Report on Vibratory Stress Relief

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M H EBY MANUFACTURING

Blue Ball, PA

M H EBY MANUFACTURING, located in central Pennsylvania, is a manufacturer of horse and livestock trailers, and truck bodies. A plant upgrade involved installation of a robotic welding manufacturing cell. EBY's fabrication shop welded the main frame for the robot. To assure dimensional accuracy, they called upon VSR Technology's On-Site Stress Relief Service. Other considerations for using the service included speed and convenience of having it stress relieved within a few hours, and not having to transport the Frame to a Heat Treater. The welded square-tubing frame was 134" L, 69" W, 8" H, and weighed 1075 lbs.

M H EBY MANUFACTURING is a manufacturer of horse and livestock trailers, bulk commodity trailers, and truck bodies. To assure dimensional accuracy of a Robot Frame, fabricated in-house, they chose to have it stress relieved using VSR Technology On-Site Service.

The welded square-tubing frame was 134" L, 69" W, 8" H, and weighed 1075 lbs.

VSR Setup

The Frame was placed on 3 Isolation Load Cushions, set far from the corners of the workpiece. This arrangement minimizes the damping of the workpiece, which increases the response of the workpiece, resonances are greater.

The VSR Process uses resonant frequency vibration to cause sufficient flexure of the workpiece, so as 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 on the stiffest cross member, and oriented so the Vibrator's Axis of Rotation was parallel (AOR-P) to the length of the workpiece. The Vibrator's unbalance, adjustable over a continuous range of 0.2 thru 4.0 in-lbs., was set at 15%, or 0.6 in-lbs. This setting was high enough to generate resonant peaks, while not causing either excessive vibrator amplitude or movement of the workpiece on the Cushions, although tethering of the workpiece to the floor was required.

Figure 1: **1/2 ton Frame, setup for VSR Treatment. The Frame was set on 3 Isolation Load Cushions. Two are visible in the photo foreground (circled), and the third is obscured by the Vibrator (circled), on the far side, centered. The Vibrator was clamped on a stiff cross-member, and oriented so that its Axis of Rotation was parallel (AOR-P) to the length of the Frame. An Accelerometer was clamped on the far left corner (circled), oriented so as to be most sensitive to vertical deflections. Since the Frame was light, it started to walk off the Cushions during Treatment, so it was then tethered to the floor by the lifting strap in the foreground (arrow).**

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

After the VSR Setup was accomplished, a Quick-Scan (used for calibration purposes, this scan is done at a rate of 50 RPM / second, and recorded in *blue*) was performed, and saved, *see* Figure 2.

