Report on Vibratory Stress Relief

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THREE D METAL

Andrews, SC

Clamshell Buckets Job

THREE D METAL is a SE South Carolina fabrication and machine shop of large components for a variety of industries. As a previous user of VSR Technology's On-Site Service, we were the vendor of choice to stress relieve a pair of Clamshell Bucket Halves, each half weighing 24.5 tons, being manufactured for the steel industry.

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THREE D METAL is a SE South Carolina fabrication shop. Because of previous successes using VSR Technology's On-Site Service, the service was again chosen to stress relieve a pair of mild steel Clamshell Bucket Halves, each half weighing 24.5 tons, and measuring 180" H and 280" in diameter.

VSR Setup

The first workpiece was placed on four Isolation Load Cushions. These Cushions were placed in such a manner as to minimize damping of the workpiece, which maximizes resonant response, *see* Figures 1 and 2. Resonant frequency vibration is used because of its ability to maximize the flexure of the workpiece, which is key to the effectiveness of vibratory stress relief. Several independent research works, including those of Hahn[1], Shankar[2], and Yang, Jung and Yancey[3], have proven that resonance frequency vibration is the most effective form of vibration to relieve stress.

Strong, rigid structure, eg, these Clamshell Buckets, have very narrow resonant peaks, which require tightly-controlled vibration frequency to achieve full resonant response during Treatment. The VSR-8000 System used to stress relief these workpieces offers speed control of ± 0.03% of full range, so that such strict resonance requirements can be achieved.

The Vibrator was clamped to a vertical plate on the side of the workpiece, *see* Figure 2.

Figure 1: **24.5 ton Clamshell Bucket half setup for VSR Treatment. Note location of two Load Cushions (circled); the other two Cushions were placed on the opposite side (one being visible in Figure 2). The Accelerometer is visible on right lifting arm (circled), near the top of the photo. This particular Accelerometer location was used during a second Treatment of this workpiece, which turned out to be unnecessary (first VSR Treatment was fully effective), as indicated by the VSR Treatment Charts shown in Figures 3 – 6.**

