

Report on Vibratory Stress Relief

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CARPENTER JOB

418" L X 60,000 lbs Ingot Stripper

THE ROSE CORPORATION, a Job Shop specializing in large components, is a regular user of VSR Technology Group's stress relieving service. In this project, a 418" L, 30-ton mild steel weldment, an Ingot Stripper for CARPENTER TECHNOLOGY, was stress relieved on the shop floor in less than three hours.

THE ROSE CORPORATION, Reading, PA, specializes in the fabrication of large components for heavy industry. Several projects have utilized the VSR Process for stress relieving because it reduces energy costs and minimize production (see http://www.vsrtechnology.net/pdf/The_Rose_Corporation.pdf), with full maintenance of quality. This latest project involved a 418" L, mild steel weldment, weighing 60,000 lbs, destined to become the Frame of an Ingot Stripper for CARPENTER TECHNOLOGY.



Figure 1: View from near one end of the 30-ton Ingot Stripper Frame. The Frame was isolated on 3 Isolation Load Cushions (1 is visible [circled], midway down the length of the Frame). Each Load Cushion was placed on a 10" X 10" wood block to achieve leveling and floor clearance (Frame is \approx 4" above the floor in the foreground.) The BL-8 VSR Vibrator, clamped to the Frame, can be seen directly above the Cushion (circled).



Figure 2: View showing opposite side that shown in Figure 1. Note the two wood blocks spaced at the 1/3rd points along the length. These leveling blocks hold the other 2 Cushions. This 3 point Cushion arrangement minimizes the damping of the Frame during Treatment, allowing effective resonating to take place, which produces the flexure required for the VSR Process. The Accelerometer Clamp and cable is visible on the near left corner (circled).

During Treatment, which requires resonant frequency vibration, the edges and corners of the workpiece became blurry, ie, workpiece amplitude was visible and blurred the visual image.

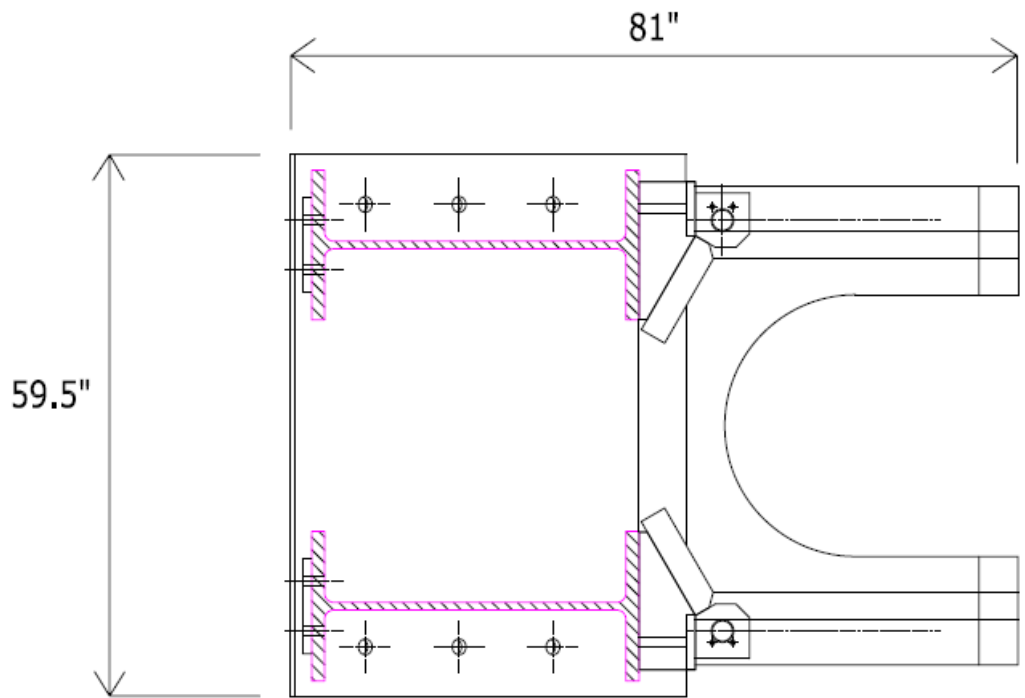


Figure 3a: Cross-sectional view of Ingot Stripper Frame. This portion is seen in Figure 1.

