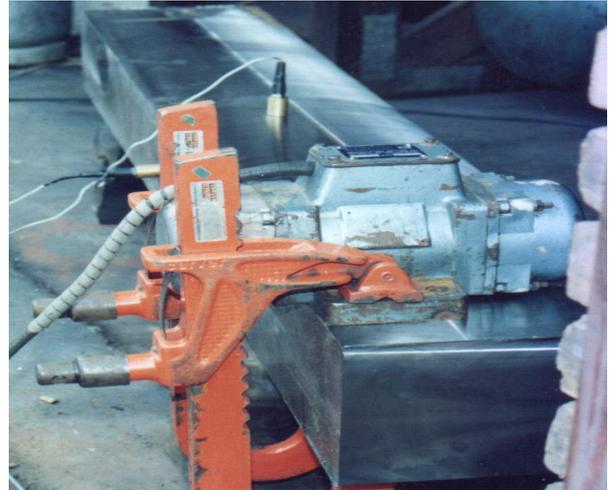


VIBRATORY STRESS RELIEF

Vibratory Stress Relief - recent developments

VSR (Africa) cc in association with the vibratory stress Relieving Company (UK) has more than 58 years experience of VSR research, equipment manufacture and onsite service. This have led to the development of the renowned VCM series of VSR equipment. Vibratory stress relieving of ferrous, non-ferrous and mixed metal components, welded, cast, bar or otherwise in now commonplace. Here J S Hornsey and R A Claxton describe the changing face of VSR highlighted in recent research. They provide some interesting examples of its use drawn from their combined experience from over 3500 customers and over 100,000 different VSR applications*



A series of reliable research programs has exposed the false philosophy associated with some VSR systems, which have been responsible for so much controversy in recent years and return us firmly to reliable traditional VSR equipment and its clearly defined areas of application. The main purpose of VSR is to lower and redistribute stresses to safe levels such that the component's accuracy and long term stability are assured.

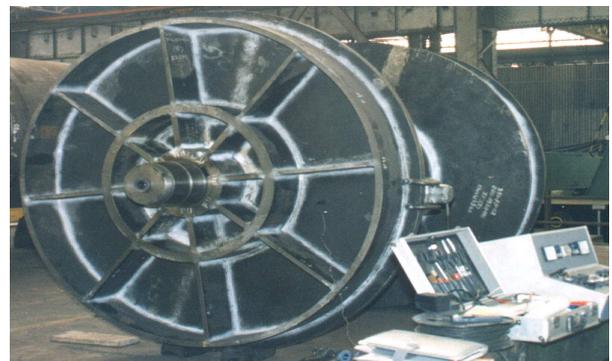
Although any equipment can satisfy the "easy to treat / little need" category, only the best equipment with optimum force / frequency characteristics and maximum "g" tolerance successfully treats the most challenging end of the range. As examples and research show, it is a range that spans the entire materials and engineering spectra. As this paper attempts to show, new applications are being found daily.

Range of application

When using the most effective equipment, the widespread use of, and general satisfaction with VSR has been shown by the extent to which it has been adopted by virtually all sectors of industry. An extensive database and testimonials are available from the authors, with regard to applications, equipment and on-site service.



The VCM R-VSR equipment is specified by MOD for stabilising 0.5kg aluminum aerospace camera frames that had previously been unstable in service.



The VSR service is specified by many large South African manufactures on items such as this mooring winch for South African harbor authorities.

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A typical example of a medium weight fabrication being VSR treated after completion of welding and fabrication

Gone are the days when heat treatment contractors took an adversarial attitude to VSR.

Some have purchased their own VSR equipment; and many others use an on-site service. As well as enabling them to treat parts hitherto too large for their furnace, VSR opens up completely new areas of business.

However, for coded components such as pipework and pressure vessels etc. thermal stress relief must be used as only this gives the required metallurgical benefits.

Stability, is the main requirement for which VSR is applied. When VSR is used stability more than matches that of thermal stress relieving. Stability can be improved by re-applying VSR to components in near finished condition thus saving components that might otherwise have been scrapped. VSR does not reduce rigidity or affect material properties or fatigue life. Some interesting examples follow.