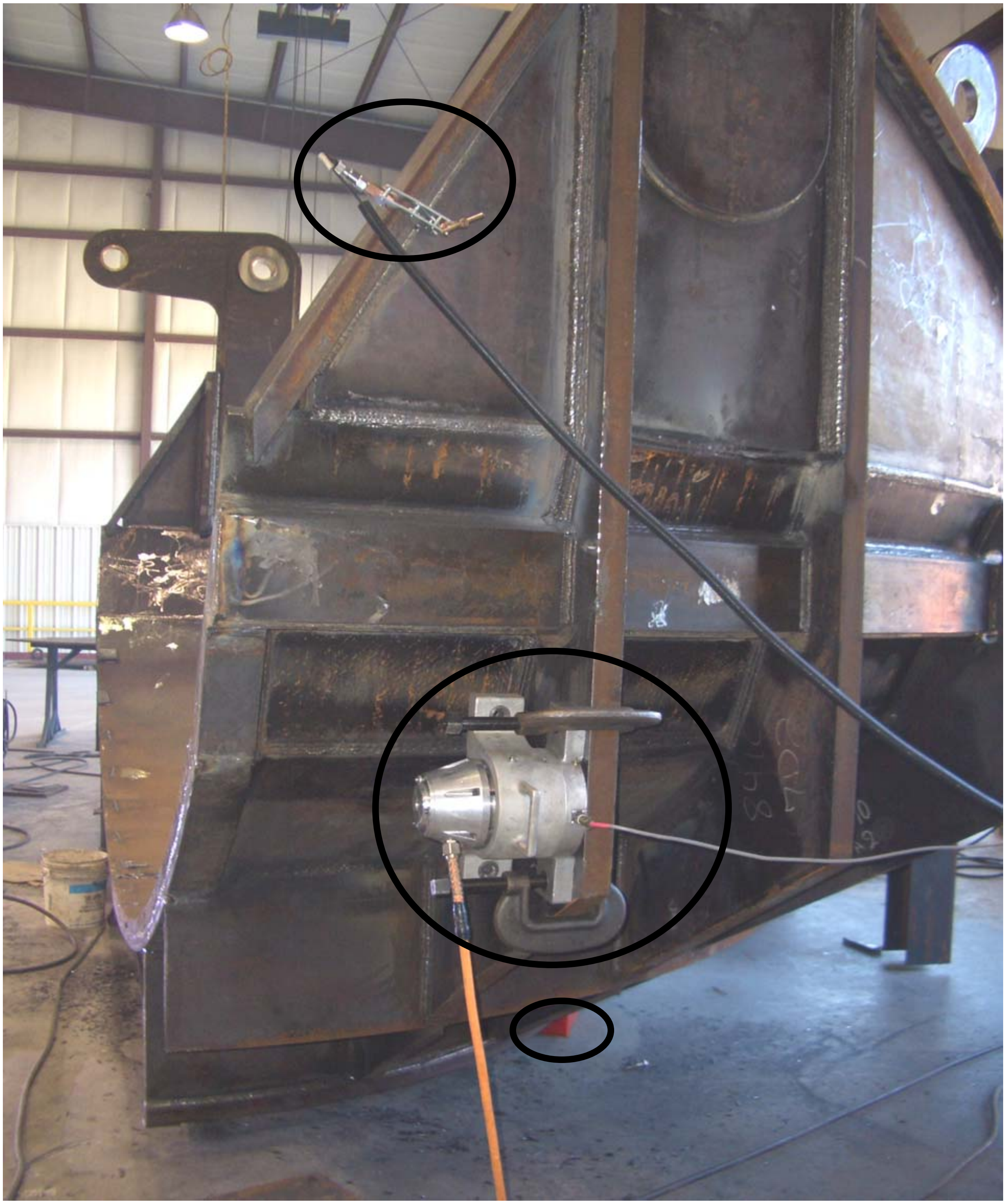

Figure 2: **Another view of Clamshell setup for VSR Treatment. One of two Load Cushions supporting the rear of the Clamshell is visible (circled), below the Vibrator (circled). Note that the support leg on the right is purposely not touching the floor; the full weight of the workpiece rested on the 4 Load Cusions.**

Test scans, using the VSR-8000 System's Quick Scan mode, showed that this workpiece had resonances that were relatively low in frequency, but required high unbalance settings to generate resonance peaks large enough to perform the Treatment, so a 100% unbalance setting, equal to 4.0 in-lbs, was used for all Treatments.

The Vibrator oriented with its Axis of Rotation Horizontal (AOR-H), as shown in Figure 2, was found to produce the best resonances.

An Accelerometer (a sensor whose output is proportional to acceleration) was placed on a corner of the workpiece. Acceleration has been found to be the best parameter to gauge vibration intensity, due to its proportionality to force, based upon Newton's Second Law: **F = ma** where F is force, **m** is mass, and **a** is acceleration. A trial mounting showed that a horizontal orientation of the Accelerometer generated the best resonance data, ie, detected the most number of resonance peaks.

The Accelerometer was initially placed in the location shown in Figure 2. Later, after the first VSR Treatment, the Accelerometer was moved to the location shown in Figure 1. Although this Accelerometer location did pick-up some additional resonance peaks, shown in Figures 5 and 6, Vibration dwell on these peaks did not cause them to grow or shift which proved it did not stress relieve the workpiece any more than the peaks displayed in Figure 3 and 4.

The scan rates used to produce all the Pre- and Post-Treatment data was 10-RPM/sec.