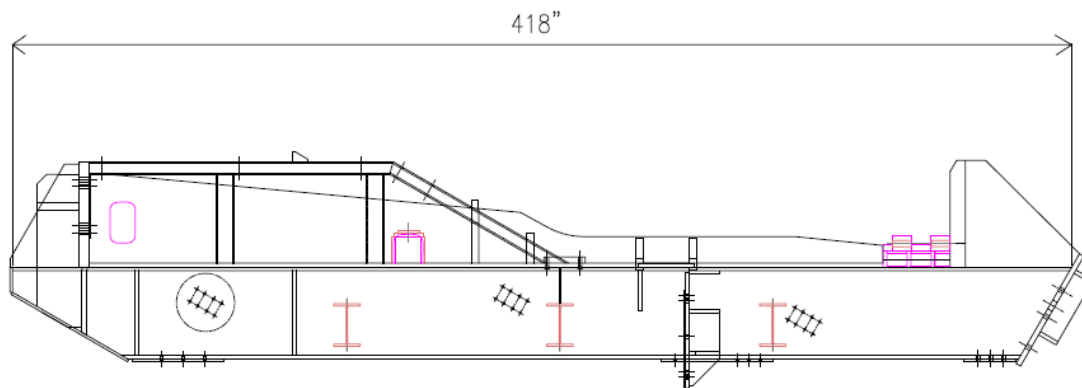


Figure 3b: Overall plan view of Frame, as oriented during Treatment. Right portion of this view is in the foreground of Figures 1 and 2, as is the cross-sectional view (3a). Note flange on bottom, which is visible on the left in Figure 2.

VSR SET UP

The workpiece was placed on 3 Isolation Load Cushions, which measure 10"L X 6"W X 4"H. Three is the minimum number to determine a plane, and was used to minimize damping of the Workpiece. The Load Cushions were located far from the corners or ends of the Workpiece, which also minimizes damping. Minimizing damping maximizes resonance, and flexure. Independent research has shown that flexure is required to maximize the effectiveness of vibratory stress relief. One of the Load Cushions can be seen in Figure 1; the locations of the other two are described in Figure 2.

The Vibrator was securely clamped at the midpoint of one side, and oriented so that the Axis-of-Rotation (AOR) was aligned at an angle midway between the major axis (length) and minor axis (width) of the workpiece. The Vibrator is visible in Figure 2, and a close-up of the mounted Vibrator is shown in Figure 4.

The Vibrator's unbalance was initially adjusted to 40% of the available 4.0 in-lbs of unbalance, ie, 1.6 in-lbs. After running the System's Quick Scan for calibration purposes, the unbalance was increased to 80%.

An Accelerometer, a vibration sensor whose output is proportional to acceleration, was positioned on one corner of the workpiece, and oriented to be most sensitive to vertical Amplitude. Both science and experience have shown that acceleration (not velocity or

deflection), is the best parameter to gauge vibration intensity at the height of resonance peaks, due to its proportionality to force, based on Newton's second law: $F = ma$ (where **F** is force, **m** is mass, and **a** is acceleration).

