2024. Volume 8, Number 2 *Pages 74-78*

UOT: 531.43/49

Doi: https://doi.org/10.30546/09090.2024.02.330

STABILIZATION OF RESIDUAL STRESSES IN WELDED STRUCTURES OF PRESSES BY PULSE UNLOADING BEFORE VIBRATION

A.H.GULIYEV[1], B.H.ALIYEV[2], Y.A. ABDULAZIMOVA[3], M.S. NASIROV[4]

[1] *Baku Engineering University, "Mechanical Engineering" department, Baku, Azerbaijan*
e-mail: asquliyev@beu.edu.az

[2] *Baku Engineering University, "Mechanical Engineering" department, Baku, Azerbaijan,*
e-mail: baeliyev@ beu.edu.az

[3] *Baku Engineering University, "Mechanical Engineering" department, Baku, Azerbaijan,*
e-mail: yabdulazimova@beu.edu.az

[4]*Baku Engineering University, "Mechanical Engineering" department, Baku, Azerbaijan*
e-mail: munasirov@beu.edu.az

ARTICLE INFO

Article history:
Received: 2024-12-02
Received in revised form: 2024-12-02
Accepted: 2024-12-06
Available online

Keywords:
residual stresses, geometric stability, vibration treatment, pulse unloading, welded samples

ABSTRACT

This study focuses on the stabilization of residual stresses in welded structures of presses through pulse unloading prior to vibration treatment. Residual stresses in welded components can compromise structural integrity, reduce fatigue life, and lead to premature failure. The proposed approach involves applying controlled pulse unloading to redistribute and stabilize stress fields, creating a more uniform stress state before subjecting the structure to vibration. Experimental and analytical results demonstrate that the combination of pulse unloading, and vibration treatment significantly reduces peak residual stresses and improves the mechanical properties of welded assemblies. This method provides an efficient solution for enhancing the durability and performance of welded structures in industrial applications. The influence of various stabilizing treatments on the properties of steel welded samples is investigated. The efficiency of the vibration method with pulsed unloading for reducing the level of residual stresses in samples by 1.3-2.3 times and ensuring their geometric stability is demonstrated.

Introduction. Stabilization of the level of residual stresses and the dimensions of welded press frames is one of the most important tasks in mechanical engineering. The most probable potential source of such stresses is non-uniform plastic deformation caused by thermal stresses during welding. Various relaxation processes are used to stabilize the level of residual stresses [1]. The most universal of these is thermal action by high tempering of parts (600...650ºC). However, this method requires significant expenditure of natural gas. Therefore, methods of stabilizing residual stresses and the geometry of parts using vibration processing have become widespread at present [2-4].

The most frequently used vibration treatment involves excitation of forced undamped oscillations of a certain amplitude in parts. This allows for a significant reduction in energy costs and labor intensity during stabilizing treatment but is associated with the use of vibrators that create a certain noise level, which is not always acceptable, as well as with the need to select the main parameters of vibration action for each specific part (type of dynamic stress state, required level of dynamic stresses, conditions for fastening the part, etc.). A vibration treatment method has been developed that is free from the above-mentioned disadvantages. Its essence lies in excitation of free damped oscillations in the part because of practically instantaneous (pulse) removal of a previously applied static load (VIR method) [5]. It is advisable to determine the efficiency of this method of vibration treatment of large parts such as crank press frames.

The aim of this work was to evaluate the effectiveness of various types of relaxation treatment to stabilize the level of residual stresses in the weld zone and ensure the geometric stability of welded parts.

Research methodology. Model welded samples made of grade 20 steel were used as objects of study. The samples were unclosed rings with an outer diameter of 240 mm with a transverse weld seam made opposite the cut.

The following relaxation treatment options were investigated:

1. tempering at a temperature of 650 ± 10ºC, 1.5 h;

2. vibration treatment by exciting forced resonant oscillations (VRC method);

3. vibration method using pulse unloading (VIR method).

