VSR Report

Colonna Shipyard / Steel America

Stress Relief of four Storm-Surge Flood Gates

for the City of New Orleans

The Steel America division Colonna Shipyard, located in Norfolk, VA., produced a series of storm-surge gates, destined for installation near the City of New Orleans. Colonna chose VSR Systems & Service to perform stress relief upon these critical components, to enhance the dimensional stability and structural integrity.

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The gates measured 26+ feet high, 32+ feet, front-to-back, and 37+ feet across the arc of the gate, and each weighed ~ 40 tons. A 3D view appears in Figure 1.

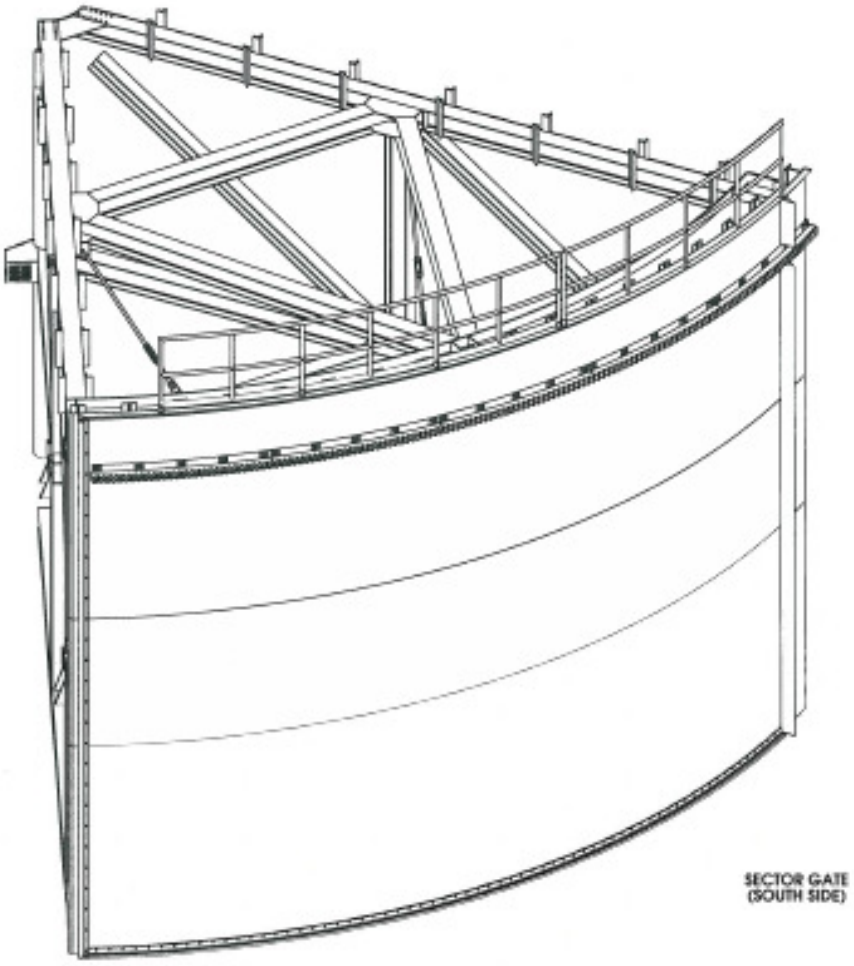

Figure 1: Storm Surge Gate Layout. The gate measured 26+ feet high, 32+ feet, front to back, and 32+ feet across the arc of the gate wall, and weighed ~ 40 tons.

VSR Setup

Each gate was placed on a group of 4 load cushions, but two were located close together, effectively functioning as one cushion. This 3 point load cushion placement, depicted in Figure 2, minimized damping, and thus promotes resonance.