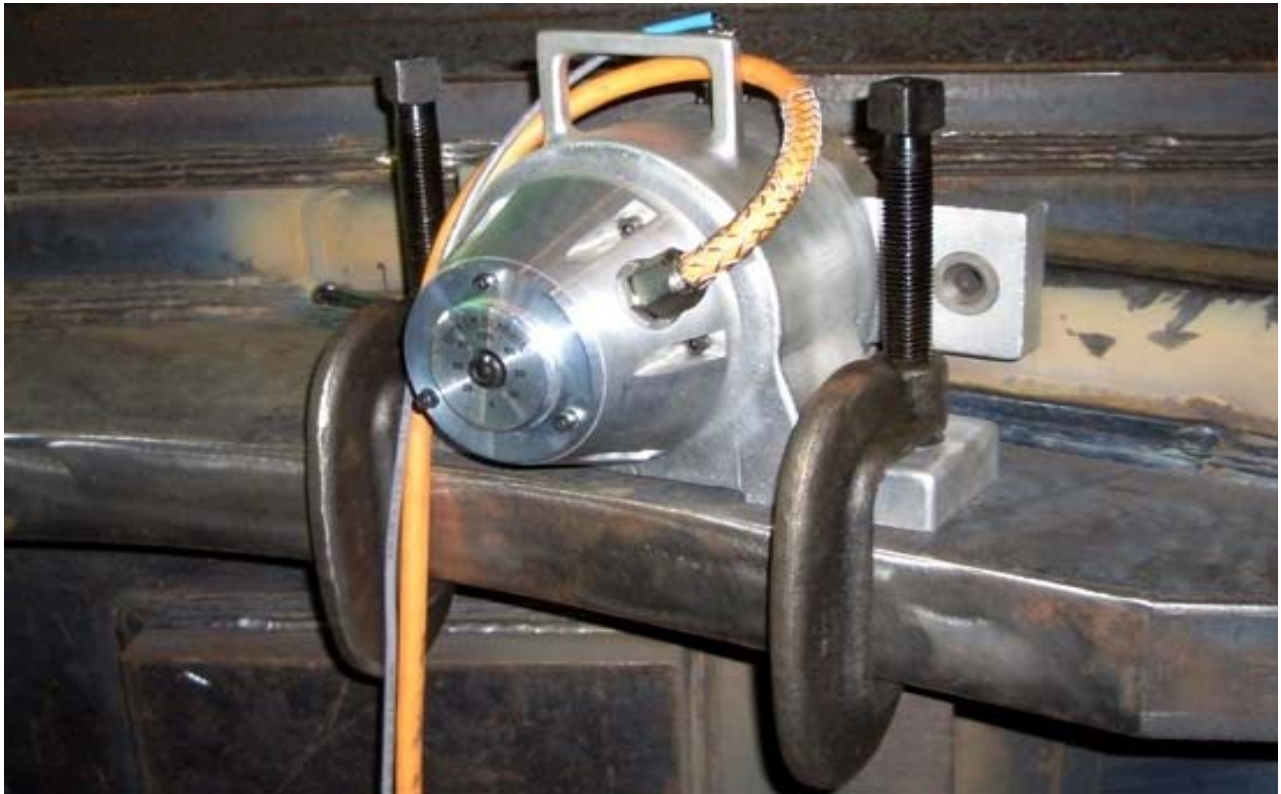


Figure 4: Close-up of System's BL8 Vibrator. This Vibrator has adjustable speed (10 – 8,000 RPM) and adjustable unbalance (0.2 – 4.0 in-lbs.), the unbalance scale is visible on the back of the vibrator. It also features two sets of mounting feet, so that it can be oriented most effectively. Hardened steel inserts (Rc 50) in the mounting feet allow strong, effective clamping, without crushing the aluminum-magnesium alloy housing. Vibrator is driven by a 3 HP (\approx 2.3 kW) brushless DC motor.

VSR TREATMENT

After this initial setup, a Pre-Treatment Scan was run, which uncovered two large resonance peaks. This Pre-Treatment Scan is shown below as Figure 5.

