VSR Report: Jasper Steel

Performed at the Rose Corporation, Reading, PA

July 2012

Jasper Steel is a repeat user of the VSR Process. This particular project involved the on-site stress relief of a motor – generator base, fabricated out of mild steel.

Report written by Bruce Klauba

Jasper Steel is a repeat user of the VSR Process. This particular project involved the on-site stress relief of a motor – generator base, fabricated out of mild steel.

This particular project involved the on-site stress relief of a motor – generator base, fabricated out of mild steel. The base measured overall 160" L X 84" W X 43" H, and weighed 7250 lbs. See Figure 1.

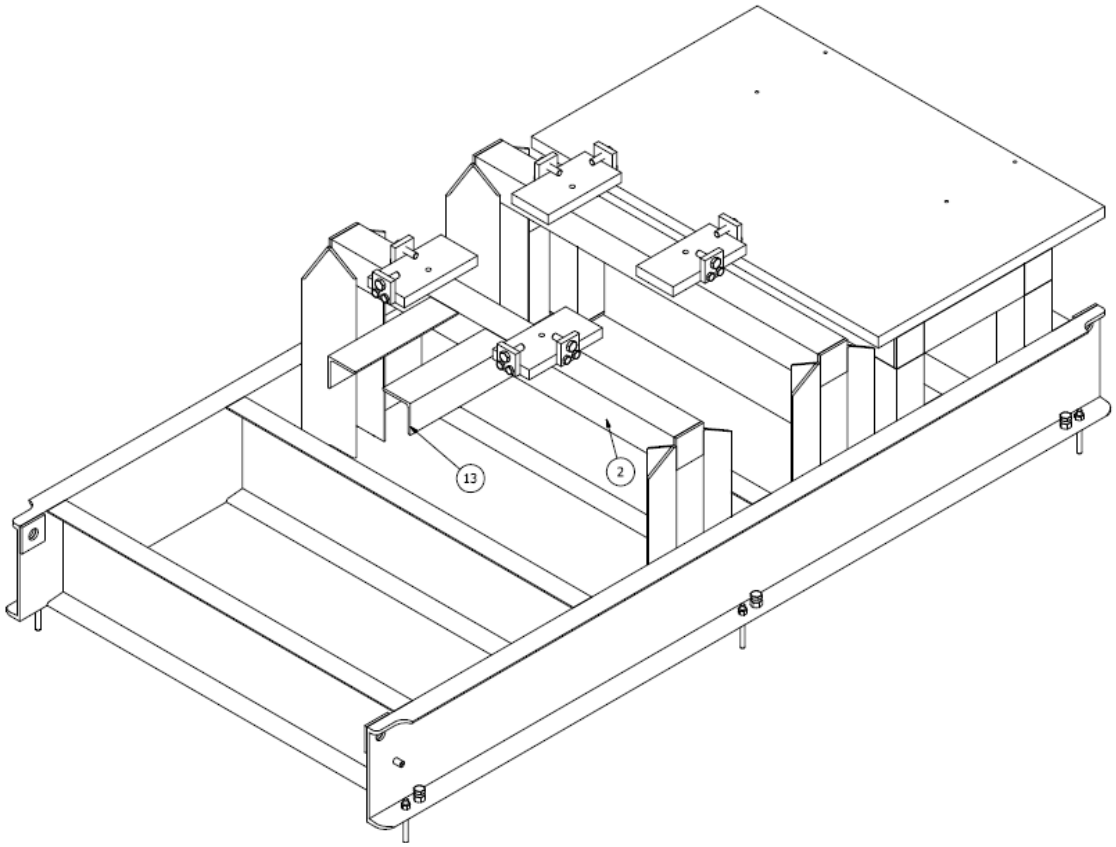

Figure 1: Ortho view of motor generator base.

VSR Setup

The work-piece was placed upon three urethane isolation blocks, two on one side, at first positioned roughly 30% from each end, and one located at the center of the opposite side. These were then shifted in the direction of the center of gravity of the structure, which was only 30% from the heavy end of the work-piece. This cushion

arrangement minimizes the damping of the work-piece, allowing the greatest ease in generating resonant vibration. See Figure 2.

