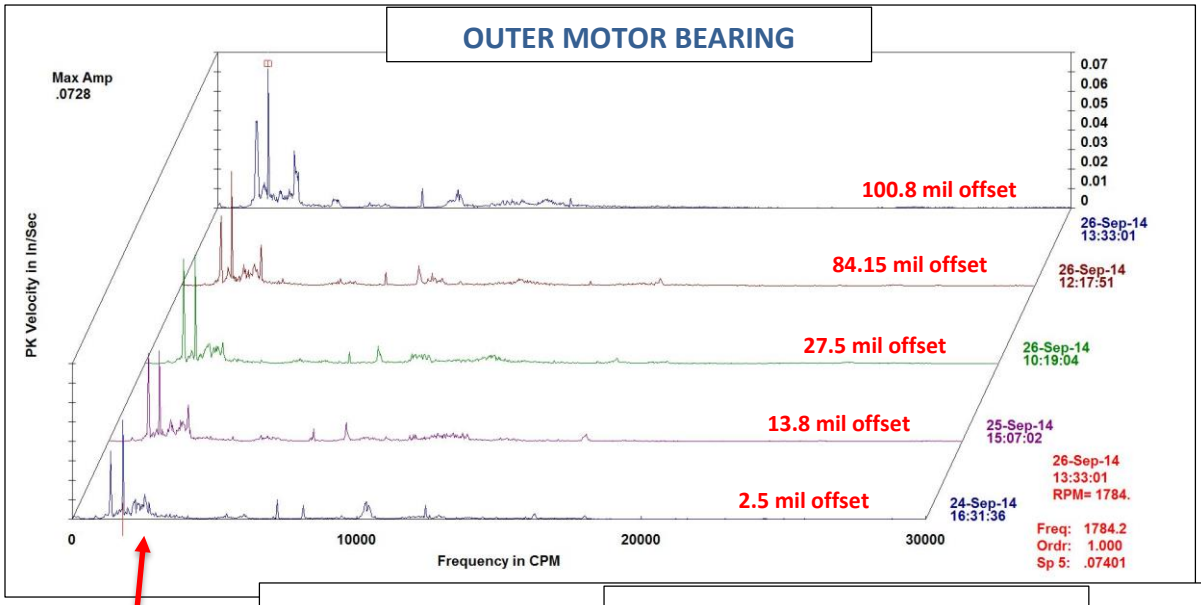
The table below reflects five different alignment conditions with the SmartCOUPLING installed between the motor and pump. Spectrum #1 reflects a laser-aligned condition, with all levels of offset confirmed to be within normal tolerances for flexible couplings. The next four conditions were created by intentionally misaligning the pump and motor with increasing levels of horizontal offset and angle. The maximum level of misalignment was recorded at a very significant *100.8mil* of horizontal offset – far beyond the operating tolerance of other types of flexible couplings. Since the SmartCOUPLING was configured with an air gap spacer that results in a 0.150" air gap, however, it was able to comfortably accommodate the 0.1008" offset.

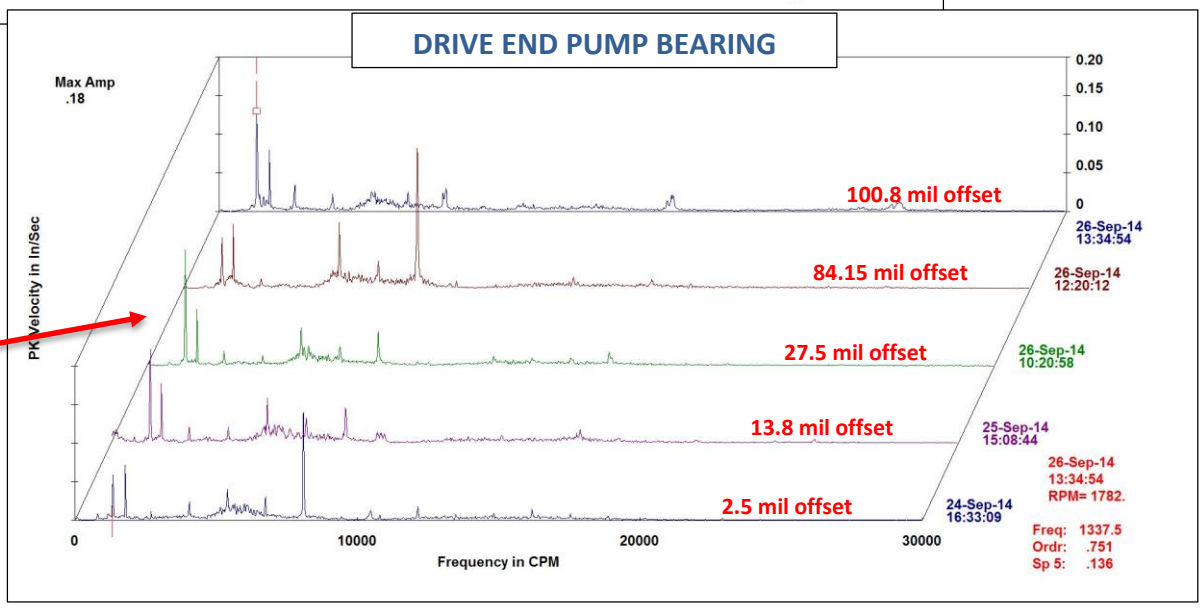
FSC Alignment (multiple levels of offset and angle)				
	Vertical Offset (mils)	Horiz. Offset (mils)	Vertical Angle (mils/10in)	Horiz. Angle (mils/10in)
Spectrum 1	4	2.5	1	1
Spectrum 2	-2	13.8	-1.2	-0.16
Spectrum 3	-2.3	27.5	-0.2	3
Spectrum 4	3	84.1	-3	10
Spectrum 5	-7.5	100.8	-4.2	118.6

