The cost effective alternative to heat treatment

Report on Vibratory Stress Relief

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Mertztown, PA
Job #1

TRI-ALLIANCE FABRICATING subcontracted VSR TECHNOLOGY to stress relieve a 28' x 8' x 1.5' mild steel, welded Trunnion Base. The workpiece fabrication consisted of two (2) heavy-walled, rigid, 28' beams joined by three (3) much lighter structural cross members.

Such workpieces require more than one VSR Treatment to assure dimensional stability, since the two high-rigidity segments respond independently when vibrated. Using the high accuracy and repeatability instrumentation contained in VSR TECHNOLOGY's Model VSR 790A System, which utilizes the advantages of resonant vibration, an Auto-Scan feature, and high resolution plotting of pertinent data, provided clear evidence of the workpiece's response to the Vibratory Metal Stabilization process. The two-treatment procedure assured good dimensional stability during machining, transport and assembly.

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TRI-ALLIANCE FABRICATING chose to use the VSR Process upon a 28' L x 8' W x 1.5'H weldment weighing 16,000lbs. The workpiece was a Trunnion that would later have both its flat surfaces machined and a bolt pattern. The engineering drawings required Stress Relieving because of the need to maintain dimensional tolerances. Not stress relieving the Trunnion Base increased the very real chance that the workpiece would suffer permanent bowing or twisting, which could occur during transport, machining, installation or early in its use. Distortion of ≥ 3/16" over the full length was possible.

This fabrication consisted of two (2) fabricated heavy beams (2.5" thick) connected by three (3) much lighter structural beams.

The Vibratory Stress Relief was performed using a VSR 790A System.

VSR SETUP

The Trunnion was placed on three load cushions, which act to isolate the workpiece. The Cushions, made of orange urethane and circled in black, are visible in Photo 1, pg 6. One cushion, not visible in the photo, was directly beneath the Vibrator (blue circle), ≈10' in from the far side, back corner of the workpiece. A second cushion on the same side was 8' closer (visible near center of photo), also was 10' from the far-side, front corner of the workpiece. The third cushion was placed beneath the opposite (near-side) heavy beam, midway (≈14') along its length. A fourth cushion, not used during the VSR Treatment, can be seen in front of the “centered” cushion.

The Vibrator was oriented so that its axis of rotation was parallel to the length of the workpiece. The Vibrator’s force output is primarily radial, *ie*, perpendicular to the axis of rotation. This workpiece (like most) is more likely to have resonances that cause deflection perpendicular to its length. Thus, the vibrator orientation chosen caused the workpiece’s primary resonances (major peaks) to be most responsive; the Vibrator placement location (along the length of the workpiece), was chosen so as to minimize the amplitude the Vibrator would undergo during resonance.

The Accelerometer (an acceleration sensor) was placed near a corner of the workpiece (*as shown in* Photos 2 and 3, pg 6), and oriented so as to be most sensitive to horizontal deflections, which provide the greatest signal level. (The other possible Accelerometer orientation, one that would be most sensitive to vertical deflections, was tried, but it did not provide clear data. The Accelerometer orientation that would be most sensitive to deflections parallel to the length of the workpiece is rarely, if ever, used, since the workpiece is least likely to resonate in that direction.)

After a quick calibration scan through the Vibrator’s speed range, an unbalance setting of 30% of the 6.0 in-lbs available from the System’s MV1 Vibrator was used to perform the first of two treatments.

FIRST TREATMENT

The VSR 790A System's Auto-Scan feature was used to generate a Pre-Treatment Scan. The scan depicts two curves (*as shown in* Photo 4):

1. workpiece acceleration (vertical axis) vs Vibrator RPM (horizontal axis) is recorded in green ink;

2. Vibrator input power (vertical axis) vs Vibrator RPM (horizontal axis) is recorded in red ink.

The Scan is done at the very slow rate of 10 RPM/Sec to maximize the print resolution of both curves.

The span of data depicted in these linear scales is:

- ACCELERATION: from the horizontal green line (zero), to top of scale is 12g.

- VIBRATOR POWER: from left portion of red curve (30 watts), to vertical max (right most peak), is 600 watts.

- VIBRATOR RPM: from left portion of either curve (which is 1000 RPM), to right portion of either curve (which is 5000 RPM), is a span of 4000 RPM.