The VSR Process uses resonant vibration to cause sufficient flexure of the work-piece, so to combine the dynamic load from resonant vibration with residual stresses trapped in the material, resulting in plastic flow. 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.

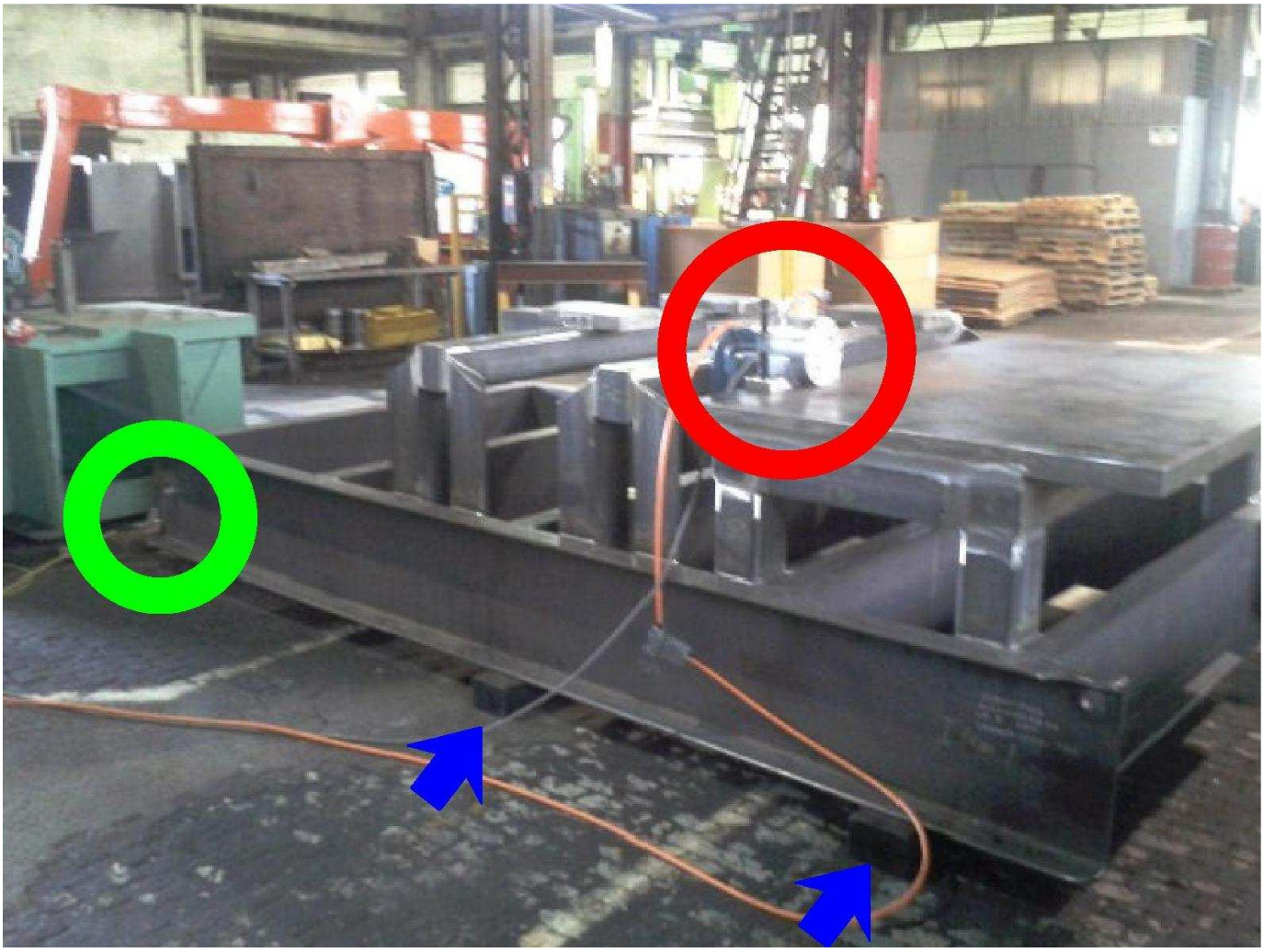

Figure 2: VSR Setup showing vibrator (red circle), accelerometer (green circle) and 2 of the 3 isolation cushions used (blue arrows).