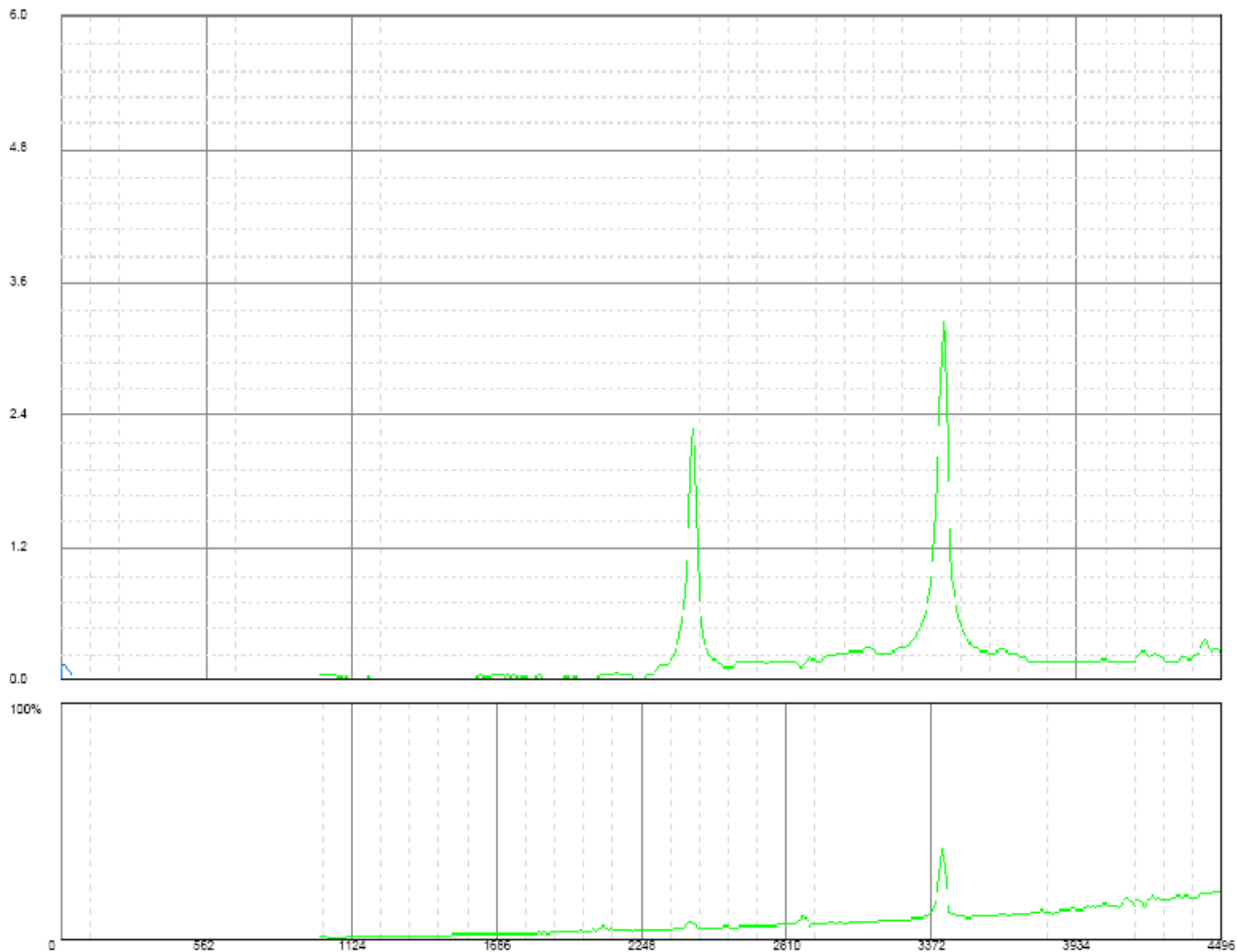


Figure 5: First Pre-Treatment Scan. VSR Treatment Chart Data consists of two plots, an upper plot showing workpiece acceleration (or Acceleration Curve), and a lower plot showing Vibrator Input Power (or Power Curve). Both data sets are plotted on a vertical axis vs a common horizontal axis of Vibrator RPM. Scanning is done automatically by the VSR-8000 System, and was done at a rate of 10 RPM / sec. – a speed which will produce high-resolution charts, accurately depicting the resonance pattern.