The initial option was welding without subsequent processing.

Excitation of forced resonant vibrations was carried out using a model 489P installation, consisting of a spring-loaded vibration table with an unbalanced vibrator of the IV-98 type mounted on it and a control panel that allows changing the frequency of the vibration exciter from 20 to 100 Hz.

The experimental setup for processing by the VIR method is a special device for pulsed unloading of samples, installed on a universal machine of the UME-10TM type. The device consists of a loading device, which, with the help of disk springs and a trigger mechanism, throws the punch away from the sample at high speed, because of which free damped oscillations arise in the sample released from the static load (Fig. 1).

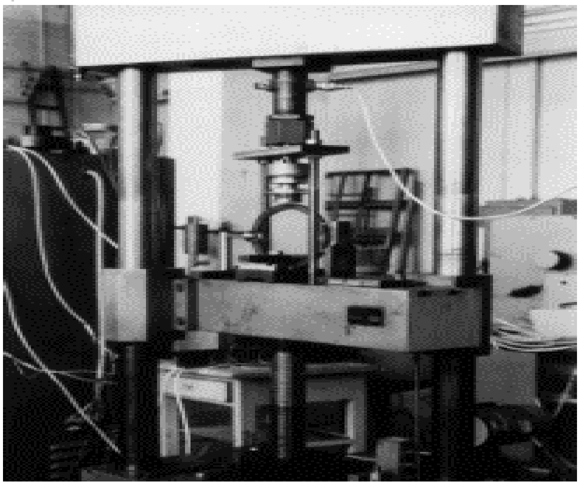

Fig. 1. General view of the installation for VIR processing

Discussion of results. Residual macro stresses were determined on the surface of the samples by the X-ray sin2ψ method on a stationary diffractometer of the DRON-3 type in Cr-anode radiation. The geometric stability of the samples was assessed by determining the residual deformation (ΔL) after testing the samples under the action of a static load equal to 0.8 of the proportionality limits (σpts) for 144 h.

Statistical processing of the obtained results was carried out using the standard method [6]. The assessment of the homogeneity of the distribution of residual stresses near the weld was determined by the value of the standard deviation (S).

The VIR method processing was carried out at different values of the initial static force (0.6 kN; 1.0 kN; 1.4 kN), which correspond to stresses in the welding zone equal to 0.28$\sigma_{пц}$; 0.45$\sigma_{пц}$; 0.6$\sigma_{пц}$, and at a different number of loading cycles.

The results of determining the values of residual stresses in welded samples are given in Table 1.

Table 1. The influence of VIR processing parameters on the magnitude of residual stresses in welded samples

No. p/p	VIR processing parameters		Average value of σ_{ost}, MPa	S
	Initial static load, kN	Number of loading cycles		
1	0.6	original	-220	29.8
		1	-215	15.1
		5	-205	42.0
		10	-230	25.7
2	1.0	original	-265	34.2
		1	-260	20.5
		5	-213	9.6
		10	-270	38.4
3	1.4	original	-260	36.1
		1	-240	35.3
		5	-233	25.9
		10	-250	38.6

As the obtained data show, the most appropriate is fivefold processing by the VIR method, since with a single processing there is practically no change in the value of residual stresses compared to the initial version, and an increase in the number of processing cycles to 10 leads to some growth in the values of residual stresses compared to fivefold processing and causes an increase in the heterogeneity of their distribution. It was established that a decrease in residual stresses near the weld seam along with their greatest homogeneity is ensured at an initial static load of 1.0 kN.

Therefore, further results are given for VIR processing in the optimal mode (initial static force 1.0 kN, number of loading cycles – 5).

Tables 2 and 3 present the results of the study of residual stresses and residual deformation, characterizing the influence of various stabilizing treatments on them.

Analysis of the obtained results (see Table 2) shows that tempering at a temperature of 650 ± 10ºC leads to a decrease in residual stresses by 2.2 times, significantly increasing the homogeneity of their distribution, which is confirmed by calculating the sample standard deviation. The decrease in residual stresses during such tempering is accompanied by some residual deformation of the samples (see Table 3).

