The cost effective alternative to heat treatment

Report on Vibratory Stress Relief

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TRIALLIANCE FABRICATING:
Mertztown, PA
Job #2

TRIALLIANCE FABRICATING, a steel fabricator, subcontracted VSR Technology to stress relieve a second mild steel, welded Trunnion Base. The workpiece was, 28' x 8' x 1.5' and consisted of 2 heavy-walled, rigid 28' beams joined by 3 much lighter structural cross members. A similar workpiece had been successfully threaded (based on dimensional stability during machining, and subsequent assembly and usage in January, 2004).

For this job, VSR Technology used its newest model stress relief system: the VSR-8000 System. This report details the benefits of this completely automated system and the resulting cost savings and reduction in stress relief time that the new system provided.

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VSR SETUP

The Trunnion Base was placed on 4 load cushions to isolate the workpiece. Two cushions were placed on each side, 1/3rd of the distance from each end. Positioning the load cushions in this manner (far from the corners of the workpiece), minimized damping, which allowed maximum flexure. The ability to flex is required whether the natural frequency of the workpiece is a bend-mode resonance, or torsional-mode resonance. Maximum flexure must occur, in both the bend and the torsional (twisting) modes of vibration, if the workpiece is to achieve the maximum benefit of vibratory treatment.

The System's BL-8 Vibrator was mounted above one of the cushions, and oriented so that the vibrator's axis-of-rotation (AOR) was aligned with the length of the workpiece. This alignment allowed the workpiece to be driven in the two primary directions it can resonate: vertically (Z-axis) and laterally (Y-axis); the workpiece will resonate little, if at all, along its length (X-axis direction).

The initial unbalance setting on the BL-8 vibrator proved too low (resonance not achieved), a second, higher, setting caused an excessive power peak, but the third setting at 25% of the 4.0 in-lbs available (in between setting 1 & 2) proved effective.

Next, the System's Accelerometer (an electronic sensor whose output is a proportional third unbalance setting (in between 1 and 2) to acceleration), which is used to measure and record the intensity of the workpiece vibration, was attached to the workpiece. The VSR process uses an accelerometer because acceleration is proportional to force (F = ma , Newton's 2nd Law), and VSR Technology has standardized on relative force measurement because it is the most scientifically indicative parameter of a workpiece's response to vibration treatment. The Accelerometer was clamped to a corner of the workpiece on the far beam (away from the vibrator), and oriented so as to be most sensitive to vertical deflection.

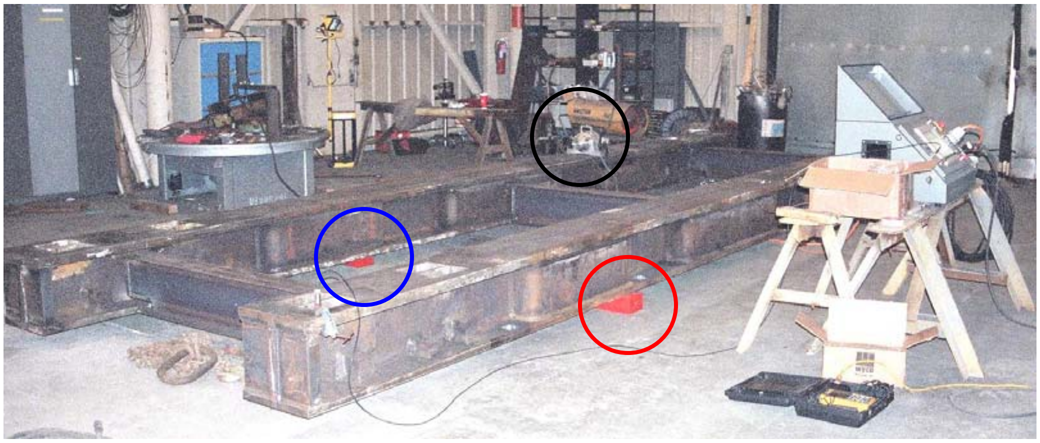

Photo. 1: VSR Setup. The workpiece shown resting on Isolation Cushions (circled); Accelerometer (circled) in the left foreground; Vibrator (circled) in background. MX-8000 VSR Control Console rests on shop saw-horses in right foreground.