Peaks in the upper curve are resonance peaks of the workpiece. If a peak occurs in the power curve, it indicates that a load upon the Vibrator has also occurred. In the Chart above, the full-scale of the acceleration (adjustable from 1g thru 50g) was set at 6g. Full-scale for the power is preset permanently at the power capacity of the BL8 Vibrator's motor: 100% = 2.3 kW. Full-scale of the RPM (adjustable to 8000-RPM) was 4500-RPM. Scale adjustments can be made after a scan has been performed, even displaying data (such as a tall peak) that was originally off-scale, one of many "user-friendly" aspects of the VSR-8000 System. Pre-Treatment Scans are recorded in **green** since the Workpiece is "**green**" (freshly welded or cast).

Treatment is done by tuning on and dwelling upon the peaks identified in the Pre-Treatment Scan. The VSR-8000 System has very tight speed regulation ($\pm 0.02\%$). The Vibrator can be tuned in increments of 1-RPM. This enables the Vibrator to be tuned directly on the resonance peaks, so that maximum flexure, and stress relief take place.



Figure 6: MX-8000 VSR Console. Touch-screen computer displays VSR Scan Data, digital data (RPM, power, and acceleration). Scan data is saved in Adobe/pdf format. Low voltage connections are on left (2 USB Ports, Accelerometer, and Vibrator resolver / tachometer), and higher voltage connections on right (power in, motor).

After tuning on the 2370-RPM peak, peak growth occurred within two minutes, rising from 2.4g to 3.0g. The remaining increase, amounting to growth of 35%, took an additional 25 minutes to achieve. The peak at 3394-RPM was then tuned on. An increase had already taken place, due to the earlier Treatment of the first peak, this peak started out at 4.1g. The peak continued to grow, maxing out at a level 66% higher. These changes were then documented by performing a Post-Treatment Scan, shown in Figure 7.

