16th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2012, Dubai, UAE, 10-12 September 2012

NUMERICAL INVESTIGATIONS FOR THE VSR METHOD APPLICATION TO THE SPECIFIC CASE

Fuad Hadžikadunić
University of Zenica
Fakultetska No.1, 72 000 Zenica
Bosnia and Herzegovina

Nedeljko Vukojević
University of Zenica
Fakultetska No.1, 72 000 Zenica
Bosnia and Herzegovina

Mustafa Imamović
Mittal Steel Zenica
Bulevar Kralja Tvrtka I No.17, 72 000 Zenica
Bosnia and Herzegovina

ABSTRACT
The work presents an analytical and numerical approach to the study of VSR method on the model of welded steel beam. This part (among the others of total analysis) is a good basis for the determination of the actual behavior of structures, reliable prediction of structural response in service, determining the parameters of choice and decision, determining the causes of bad behavior, pointing the methodology and parameters that will increase the level of structure relief, and enhance its stability. The presented method is applicable to various types of structures, but with appreciation of its geometric, technological, dynamical and all other specifics. This means that different types of constructions require in a certain domain the general approach of treatment applying, but there is also a domain specific to each type of structure that must be taken into account in terms of overall effectiveness of treatment. There are many influential parameters on the final effect of treatment, and one of the most important are dimensions of treated objects, material and applied welding technology.
Keywords: residual stresses, VSR method, space beam.

1. INTRODUCTION
In the past 60 years, VSR (Vibratory Stress Relieving) has grown from a little-known to the respective process, especially important in treating of large structures, which was established as an alternative to thermal treatment of castings, pieces requesting additional machining and non-metallic materials. It is important to note that the VSR is not an alternative for all procedures of thermal processes, but there are areas where these procedures are and will be predominant. Thermal and VSR procedure covers three areas, reducing stress, dimensional inspection and dimensional stabilization. Although the complete relief of residual stresses can not be achieve by any commercial process, VSR can stabilize stress and relief its values in components at any stage of the manufacturing process or machine without changing the metallurgical state of materials, without the distortions with low cost and short time. There are three main VSR approaches: resonant (R-VSR), modal sub-resonant (SB-VSR) and sub-harmonic (SH-VSR). The process of applying vibration technology in relieving residual stresses in the real industrial structure contains several phases of which are very important: the determination of the expected dynamic behaviour of the treated structure, determining the boundary conditions of application of available equipment, and monitoring the process during the execution of relaxation technology of residual stresses. The importance of applying a preliminary numerical analysis of structures with complex configuration is to detect the shape and natural frequencies of oscillation to

achieve the excitation of the structure caused by a specific frequency oscillations with corresponding shape.
The adequate supporting of structures must be provided for all excitation of bending and torsional oscillations in terms of achieving the effect of reduction of residual stress in welded construction, [1].
If the most important bearing welded joints are concentrated in a particular part of the structure, then the supporting of the structure must be designed to cause significant excitation of oscillations in that zone. Therefore, although the" scan" of the structure can be done during the application of vibration procedure, in order to detect the reference frequency of oscillation, the application of numerical analysis gives a more comprehensive approach because it indicates the distribution of the supports, i.e. the number of" phase" in which the process is complete.

2. ANALYTICAL APPROACH

For industrial applications, numerical and experimental approach are more important than analytical. So here is an analytical approach to states only as a comparative. The entire principle can be presented as a system with one degree of freedom, [2]. Figure 1 presents a schematic representation of the dynamic model of the observed vibratory system, and here is a very concise review of the theoretical analysis.

