Report on VSR Treatments Performed at

Alloy Fabrication, Reading, PA

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Report prepared by:

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A drawing of the fabrication can be seen in Figure 1.

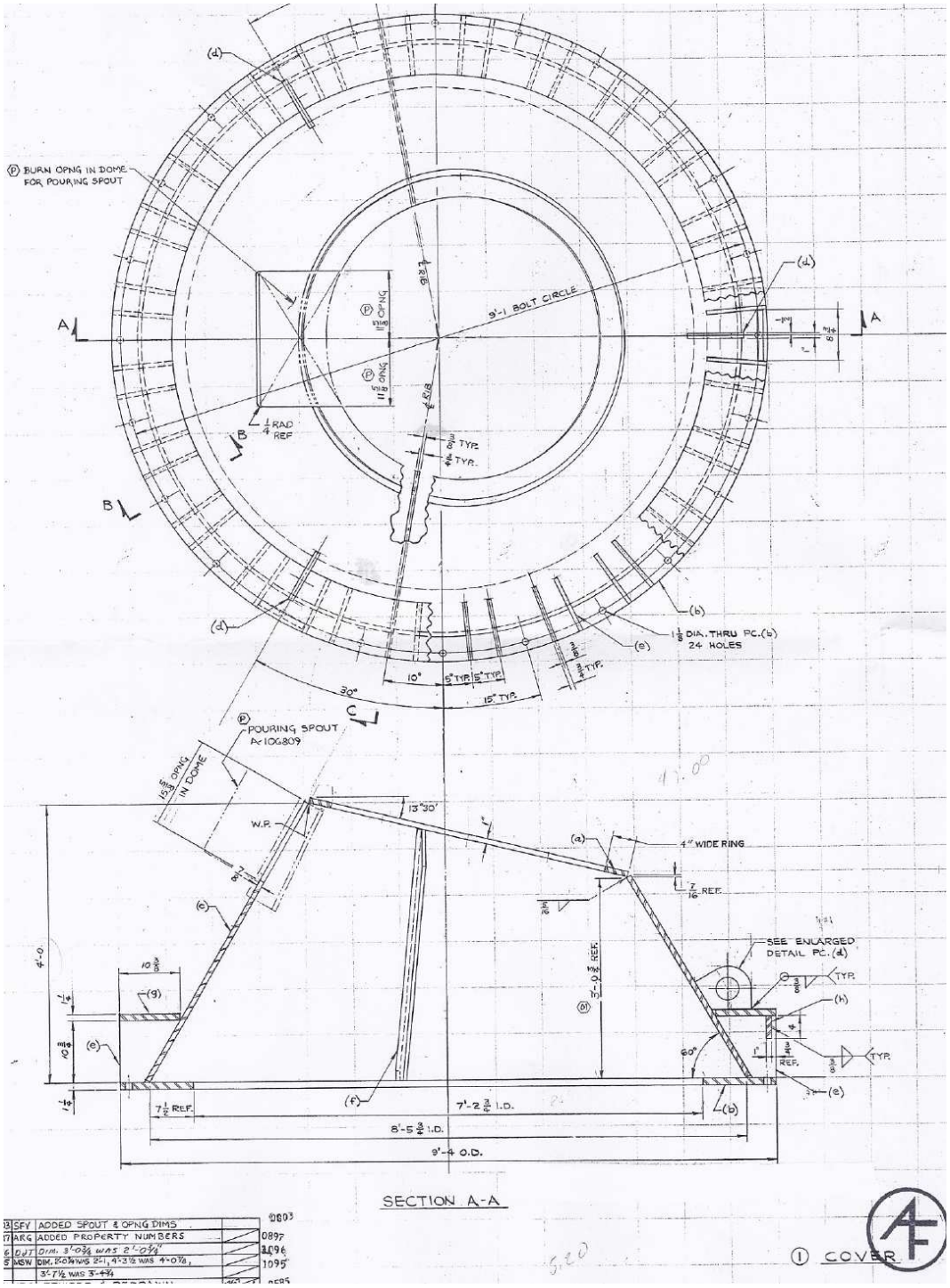

Figure 1 shows details of the furnace component. Overall size of the work-piece was 9’ – 4” (112”) diameter and 4’ high.