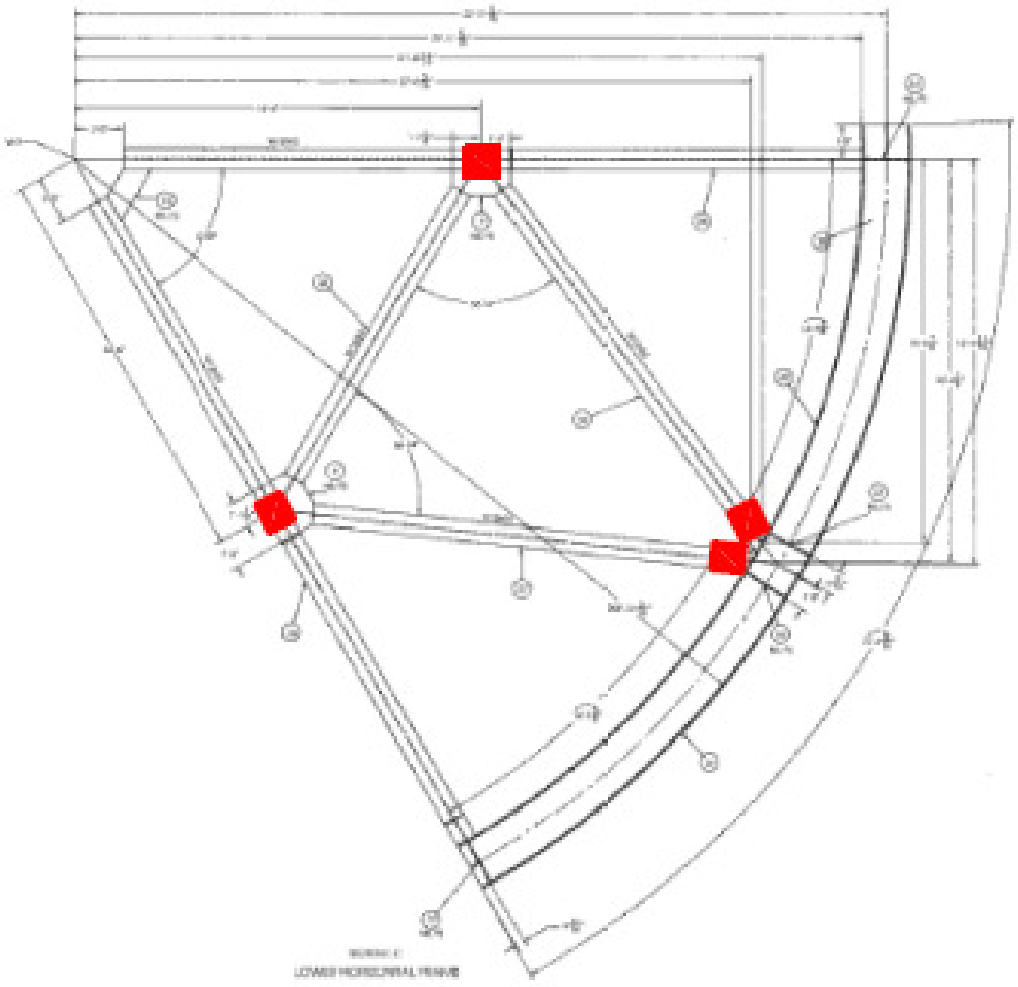

Figure 2: Plan view of gate, showing cushion layout. Four cushions were used, but two were very close together, effectively functioning as one cushion. This three point support, with the cushions located far from the corners, minimized damping, and thus allowed resonant response to be maximum.

The VSR Process uses resonant vibration to cause sufficient flexure of the workpiece, 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.

The vibrator was placed at the intersection of five members, so to transmit vibration efficiently throughout the structure. The vibrator's Axis of Rotation (AOR) was vertical. Two VSR Treatments were performed on each workpiece, due to a disparity between the major resonance frequencies: The 1st treatments on each gate were done focusing on the RPM range of 5000 – 5500, using a vibrator unbalance of 35% of the total of 4 in-lbs available from the BL8 vibrator (1.4 in-lbs).

The 2nd treatments focused on the RPM region 3600 – 4300, using a higher unbalance (80 %, or 3.2 in-lbs.). This 2nd unbalance setting was sufficient to drive the workpiece into healthy resonance levels, but was too high to allow operation at higher frequencies. Resonances were apparent not only on the VSR Charts (shown later), but sonically and visually, both in visible amplitude and the generation of nodal patterns that appeared on the workpiece (see Fig. 6).

An accelerometer was placed on the corner of the workpiece, and oriented so to be most sensitive to vertical deflection. 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.

[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. The work-piece was placed on 4 load cushions (measuring 1' X 1' X 4" H), two of which were very close together, effectively functioning as one cushion.