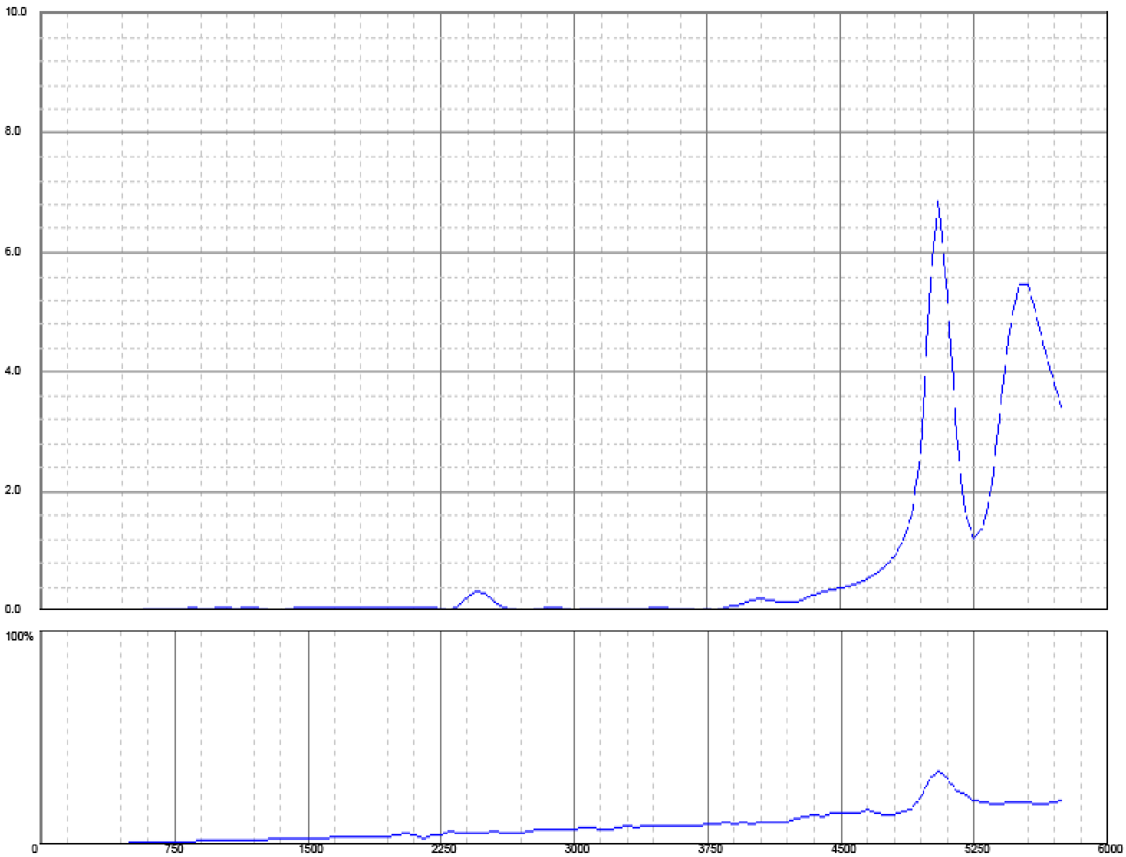

Figure 2: **Quick-Scan (QS) is done for calibration purposes. A QS has a scan rate of 50 RPM / second, and takes less than two minutes to produce. VSR Treatment Charts consist of two plots: An upper plot of workpiece acceleration (Acceleration Curve); A lower plot of vibrator input power (Power Curve). Both data sets are 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 on the workpiece, or combination of both).**

Full-scale for acceleration is adjustable from 1 – 50g, and can be adjusted after a scan is made, in the event the plot is too "short" or "tall". 10g full scale was used for this scan.

Full-scale for vibrator power is factory set, 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 max speed of the BL8 Vibrator. For this chart, 6000-RPM was the max RPM used.

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

A Quick-Scan is recorded in *blue*, Pre-Treatment Scan data is plotted in *green*, since the workpiece is *green* (not stress-relieved, like a green casting.), and Post-Treatment Scan data is *red*.

Note the peak in the power curve; it was kept under control (not allowed to go too high) by a combination of good vibrator placement, and sufficiently low unbalance setting.

VSR Treatment

VSR Treatment is done by tuning and then dwelling on 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 stronger response)
2. A shift of the resonance frequency in the direction of lower frequency (to the left on VSR Treatment Charts)

For this workpiece, the VSR-8000 System's AutoTreat mode was used. This software automatically tracks the movement of resonance peaks, as stress relief occurs. The software also tracks a history of Vibrator RPM and workpiece acceleration levels, plotting them in a series of small black circles, referred to as "Progress Dots".

In this instance, both the selected peaks, one at ≈ 5300 and the other at ≈ 5600-RPM, grew, and then stabilized, over a period of less than one-half hour. After stability was achieved, a Post-Treatment Scan, recorded in red, was made and superimposed on the Pre-Scan. *See* Figure 4.

