Users' Group Conference 2018

Frame Movement Data Collection and Analysis

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Discussion guideline

Reciprocating forces

Foundations and frames

Grout and bolting failure

Cylinder stretch

Bolt failure

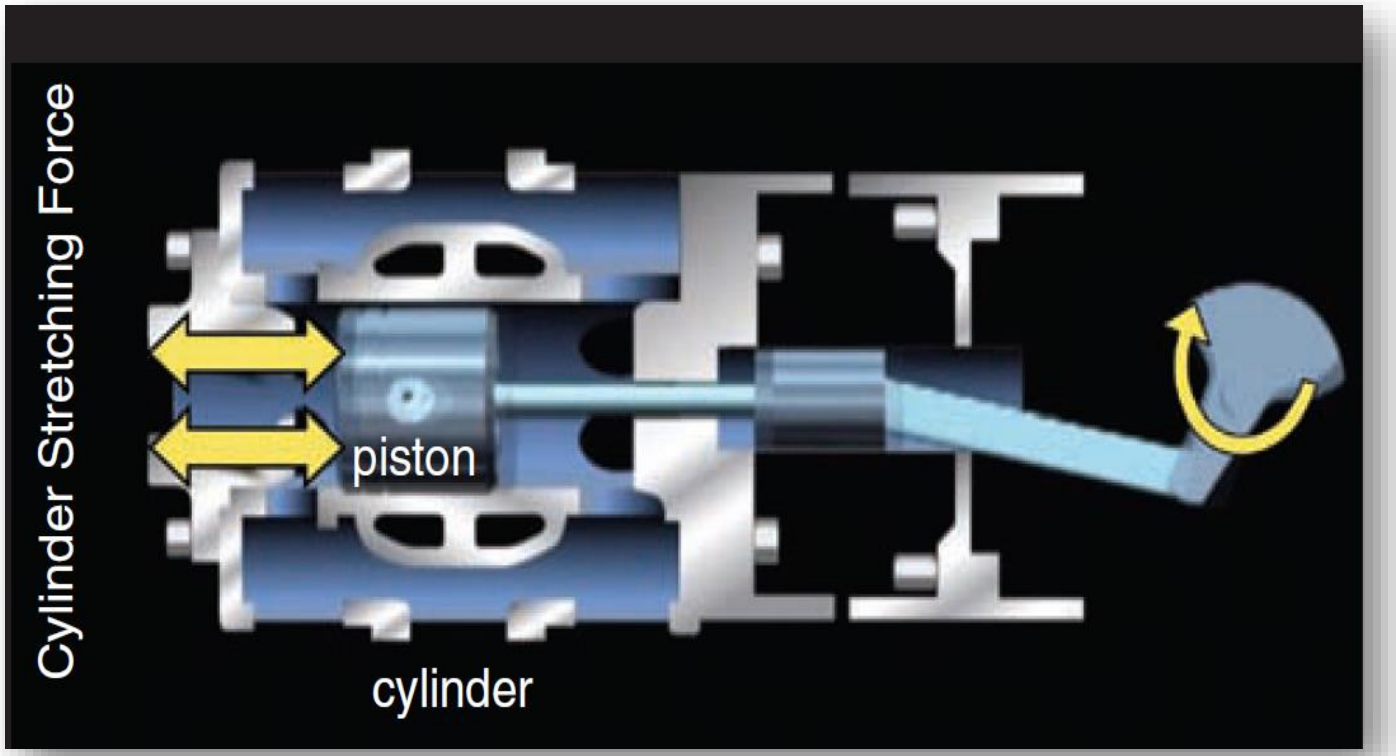
Correct data collection

Diagnostic Technique – Vibration profiling

Reciprocating forces

The reciprocating engines and compressors are always exerting forces due to their unbalanced nature.

The bolting to the skid or foundation is there to resist this unbalance.



The foundation

The foundation is considered to be a part of the frame and helps to provide overall strength to resist the unbalanced forces transmitted by the crankshaft.

Both compressors and engines whether integral or separable should have data routinely taken to make sure the frame is connected to the foundation.

If the frame is not strengthened by the foundation it can distort.

Effects of frame distortion

Broken and Bent crankshafts

Bearing damage

Bearing cap stud bolt failures

Engine frame failures

Engine support failures

Crosshead guides, distance pieces

Cylinder scuffing

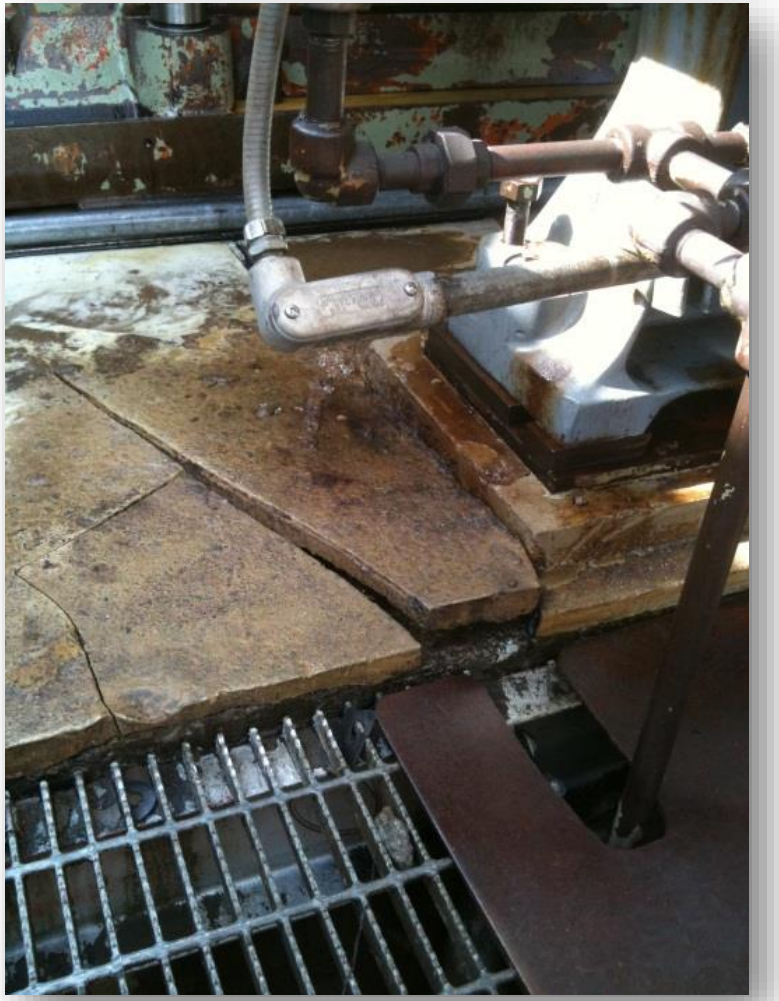
Wrist pins and crank pins

Grouting failures

Grouting failures on units can lead to bolting problems.

Repeated grout failure can indicate that the anchor bolts do not have sufficient force to withstand the shaking forces.

Thermal differentials between the grout under and away from the frame can also cause failures.



Skid failures

Skid mounted units are seen in the field a lot as they allow the unit to be packaged in a controlled environment.

The skid will act as an additional element of bolting between the frame and foundation.