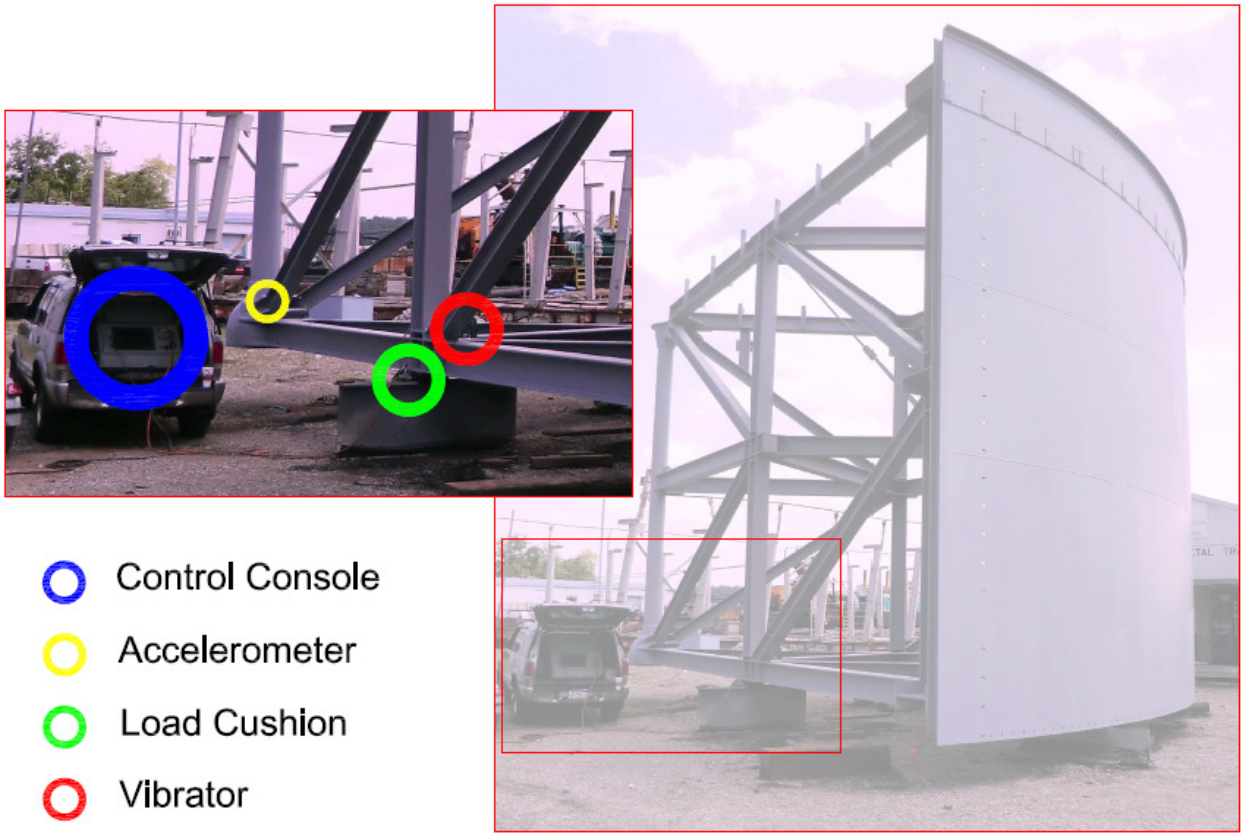

Fig 4: Labeled view of gate, showing location of vibrator, accelerometer, cushion, and console.

VSR Treatment

VSR Treatment is done by tuning upon the workpiece 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)

Figure 5: View from hinge point of gate, showing vibrator location of the right, and accelerometer on the left.

For these specific workpieces, the first treatments were done focusing chiefly upon resonances in the upper RPM range, above 4800 RPM. The 2nd treatments were done focusing chiefly on resonances in the 3600 – 4300 RPM range.

Treatment consisted of tuning upon peaks in these ranges, and monitoring any changes that took place. If required, the vibrator RPM was adjusted, as the peaks (which chiefly grew) shifted slightly to the left.

Figure 6: During resonance, patterns of high and low amplitude become apparent, even visible, on the work-piece. During the treatment of the 3rd work-piece, which was done not long after it had been shot-peened, these patterns become evident, as shot-peen that had been resting on the work-piece was driven off the high-amplitude locales, and came to rest on low-amplitude locales. Such patterns define the ***nodes*** of the work-piece, and are referred to as a ***nodal pattern***. Different resonant peaks generate different nodal patterns, indicating that the effect of the vibrator is relocated, not by moving the vibrator, but by tuning the vibrator to different resonance frequencies, which generate a different nodal pattern.