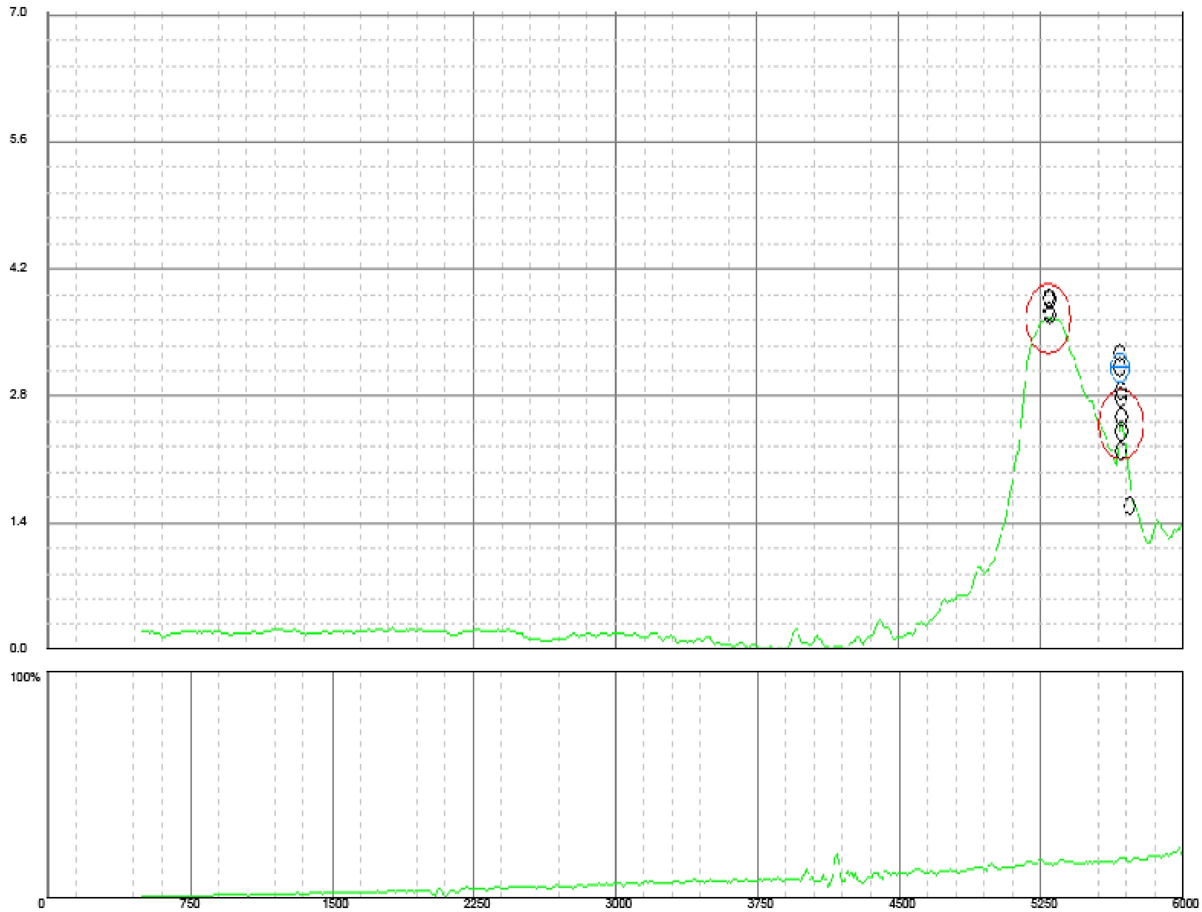

Figure 3: **Pre-Treatment Scan with series of Progress Dots (small black circles) made by VSR AutoTreat software. The green curve is first recorded, which is a higher resolution version of the 50-RPM/sec Quick-Scan. The scan rate used was the normally recommended 10-RPM / second, which meant that a 500 – 6000-RPM scan would take 550 seconds (≈ 10 minutes) to run.**

The AutoTreat software then allows up to five peaks to be selected, which is done by touching a peak on the touchscreen PC, causing a red circle to envelope the selected peak. (Deselecting can be done by touching the circle.) After the peaks are selected, touching the Perform Auto-Treat button (not shown) that appears in the upper left corner of the Acceleration Curve portion of the Pre-Treatment Chart, sends the vibrator and PC on the hunt to tune first upon the highest peak, then next highest, etc. When tuned upon, AutoTreat will tune slightly faster than the peak's original location, than "back-up" upon the peak. As the peak grows and / or shifts, AutoTreat will track it to its final, stable locale. When all peaks are stable, a Post-Treatment Scan is performed (*see* Figure 4), recorded in *red*. and superimposed over the Pre-Treatment Scan