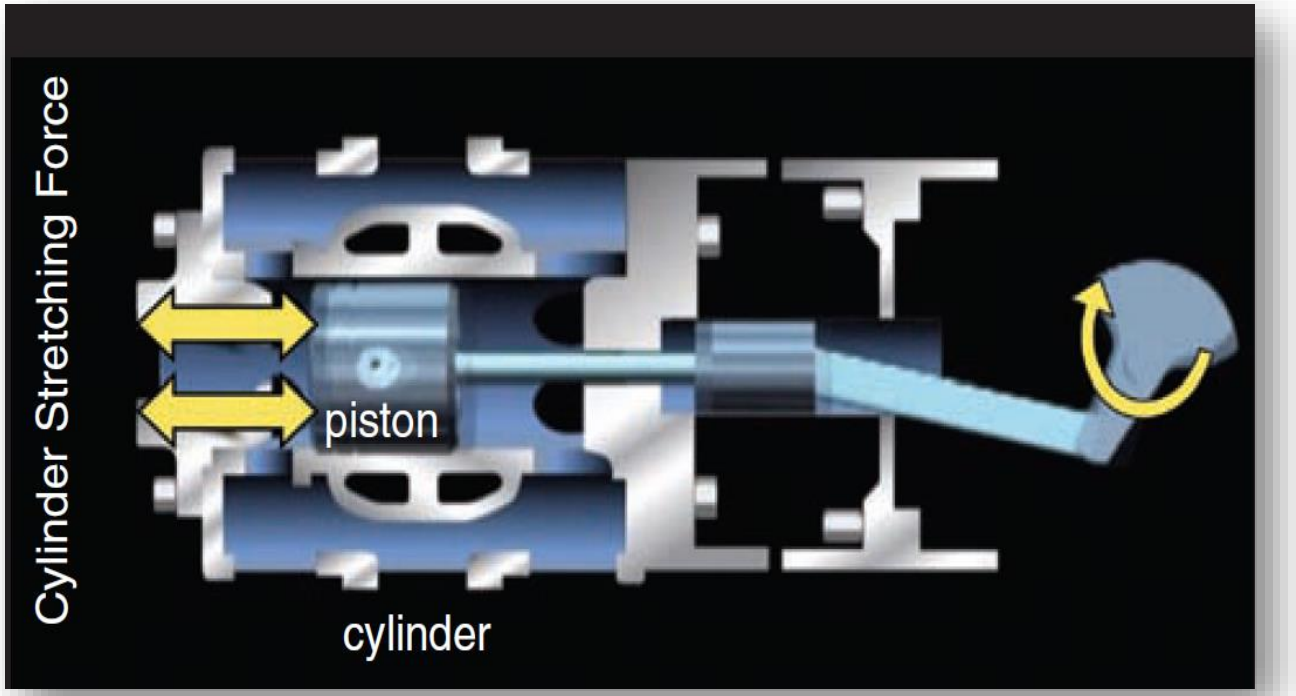
Essential elements of cylinder stretch

Cylinder Stretch

Cylinder stretch is the movement of the cylinders in relation to the frame.

It would be better to name this bolt stretch as the cylinders are not stretching.

The cylinder internal gas forces against the reciprocating piston face cause the bolting to stretch and move

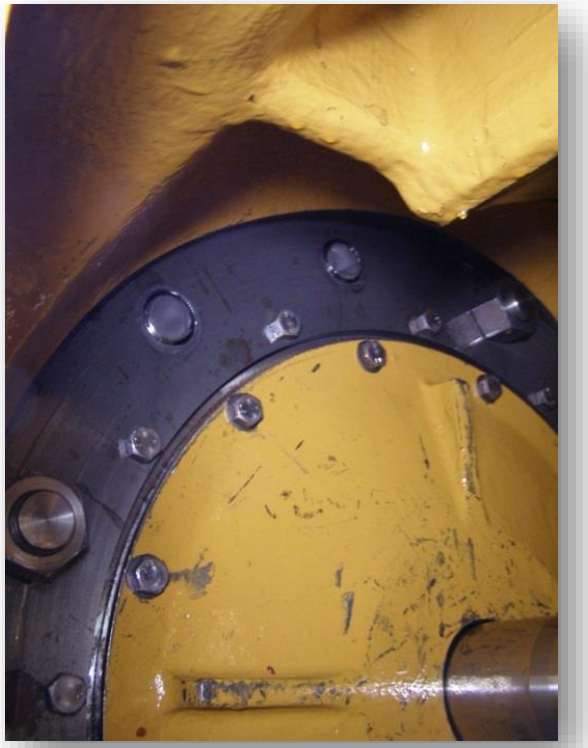


Distance piece stretch

Cylinder stretch and movement can also be due to stretching in the cross head housing

This is due to the big crosshead doors . That leaves less mass to support the structure.

Excessive distance piece stretching can lead to eventual bolting failure.

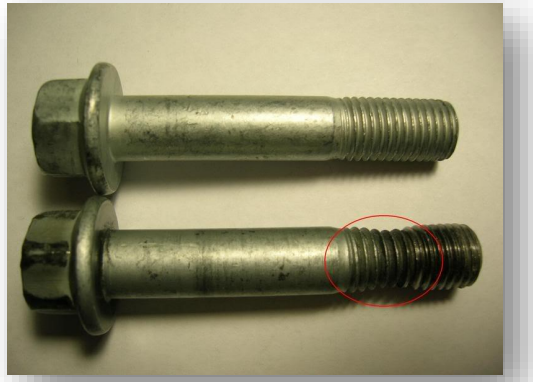


Bolt stretch

The movement we are measuring is the elongation of the bolts that are loose, or have exceeded their elastic limit.

A bolt and nut are designed to act together. As the internal threaded fastener (nut) is tightened onto the externally threaded fastener (bolt). The bolt is forced to stretch and elongate.

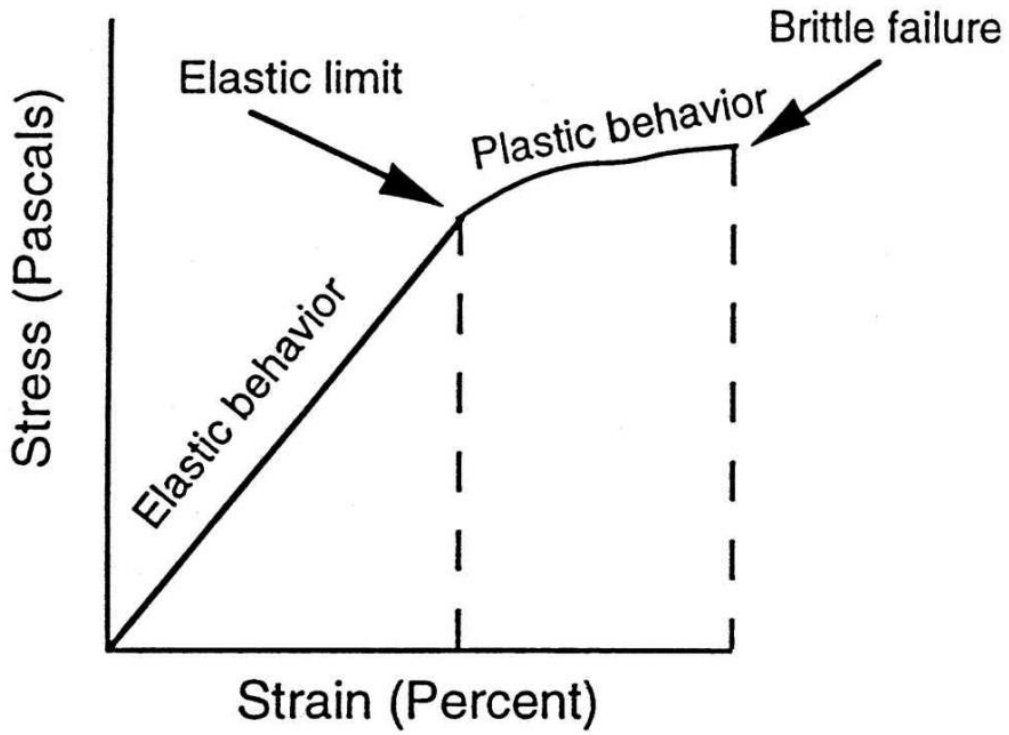
This stretching/elongation is maintained by the head of the bolt and the nut on the joint thereby maintaining the joint at the desired tension (Bolt tensioning).