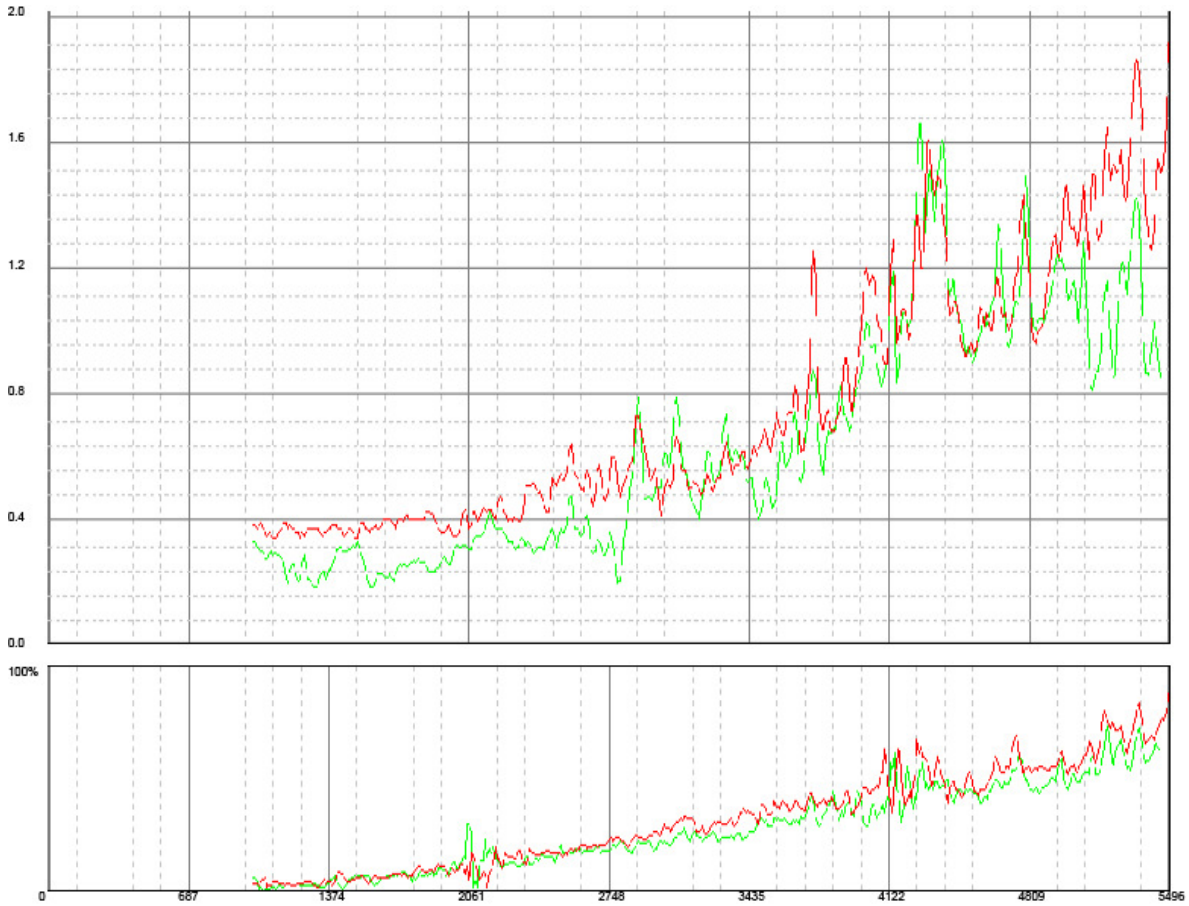

Figure 7: Workpiece 1, 1st VSR Treatment. Max RPM = 5800, 35 % vibrator unbalance. VSR treatment charts consist of two curves: An upper acceleration and a lower vibrator power, both of these plotted vertically vs. a common horizontal (X – axis) of vibrator RPM. Peaks in the upper curve depict resonances of the workpiece. Large peaks, or data near the max (100%) in the lower curve indicate that the vibrator, per se, is undergoing high-amplitude, and some adjustment to the setup, either lowering of the unbalance or repositioning / reorienting of the vibrator might be required.

The initial scan, recorded in green, depicts the original, base-line resonance spectrum. Treatment is done by tuning upon the green resonance peaks, one at a time, and monitoring them for increases in amplitude or shifting to the left.

Peak growth can be seen, esp. in the higher RPM range, above 4800 RPM.