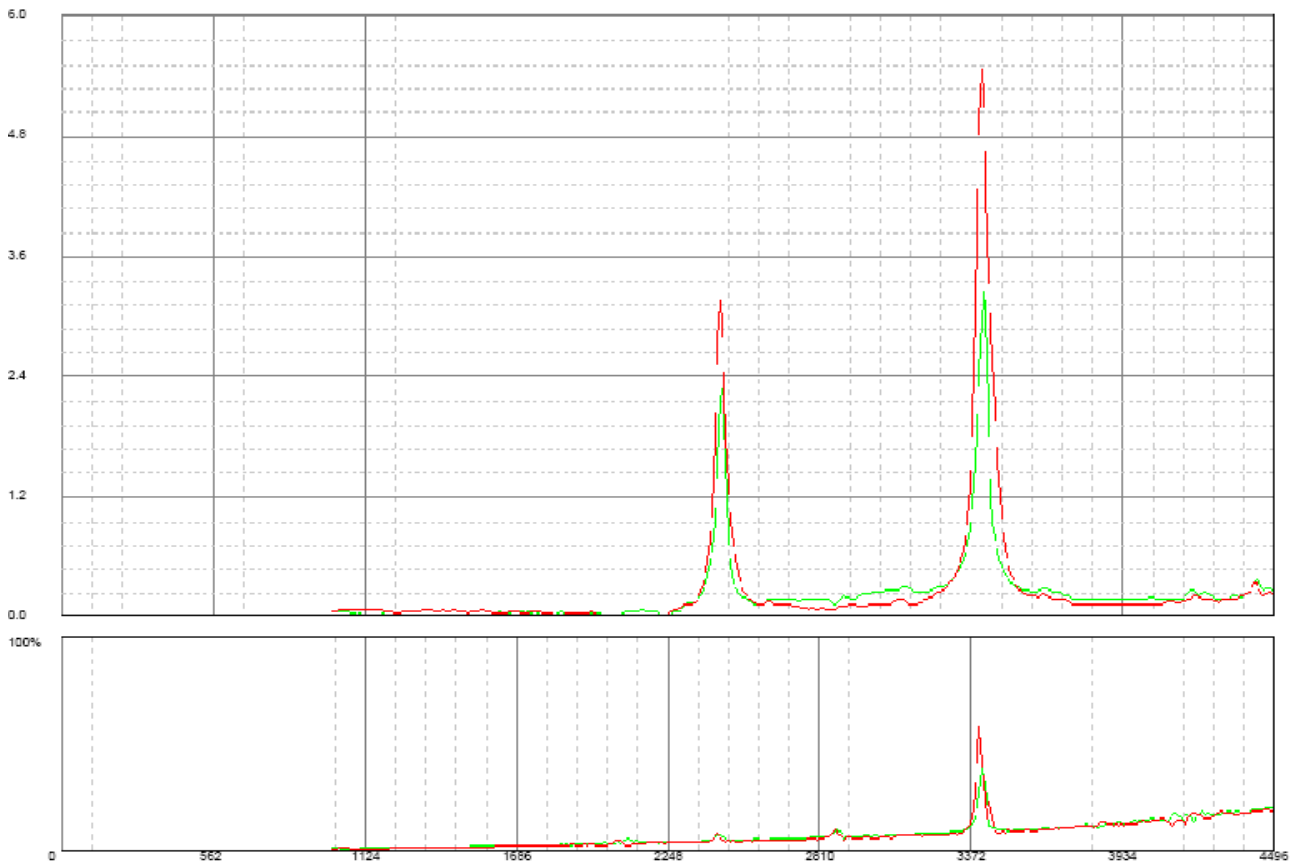


Figure 7: First VSR Treatment Chart. After the operator determined that peak growth (major response), and peak shifting (minor response) had been completed, a Post-Treatment Scan in **red** was automatically recorded, and superimposed upon the **green** Pre-Treatment Scan. Peak growth for the smaller peak, located at 2370-RPM, was $\approx 35\%$, and for the larger peak, located at 3394-RPM, peak growth was $\approx 66\%$.

During the scanning, there was an audible hum emanating from the workpiece. Normally associated with a resonance peak, this hum occurred at a vibrator speed between the two peaks, but no peak was visible. This peak was uncovered by reorienting the Accelerometer, so as to be sensitive to horizontal amplitude. A new Pre-Treatment Scan was run, which uncovered the "hidden" peak, allowing a Treatment of this peak, *see* Figure 8.

