Report on Vibratory Stress Relief

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TIMET Job

THE REES COMPANIES, a job-shop located West of Philadelphia, PA. As a previous user of VSR Technology's On-Site Stress Relief Service, we were the vendor of choice to stress relieve a Down-Ender Metal Processing Assembly being fabricated for TIMET. This mild steel weldment measured 16'L X 11'W X 5.5'H, and weighed ≈ 3 tons. REES cited both the speed of the VSR Process, and the completeness and quality of stress relief documentation as key reasons for again choosing the service.

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THE REES COMPANIES have used VSR Technology's On-Site Stress Relief Service several times. In a project to produce a Down-Ender Metal Processing Assembly for TIMET (TITANIUM METALS CORP), they used VSR Technology once again to stress relieve a mild steel weldment, measuring 16'L X 11'W X 5.5'H and weighing ≈ 3 tons.

VSR Setup

The workpiece was placed on 3 Isolation Load Cushions, set in a triangular pattern and far in from the corners, so as to minimize damping, which maximizes resonance response. The VSR Technology 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 clamped securely at an intersection of two heavy members of the workpiece, a location of high-rigidity, two-thirds down the workpiece length. The Vibrator's Axis-of-Rotation was horizontal (AOR-H), and aligned with the workpiece width. After adjustment of the Vibrator's unbalance to a low setting (10% of the available 4.0 in-lbs.) and then a high setting (50%), an unbalance setting of 20% (0.8 in-lbs.) was chosen. This unbalance setting proved to be correct, as evidenced by the significant change in resonance pattern that took place during Treatment.

An Accelerometer (a sensor whose output is proportional to acceleration), was placed on the corner of the workpiece. The Accelerometer was oriented so as to be most sensitive to Direction of Sensitivity Vertical (DOS-V). Science and experience show that Acceleration is the best parameter to gauge vibration intensity (not velocity or deflection), 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 a trial run, it was determined the Accelerometer was oriented for DOS-H (horizontal). This generated the greatest number of resonance peaks.