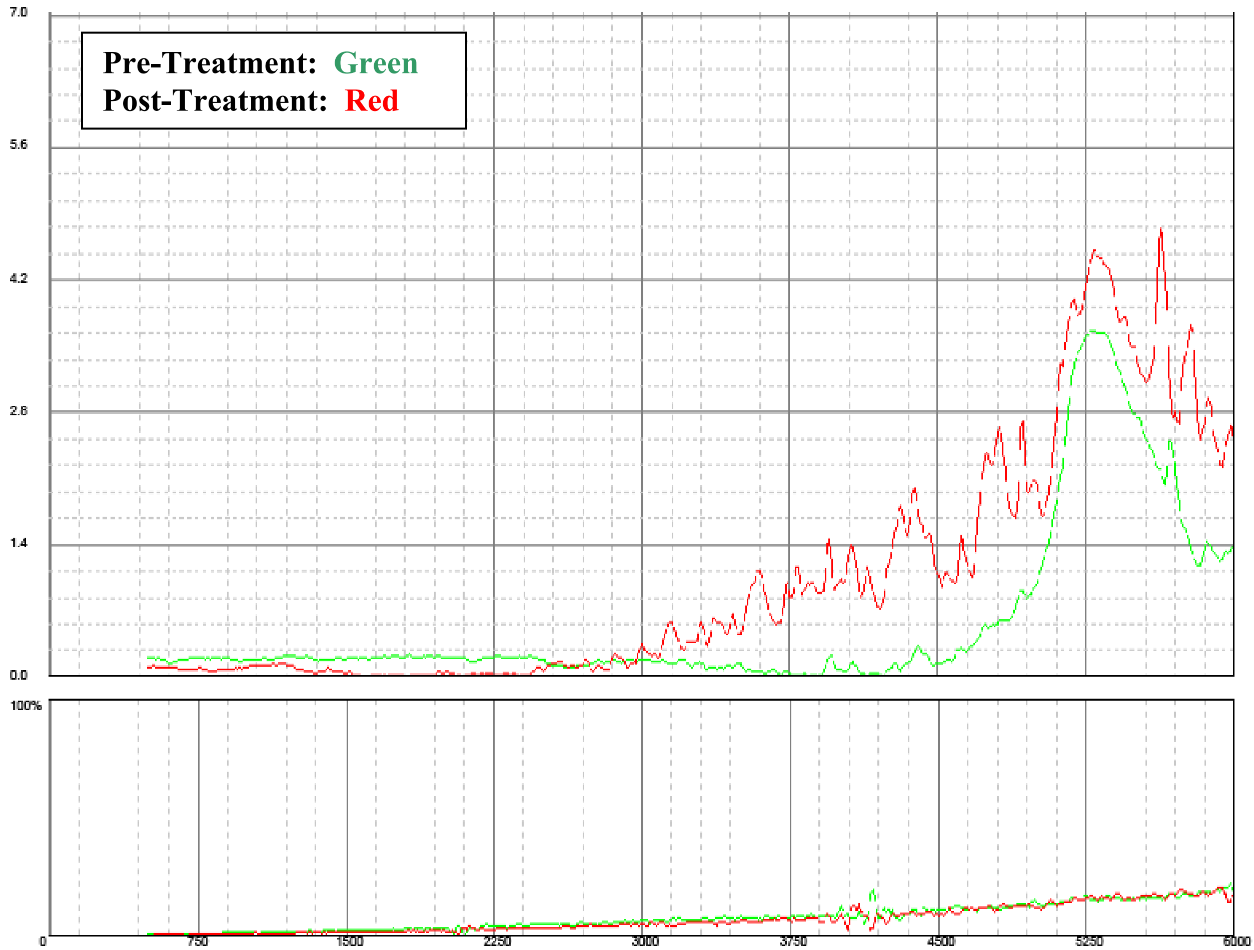

Figure 4: Completed VSR Treatment Chart. The Post-Treatment Scan is recorded in *red*, and superimposed on the original Pre-Treatment Scan. Growth and/or shifting of the resonance peaks to new, higher levels is common; in this instance, the overall curve increased.

Conclusion

As a result of the clear change in resonance pattern, this workpiece will display excellent dimensional stability during subsequent machining, assembly, 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 @ 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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