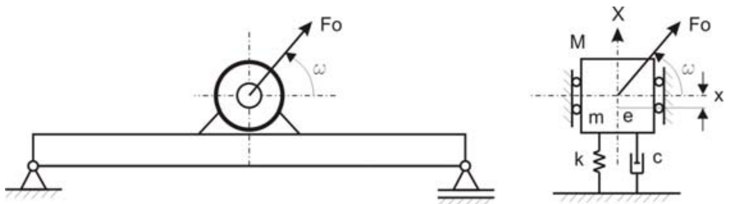

Figure 1. Vibratory system with eccentric rotating mass

Differential equations of the dynamic behavior of the system can be represented as follows:

$$(M-m)\ddot{x}+m\frac{d^2}{dt^2}(x+e\sin\omega t)=-c\dot{x}-kx \quad ...(1)$$

$$M\ddot{x}+c\dot{x}+kx=me\omega^2\sin\omega t \quad ...(2)$$

where: M – system mass, m – eccentricity mass, c – damping coefficient, k – rigidity of the system.

Total system solution will be created from the general solution of homogeneous left side of equation (damped free vibration), and the particular solution of the whole equation, and displacement caused by forced component (damped forced vibration):

$$x(t)=x_1(t)+x_2(t)\,,\ x_1(t)=Ae^{-nt}\sin\left(\sqrt{p^2-n^2}\,t+\varphi\right),\ x_2(t)=X\sin(\omega t-\varphi) \quad ...(3)$$

In this particular case, the disturbance force depends on the disturbance frequency and disturbance mass "m" and the eccentricity value "e" are also taken into account. Amplitude and phase shift are:

$$X=\frac{me\omega^2}{\sqrt{\left(k-M\omega^2\right)^2+(c\omega)^2}}\,,\ \varphi=\arctan\frac{c\omega}{k-M\omega^2} \quad ...(4)$$

The following relationship between vibration parameters of the system can be established as:

$$\frac{MX}{me}=\frac{\lambda^2}{\sqrt{\left(1-\lambda^2\right)^2+(2\zeta\lambda)^2}}\,,\ \varphi=\arctan\frac{2\zeta\lambda}{1-\lambda^2} \quad ...(5)$$

General solution consists of a superposition of damped and forced vibrations. After a while the free damped vibration disappears and there remains only forced vibrations. Taking into account the equivalent damping coefficient of C_{eq}, the response of the system is:

$$X = \frac{me\omega^2}{\sqrt{\left(k - M\omega^2\right)^2 + \left(C_{eq}\omega\right)^2}} = \frac{me\lambda^2}{M\sqrt{\left(1-\lambda^2\right)^2 + \left(\frac{a}{k\pi}\right)^2}} \; ; \; \frac{MX}{me} = \frac{\lambda^2}{\sqrt{\left(1-\lambda^2\right)^2 + \eta}} \quad \text{... (6)}$$

3. NUMERICAL APPROACH

In this part of the research the numerical analysis of the model of a beam is applied, which is of great help to confirm the boundaries of the planned application of measuring equipment, and proper conduct of VSR process to achieve the maximum desired effect, [3,4,5]. Discretization of the beam model is carried out with 1596 points and 1500 plain finite elements. Since the vibration treatment include two beam positions, vertical and horizontal position, the dynamic analysis gives the first five forms of oscillation and frequencies of the beam model to the level of 100 Hz. In the analysis, the mass of vibration equipment with 27,3 kg is included. In Figures 2, 3 and 4 views of vibration modes for the three characteristic cases of the vertical beam position are given.

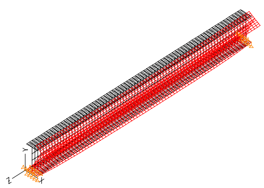

Figure 2. The first natural frequency 18,53 Hz

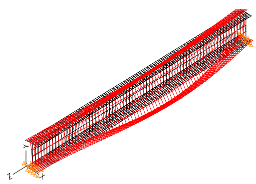

Figure 3. The third natural frequency 52,74 Hz

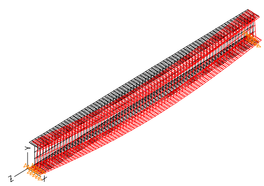

Figure 4. The fifth natural frequency 85,49 Hz

Figures 5 and 6 show frequency response of the structure in the vertical plane, which clearly show the resonant frequency response and dynamic factors. These values are compared with the actual values of the FFT analysis after "scanning" the structure with measuring equipment.