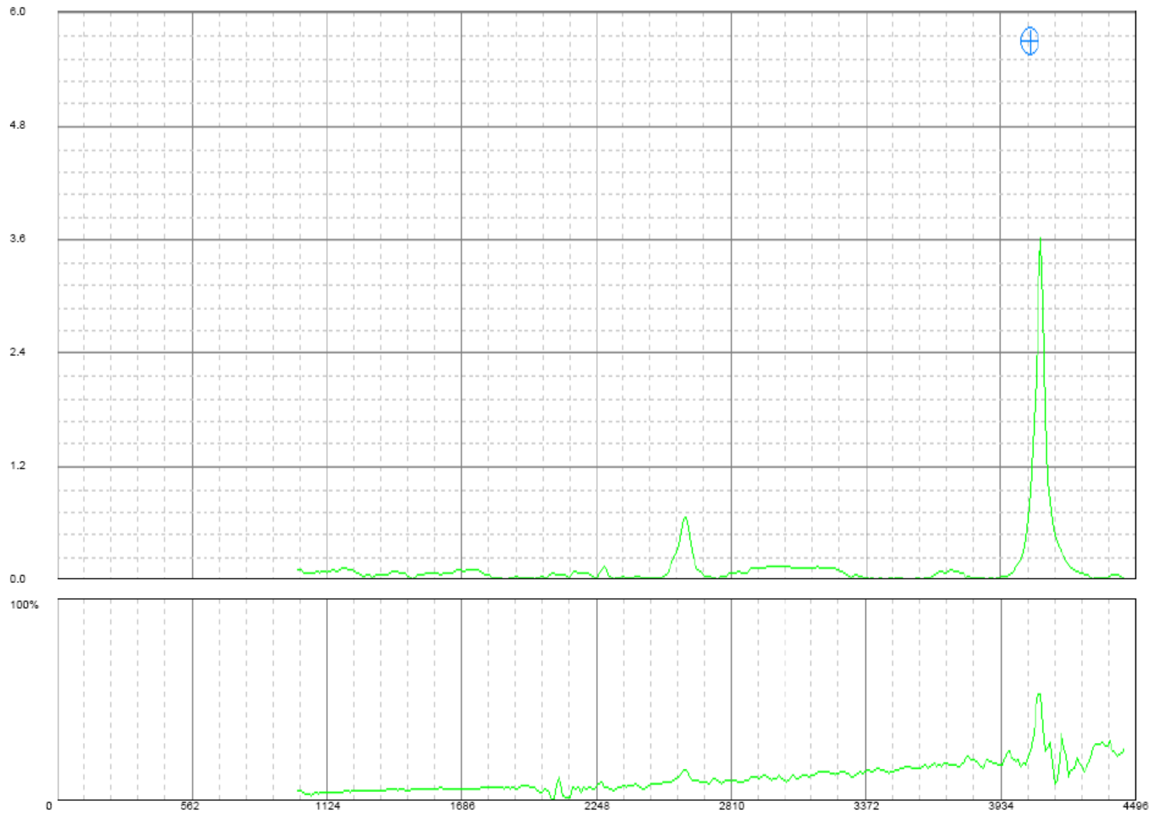

Figure 3: First Pre-Treatment Scan. VSR Treatment Charts consist of two plots: An upper plot of workpiece acceleration and a lower plot of vibrator input power, both of these plotted on a vertical axis vs. a common horizontal axis of vibrator RPM. Peaks in the upper plot are resonances of the workpiece. Peaks in the lower plot are resonances that cause increased, perhaps excessive, vibrator input power (excessive power is easily rectified by lowering the Vibrator unbalance setting, repositioning the Vibrator, or a combination of both).

Full-scale for acceleration is adjustable from 1g – 50g, and can be adjusted after a scan is made, in the event the plot is too "short" or "tall". Max setting for this Chart was 6g.

Full-scale for vibrator power is preset / fixed, with 100% = 3 HP (≈ 2.2 kW), the power capacity of the brushless DC motor that powers the BL8 Vibrator.

Full scale for Vibrator RPM is adjustable up to 8000-RPM, the maximum speed of the BL8 Vibrator. For this Chart, 4500-RPM (defaulting to 4496) was the max RPM used.

By having the data from both plots, a VSR operator can gauge the correct Vibrator RPM range, acceleration range, vibrator unbalance setting, and Vibrator location.

Pre-Treatment Scan data is plotted in **green**, since the workpiece is "green" (not stress-relieved, like a green casting).

The real-time cursor (blue circled) is visible above the large peak.

VSR Treatment

Treatment is done by tuning on and then dwelling upon the workpiece resonant peaks, and monitoring any changes in resonant response. Generally, stress relieving causes two distinct changes in resonance pattern:

1. An increase in the height of the resonance peak (typically the stronger response)
2. A shift of the resonance frequency in the direction of lower frequency (to the left on VSR Treatment Charts)

The first of these changes (peak growth) is consistent with a reduction in the stiffness of a workpiece, which is a consequence of effective stress relief. The second change (shifting) has been shown to often be a consequence of the first change, ie, peak growth[4].

The first resonance peak, located at ≈ 2600-RPM, was tuned upon and monitored. Within one minute, an increase in the height of the acceleration data was noted. Over the course of the next 25 minutes this increase continued, and then stabilized. The next peak, at ≈ 4100-RPM, was then tuned upon. An increase in its height and location had already occurred, but even further growth took place, and then stabilized. A Post-Treatment Scan was then performed (recorded in red) and is superimposed on top of the Pre-Treatment Scan data. The completed VSR Treatment Chart is shown in Figure 4.