Rolls, bars and shafts: Straightening and reclamation

Bowing of shafts whether during machining, weld depositing of worn items or in service had proved to be a virtually insurmountable problem for major pump and moulding screw manufactures etc. (Typical component range 12mm ϕ 200mm long to 220mm ϕ x 10mm long). Now with the pooling of experiences and resources of the VSR Co. (UK) and J Macnabs straightening services (UK), completely stable close tolerance shafts are regularly supplied. (Typically 100mm ϕ x 3500mm long within 0.08 TIR). This is achieved by applying VSR to the shaft initially to obtain its true shape, then over-straightening commensurate with the severity of the bow and the material type. VSR is then applied again to remove the stresses induced by the straightening operation. The shaft is then checked for straightness and the VSR / straightening processes are re-applied if necessary to achieve the customer's stated tolerances.

Particularly difficult materials such as duplex stainless steel, nitronic50, E4340PQ etc. are stabilized using this method, saving companies a fortune in material, time and labour costs.



Shafts and rolls being VSR treated after rough machining

Jigs, Fixtures and Frames

Fabrications consisting of mild steel, stainless steel, aluminum etc. are treated using the VSR process. Typical user industries are aerospace vehicle, food machinery, paper / steel mill machine tools military equipment etc.

During 1997, VSR (Africa) cc was called upon to treat in excess of 2,000 tons of various sized assembly tables and jigs for the South African motor industry. End users included BMW, Toyota, Delta and Land Rover. The inclusion of VSR enabled the fabricators to meet the stringent delivery schedules without any loss of stability either in service or during manufacture.

Mixed metal components

VSR successfully treats many composite fabrications such as CI/MS, cast manganese/MS that would normally crack if thermally treated. The following examples give an idea of components covered.

A rotary shear housing was made up of a cast steel base, 90mm thick mild walls and four off 1m ϕ x 400mm cast iron bosses. The fabrication weighed 22 tons when completed. TSR was totally out of the question.

MS/Stellite deposited carpet knife blades are specified to be VSR treated (5m x 150mm x 10mm). Thermal stress relieving was ruled out after causing unacceptable distortion to the mild steel, due to the high TSR temperature of the Stellite. These high volume components are completely stable after manufacture, transport and in service.

CI or cast steel/alloy matrix lined half bearings approximately 1m in diameter x 1m long are VSR treated not only to ensure stability but also to test the integrity of the alloy bond to the substrate.

For close tolerance mixed metal friction welded components with sealed air pockets working in an environment of heat and magnetic forces. VSR is standard practice.

Large fabricated buckets consisting of chilled forgings wear resistant plates and steel bodies are regularly treated in South Africa in many cases reducing downtime by up to 40%. Typically a bucket came in for repair every 8 to 10 weeks taking up to 3-4 weeks to complete the repair / refurbishment. Now with VSR the service life of the buckets has dramatically increased and the 3-4 week repair time vastly reduced.



Treatment of a new dragline bucket. Major benefits of treating repaired buckets include the highlighting of cracks, which previously may have gone unnoticed.

Cost of VSR compared to TSR

Colossal cost savings are often realized with the exclusion of transport costs and the associated downtime and lengthy cleaning and straightening costs normally associated with TSR.

The average downtime of a large fabrication treated by VSR is normally in the region of two hours; this compares with up to three days with thermal treatment depending on the location of the component.

Almost all the major centers of South Africa are serviced by an on-site VSR service crew. Neighboring countries are also covered. In the case of breakdowns or production delays, service personnel can be dispatched by light aircraft from our Witbank office.

Enormous cost savings are realized where components such as the rake (pictured) off a stacker reclaimer that can be treated in the field, rather than dismantled and thermally stress relieved in sections.



A fabricated rake being VSR treated on site after fabrication before installation.

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In 1998, an engineer attached to Anglo-American carried out a cost analysis on the above example treated in 1996, as part of his B.Sc. studies. A cost saving of R51, 000 was realized by using VSR in place of thermal treatment. To date the rake is still in service with no signs of cracking or instability.

VSR Ahead of the field

There are various VSR systems, some effective some less so. The only common denominator being that the component to be treated is placed upon rubber isolators and subjected to a cyclic force. Recent research has identified the successful and not so successful processes.

The three main VSR approaches are resonant (R-VSR), modal sub-resonant (SB_VSR) and sub harmonic (SH-VSR). The British "VCM series" is the only equipment range that is specifically designed for R-VSR. It has superior frequency/force ranges and a remarkable tolerance to high "g" forces. The formula 62 and Foriermatic systems claim to be successful for resonant VSR but research mentioned below casts doubts on their effectiveness – possibly because of poor frequency range, "g" tolerance etc. Practice seems to support this.