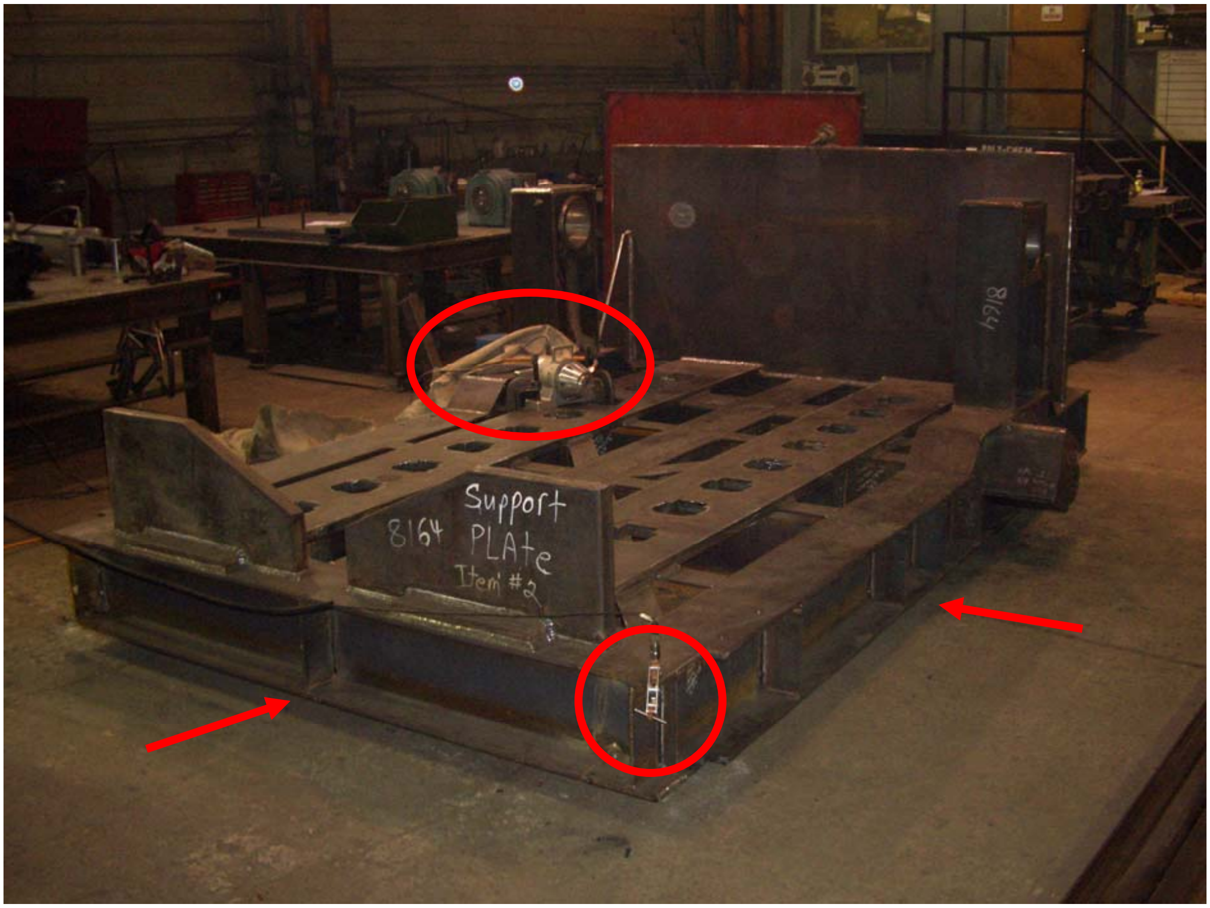

Figure 1: **Mild steel weldment setup for VSR Treatment. Vibrator is visible in the central mid-ground (circled), and the Accelerometer is visible mounted on the near corner in the foreground (circled). The workpiece was placed on 3 Load Cushions (not visible): One near the Vibrator, and one located the same distance down the length of the workpiece, but on the right. A third Cushion was located centered along the width, 3' from the near end (intersection of lines extending from arrows). Overall size of workpiece was ≈ 16'L X 11'W X 5.5'H, and the workpiece weighed ≈ 3 tons.**