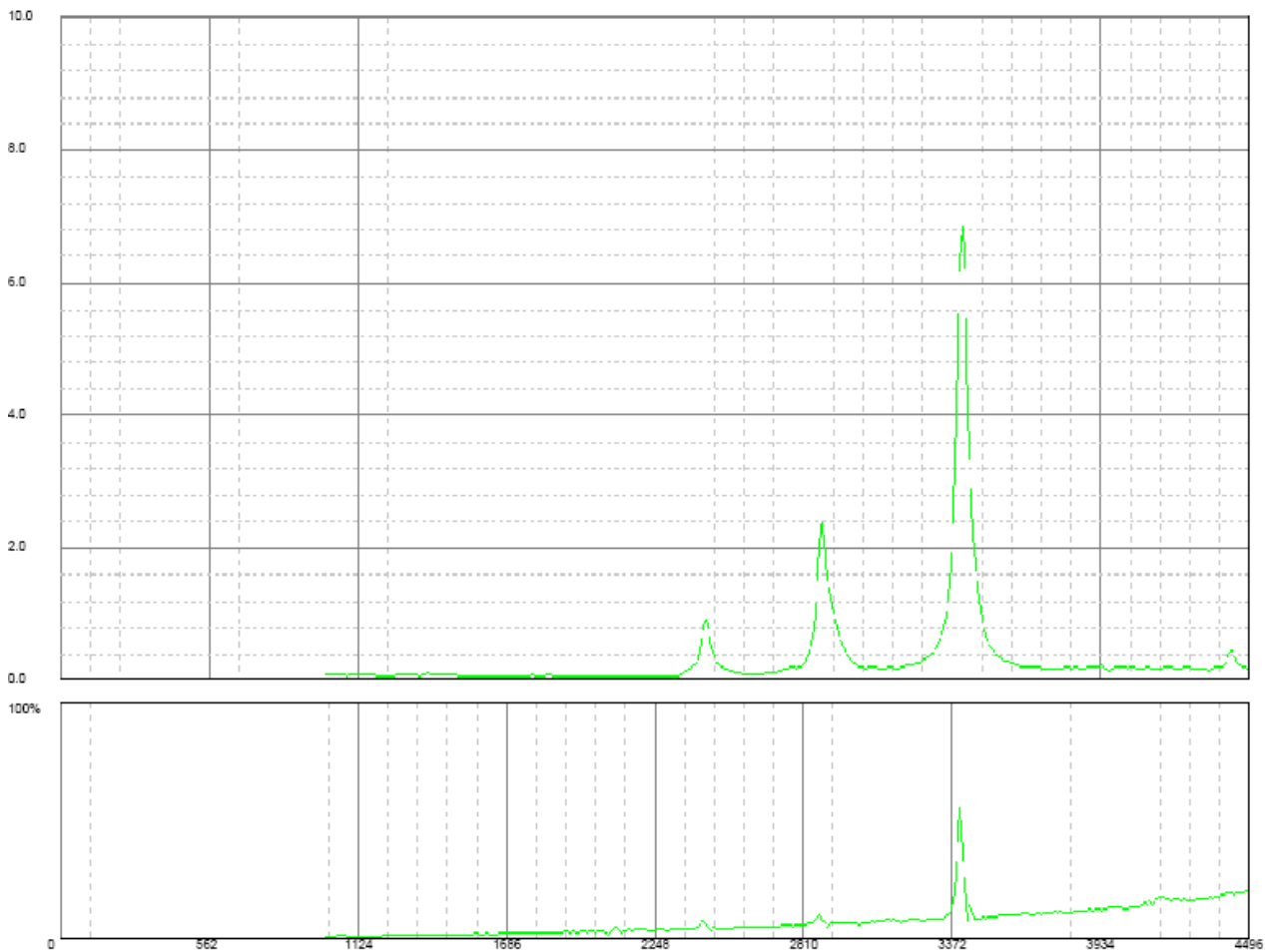


Figure 8: Second Pre-Treatment Scan with horizontally oriented Accelerometer. This was recorded with the Accelerometer reoriented so as to be most sensitive to horizontal deflection. By reorienting the vibration sensor, an additional "hidden" peak at 2843-RPM was revealed. However, tuning upon this new peak, caused very little additional peak growth or shifting, see Figure 9.