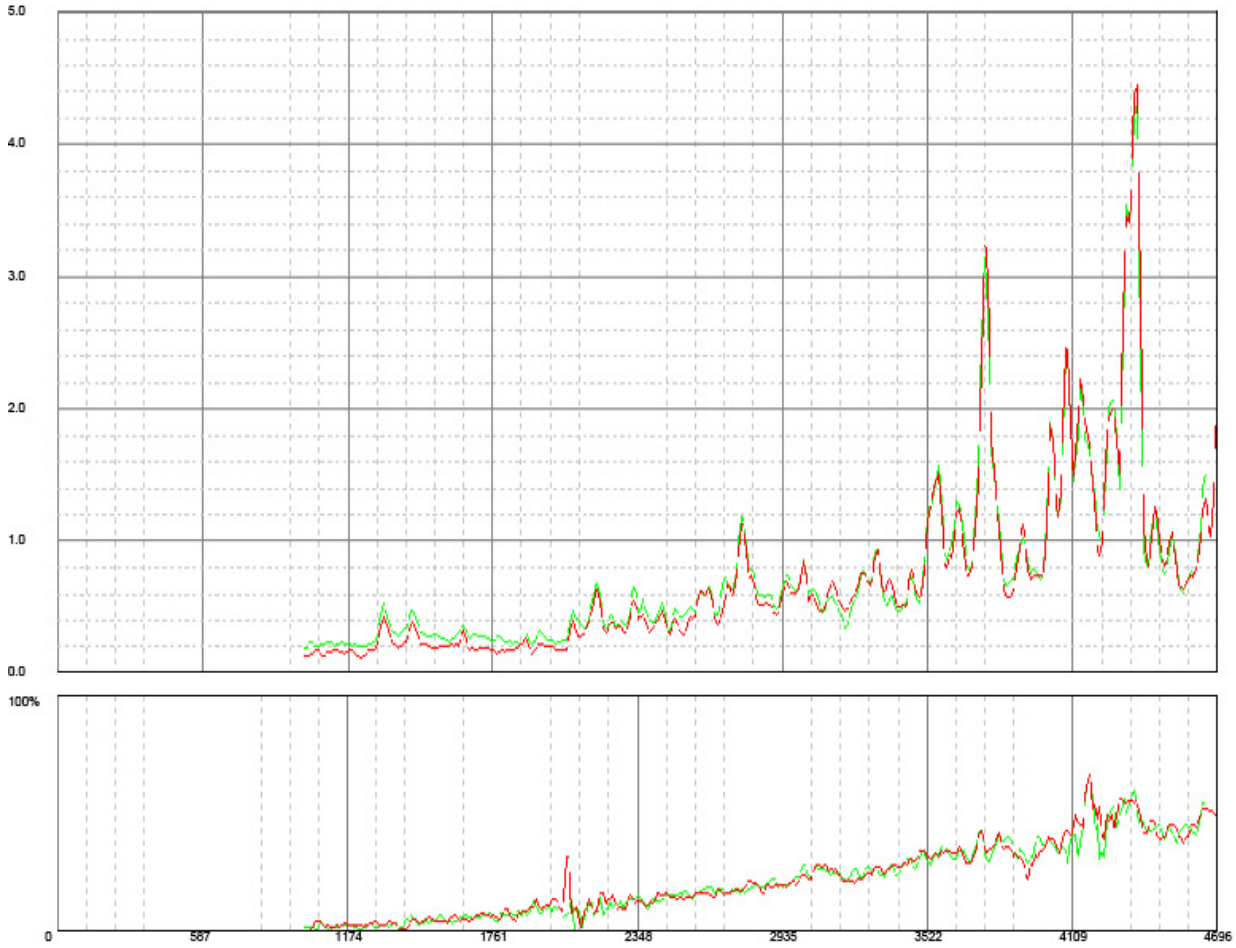

Figure 8: Work-piece 1, 2nd treatment, max RPM = 4700, vibrator unbalance 80%. Peaks at ~ 3600 and 4600 RPM show mild response to VSR Treatment. After slow and steady peak growth, each peak stabilized after being held for ~ 15 minutes.

Figure 9: Work-piece 2, 1st treatment, max RPM 5500, vibrator unbalance 35%. Larger peak growth (as compared to the 1st workpiece) can be seen during this treatment, esp. above 4800 RPM.

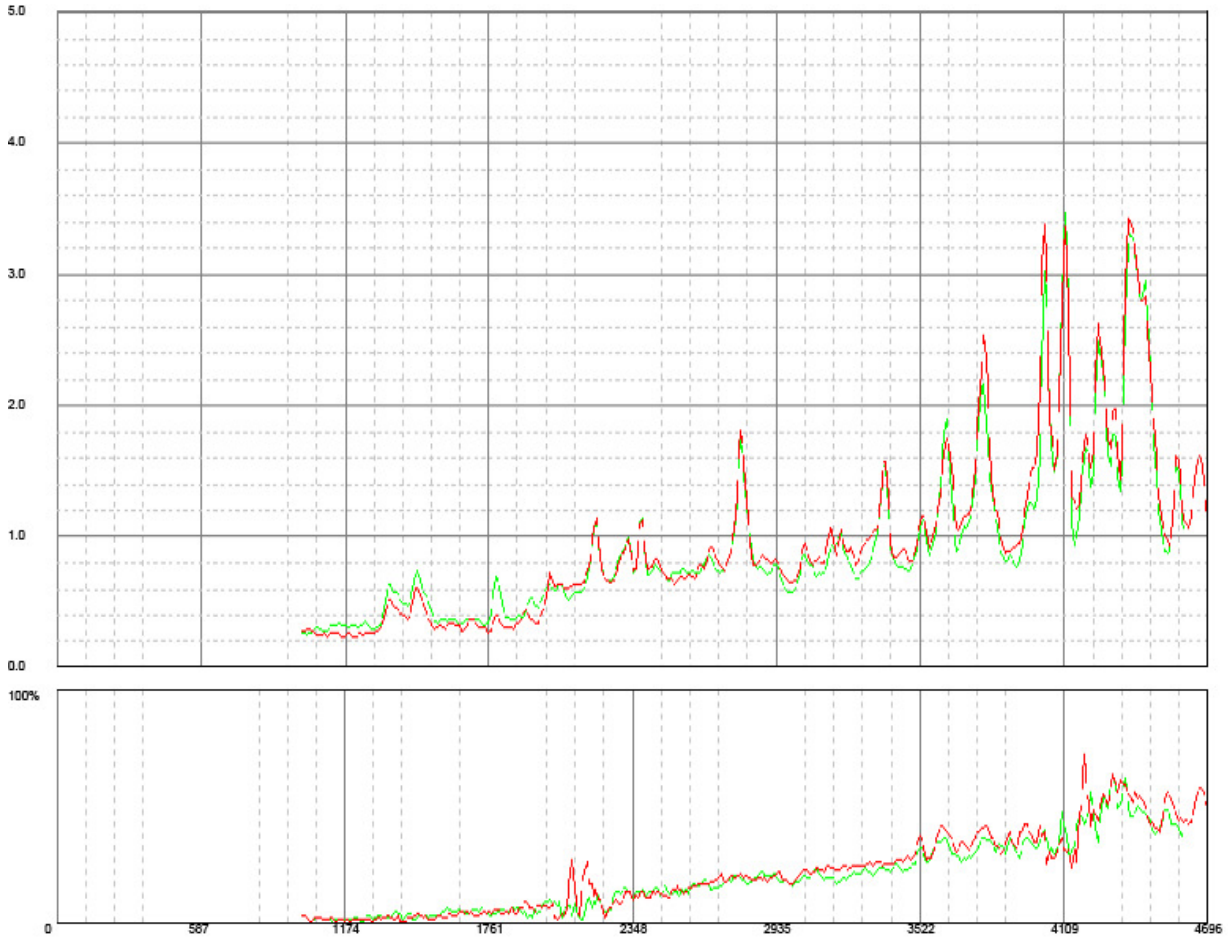

Figure 10: Workpiece 2, 2nd treatment, max RPM 4700, 80% unbalance. Changes in resonance pattern were subtle, and were chiefly seen in the peak near 4000 RPM.