Yield point of fasteners

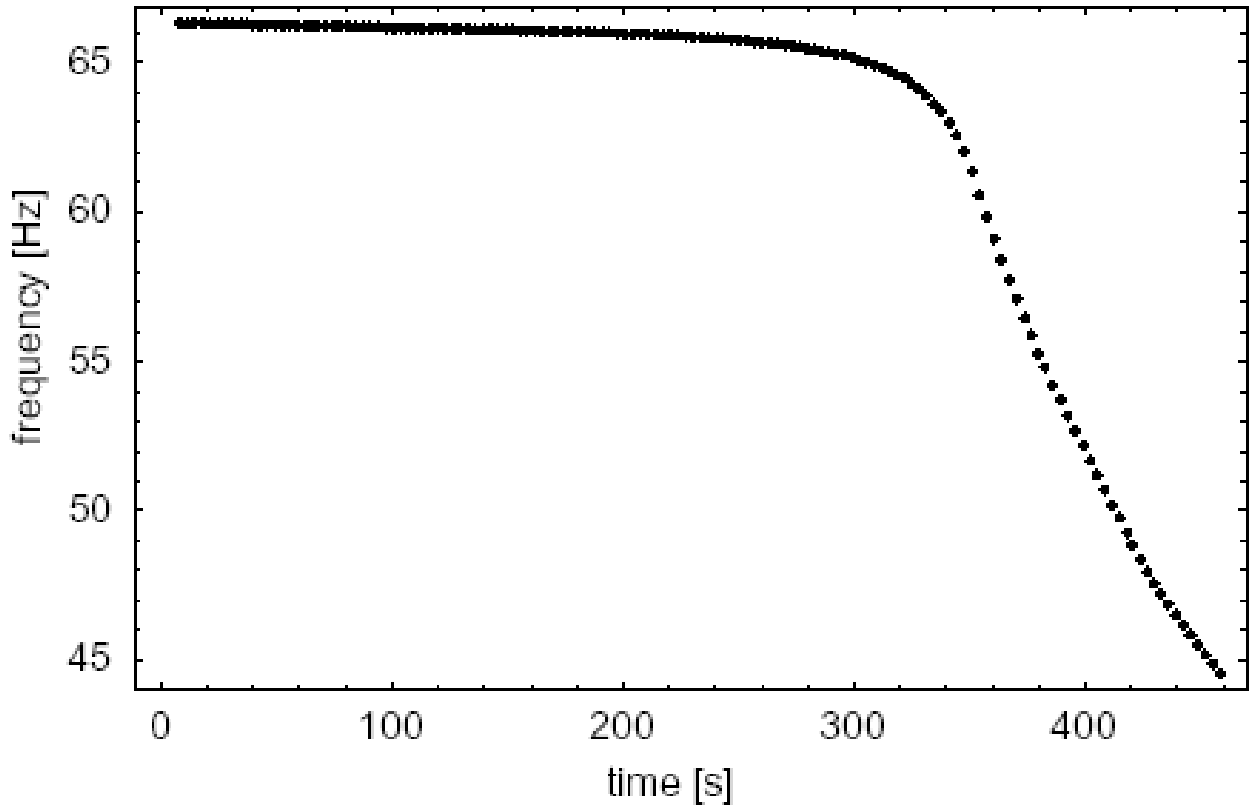
As a rule, the joint will have been designed with sufficient fastener to apply the required clamp load at 65% of the fastener proof load stress figure.

This is well below the fastener's yield point.



Cyclical life of bolts

As the bolt is under constant cycling of loads from tension to compression the life is reduced significantly when compared to a bolt that is under a static load

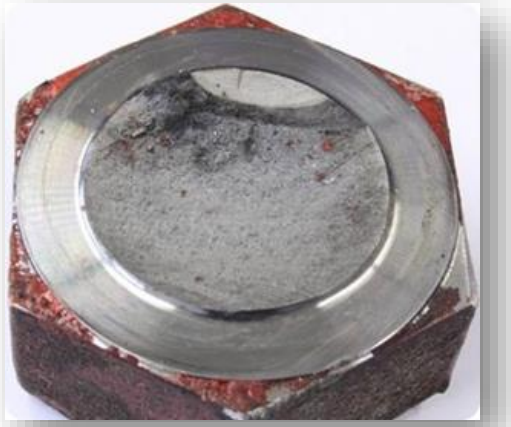


Bolt fatigue failure

Bolts that are installed for longer than recommended will fail due to fatigue.

In most cases you may not be able to see the crack in the bolt before failure.

The common signature on a fatigued bolt is the wavy striations on the failure surface

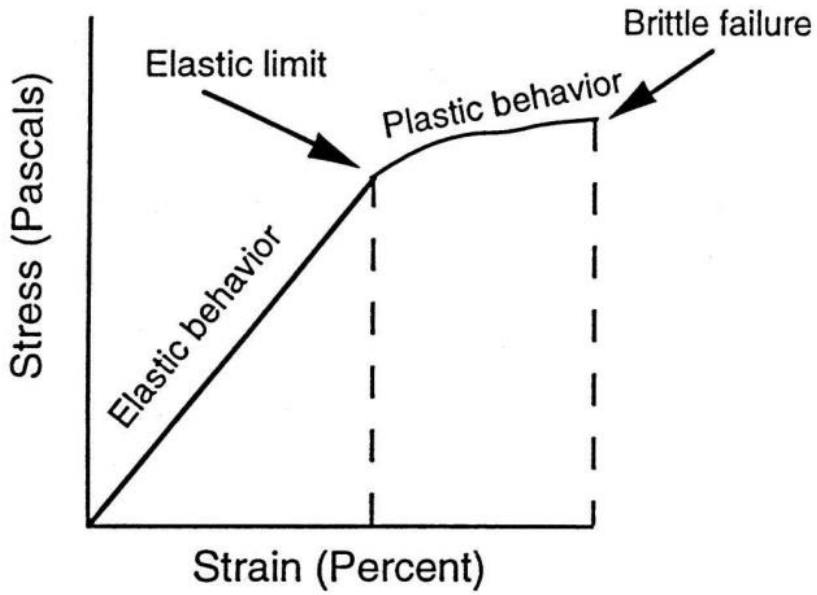


Fatigue failure signs

A bolt that has gone past its yield point and is now failing can still be torqued.

If the bolt is torqued but the movement did not change suspect that the bolt is fatigued.

If a bolt thread is damaged the torque will be approximate at best, and can be much lower.