Figure 4: **First VSR Treatment. During Treatment each of the peaks at 2600- RPM and 4100-RPM were tuned upon and monitored. The peaks shifted nominally but grew as shown. Each peak required roughly 25 minutes to stabilize. After stability of both was achieved, a Post-Treatment Scan was performed which recorded (in red) the clear increase in height of both resonance peaks.**

During Treatment, these workpieces emitted a number of audible "hum" tones, which increased, then decreased in volume. This is a typical occurrence as the VSR System scans through resonance peaks. On occasion, however, no relevant peaks appear on the scan data even though they've been heard. This job was one of those occasions.

When this occurs, it is prudent to either move the Accelerometer to a different location and/or change its orientation, so that peaks which were heard but not recorded, can be located and recorded during a subsequent scan. This can be done immediately by refining the original VSR setup, or done later by changing the VSR setup and performing a second Treatment.

The decision as to when to change the setup (immediately or later) is based on the scan data. If good, responsive peaks are present in the first scan, which was the case with the first Clamshell, the Treatment in progress should be completed, and a subsequent Treatment with a different setup should be performed. If not, the operator should stop treatment, refine the setup so that "hidden" peaks become more pronounced during a subsequent scan, and then perform the Treatment based on the new Pre-Treatment scan data.

On the first Clamshell a second Treatment was performed with a new setup which relocated the Accelerometer to the top of the Clamshell's lifting arm. The results of the second Treatment indicated this additional Treatment was not necessary (no audible tones or additional peaks occurred, *see* Figure 5, and so only one Treatment was deemed necessary on the second Clamshell, *see* Figure 7.