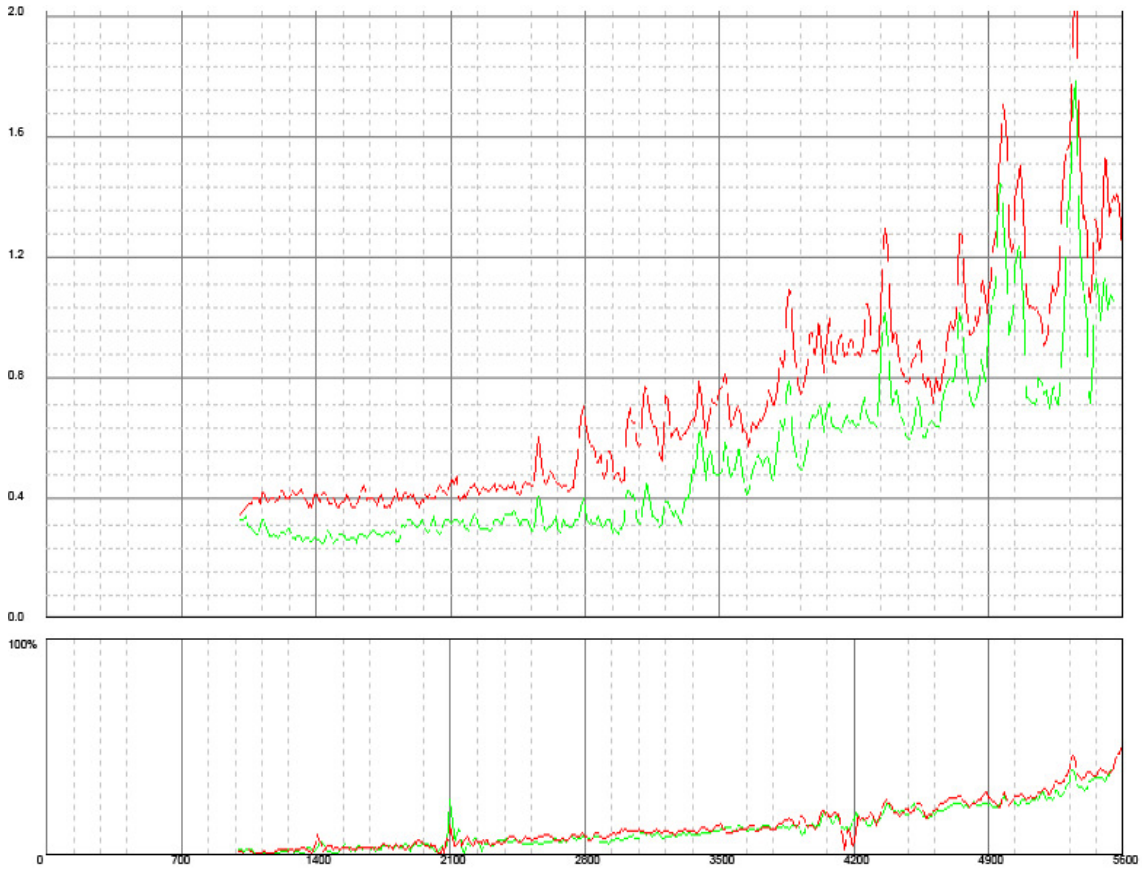

Figure 11: Workpiece 3, 1st treatment Significant peak growth can be seen in almost the entire RPM range. Treatment time ~ 45 minutes.