[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

Figure 3: VSR Setup from opposite side showing vibrator (red circle), accelerometer (green circle) and single cushion (blue arrow) located near work-piece's center-of-gravity.

The vibrator was securely clamped on the upper plate of the work-piece, and aligned so the vibrator's AOR (Axis of Rotation) was parallel with the length of the work-piece. This arrangement generates both the greatest number and the highest amplitude resonance peaks.

The vibrator's unbalance was adjusted to 20% of the available 4.0 in-lbs, or 0.8 in-lbs. This level of unbalance generated very significant resonance peaks, but also caused some high peaks in vibrator power, which were later ignored / not used during VSR Treatment.

The accelerometer (a sensor whose output is proportional to acceleration) was placed on a corner of the work-piece, visible in Figure 2 (green circle), and was oriented so as to be most sensitive to vertical amplitude. Acceleration is used, since it is the best parameter to monitor the dynamic load (force) induced in the work-piece, consistent with Newton's 2nd Law: **F = ma** (Force is equal to mass X acceleration).

VSR Treatment

VSR Treatment is done by tuning upon the work-piece resonant peaks, and monitoring any changes in resonant response. Generally speaking, stress relieving causes two distinct changes in resonance pattern to take place:

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

After the Quick Scan is performed, a Pre-Treatment Scan (or Pre-Scan) is made. The Pre-Scan plots a high-resolution version of the data shown in the Quick Scan, and is used as a base-line: Quick Scans are fine for calibration, but often record the peaks shorter than they actually are, and also can miss very narrow peaks.