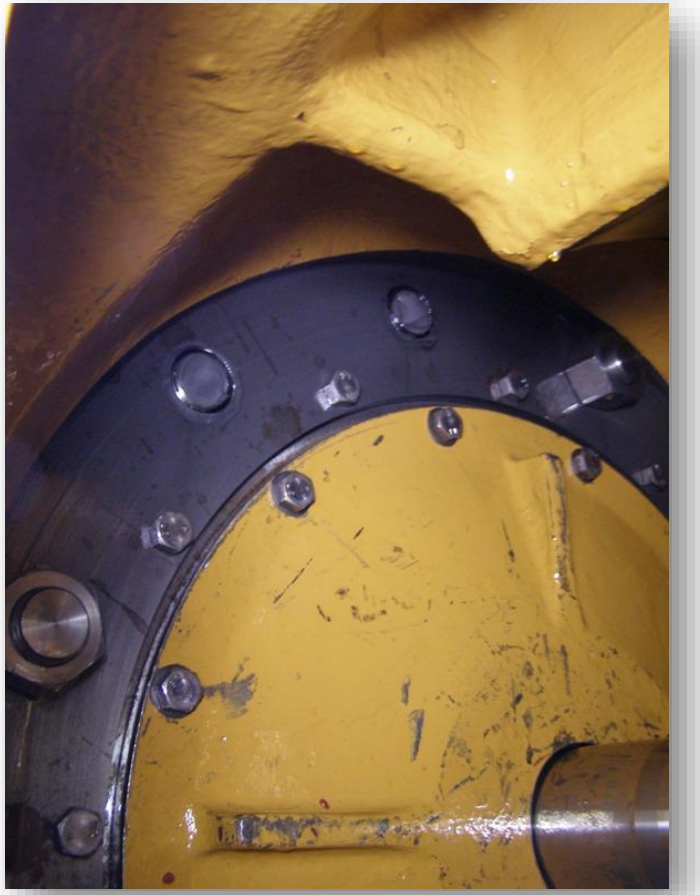
Example of failed fastener – bolt reattached with RTV….

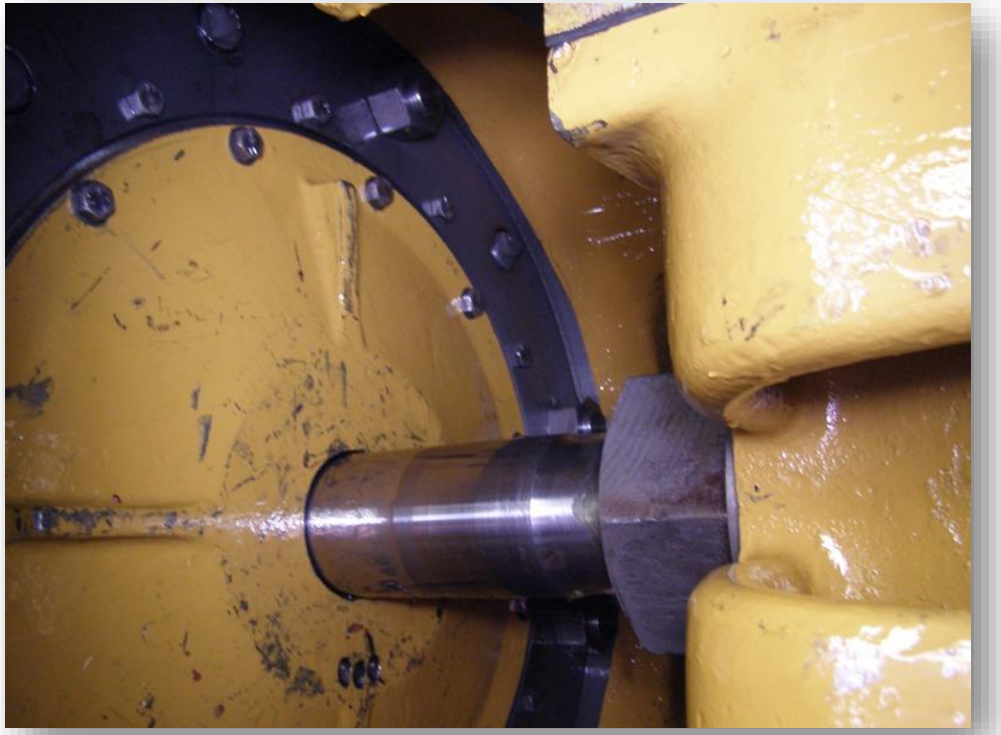
Frame corner movement with bubbling oil

Shims migrating due to loose bolting

Broken distance piece bolts at the nut – fatigue failure

Broken bolts inside distance piece





Correct Data Collection Techniques

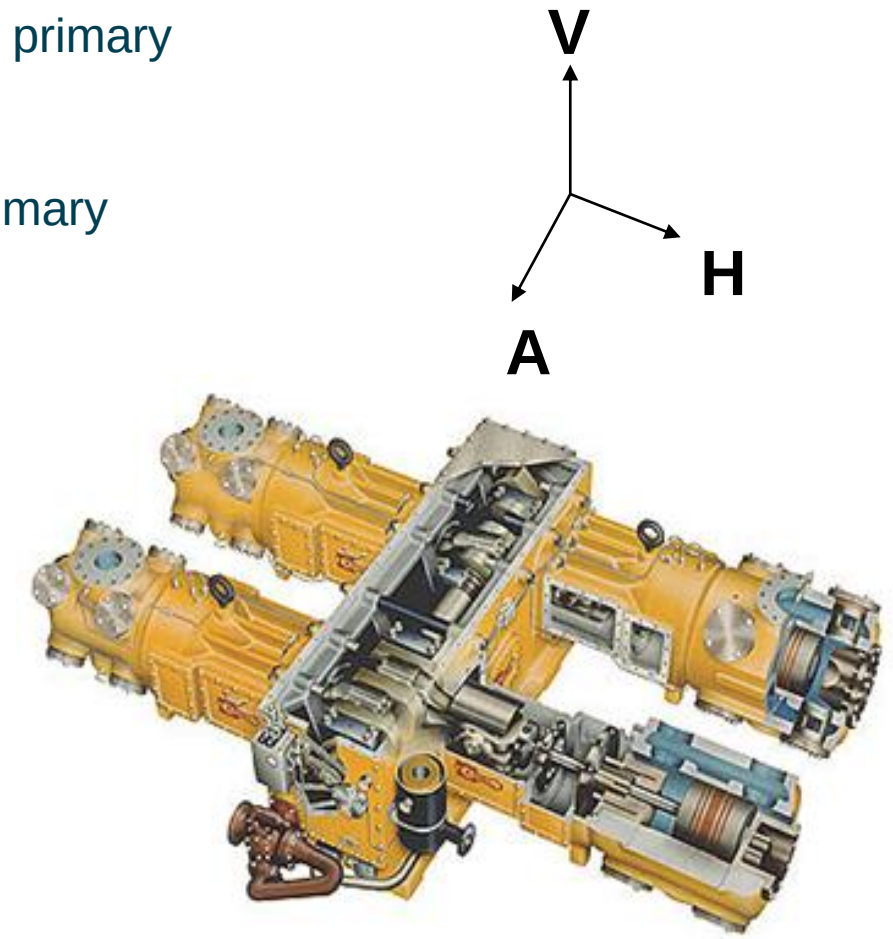
Vibration test point examples

Using the crankshaft as a reference.

The **Horizontal** plane is 90 degrees to the centerline of the primary rotating element and parallel to the ground.

The **Vertical** plane is 90 degrees to the centerline of the primary rotating element and perpendicular to the ground.

The **Axial** plane is in line with the primary rotating element.