VSR Setup

The work-piece was placed upon three urethane isolation cushioning blocks. The blocks were not equally spaced, but rather were arranged in a "5 – 7 o'clock, noon" arrangement. This cushion spacing minimizes the damping of the work-piece, allowing the greatest ease in generating resonance during vibration, and thus maximizing amplitudes during treatment. Photo of the work-piece setup for VSR Treatment appears in Figures 2 and 3.

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.

[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 2: Work-piece setup for VSR Treatment. Blue arrows point to two of the three load cushions; the third is on the opposite side, centered. BL8 Vibrator appears inside red circle, securely clamped using machinist's clamps. The BL8 has hardened steel inserts frozen into the dual mounting flanges, assuring tight clamping throughout the VSR Treatment, which lasted roughly one hour. Accelerometer can be seen in the green circle, on top of the work-piece.

Figure 3: View from other side of VSR Setup. Again, vibrator in red circle, accelerometer in green circle. The single load cushion visible from this view, which is centered and opposite to those shown in Fig. 2, is labeled with a blue arrow on lower right.

The vibrator was placed on the lower horizontal flange, and oriented so the vibrator's AOR (Axis of Rotation) was horizontal. The vibrator's unbalance, adjustable over a continuous range of 0.2 thru 4.0 in-lbs., was adjusted after some experimentation to 15%, or 0.6 in-lbs.

An accelerometer was placed on the "cone-shaped" portion of the work-piece and oriented so to be most sensitive to horizontal 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.