Highlighted values exceed acceptable tolerances

After each increasing level of offset was configured, a new vibration spectrum was captured for both the motor and pump. These new spectrum are plotted three dimensionally in the following charts. The original laser aligned spectrum is shown at front, and the most severely misaligned spectrum is at back.

Typically, with any form of physical coupling, one would expect to see significant increases in overall vibration at each level of misalignment. However, the spectra on the following page show almost no increase in vibration levels as the misalignment levels are steadily increased. Once again, the air gap completely disconnects the motor from the pump, so each devices is allowed to operate within its own plane, with no external forces working to deflect the shaft and cause vibration.





No significant increase in vibration level on either motor or pump despite increasing levels of misalignment

Conclusion

As demonstrated above, the Flux Drive SmartCOUPLING provides a number of unique benefits in terms of misalignment analysis and correction:

1. Vibration technicians can easily determine where the vibration is coming from
2. Harmful frequencies can be isolated to one component - and dealt with accordingly
3. Vibration is reduced compared to the grid coupling due to the SmartCOUPLING's air gap
4. Increasing levels of misalignment result in no appreciable increase in overall vibration with the SmartCOUPLING installed

The SmartCOUPLING is a truly new and unique technology that provides benefits not available from any other form of flexible coupling. For more information on available models, see the brief overview below, the Flux Drive website at www.fluxdrive.com, or contact us at 1-800-236-3581.

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About the Flux Drive SmartCOUPLING

Flux Drive designs and manufactures coupling products that provide a wide range of benefits – including significant maintenance reduction and energy savings on all types of rotating equipment. Two models are offered: the Flux Drive Inline SmartCOUPLING (FSC-IL) and Flux Drive Belt-Pulley SmartCOUPLING (FSC-BP). The product is sized by the torque requirement of the load. The Inline FSC is currently available for applications with load horsepower of 5-250hp @ 1800rpm (up to 750 lb ft of torque) and the Belt-Pulley FSC is available from 5-125hp @ 1800rpm (up to 375 lb ft of torque).

INLINE SmartCOUPLING

Benefits

- Ability to reduce load speed & save energy with SmartPOWER™ adjustment
- Zero vibration across air gap extends the life of seals, bearings & other components
- Soft-start and over-torque protection
- Runs with shaft misalignment and allows for thermal shaft growth
- No replacement components to purchase
- Reduced noise and cavitation/turbulence
- Lower motor & load operating temperatures
- Replaces need for impeller trimming and compensates for long-term impeller wear
- ABS (American Bureau of Shipping) Approval Pending

BELT-PULLEY SmartCOUPLING

Benefits

- Cushioned start for reduced shock/vibration and lower utility demand charges
- Extreme durability, reliability and simplicity compared to electronic or fluid-based cushioned start solutions
- Energy savings through load speed reduction using 100% *mechanical* SmartPOWER™ adjustment feature
- Reduced torsional vibration transfer between motor and load
- Over-torque and load seizure protection for belts/chain
- Longer bearing life and lower motor/load operating temperatures due to reduced belt tension
- Motors sized for running horsepower – not starting horsepower
- Operates in harsh environments – no external power required

About Flux Drive

Flux Drive Inc. manufactures the permanent-magnet Flux Drive SmartCOUPLING™ and provides vibration monitoring and mitigation services that increase the life and performance of rotating equipment. The company's technology greatly lowers energy consumption and extends the life of motor driven systems. For more information about Flux Drive, please visit www.fluxdrive.com.

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