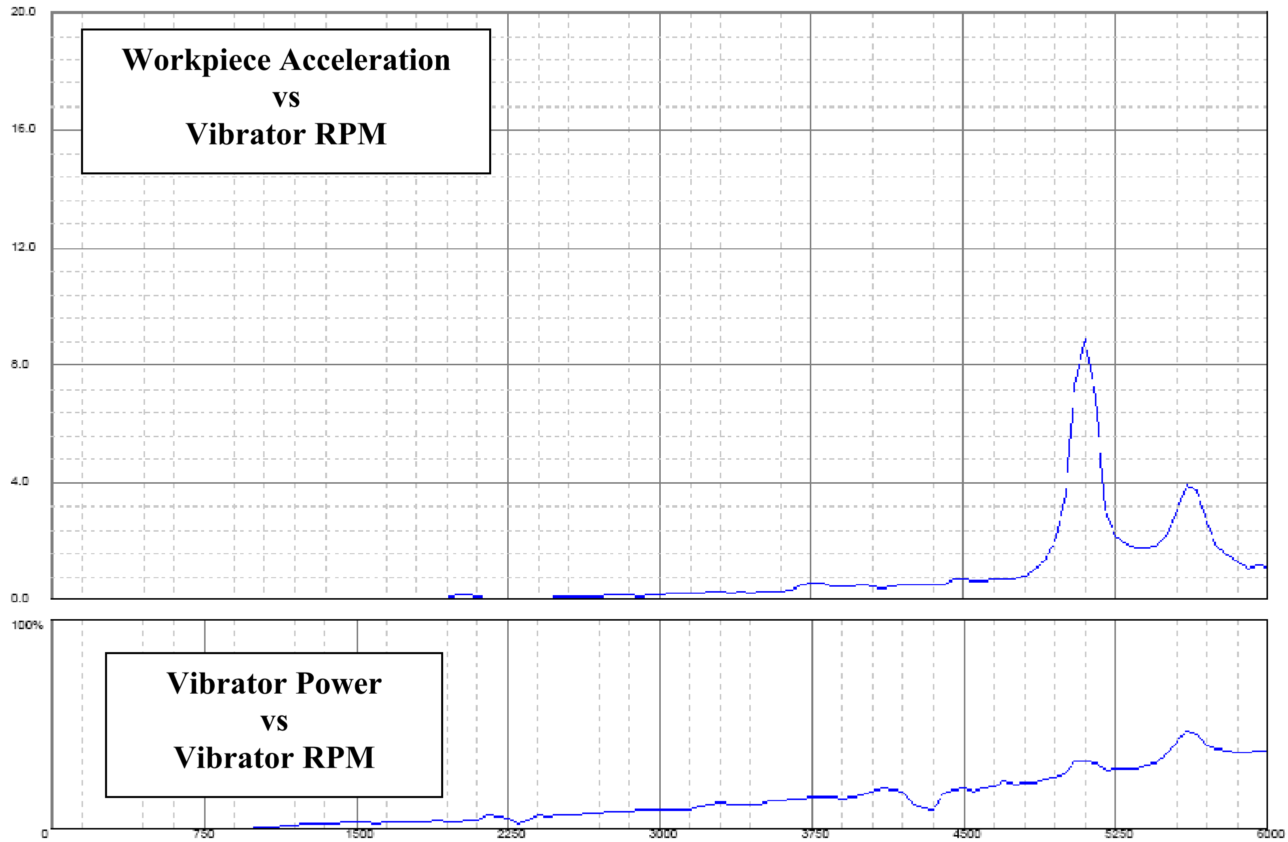

Figure 2: Quick-Scan Charts: VSR Treatment Charts consist of two plots: An upper plot of workpiece acceleration and a lower plot of Vibrator input power, both of these plotted on a vertical axis vs a common horizontal axis of Vibrator RPM. Peaks in the upper plot are resonances of the workpiece. Peaks in the lower plot are resonances that cause increased, perhaps excessive (easily addressed by either lowering the unbalance or repositioning the Vibrator), Vibrator input power.

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". 20g 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, 6000-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 mount location to use when running a Pre-Treatment Scan (see Figure 3), which is used when performing the actual Treatment.

Quick-Scan Data is recorded in *blue*, Pre-Treatment Data in *green*, Post-Treatment in *red*.