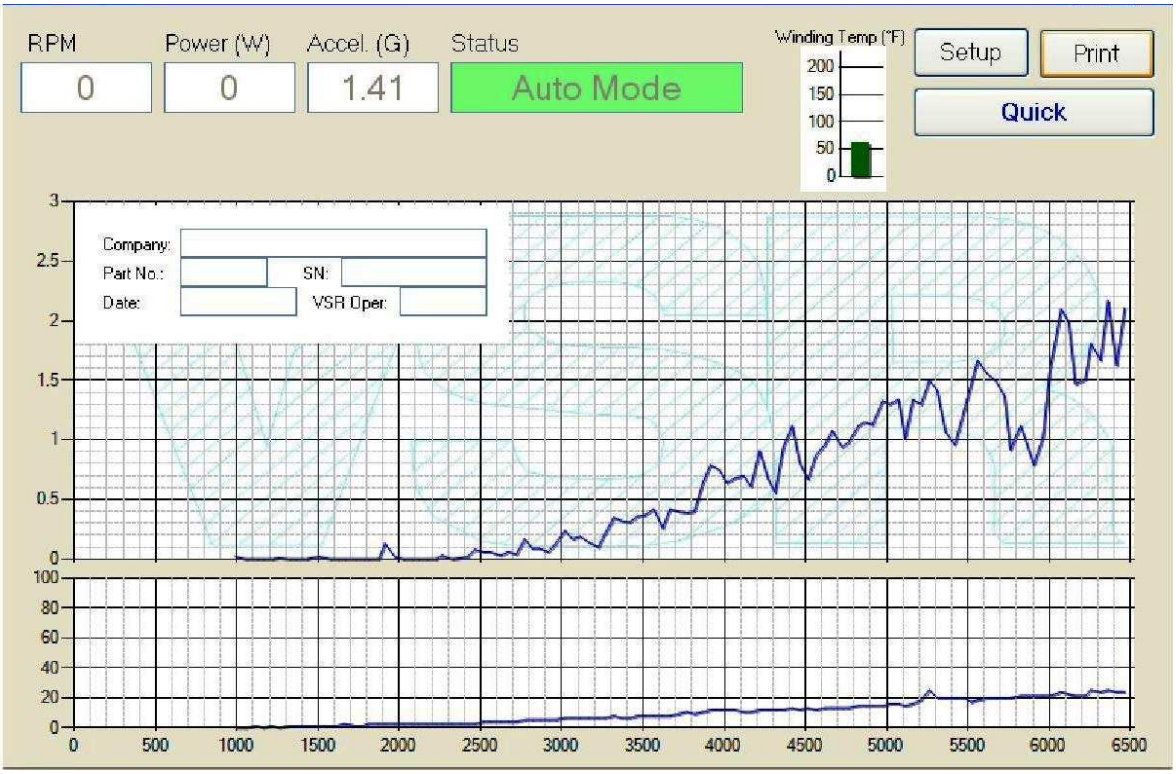

Figure 4: Quick Scan shows a preliminary view of the vibration data, and is used also for calibration. VSR Charts consist of two curves: An upper, acceleration curve and a lower, vibrator power curve, each plotted vertically vs. a common horizontal axis of vibrator speed (RPM). Peaks in the upper curve represent resonances of the work-piece; peaks in the lower curve represent a resonance that generates increased vibrator amplitude. Quick Scans are made at a rate of 50 RPM / sec, which is 5 times faster than the rate used to generate both Pre- and Post-Treatment Scans (10 RPM / sec), hence the term “Quick”. Quick Scans are plotted using blue “ink”.

Full-Scale (FS) settings:

RPM	6500
Acceleration	3 g’s
Power	2300 watts (fixed)

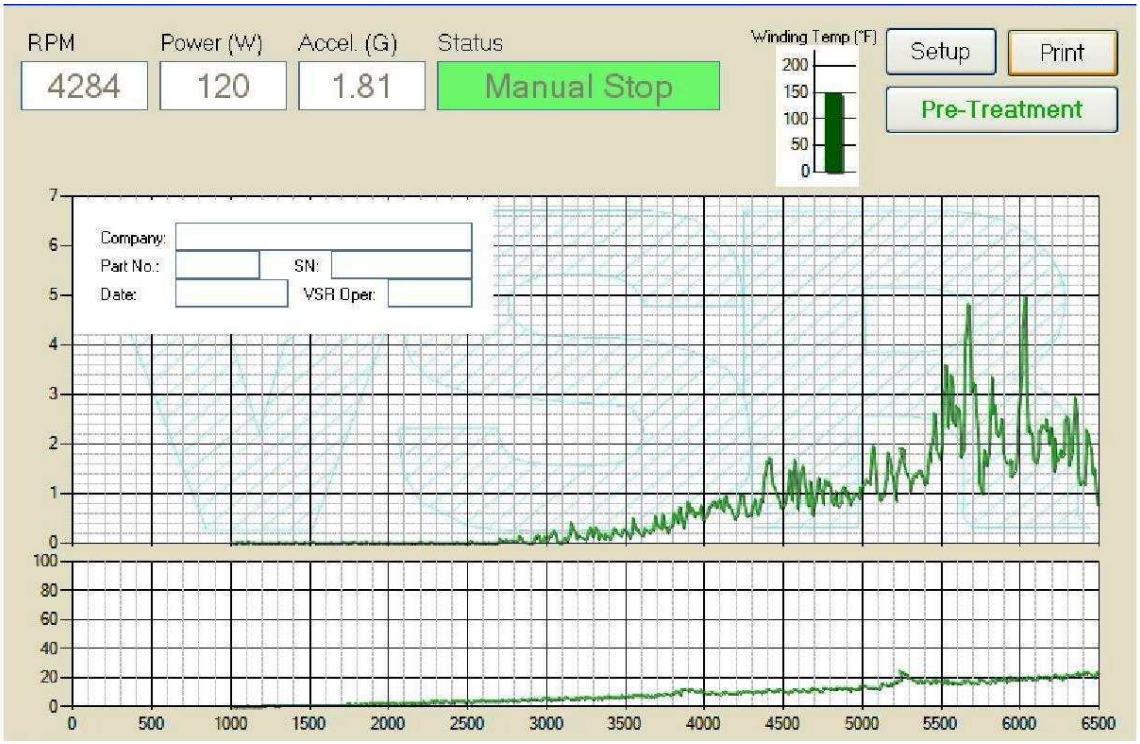

Figure 5: Pre-Treatment Scan of the work-piece shows the work-piece's initial resonance pattern, and shows a higher-resolution set of data compared with the Quick Scan. This data functions as the base-line resonance signature, and is used to perform VSR Treatment. Changes in the resonance pattern are detected and documented by comparisons between this data, and the final, Post-Treatment Scan. Pre-Scans are recorded in green "ink".