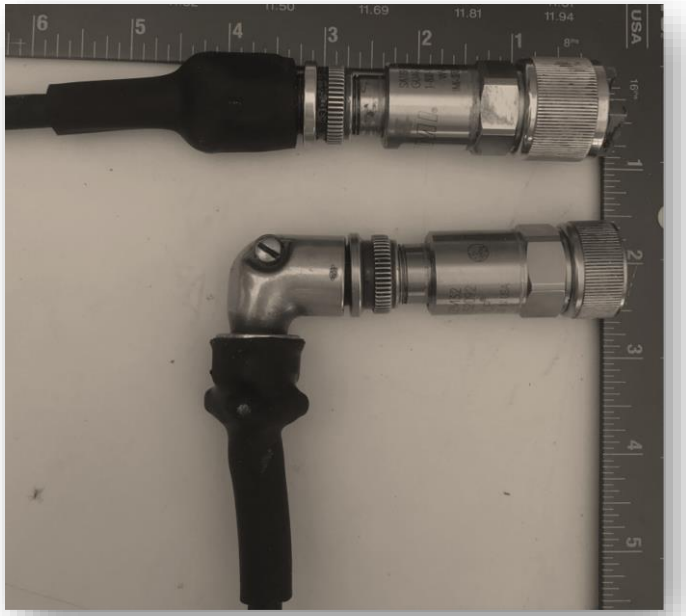


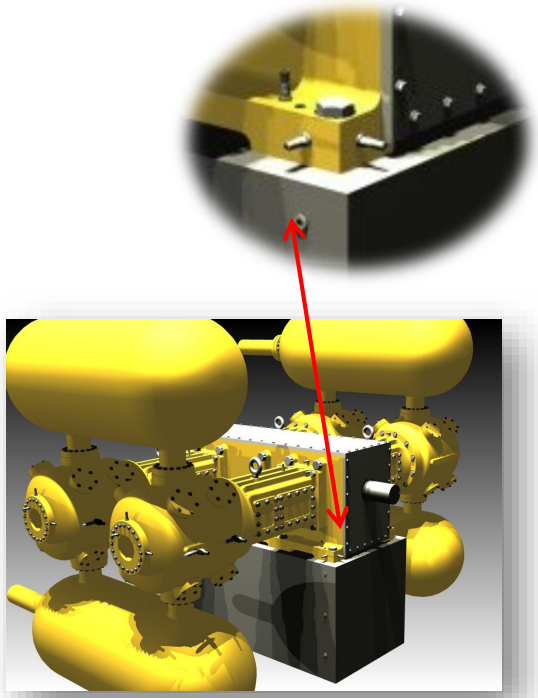
Compressor frame testpoints

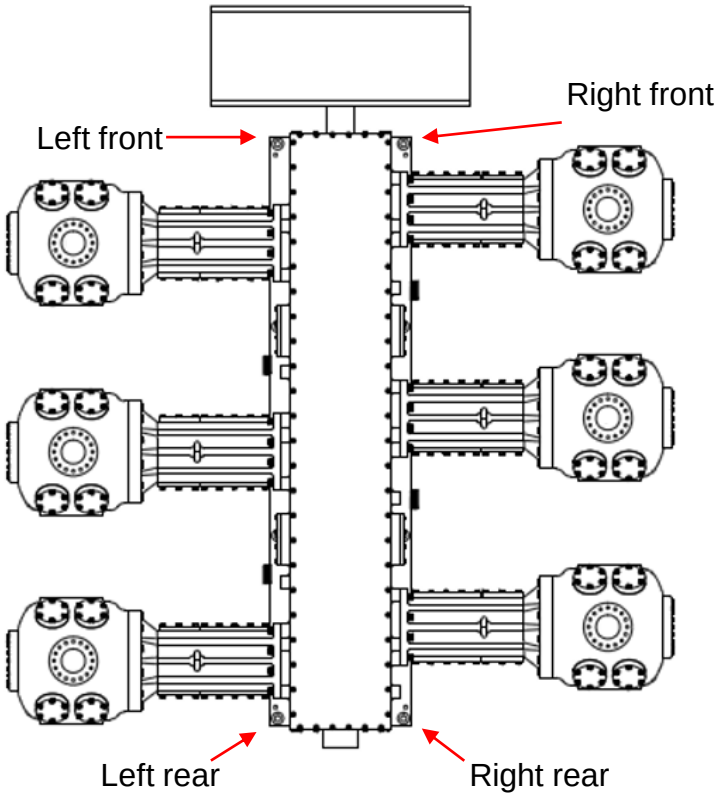
Use mils or in/sec.

Take each corner in all three orientations.

A 90° cable along with a flat magnet can help data collection in tight spots.







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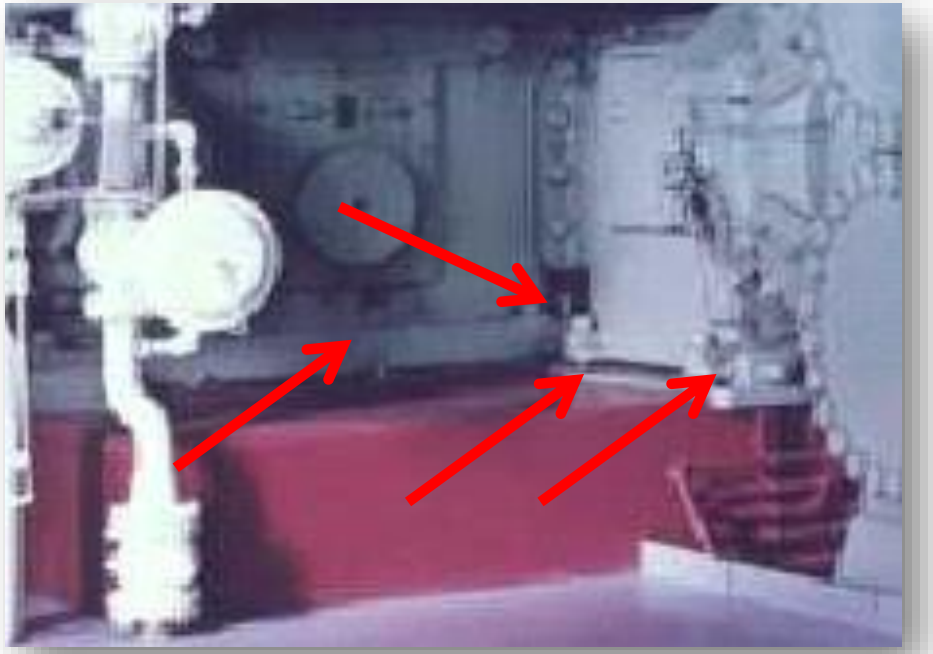
Integral gas engines

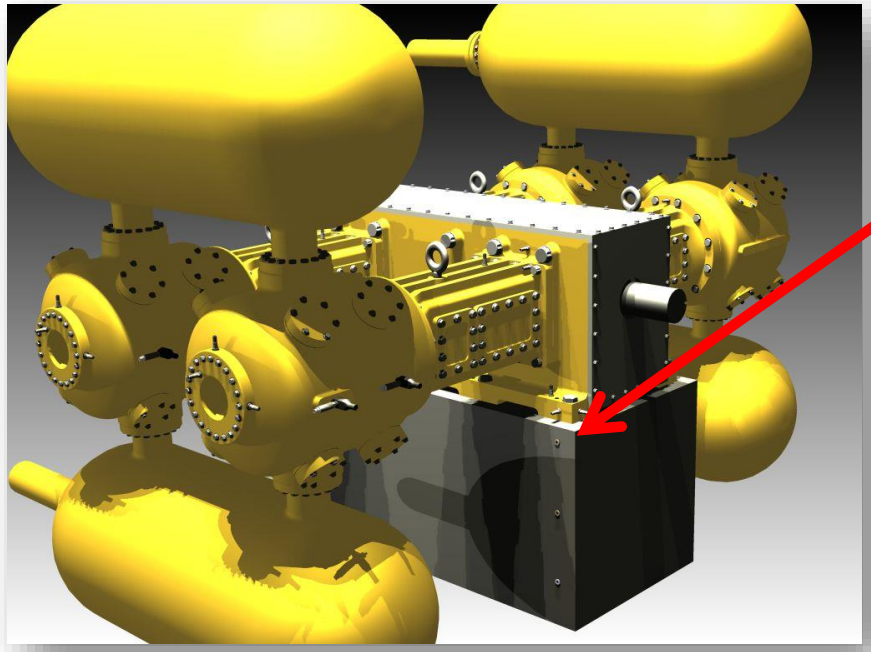
Some Large machines may require readings at each foundation bolt.