The peaks in the green curve are resonant peaks of the workpiece. VSR Treatment is performed by tuning the vibrator upon each peak, which causes changes in the resonance pattern. These changes are:

- *Growth* of the resonance peaks to higher acceleration levels (upwards on the Chart).

- *Shift* of the resonance peaks to lower RPM levels (leftwards on the Chart).

Each of these changes depicts a lowering of the rigidity of the workpiece, which had been inflated to a higher level because of the presence of residual stress. These stresses represent a form of potential energy, which, if not released, threaten the dimensional stability of the workpiece.

Thus, the rate of change, *ie*, how quickly the peaks *grow* and/or *shift* (usually a combination), is rapid at the beginning of a VSR Treatment, because potential energy levels are high. Later, as effective Treatment progresses, the rate of change begins to diminish, and eventually is reduced to a level undetectable, even with the sensitive instrumentation found in the VSR 790A System.

This "Rate of Change" phenomenon is exactly what occurred in this workpiece. Within 15 seconds of tuning upon the large peak, which occurred at a vibrator speed of ≈ 4172 RPM, the acceleration level grew ≈ 10% from 4.36g to 4.78g. This *growth* continued, although at a slower rate until it eventually stopped; additionally, a mild *shift* of ≈ 32 RPM also took place. The peak stabilized up 4140 RPM at a height of 10.48g (*as shown in* Photo 5).

The shorter peak, which had grown (*it tripled in height !*) as a result of the Treatment of the larger peak, increased by another 20% when treated. As with the larger peak, after additional *growth* and a mild *shift*, this peak also stabilized.

After the resonance pattern stabilized, the Plotter's color pens were reversed (red now on top for acceleration; green now on bottom for vibrator power), and a Post-Treatment Scan was performed and superimposed upon the Pre-Treatment Scan. The resulting VSR Treatment Chart is reproduced, along with calibration notes, on page 8. The large peak which was ≈ 10.5g while being treated, grew to a final height of > 12g, and went "off-scale" during the Post Treatment Scan. This additional increase was undoubtedly due to the successful treatment of the shorter resonance peak – treatment of Peak A will cause Peak B to grow and/or shift.

SECOND TREATMENT

Since the workpiece consisted of two highly rigid, heavy segments, joined by a lighter set of cross member structurals, a second VSR Treatment seemed prudent. Even though the 1st Treatment did, in all likelihood, cause stress relief in the "far" beam, it is sound practice to perform a 2nd Treatment, with the Vibrator positioned directly upon the far beam, to guarantee workpiece stabilization.

The Vibrator was, therefore, moved onto the far beam (*as shown in* Photo 6), but placed in the same relative location as used on the 1st beam. It was immediately determined that the unbalance setting was too high; it was concluded that the "too high" setting was for two reasons: (1) there was no load cushion beneath the Vibrator, which caused excessive vibrator amplitude; (2) that the workpiece was now less rigid, due to the 1st Treatment. The unbalance setting was lowered from 30% to 20%.

The 2nd Treatment of the workpiece resulted in a slight, but still important, response. This response can be seen on the completed VSR Treatment Chart reproduced on page 10. Note that the growth of the resonance peaks during this 2nd Treatment was a mere 30%; compare this with the 1st Treatment's growth from 4.36g to over 12g (>250%) – which was a very strong response.

CONCLUSION

Based on the strong response of this workpiece, and the comprehensive treatment techniques employed, this fabrication should be stable during subsequent machining, assembly, transport and utilization.

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 ", 1983, *Productive Applications of Mechanical Vibration*, ASME.
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. Mr. Klauba, in addition, 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.

THE WORKPIECE, a 28' x 8' x 1.5' MILD STEEL FABRICATION. 3 load cushions (orange in color & circled in black) were used, two (2) of which are visible beneath Workpiece (a 4th not used, cushion can be seen in near-side mid-ground). The Vibrator (blue circle) is mounted to the beam on the far-side, and the VSR 790A System's Control Console and XYY Plotter (gray cabinets), are visible just to the right of the Vibrator.