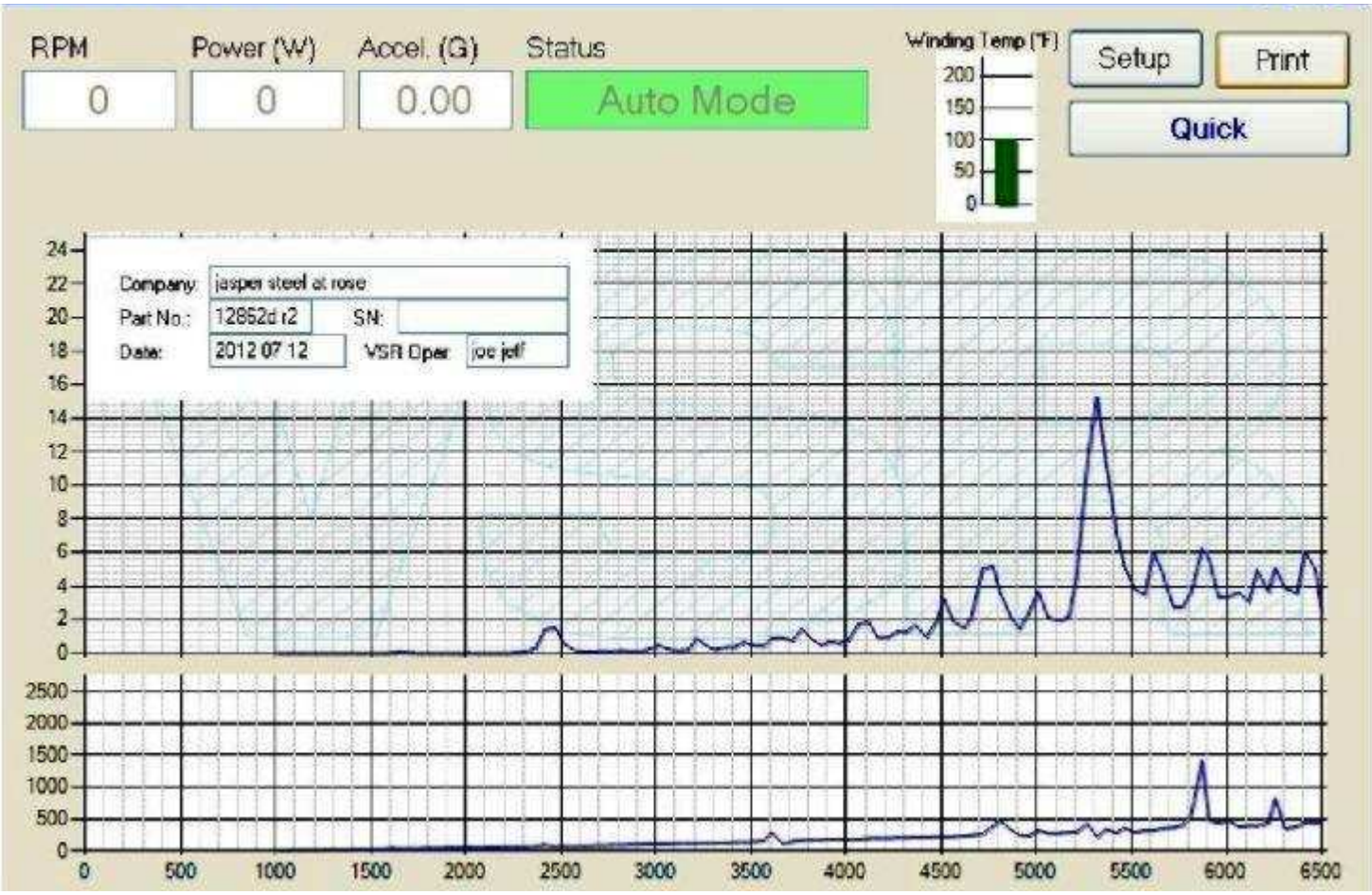

Figure 4: A Quick Scan (QS) of work-piece is done for calibration purposes. QS's use a scan rate of 50 RPM / second, and take less than two minutes to produce. VSR Treatment Charts consist of VSR Treatment Charts consist of two plots: An upper plot of work-piece acceleration and a lower plot of vibrator 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 work-piece. Peaks in the lower plot are resonances that cause increased, perhaps excessive, vibrator input power.

Full-scale for acceleration is adjustable from 1 – 50 g's, and can be adjusted after a scan is made,in the event the plot is too "short" or "tall". 24 g full scale was used for this scan.

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 8,000 RPM, the max speed of the BL8 vibrator. For this chart, 5000 RPM 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.

Quick Scans are recorded in blue, Pre-Treatment Scan data is plotted in green, since the work-piece is "green" (not stress-relieved, like a green casting.), and Post-Treatment Scan data is red.