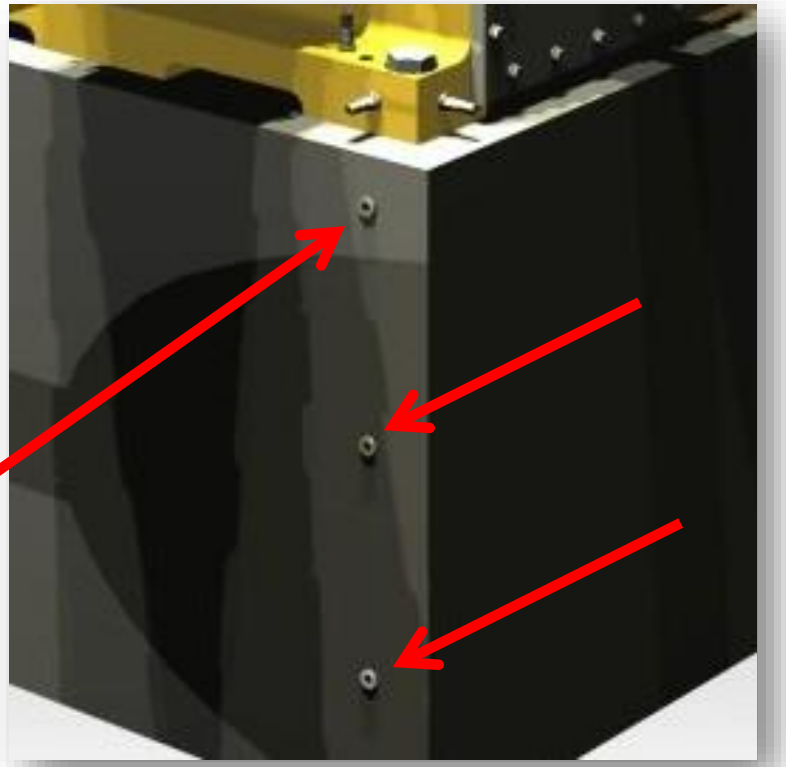


Compressor foundation

Epoxy steel washers to cement as needed.

Other test points will be needed if cement is cracked. Take a data point above and below a crack and review phase changes.





Vibration Profiling

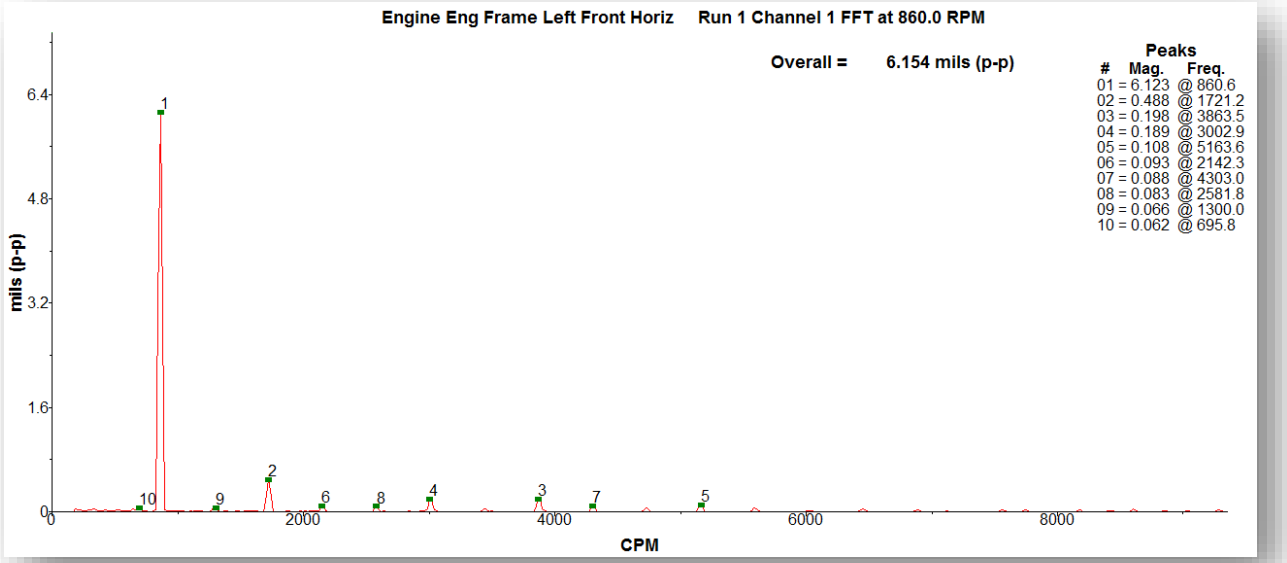
Vibration profiling

Vibration profiling to help visualize the vibration.

When data is profiled you get a visual review which can help diagnose issues.

Once the issue has been diagnosed you can create before and after profiles.

Vibration profiles are drafted from the spectrum data



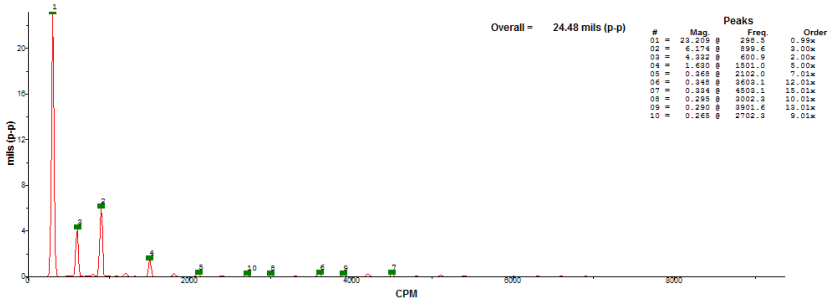
Vibration profile example

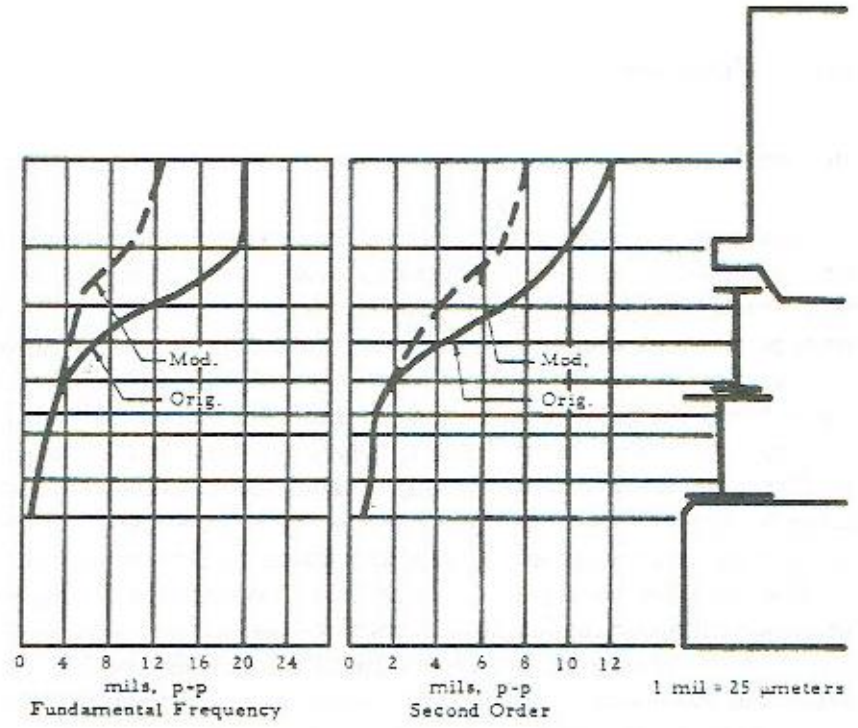
A foundation vibration profile showing the original and modified displacement levels.