PHOTO 1

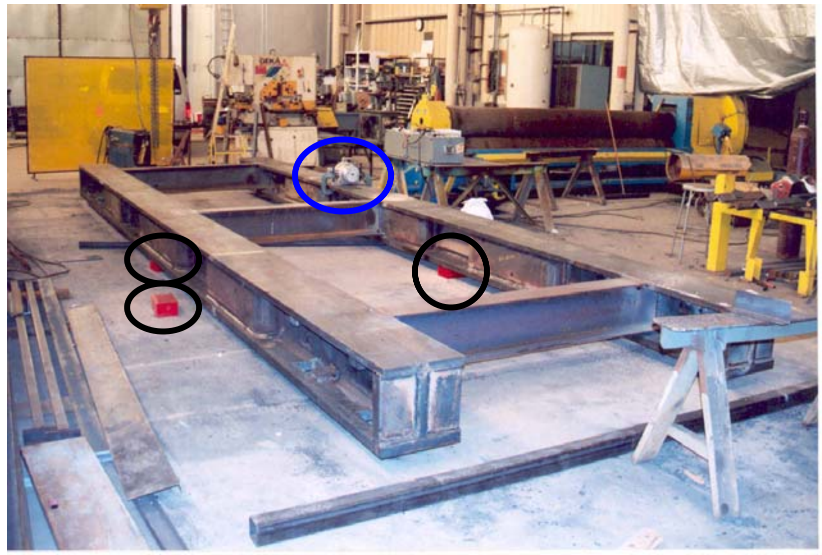
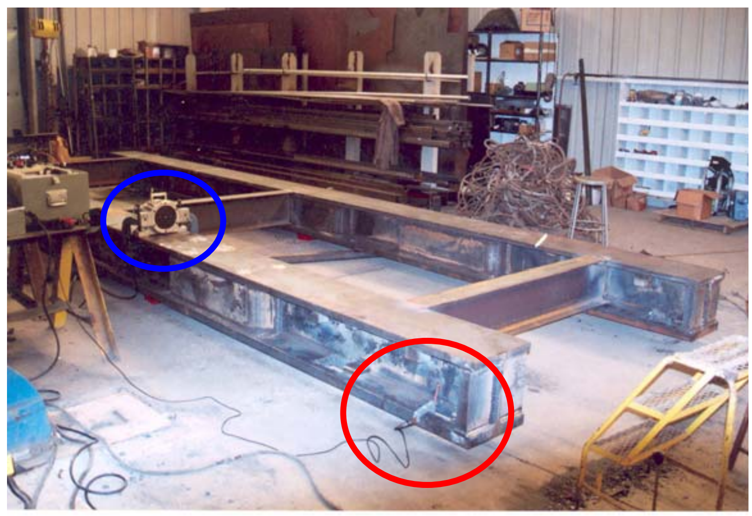
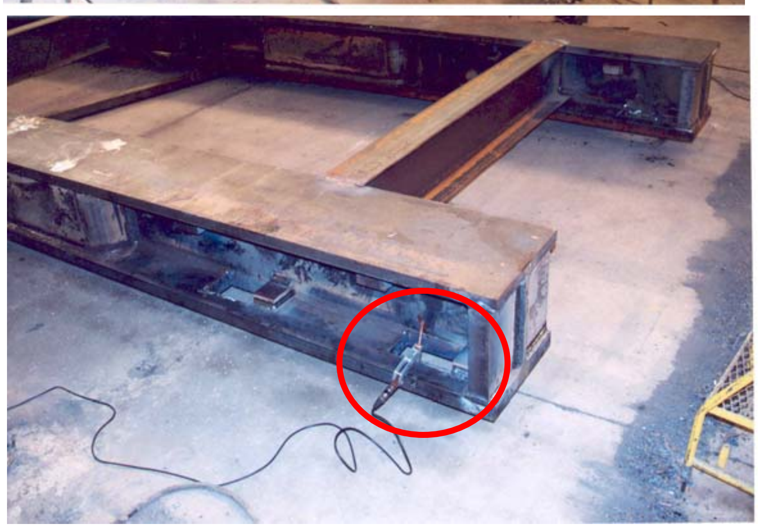


PHOTO 2 & 3





OPPOSITE VIEW OF THE WORKPIECE. The Accelerometer (red circle) can be seen in fore-ground, with a close-up shown in Photo 3. The Accelerometer is oriented so as to be most sensitive to horizontal (relative to workpiece length) motion.