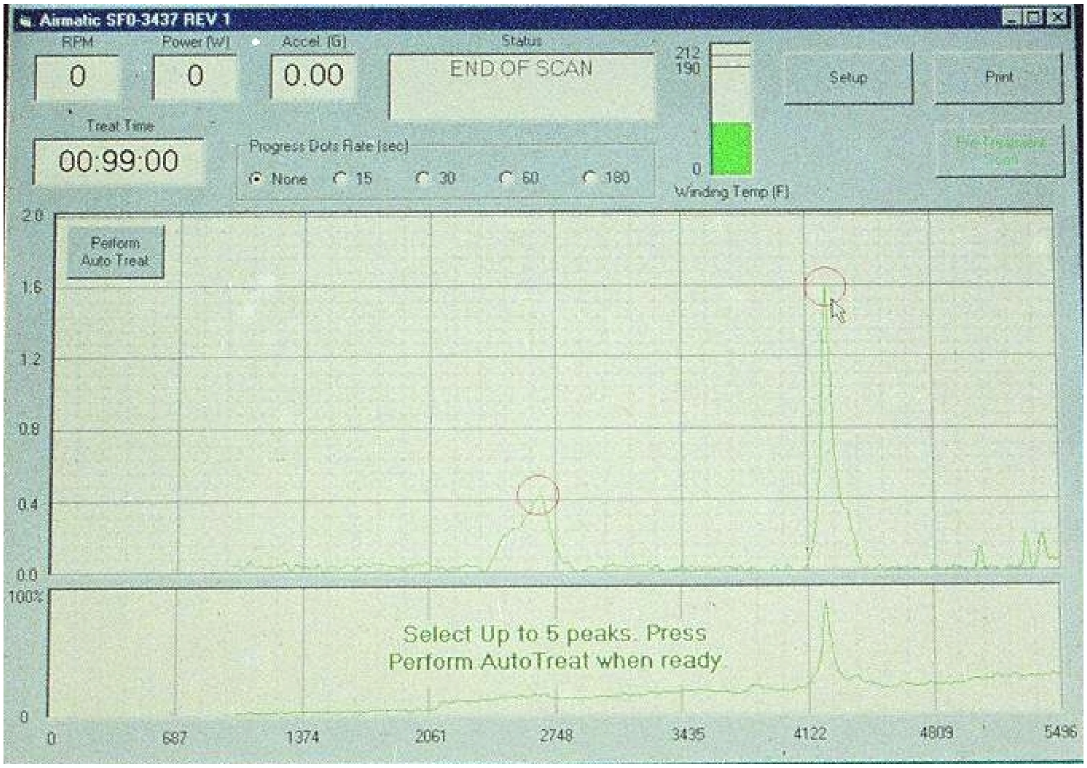

Photo. 2: Pre-Treatment Scan. This scan shows the resonance pattern of the workpiece, prior to stress relief. The Pre-Treatment (and Post-Treatment) scan screen displays on 2 charts:

1. Upper Chart: This depicts workpiece Acceleration vs Vibrator Speed. Acceleration is the vertical axis, scaled in "g's" (adjustable from 1g to 50g, full scale); speed is the horizontal axis, scaled in RPM (Vibrator Speed is adjustable from 10 RPM to 8000 RPM). NB: Acceleration curve in green.

2. Lower Chart: This depicts Vibrator Power vs Vibrator Speed. Power is the vertical axis, scaled in percentage of full load power capacity, and Speed is the horizontal axis scaled in RPM. NB: Power curve in green.

The captured image in Photo 2 shows the AutoTreat software function requesting the operator to select up to 5 resonance peaks to tune upon and track as they change during treatment. Two peaks (circled in red) were selected. Selecting a peak is done by touching the PC screen on the peak to be treated which causes a red circle to appear around the touched peak. The peaks selected will be sought-out during performance of the AutoTreat function. The Pre-Treat and Post-Treat Scans were run automatically by the VSR-8000 System, using the standard scan rate of 10 RPM / Sec (the scan rate adjustable 1 RPM to 50 RPM / Sec).

FIRST TREATMENT

Treatment was performed using the VSR-8000's AutoTreat software, which has been designed to select the highest resonance peaks, and then tune upon and track them as they change (during stress relieving). Two changes occur:

A. The resonance peaks grow to higher levels (greater amplitude).

B. The resonance peaks shift in the direction of lower vibrator speed.

Peaks grow because rigidity is lowered during stress relief making the workpiece more compliant, an effect that can also take place during PWHT (Post Weld Heat Treatment). This change is regularly observed by metalworkers during cold-straightening operations: workpieces with high levels of stress are more difficult to bend or twist in a press than are similar components with lower stress levels. Effective stress relieving (whether done with vibration or heat) lowers the level of force needed to achieve a specific deflection.