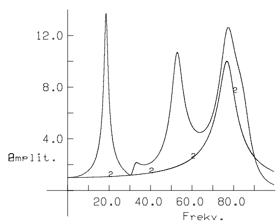

Figure 5. Amplit.-freq. Response of the structure

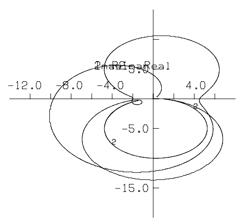

Figure 6. Real.-Imag. diagram

Figures 7, 8 and 9 show the mode shapes for three characteristic cases of the horizontal beam position.

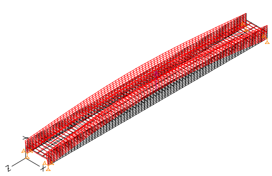

Figure 7. The first natural frequency 29,75 Hz

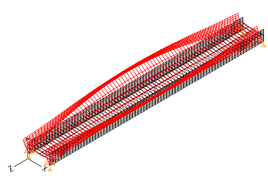

Figure 8. The third natural frequency 53,46 Hz

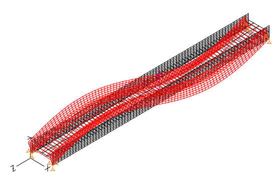

Figure 9. The fifth natural frequency 108,5 Hz

Figures 10 and 11 show frequency response of the structure in the horizontal plane, which clearly show the resonant frequency response and significantly higher dynamic response factors. Such informations are very important in positioning of the pieces during the VSR method treatment.

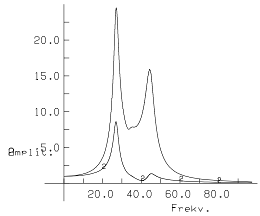

Figure 10. Amplit.-freq. Response of the structure

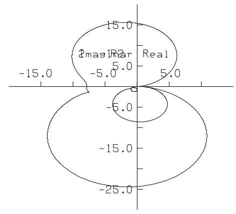

Figure 11. Real.-Imag. diagram

Based on the above implemented dynamic numerical analysis, a summary table of the obtained values for frequencies and displacements can be given, Table 1.

Table 1. Summary values of the dynamic analysis of the beam

VERTICAL POSITION		HORIZONTAL POSITION	
Nat. Frequency (Hz)	Max. displacement (cm)	Nat. frequency(Hz)	Max. displacement (cm)
18,53	0,142	29,75	0,120
32,07	0,228	46,73	0,156
52,74	0,194	53,46	0,128
76,99	0,109	101,3	0,232
85,49	0,268	108,5	0,144

The presented approach is applicable to real industrial structures with need to take into account the geometric and mass characteristics of the system, i.e. the application of this approach indicates the need for multi-planar and multi-position placement of the force transducer in order to obtain more homogenous residual stress relief effect over the structure, [6].

4. CONCLUSIONS

The analytical and numerical approach to dynamic analysis of vibration behavior of the construction indicates specificity of the VSR process and the fact where inadequate monitoring of the parameters often leads to inadequate effects of the process. Numerical dynamic analysis is particularly important for the optimization of the VSR process (proper positioning of exciter and operating parameters). This analysis is very useful in terms of planning the implementation of the VSR methodology because it gives the values of resonant frequencies of structures, mode shapes and displacement of treated structures. Also, for the complex large constructions numerical analysis of dynamic behavior is very important from the point of choosing a position for installation of supports and force exciter because the effect of VSR method depends largely on these parameters, because it is necessary to force the bending and torsional oscillations of the structure.

5. REFERENCES

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