FS settings:

RPM	6500
Acceleration	7 g's
Power	2300 watts (fixed)

The VSR BL8 Vibrators are designed with sufficient efficiency and power so as to provide "headroom" between the power curve and vibrator motor's power capacity, in this case being 3 HP (~ 2.3 kW).

Full-scale (FS) 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".

FS for vibrator RPM is adjustable up to 8,000 RPM, the max speed of the BL8 vibrator. For this chart, 6500 RPM was used.

Having both acceleration and power 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 work-piece is “green” (not stress-relieved, like a green casting).

Scans take ~ 6 minutes to generate, using a 10 RPM / s scan rate.

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, normally in the direction of lower frequency (to the left on VSR Treatment charts)

After the 1st treatment and the Post-Scan was plotted (**red** on Fig. 6).

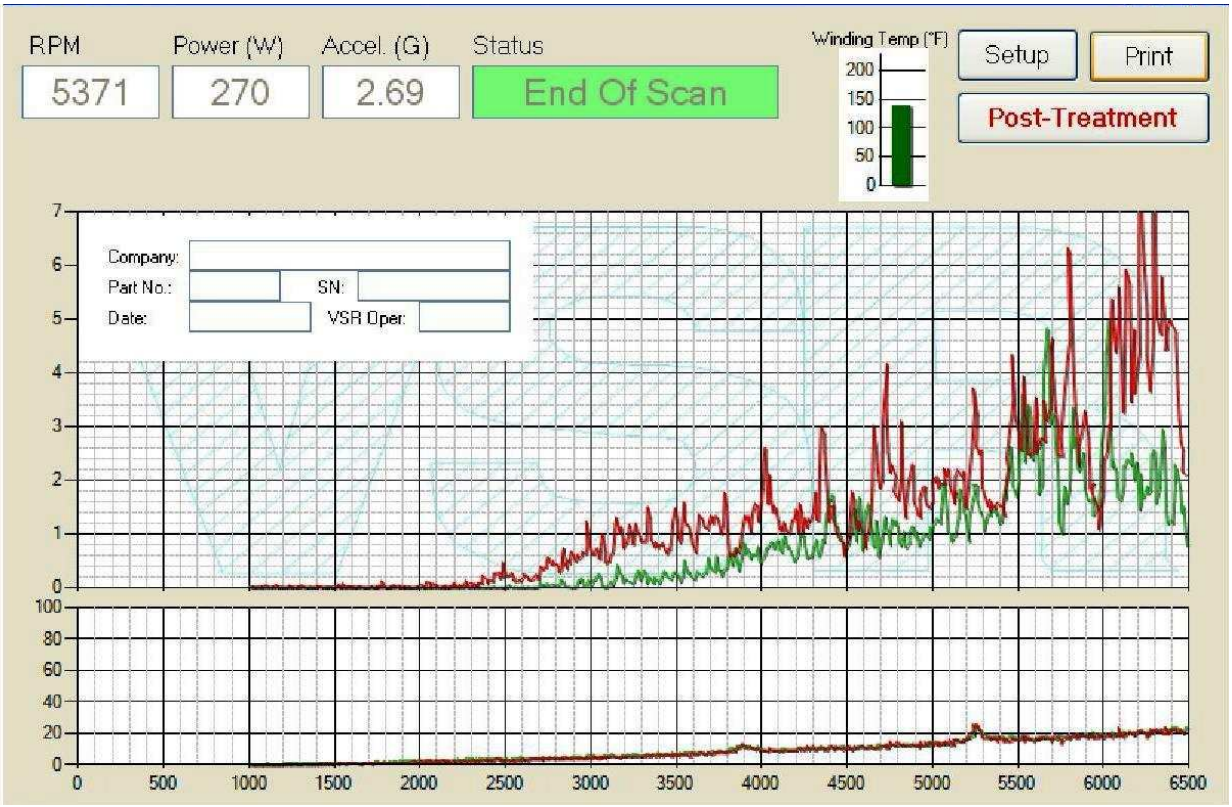

Figure 6: Completed VSR Treatment Chart shows increases in peak height. Some peaks also shifted to the left. Since the red curve, Post-Treatment Scan curve went off scale (above 7 g's), a recalibration using FS acc = 9 g's was also archived, and is shown in Fig. 7.