Peak shift is actually caused by peak growth. (See *Vibratory Stress Relief: Methods used to Monitor and Document Effective Treatment, A Survey of Users, and Directions for Further Research*, Klauba, Adams & Berry, Proceedings of ASM International, presented at Trends in Welding Research Symposium, Pine Mountain, GA, May 20th, 2005.) The same lowering of resonance peak frequency can be seen by increasing the amplitude at resonance of a stress-free structure.

After the peaks ceased to grow and shift, ie, they became stable, a Post-Treatment Scan was performed (the acceleration and power curves**,** recorded in red, are shown in Photo 3).

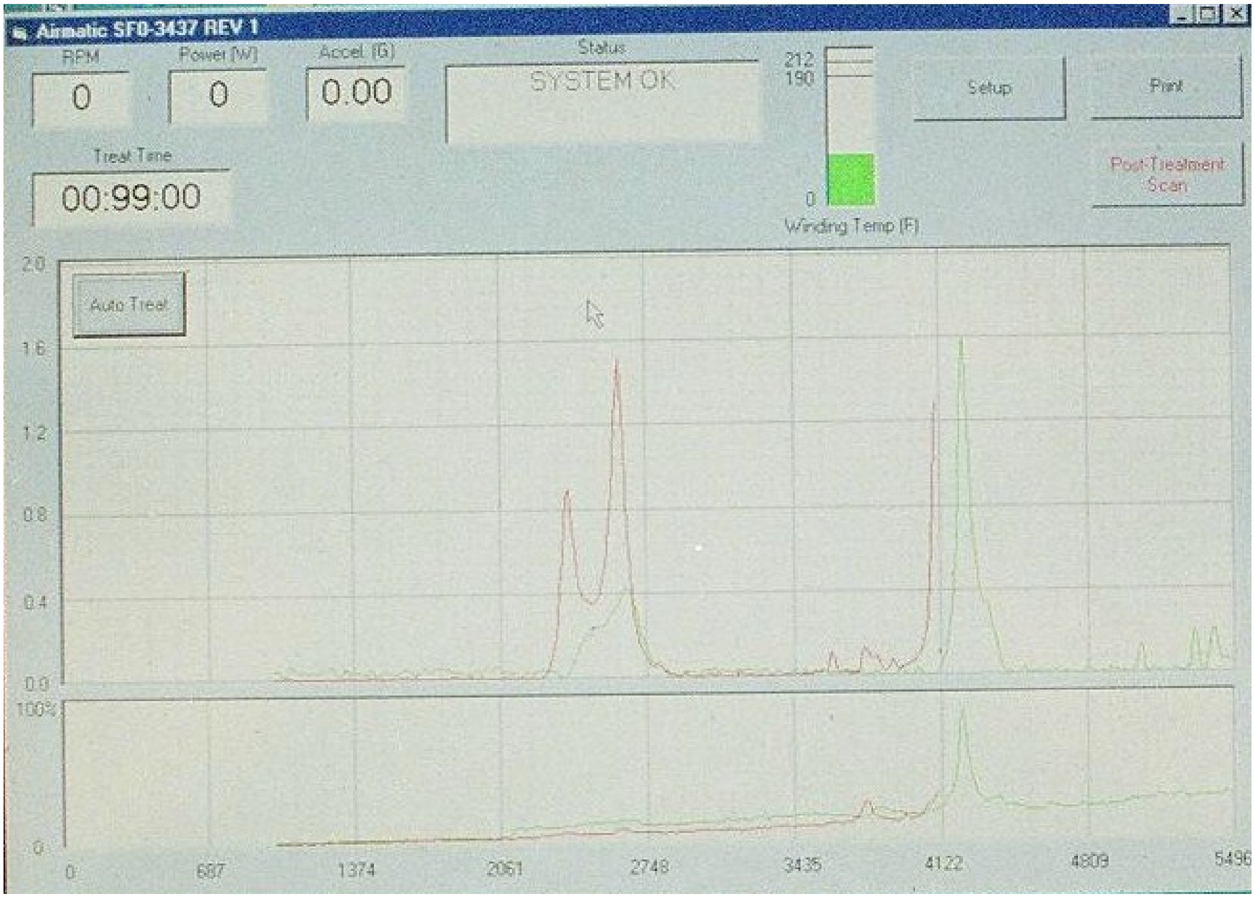

Photo 3: FIRST TREATMENT Chart. This Photo shows the Pre-Treatment Scan with Post-Treatment Scan superimposed upon it. Again, the Post-Treatment Scan's acceleration and power curves are displayed in red.