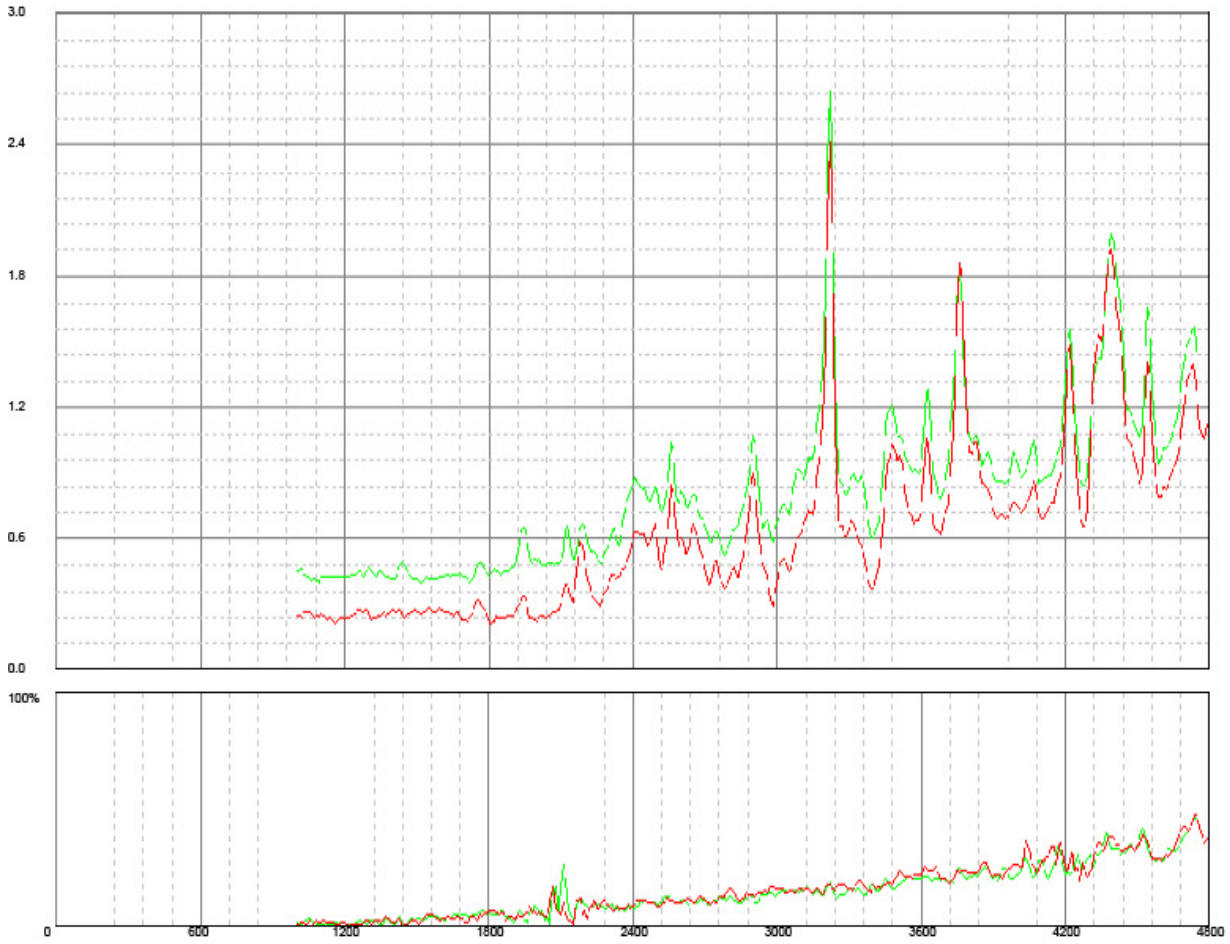

Figure 12: Work-piece 3, 2nd treatment. Changes in resonance pattern were subtle, indicating that the first treatment was successful in stabilizing the workpiece.