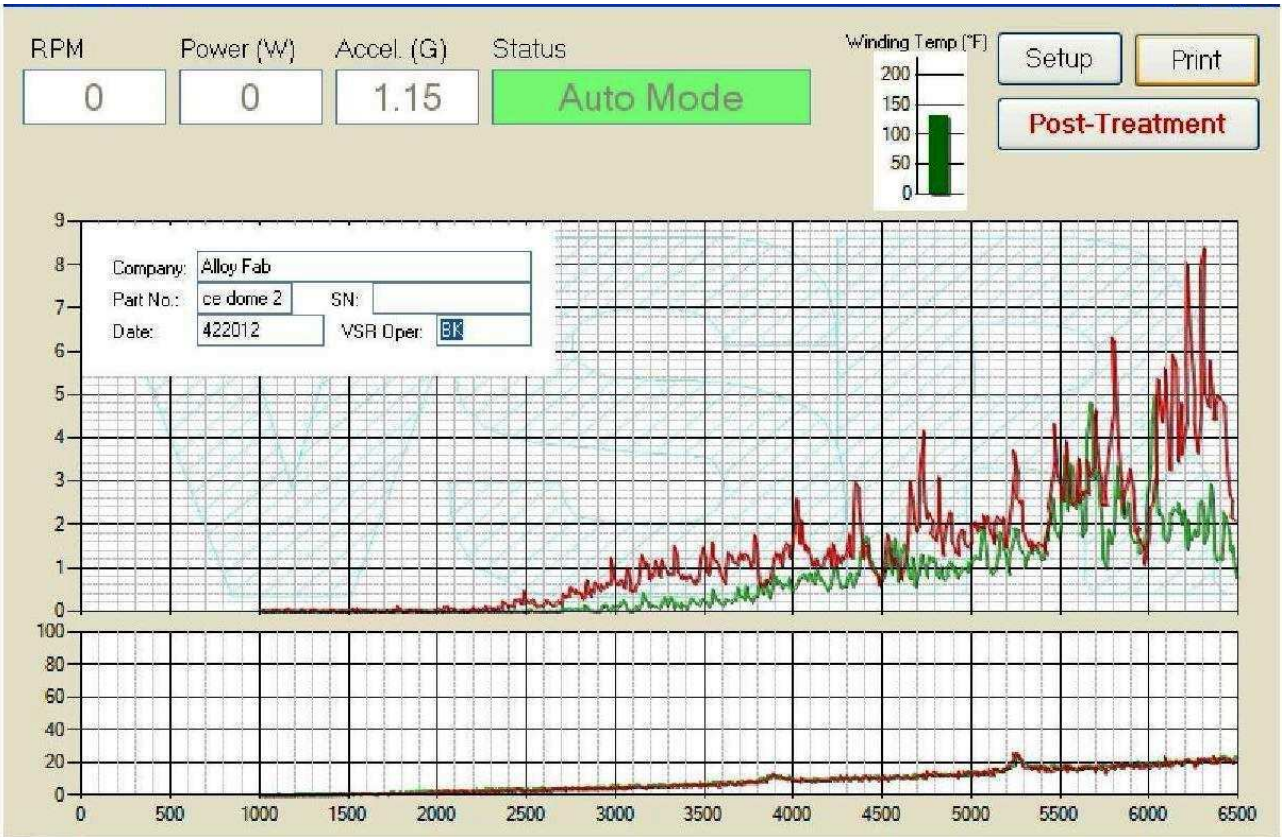

Figure 7: Same data set shown in Fig. 6, with the FS acc adjusted to 9 g's, allowing full viewing of peaks between 6 – 6.5 KRPM. (Adjustment of FS is made by opening SETUP, and entering the new FS).

Conclusion

As a result of the clear changes in resonance pattern, which resulted in a stable resonance pattern, this work-piece should display excellent dimensional stability during subsequent machining, assembly and usage.