Resonant VSR

This has evolved over a 40-year period. For the VCM series mid 1997 saw major research-led changes in both approach and equipment specification.

In well defined areas of application. R-VSR is now 100% successful in its main objective stress relief-component stabilisation. The treatment of components from less than 1kg to in excess of 100 ton is commonplace.

Procedures stipulate a progression up the peaks to resonance, consisting of a pause at the foot to allow any critically high stresses to diminish, prior to treating at the mid height region and then a short defined number of cycles at the actual peak. As long as the mean stress is allowed to float the resulting cyclic imposed, strains progressively add to the residual strains in the material to cause stress reduction and distribution as with TSR. For the most uniform stress relief and stability, as many as the natural frequencies as is

possible are reached. The greater the equipment's range and the more complex the loading pattern the better the treatment.

Research and 30 years of application have shown that there is no damage due to high resonance. This is because critically high-imposed stresses are impossible to achieve as damping increases dramatically with high cyclic strain.

R-VSR is normally applied before machining, ideally though it should be applied after rough machining as it then also reduces machining stresses. Application before final grinding achieves even closer tolerances. Treatment at this or the finished stage eliminates micro movement occurring between leaving the customer of in service. The most accurate and stable components are R-VSR treated.

Manufactures of vibrating plant use R-VSR for stress relief and fitness for purpose testing and thereby extend warranties on screen, deck support frames, moulds etc.

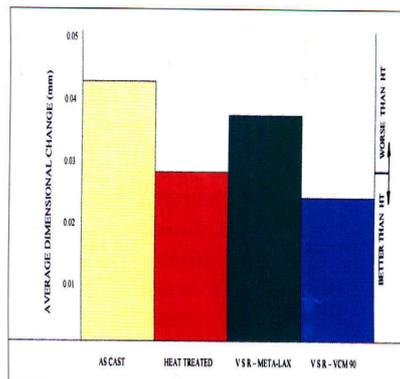


Fig A. Dimensional changes of castings after various treatments. Batch size 12. Lowest figure is best result. ERA have agreed that the original diagram showing meta-lax giving good result was incorrectly computed.

Using best practice R-VSR can achieve better results than heat treatment, graph measured in dimensional change after various treatments

Modal Sub-Resonant VSR

If when attempting R-VSR, only the base of the peak is achievable (due to the peak being just out of range). Treatment would be classed as modal sub-resonant VSR i.e. the mode shape would be evident, but the peak not achievable. Optimum results are obtained if up to 10 times the number of cycles required for R-VSR are applied in inverse proportion to the magnitude of the cyclic response. It is best carried out with the equipment used for R-VSR processing because of its superior frequency range. VCM machines have twice the range of any other equipment.

Sub-Harmonic VSR

If neither of the above conditions is met (due to resonant responses being way beyond the range of the equipment), conventional wisdom indicates that no stress relief is possible. This seems to be the domain of sub-harmonic VSR. Treatment is said to take place at the foot of a minute sub-harmonic of a true resonant peak. Sales literature states that the process depends on energy absorption being at a maximum near the foot of a sub-harmonic peak. Because exciter force increases with the square of the speed one might logically expect the highest sub-harmonic peak to be the most effective for treatment, however the manufacturers actually advocate treatment at a low one. This possibly indicates that their equipment has poor 'g' tolerance. The mechanism by which SH-VSR is said to work has no connection with either R-VSR or modal SR-VSR.

The diagram used to promote the process and its mechanism appears unconvincing if drawn to scale. SH-VSR claims to vibrate the atoms and move them relative to one another in the strained crystal lattice of the material. This seems farcical, as the energy used is so low that the vibration usually cannot be either felt or heard. Knowing of no scientific support for it whatsoever, no further space is allocated to this approach.