The first and second orders are plotted initially.

The vertical transverse of the skid mounted unit shows significant flexing in the skid at 1x and 2x RPM.

This diagram can be done by an analyst on a piece of paper by the unit. A powerful diagnosis tool.





Thanks to Engineering Dynamics Inc.

Differential Vibrations

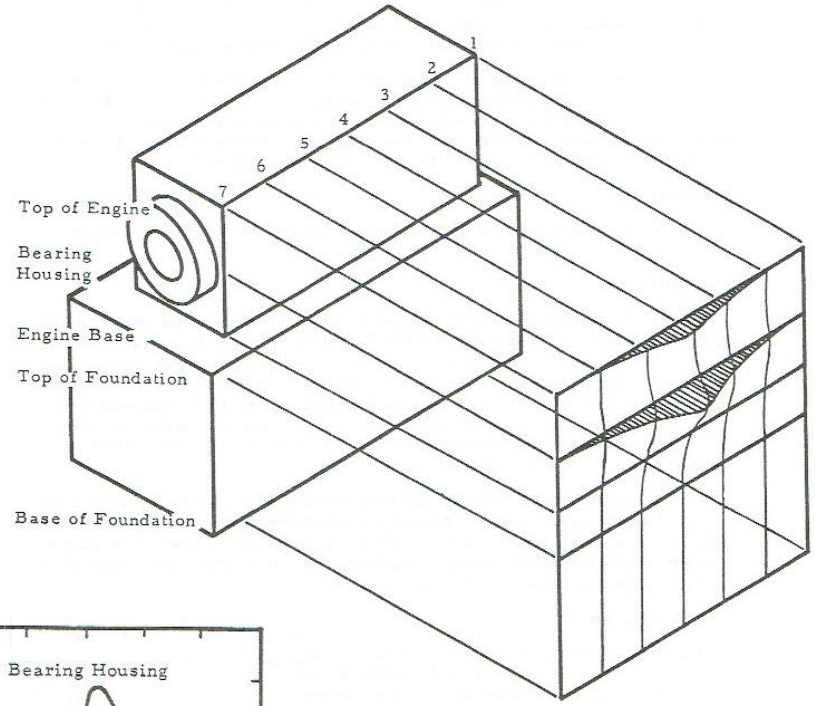
Analyzing differential vibrations on a frame can also help to diagnose frame problems.

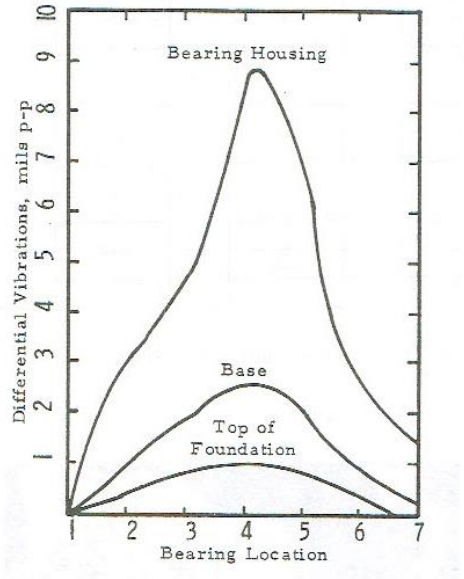
A reference point is selected and then the differential obtained between the two points using the using FFT subtraction.

With this technique the phase and amplitude are preserved.

This technique has been used by analysts to study overloaded bearings in the past. As well as

- Frame bending.
- High bearing loads.
- Inadequate frame stiffness.
- Can indicate the weakest anchor bolt.





Thanks to Engineering Dynamics Inc.

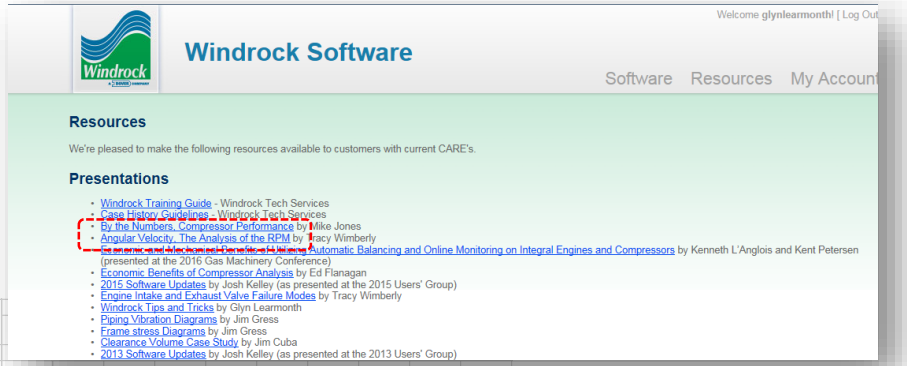
- **Frame and piping vibration profiling**

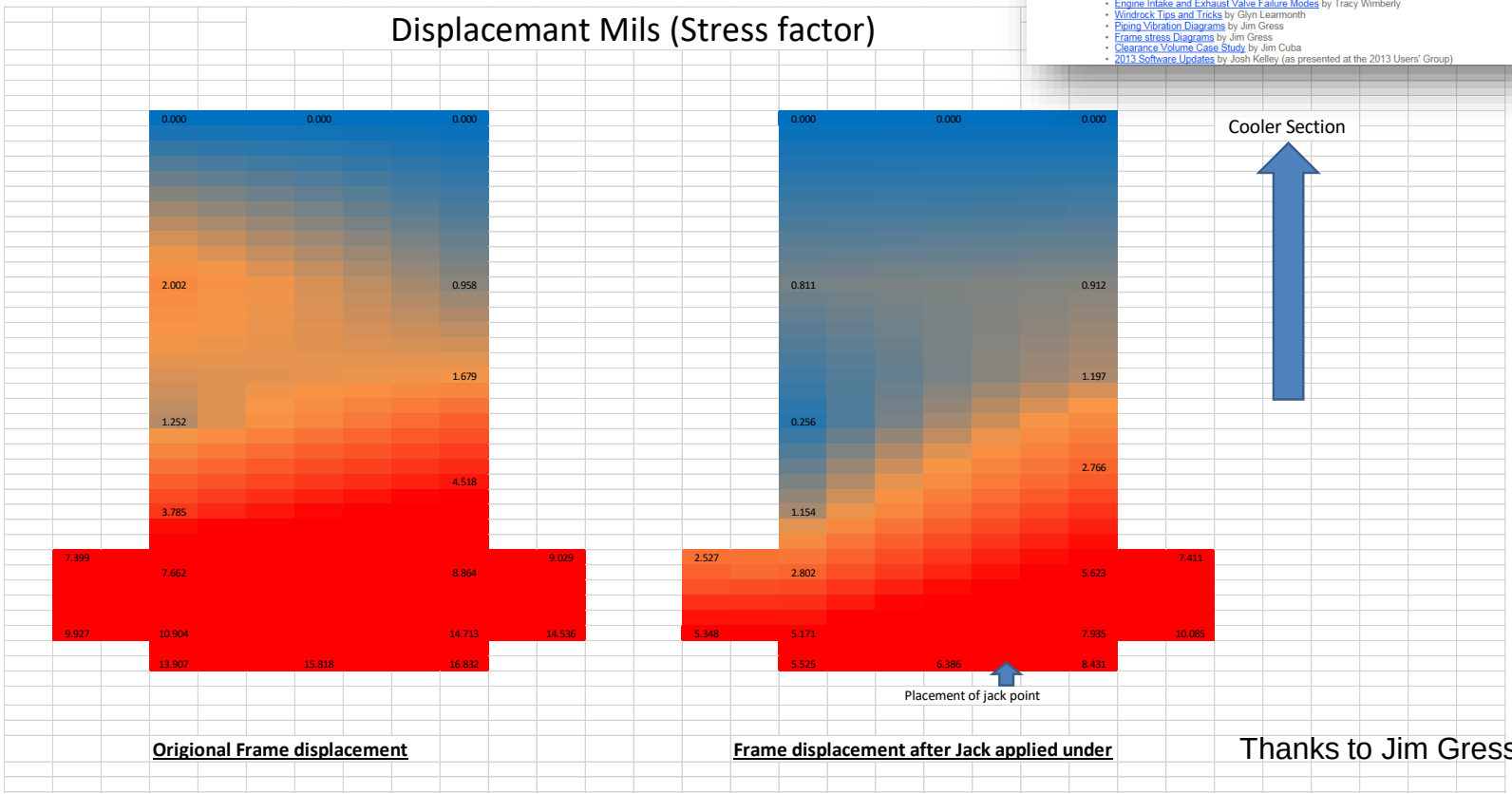
Simple frame measurements before & after