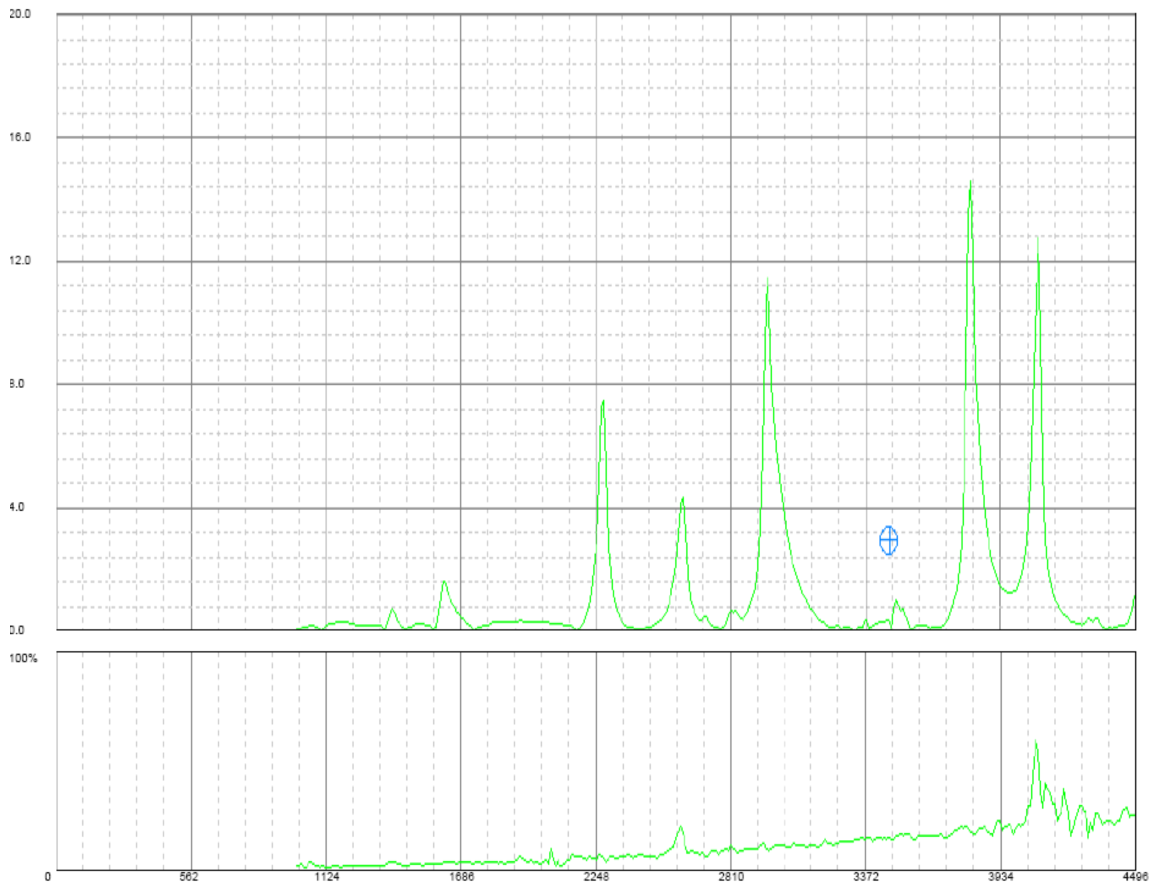

Figure 5: **2nd Pre-Treatment Scan using a new Accelerometer location, shown in Figure 1. Although more peaks were detected and treated, little change in resonance pattern occurred. The completed VSR Treatment is shown in Figure 6.**

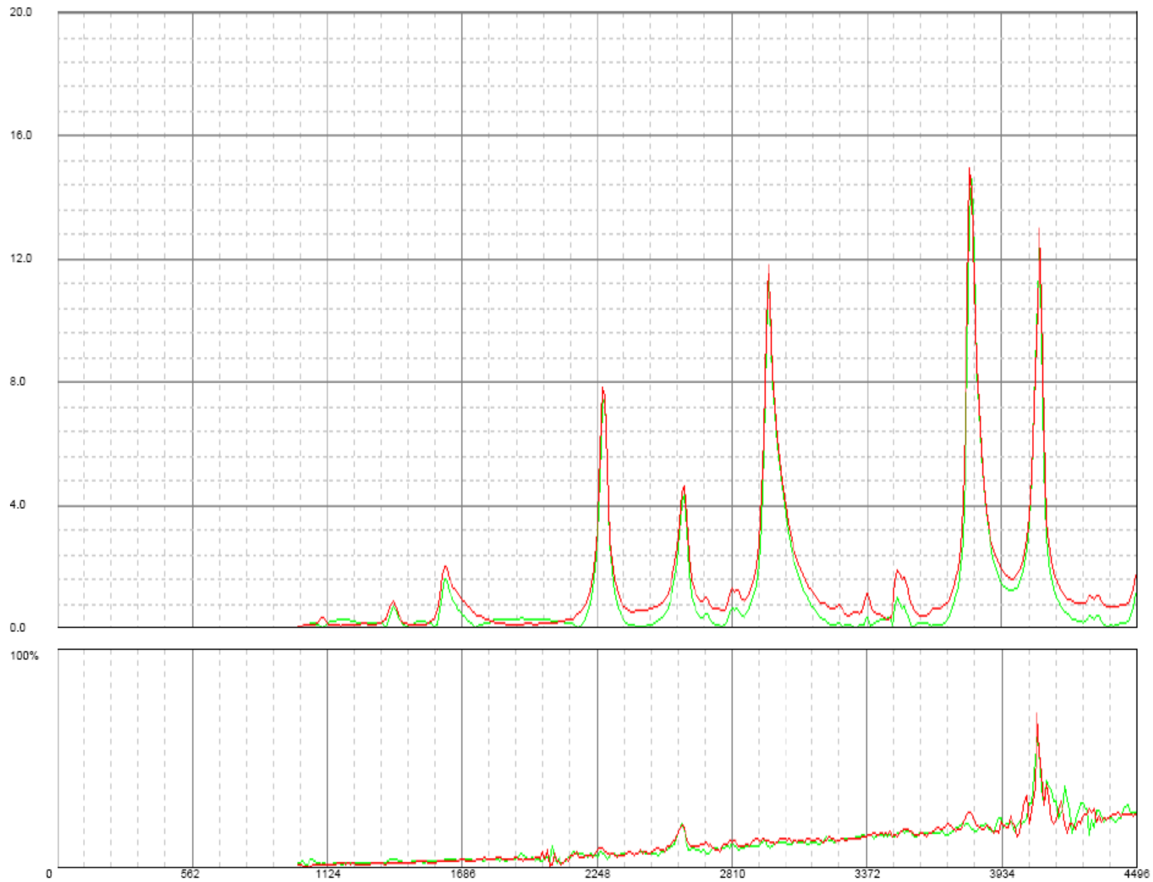

Figure 6: **2nd VSR Treatment on first Clamshell half. This Chart shows very little change in resonance pattern, ie, the resonance pattern is very stable. (Compare with Figure 4.)**