Research sorts it out

Researchers have investigated aspects of VSR for over 40 years. Some were legitimately exploring its boundaries but others have toyed with test-pieces and procedures not remotely connected with VSR resulting in some misconceptions. All the research reported below was conducted with actual VSR equipment, assisted by the equipment manufactures or their direct agents. Whereas historically research projects in the mid/late nineties have consistently disproved the effectiveness of American dc resonant, non-resonant and sub-harmonic equipment. A 2-year Dutch/German EU project tested two dc types of equipment – SRE Co, Formula 62 and VSR Eng Martin LT120/MX800 re stress reduction and fatigue of components. Little or no benefit was found. British EU and later DTI

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projects tested two other dc types; both automatic Bonal Meta-lax sub harmonic system and VSR Eng. KD16 Fourier scan re stress reduction and stability. The projects lasted nearly six years and little or no benefit was found. Particularly difficult components were tested as an adjunct to the DTI project. **They were treated using the Meta-lax and VCM 90 equipment. The results showed that Meta-lax brought about little change whereas the VCM 90 was on par with thermal stress relief** (see bar diagram). Indications from the research have led to refinements that have been incorporated in the new VCM 905 equipment. Other recent research in the UK, India, Australia and South Africa supports the foregoing.

Research and testing into VSR carried out in 2003 by an Anglo American Chief Materials Engineer on test pieces welded by the South African Institute of Welding and Stress Measurements by using the air abrasion drilling technique showed a reduction of 60% on mild steel test pieces 130 x 300 x 16. Owing to the limited size of the test pieces, treatment was difficult. On larger test pieces results of $\pm 80\%$ would have been expected. This research by Anglo American is still ongoing in conjunction with the SAIW and Wits University Johannesburg.

Summarising recent research, it clearly shows variously that:

- VSR can be as effective as TSR given the best R-VSR equipment.
- A cyclic version of a simple stress overload is one mechanism that is at work given sufficient amplitude.
- Given sufficient energy, a beneficial effect on the distorted crystal lattice of the material
- No reduction in fatigue life occurs using any form of modern VSR equipment.

Vibratory Stress Relieving and its Applications within South Africa.

Historically the first known VSR unit to be imported into South Africa was in the early sixties. It was only in the late eighties that the growth of VSR really started in South Africa. Today VSR (Africa)cc has a client base in excess of 600 ranging from specialist

heavy engineering companies such as DCD-Dorbyl and Genrec through to precision instrument manufactures and specialised military component manufactures such an example being Denel.

VSR is widely used in the mining industry throughout Southern Africa, and on site service teams can be found operating in areas from the gold mines on the Reef up to the copper mines in Zambia. From the diamond mines on the West Coast to the copper and phosphate mines in Phalaborwa.

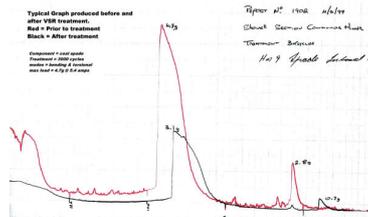


Treatment of a repaired vibrating screen on-site at one of South Africa's largest coalmines

VSR has proved invaluable on components such as crushers, vibrating screens and feeder pans as apart from the reduction in stress, VSR is also a valuable "fitness for purpose tool" as it will seek out any defective welds or poor joint design, thereby enabling repairs to be carried out in the workshop environment and not after costly failure in the plant.

A detailed graphic printout can also be produced valuable in the case of screens and feeders as it gives an accurate picture of component frequency response.

Traceability and conformability is often difficult with thermal stress relieving. For economic reasons dissimilar components are grouped together for the days firing. In contrast complete traceability is guaranteed with components VSR treated as they are individually processed and certified.



A typical graph produced before and after VSR treatment. Detailed are force and frequencies, and clearly shown is the reduction and redistribution gained after treatment.

Ongoing Research involving VSR

Worldwide new applications for VSR are being found particularly with the advancements in composites and plastics.

Here in South Africa we are currently involved in a research program to study the effects of VSR on plastics. Plastics are fast becoming a serious contender to steel in many industries. Consequently engineers and designers are faced with many similar problems that are encountered on conventional steels.



Pictured are sample pieces of HDPE piping after treatment

To date the results obtained on the VSR of plastics are very encouraging and VSR could soon become the accepted method of treatment, on this once difficult material.

More information on VSR including test reports and references can be obtained from:

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E-mail fdd-vsr@netactive.co.za

Or by contacting the following

Durban (031) 5793501
Cape Town (021) 951 2271
Port Elizabeth (083) 4063277
Phalaborwa (01524) 86427
Namibia (0926) 46323391

Further examples of component treatment can be found on our website at

<http://www.vsr-africa.com>