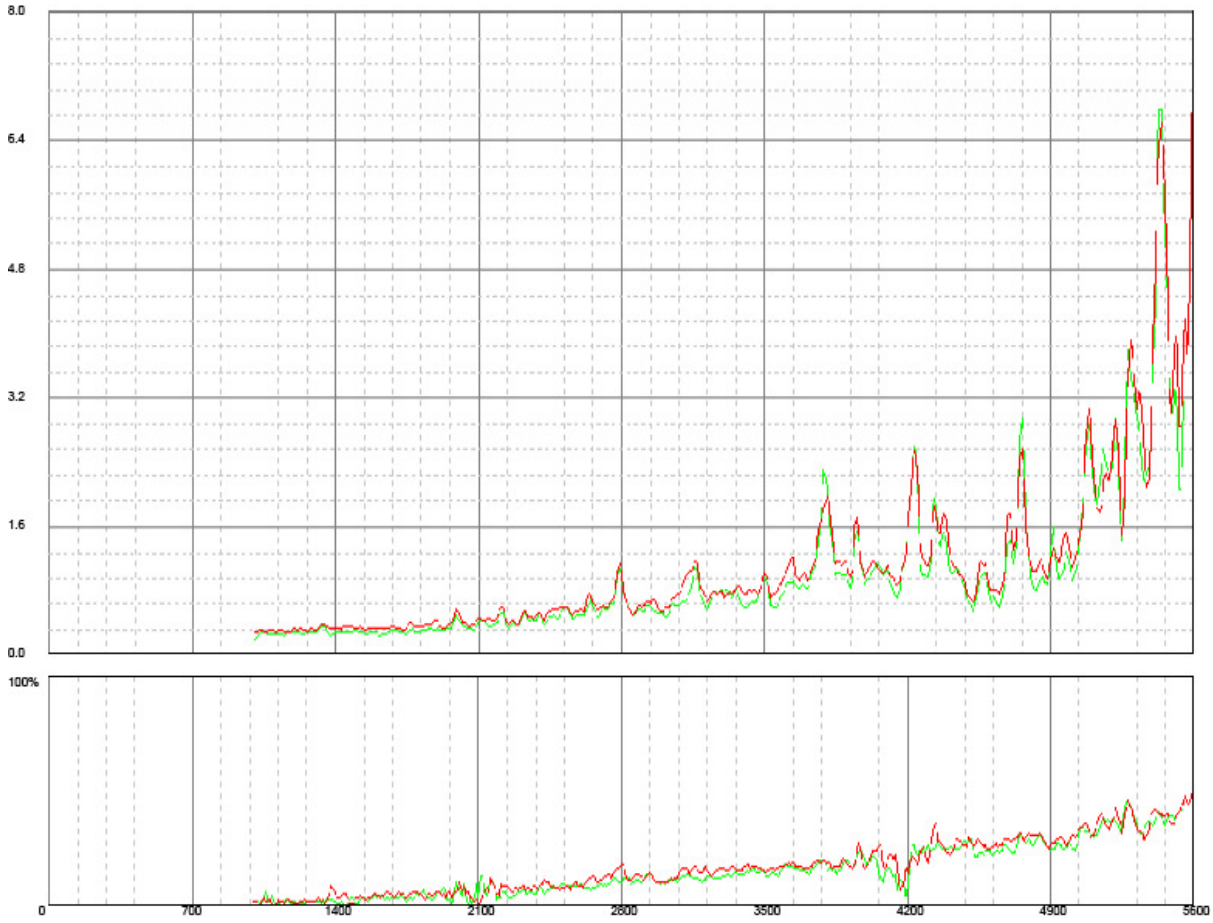

Figure 13: Work-piece 4, 1st treatment. Max RPM = 5600, vibrator unbalance = 35%. The last workpiece showed only subtle changes during VSR Treatment, both during the 1st and 2nd treatments.

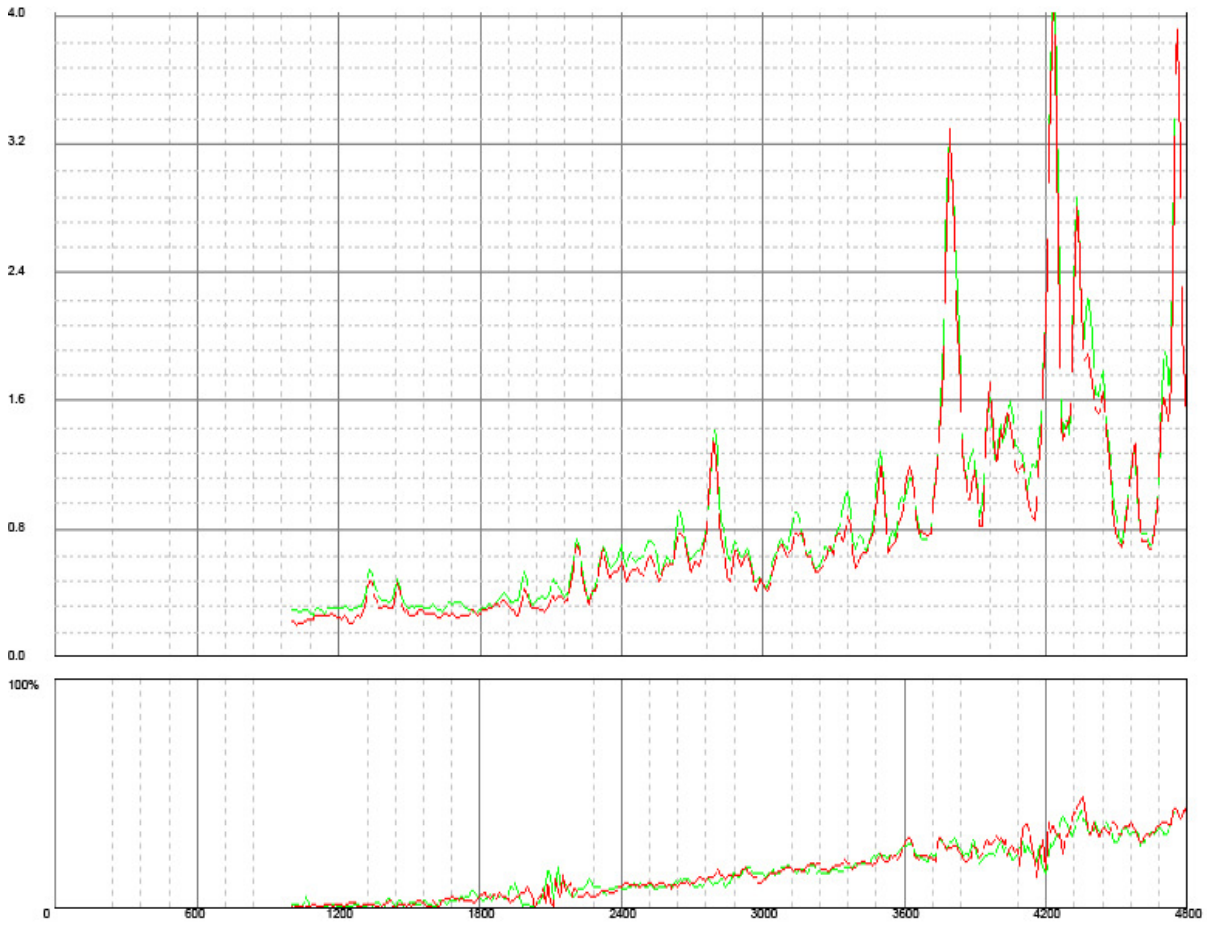

Figure 14: Work-piece 4, 2nd treatment. Max RPM = 4800, vibrator unbalance = 80%. This subtle depicts a rather stable workpiece.

Conclusion

These workpieces should display good mechanical integrity and dimensional stability if subjected to loads within their design capabilities. VSR Treatments performed upon these were effective in assuring this result.