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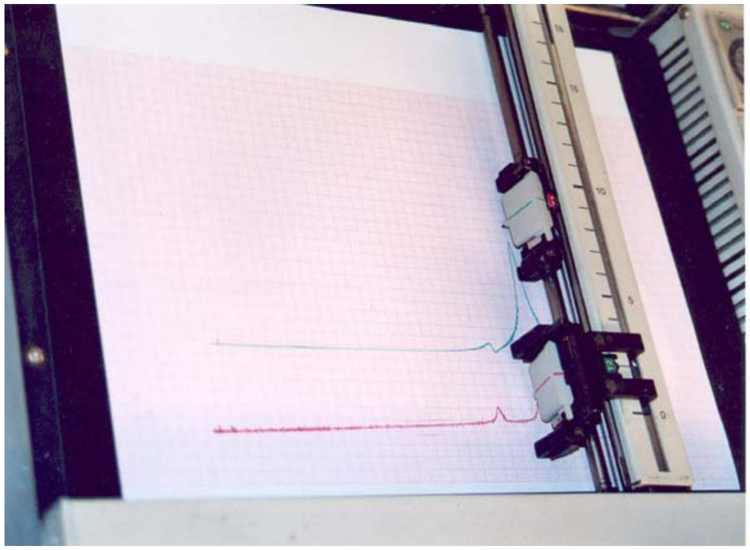
PHOTO 4

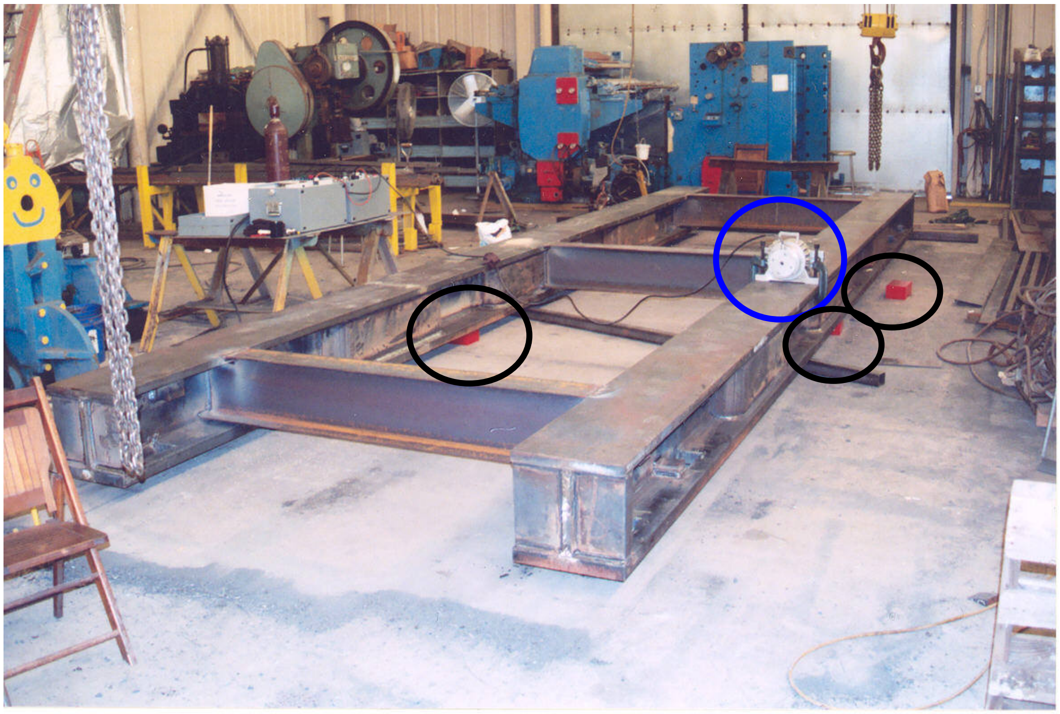


CLOSE-UP OF THE VSR 790A SYSTEM's XYY PLOTTER PAD SHOWING THE PRE-TREATMENT SCAN Upper curve (green) depicts Acceleration; lower curve (red) depicts Vibrator Power; both of these parameters are plotted vs the Vibrator's RPM, which is the horizontal axis. At the moment this photo was taken, the VSR Treatment had begun, with the Plotter's pens (which remain active but do not write during Treatment) show an ≈ 10% growth of the height of the green peak (Acceleration).

PHOTO 5

CLOSE-UP OF MX-790A CONTROL CONSOLE. This unit contains the Vibrator motor drive, Accelerometer amplifier, plus the various controls and circuitry required to perform a Treatment. Note the acceleration display (upper right) reading 10.48g at 4140 RPM. This Photo was taken at the end of the Treatment performed on the large resonance peak during the 1st Treatment.