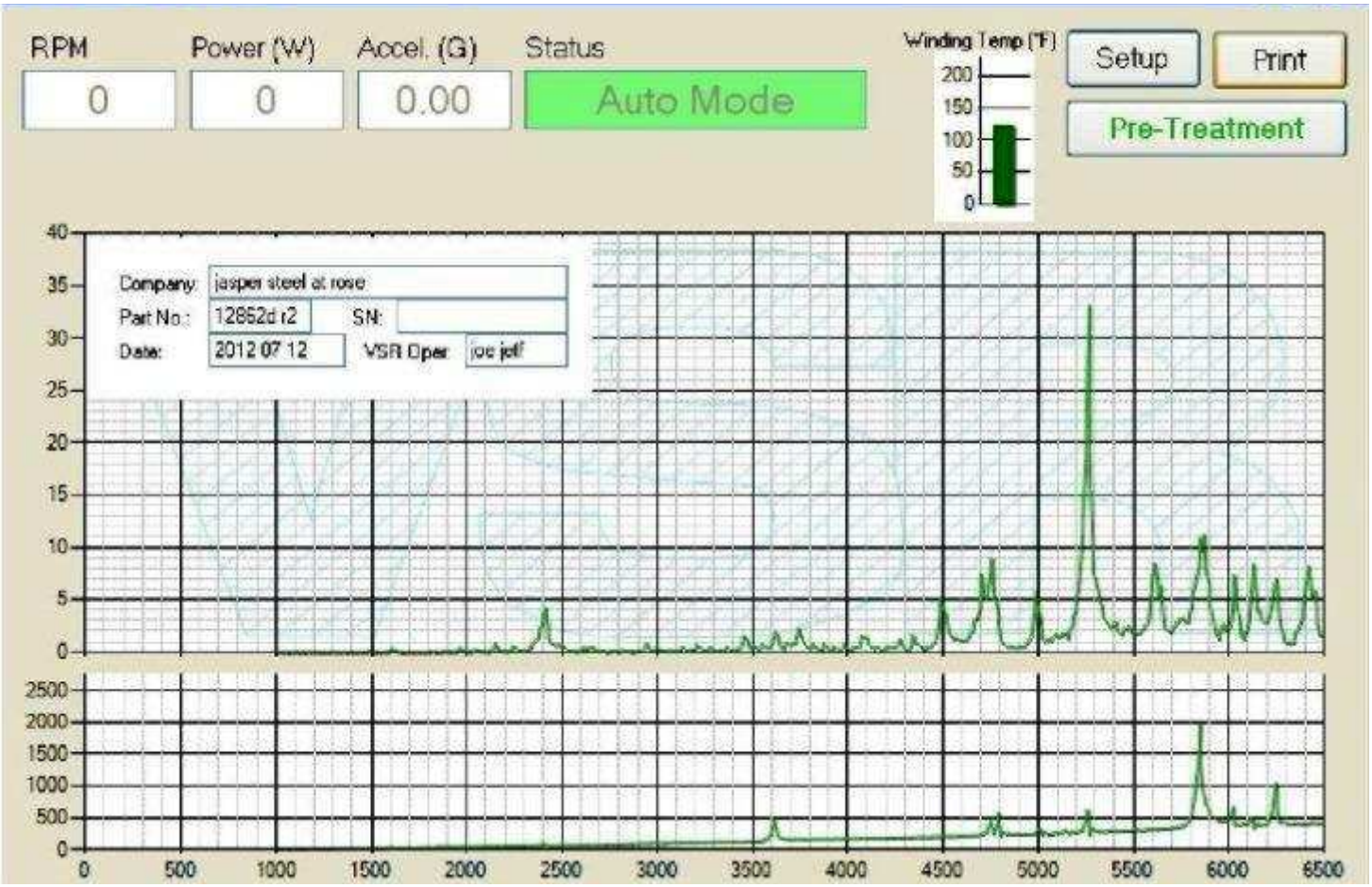

Figure 5: Pre-Treatment Scan is a high-resolution version of the QS, plotted at a rate of 10 RPM / sec. The Pre-Scan functions as a base-line which the operators uses during treatment, using the data to tune upon various resonance peaks, and monitoring them as they grow or shift, or a combination of both. These changes in the resonance pattern are evidence of stress relieving, and continue until the structure is fully VSR Processed. At this point, the new resonance pattern remains stable, this stability going hand-in-hand with the dimensional stability of the structure.

During VSR Treatment, the most common changes in resonance pattern are:

1. Peak Growth – Higher amplitudes of resonance peaks, the most common and larger of changes in resonance pattern.
2. Peak Shifting - Movement of the center frequency of resonance, normally to the left (i.e., lower resonance frequency), the smaller, percentage-wise of changes in resonance pattern.

Such changes were clearly seen, esp. peak growth, during VSR Treatment. After these changes, which occurred on several of the resonance peaks, were finished, a Post-Treatment

Scan is normally performed, plotted in red, documenting the resonance pattern changes and differences between the original (green) Pre-Scan and the final (red) Post-Scan.

Unfortunately, a loss of power during operation prevented the Post-Scan from being plotted on top of the Pre-Scan. The final Post-Scan can be seen in Figure 6.