Data taken in mils on housing of drive motor.

Plotted in excel with conditional formatting.

Download available under resources at Windrock.com





Thanks to Jim Gress (Anadarko)

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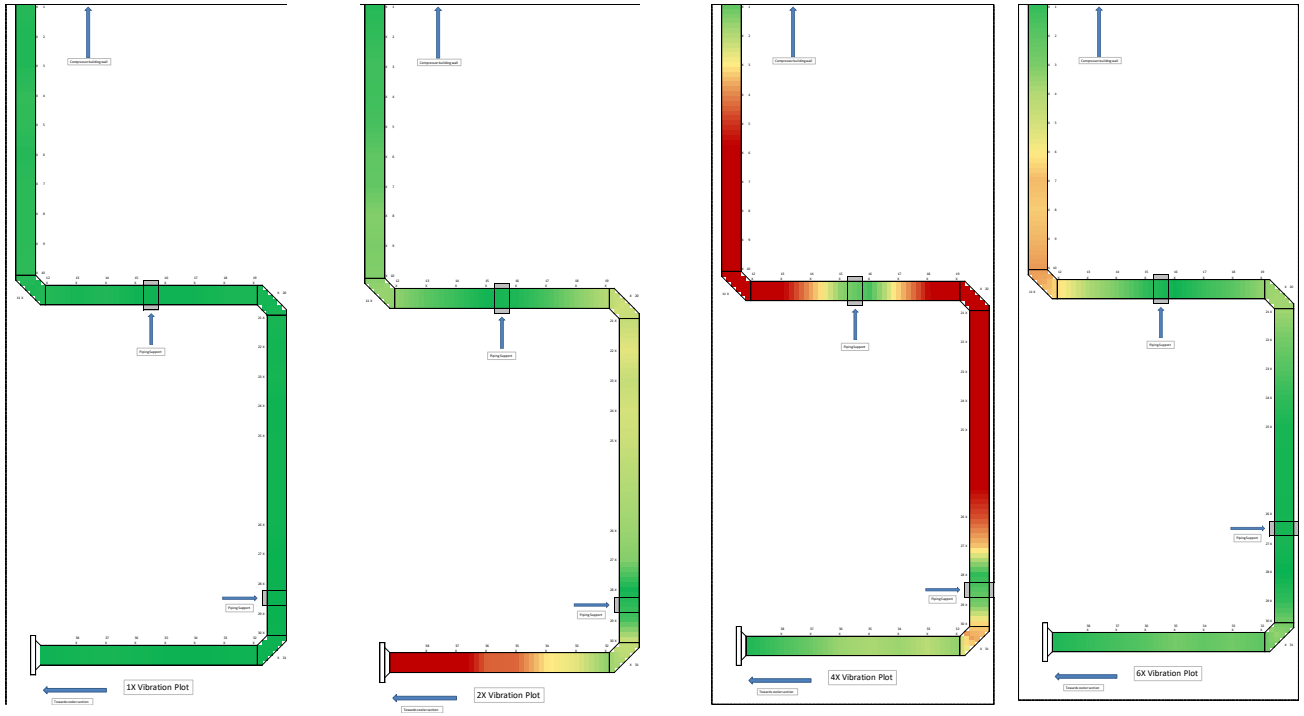
Data taken on piping for initial test

Data taken on piping that is vibrating.

Simple pipe plot in excel show amplitude of each order of run speed.

Easy to see that 1x is good, but 2x, 4x and some issues at 6x.



1x 2x 4x 6x

Thanks to Jim Gress (Anadarko)

Data taken on piping for final test

2 supports added to piping.

Most harmful vibrations removed. Some 2 x still in lower section to mitigate with 3rd support.

1x 2x 4x 6x

Thanks to Jim Gress (Anadarko)

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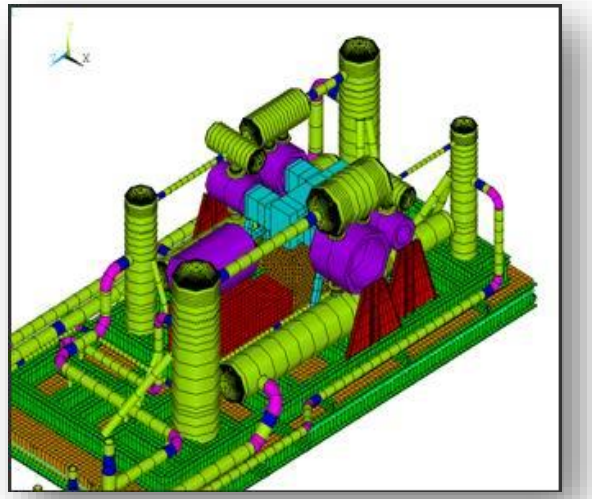
From here to ODS

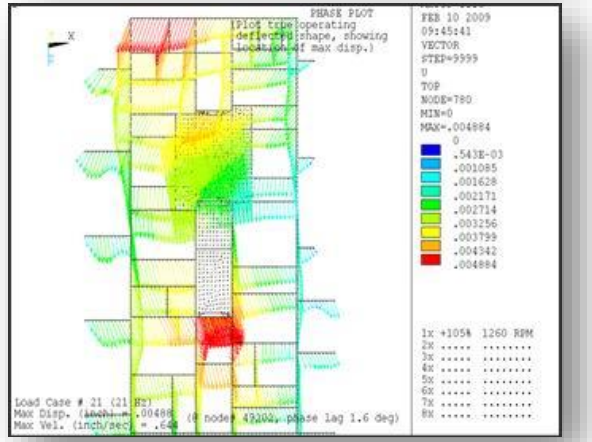
Operating Deflection Shape (ODS) models are complex and are produced with a computer.

Points can be taken simultaneously with a multi-channel recorder.

These points are plotted to compare the phased relationship between points.

The ODS models are complex but their start is similar to what we have reviewed today.





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Discussion summary

- Frame and foundation measurements will provide the analyst with valuable information.
- Data need not be taken every time, but a baseline should be obtained.
- Vibration profiling is a simple and very useful tool that can be done on a piece of paper on location.
- An analyst with a good understanding in machinery movement can provide a powerful tool in mitigating many complex issues.


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