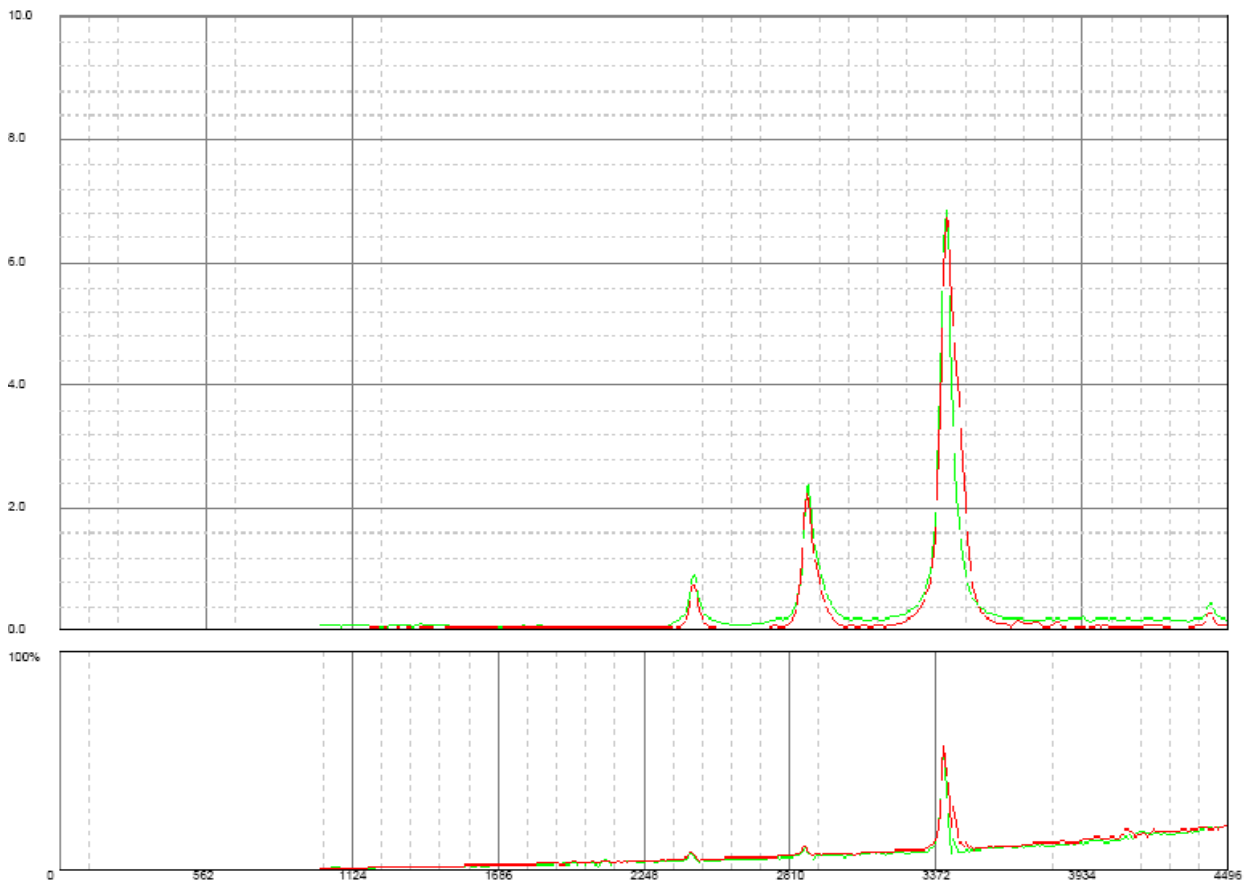


Figure 9: Second VSR Treatment Chart shows little additional growth. There is less than a 0.12g variation between the Pre-Treatment and Post-Treatment Scans, amounting to a 2 – 4% difference between the Pre- and Post-Treatment Scans.

CONCLUSION

As evidenced by the classic response to the VSR Process seen during the 1st Treatment, and the highly stable resonance pattern seen during the 2nd Treatment, this workpiece will remain dimensionally stable throughout machining, assembly, transport, and field usage.

Bruce Klauba has a degree in Physics and a Level II Vibration Analysis Certification from the American Society of Non-Destructive Testing (ASNT). As a pioneer in the cause and effect of Vibratory Stress Relief, Mr. Klauba was named chief inventor (*Klauba et al.*) in U.S. Patent 4,381,673, which is both an equipment and process patent describing advances in the technology. He has authored numerous articles and original research papers on the subject, which have been published in leading magazines and periodicals.

Published papers include:

1. "Use and Understanding of Vibratory Stress Relief", *Productive Applications of Mechanical Vibration*, 1983, American Society of Mechanical Engineers.
2. "Vibratory Stress Relief: Methods used to Monitor and Document Effective Treatment, A Survey of Users, and Directions for Further Research", 2005, *Trends in Welding Research*, ASM International.

A co-author in both papers, Dr. C. Mel Adams, is a leading authority in metallurgy and co-founder of MIT's Welding Research Department. In addition, Mr. Klauba has extensive experience in designing, building, and troubleshooting Industrial and Commercial Electrical Controls with a focus on extending the performance and reliability of Electric Motors and the systems they power.



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