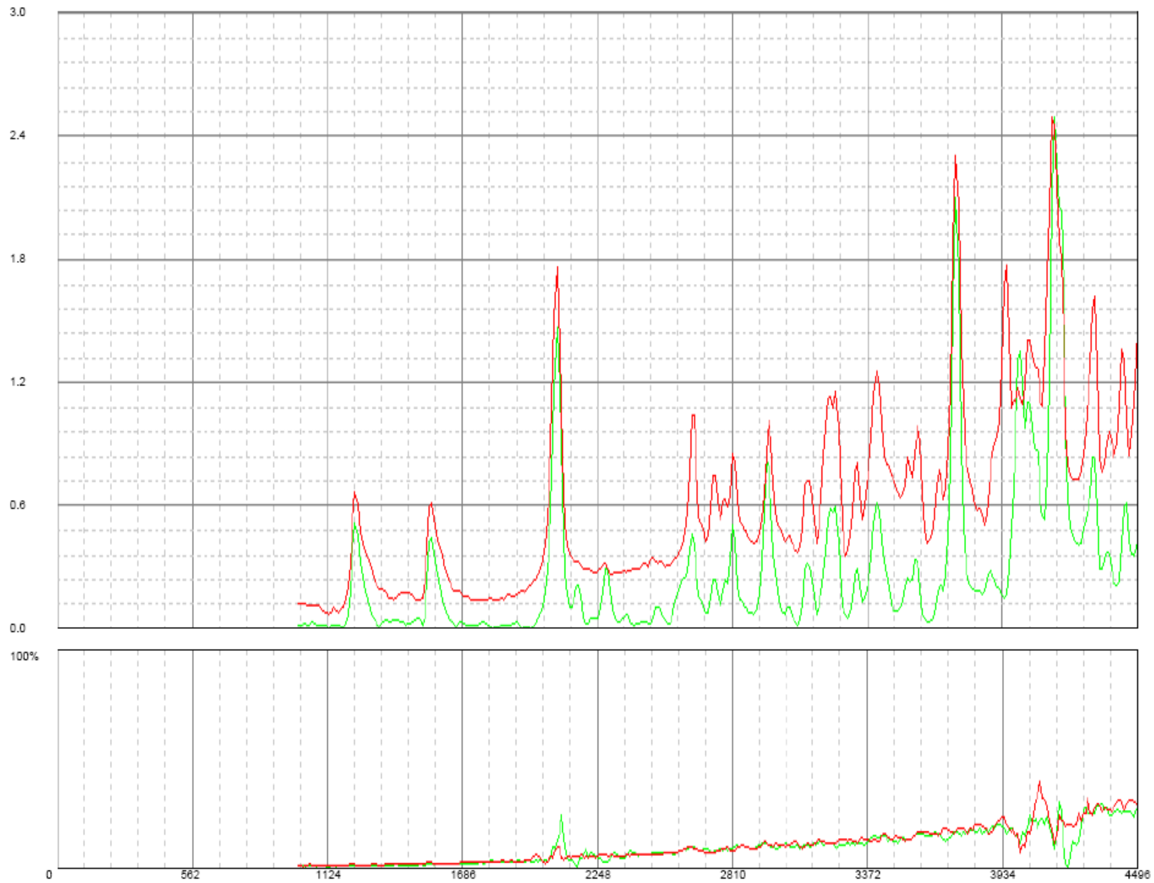

Figure 7: VSR Treatment Chart for 2nd Clamshell half. Clear change in the initial resonance pattern (green) took place, eventually resulting in a stable resonance pattern (red). Treatment time was ≈ 80 minutes.

Conclusion

As a result of the clear change in resonance pattern, later followed by very stable resonance patterns for both workpieces, these components will display good dimensional stability during subsequent manufacturing, transport, installation, and use.

Footnotes:

1 Dr. William Hahn, Vibratory Residual Stress Relief and Modifications in Materials to Conserve Resources and Prevent Pollution
2 Dr. S. Shankar, Vibratory Stress Relief of Mild Steel Weldments
3 Drs. Y. P. Yang, G. Jung, and R. Yancey, Finite Element Modeling Of Vibration Stress Relief After Welding

NB: Source Research Works available in the VSR On-Line Technical Library @ http://www.vsrtechnology.net/

Bruce Klauba has a degree in Physics and a Level II Vibration Analysis Certification from the American Society of Non-Destructive Testing (ASNDT). 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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