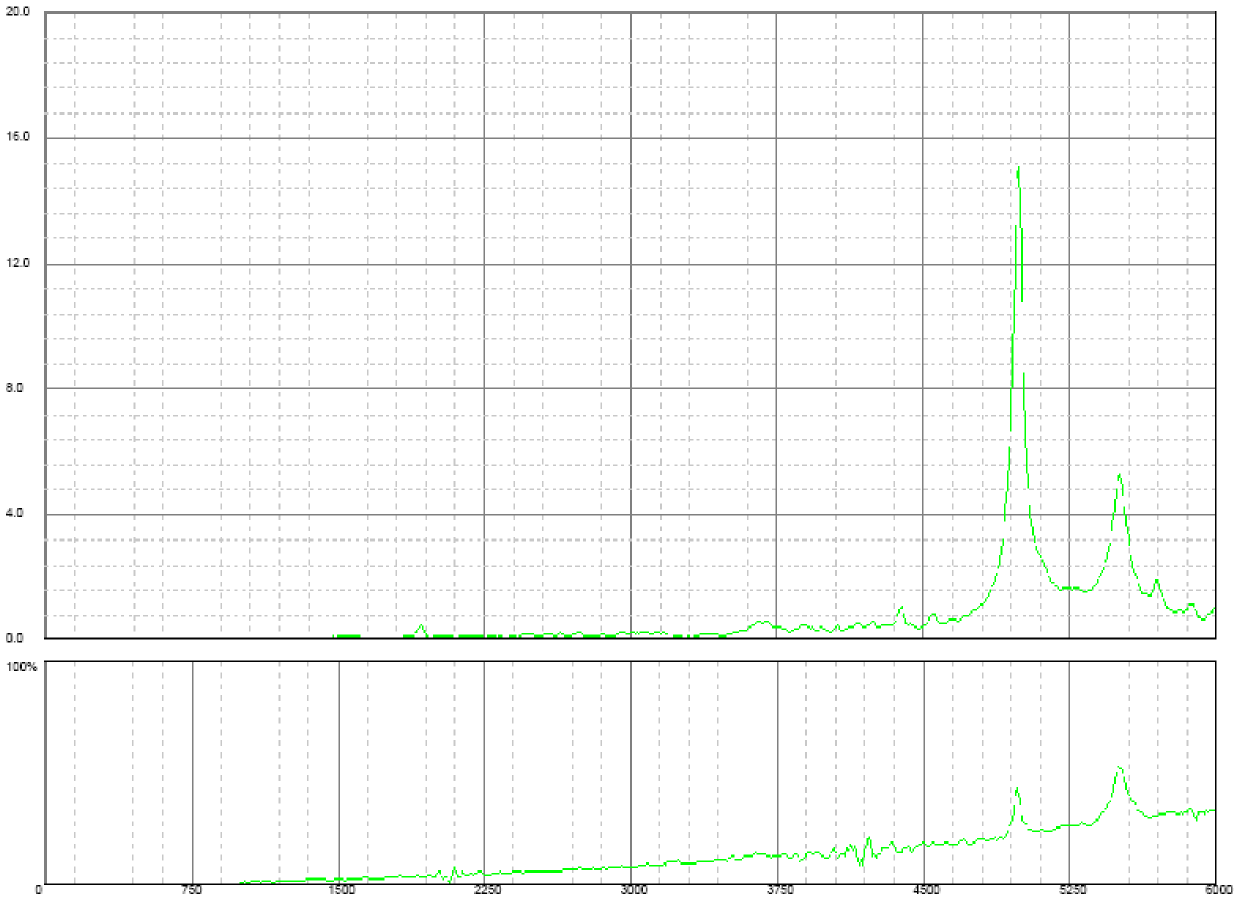

Figure 3: **Pre-Treatment Scan. After the Quick-Scan data is generated (often not saved, since it's for calibration purposes), a Pre-Treatment Scan is run. Quick-Scans use a scan rate of 50-RPM / second. The scan rate for Pre- and Post-Treatment Scans is adjustable, but the standard of 10-RPM / second was used here. Note that the peaks are larger and better defined, due to the additional time that the workpiece underwent resonance (a result of the slower scan rate), allowing the high-inertia workpiece to respond fully to resonant vibration.**

After a Pre-Treatment Scan is generated, it is used to perform Treatment, by tuning upon, dwelling on, and then tracking changes in the resonance peaks as they grow (strongest response), shift, typically to the left (weaker response). These changes do not go on continuously, but rather, occur quickly at the beginning of Treatment, then slow, and eventually cease, resulting in a permanently altered, stable resonance pattern. See Figure 4.

VSR Treatment

Stress relief was accomplished by tuning and then dwelling upon two large resonance peaks, one at ≈ 5100-RPM, the other at ≈ 5400-RPM. Both peaks grew (the stronger response to VSR Treatment), and then shifted in the direction of lower frequency (typically the weaker response to Treatment), by approximately 90-RPM.

Treatment	Before	After
5100	**15.2g**	**20.1g**
5400	**5.8g**	**14.5g**

Treatment time for each peak was slightly more than twenty minutes. With the Setup and knock-down taking about 30 minutes, the adjustments to the Vibrator unbalance taking no more than five minutes, the Quick Scan taking less than two minutes, and the Pre- and Post-Treatment Scans taking ≈ 9 minutes each, the total time for VSR Treatment, from start to finish, was less than 100 minutes.

Conclusion

As a result of the obvious change in resonance pattern, which included extensive growth and mild shifting of strong resonant peaks, which then stabilized, this workpiece is now stress relieved. It will exhibit excellent dimensional stability and predictability during subsequent machining, assembly, alignment, installation, and usage.