PHOTO 6

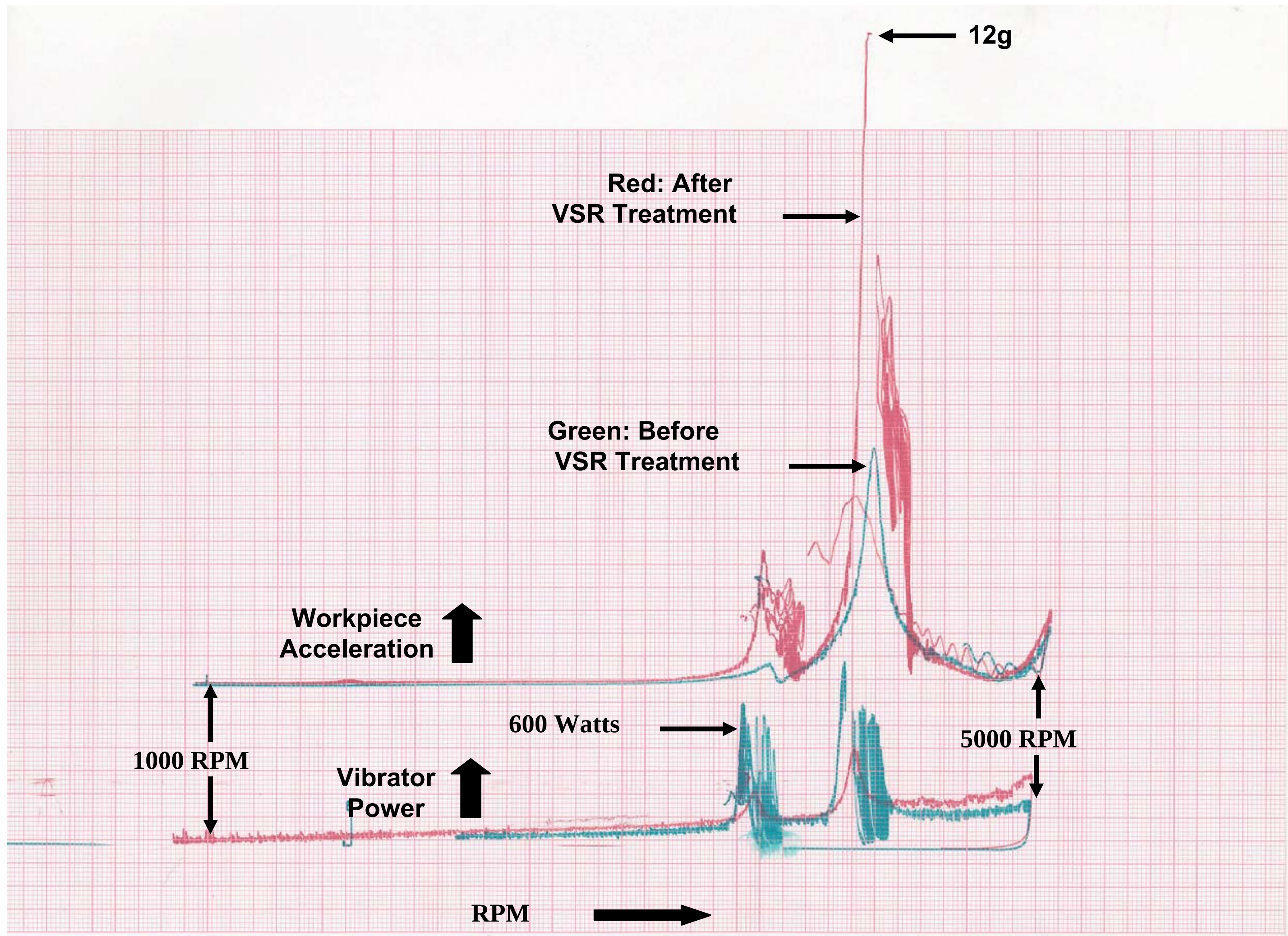


SETUP USED TO PERFORM 2ND TREATMENT. Vibrator is now on the beam farthest from the Control Console: When two (2) or more, very rigid components are joined by far less rigid structures, it's prudent to perform two (or more, if needed) Treatments. This ensures that each component, which can sometimes behave as an independent Workpiece, is properly stress relieved.