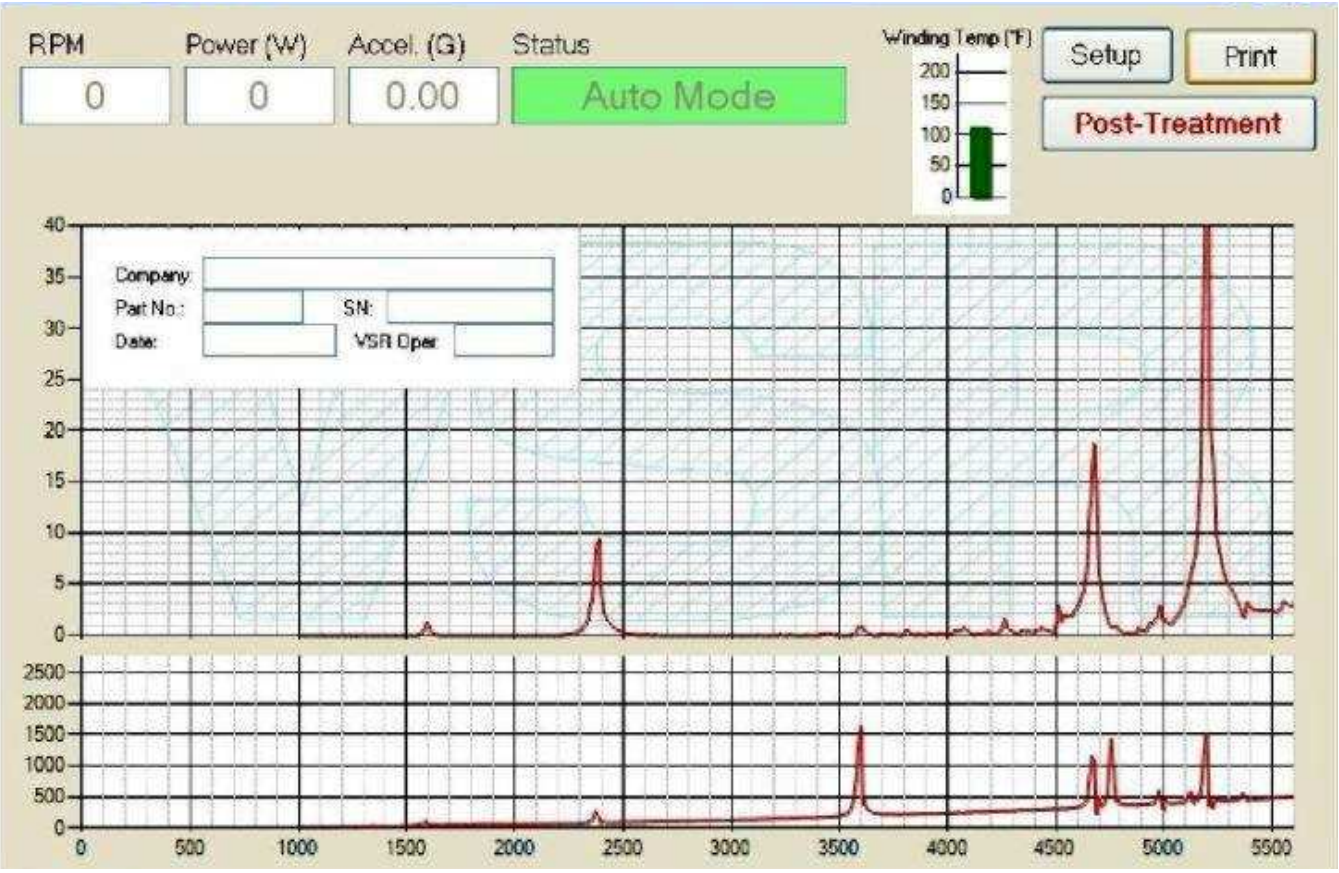

Figure 6: Post-Treatment Scan. Due to a loss of power, this plot was made on a blank VSR Chart, which is not standard procedure. However, a composite of this chart data superimposed on top of the Pre-Scan data was generated, which clearly documents the changes in resonance pattern seen during VSR Treatment. The composite appears as Figure 7.