As can be seen in the photo, the smaller, green peak (≈ 2600 RPM) both grew and shifted (it tripled in size and split into two peaks). Grow and shift movement is common for workpieces of this general configuration, ie, two primary sections joined together by structural elements less rigid than the primary sections.

As would be expected, the larger peak (≈ 4300 RPM) also grew and shifted during treatment but this resonance peak was accompanied by apex in vibrator power. It reached 85% of the vibrator motor's power capacity (the red line across the top of the power chart is 100%). A peak in the power curve indicates that the vibrator itself is undergoing large amplitude during resonance. VSR Treatment will also cause power peaks to grow and shift (just like acceleration peaks do). On this job, the new height of the power peak exceeded the vibrator motor's capacity, at which point the VSR-8000's motor protection shut down the system. This explains the truncated Post-Treatment Scan: Above 4300 RPM the power peak exceeded the vibrator motor's capacity, which is 3 HP (2238 watts).

When the power peak grew close to a 100%, Treatment continued by manually tuning the vibrator speed to the resonance peak's leading edge to keep the motor below capacity.

SECOND TREATMENT

Based on the workpiece's unusual configuration, a second treatment was performed. This is because a workpiece consisting of two highly rigid sections (the 2 fabricated full-length beams), joined together by structural elements of much lower rigidity can allow independence to exist between the two rigid sections (the beams). Based on results, as shown by the system's instrumentation, the Trunnion Base did benefit. For the second treatment, the vibrator was moved to the opposite beam, and the Accelerometer was also moved to the opposite beam, so as to best detect signal from throughout the workpiece. **(See Photo 4)**.

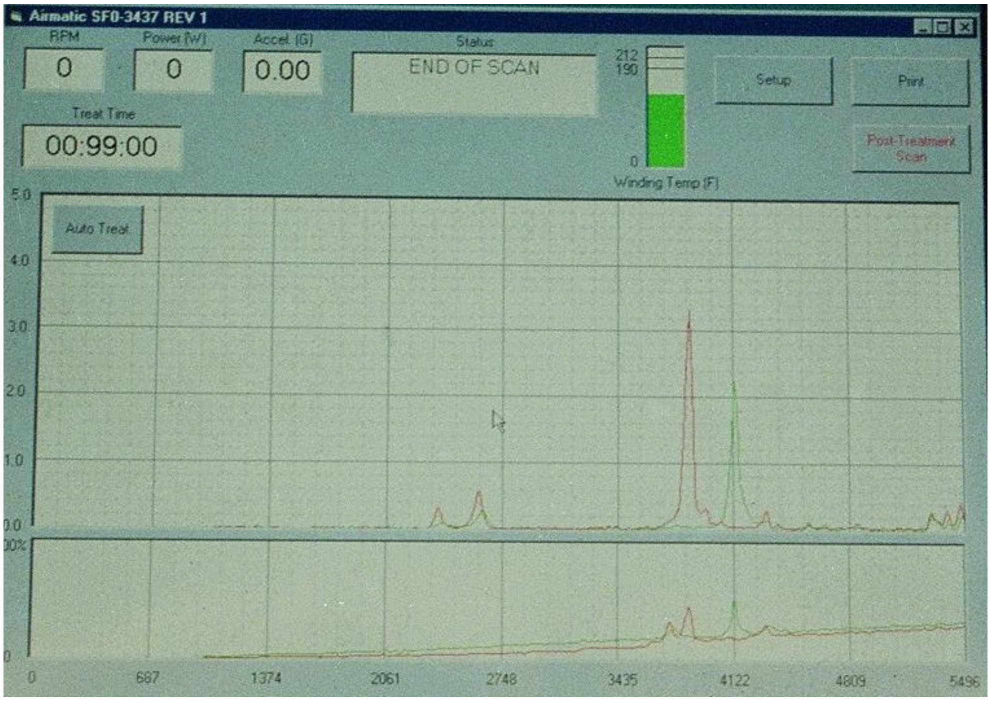

Photo 4: SECOND TREATMENT Chart To keep the power peak within limits, the vibrator was mounted in a different location on the second beam (close to a node of the large resonance). The power peak dropped from the 85% level (first treatment), to ≈50%, as shown. Again, note the growth and shifting of the large peak (the Pre-Treat recorded in green; Post-Treat in red). Less change took place in the smaller peaks, because they had been significantly stabilized by the first Treatment.

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CONCLUSION

Based on previous experience with a very similar workpiece (treated in January 2004), and the clear evidence of effective stress relief from these two VSR Treatments, this workpiece will display dimensional stability during machining, assembly and usage.

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.

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