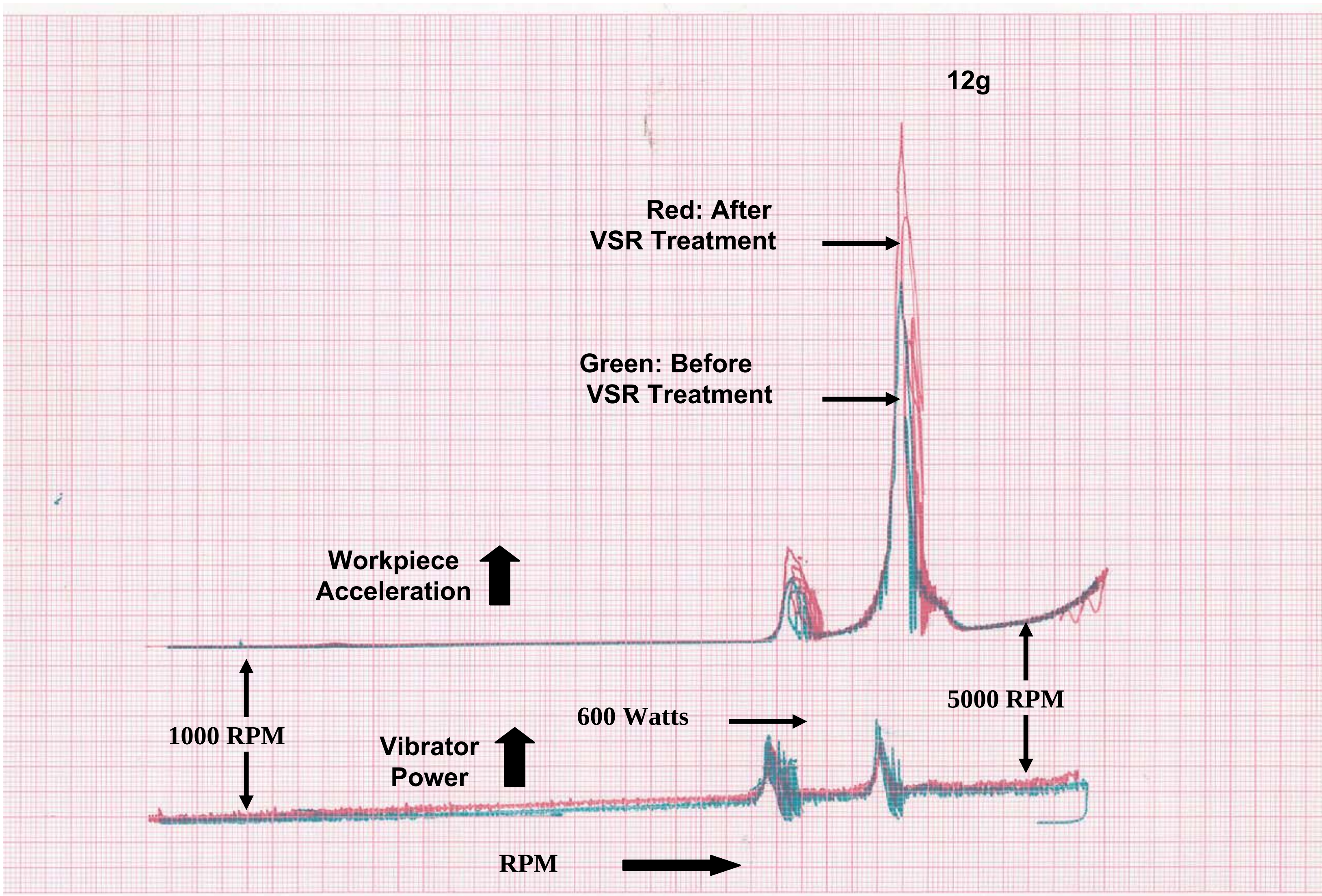
This multi-treatment principal, together with other principals and techniques discussed in this report, *eg*, Load Cushion placement, Vibrator location, orientation and unbalance settings, etc., have been developed from the feedback provided by the VSR Treatment Charts.

Using these Charts, and being able to monitor – in real time – the data from which they are generated, allows the VSR Process to be not only highly effective and repeatable, but also rather simple to perform. Without the benefit of the instrumentation feedback, metal stabilization with vibration is difficult, if not impossible, to achieve.

1st VSR Treatment



2nd VSR Treatment



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