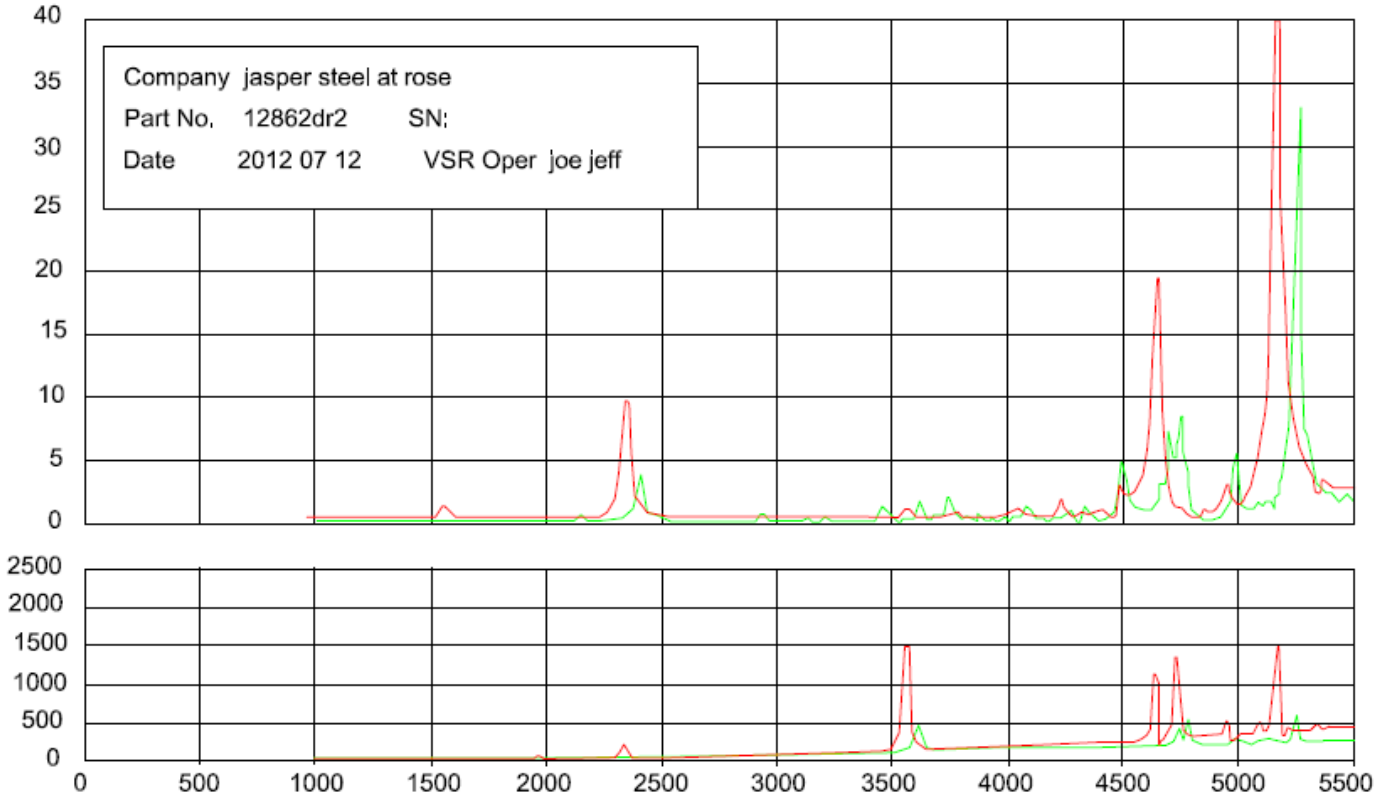

Figure 7: Composite of Pre-Scan (green) and Post-Scan (red) data show a clear change in the resonance pattern of the work-piece.

Conclusion

As a result of the clear change seen during the VSR Process, as seen in the change in resonance pattern, which resulted in stable vibration data, this work-piece should exhibit good dimensional and mechanical integrity, consistent with a structure having only nominal levels of residual stress.