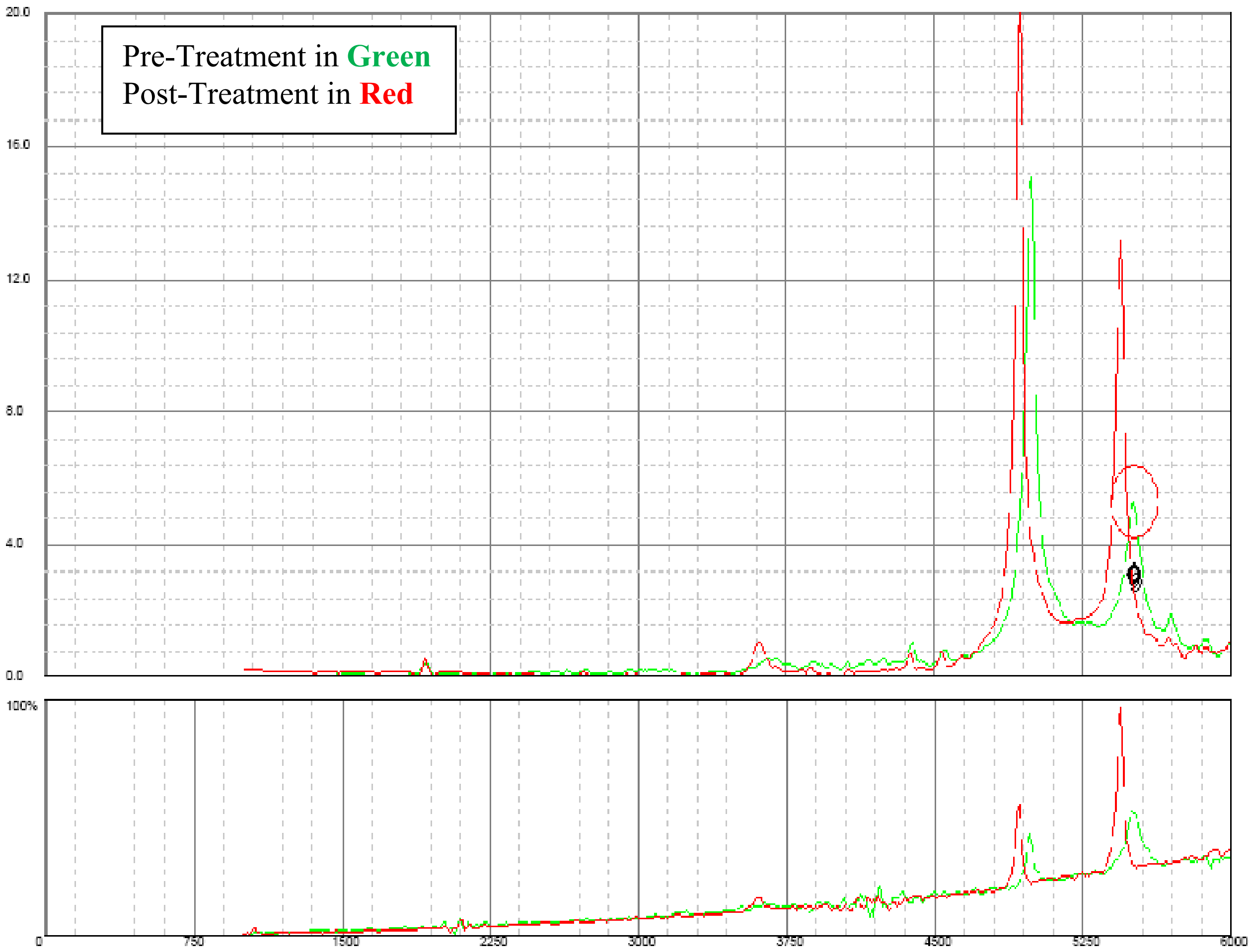

Figure 4: **Completed VSR Treatment Chart. The original Pre-Scan remains intact, and a Post-Treatment Scan (red) is superimposed on it, showing the differences between the two, ie, peak growth of the larger peak at 5100-RPM of ≈ 33%, and of the smaller peak at 5400-RPM of ≈ 150%, both accompanied by peak shifting to the left. This is the classic VSR Treatment Response that is seen on the majority of VSR Treatment Charts.**

(Note: Gaps in the green and red curves seen in Figures 3 and 4, are due to the document formatting issues which occur when changing on-screen chart data to Adobe / pdf format. Figure 5 shows original, no gap, on-screen data.)

Figure 5: **Close-up of 15" (38 cm) touchscreen PC, displaying the completed VSR Treatment Chart shown in Figure 4. To save the data, the operator prints the screen as an Adobe / pdf document. Other display data (not recorded on charts) but visible on the VSR-8000 System Main Operating Screen include (from left to right, starting at the top): Vibrator RPM, Vibrator input power (watts), Workpiece acceleration (XX.XX , gs), and an electronic bargraph / thermometer showing the Vibrator motor's winding temperature. Due to a combination of the rugged vibrator design and electronic motor protection, VSR Vibrators (along with VSR Systems in general) are very reliable.**

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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