Vibration treatment using forced undamped oscillations in resonance modes also reduces the level of residual stresses in comparison with the initial version by 1.85-2.25 times. At the same time, judging by the values of S, vibration treatment for 30 sec allows to reduce the heterogeneity of the distribution of residual stresses. Increasing the time of VRK treatment to 900 sec leads to a significant increase in the heterogeneity of the distribution of σres.

It should be emphasized that long-term vibration treatment in a resonant mode at high stress amplitudes ($0.5…0.7\sigma_{пц}$) leads to the formation of microcracks in welded seams and even to the destruction of samples. In addition, such treatment causes significant residual deformation (see Table 3).

Table 2. Effect of different stabilizing treatments on the level of residual stresses in welded samples

No. p/p	Processing option		Values of residual stresses $\sigma_{ост}$, MPa						
			Distance from the edge of the weld					σ_{ost}(average)	S
			Left side		Center of the seam	Right side			
			2mm	1mm	-	1mm	2mm		
1	vacation	original	-170	-200	+100	-250	-180	-200	35.6
		650±10⁰C, 1.5h	-80	-110	+40	-90	-78	-90	14.6
2	VRK-processing*	original	-220	-225	+180	-200	-210	-214	11.1
		30 sec	-120	-100	+50	-110	-95	-106	10.9
		900sec	-95	-65	+85	-145	-75	-95	35.6
3	VIR-processing **	original	-260	-220	+200	-280	-300	-265	34.2
		5 cycles	-220	-210	+90	-200	-220	-213	9.6

*–at a frequency of 100 Hz;

**–initial static load 1 kN Thus, when using the method of exciting, forced oscillations at a resonant frequency, the processing time should be carefully selected to avoid artificially reducing the durability of the part under subsequent operating conditions.

Table 3. Effect of various stabilizing treatments on the magnitude of residual deformation of welded samples

No. p/p	Processing option	The magnitude of residual deformation ΔL, mm
1	Welding without further processing (original)	0.51
2	Vacation at 650±10⁰C, 1.5 hours	0.21
3	Vibration treatment by VRK method* for 30 sec	0.19
4	Vibration treatment by VRK method* for 900 sec	1.3
5	Vibration treatment by VIR method (1 kN, 5 cycles)	0.2

*– at a frequency of 100 Hz

The VIR processing method is free from such disadvantages, allowing, on the one hand, to strictly regulate the stress level by setting the value of the initial static load, and on the other hand, to use a minimum number of loading cycles.

VIR processing under optimal conditions leads to a decrease in the values of residual stresses near the weld, while simultaneously ensuring the greatest uniformity of their distribution.

From the data presented in Table 3 it follows that tempering at 650 ± 10°C, vibration treatment by the VRK method for 30 sec and VIR treatment in the optimal mode lead to practically the same residual deformation, half that of the samples after welding. This allows us to conclude that vibration treatment is highly effective in stabilizing the geometry of parts.

Conclusions

The conducted comparison of the efficiency of the studied stabilizing treatments showed that these methods allow to reduce residual macrostresses by 1.3...2.3 times, and (under optimal conditions) provide a decrease in the standard deviation of the stress value, characterizing the heterogeneity of their distribution near the weld, by 1.1...3.5 times. Almost the same efficiency of the studied methods for stabilizing the dimensions of samples under the effect of long-term static loading in the elastic region is shown. It is established that residual macrostresses are not the only determining criterion of vibration treatment, since the magnitude of the reduction and their absolute values are not unambiguously related to the stability of the dimensions of the sample or part. Varying the main parameters of VIR treatment revealed that the most effective mode is the one in which the sum of the initial dynamic and residual stresses exceeds the proportionality limit σпц by approximately 10% under the selected loading scheme. Moreover, to create a more uniform stress state, the number of processing cycles should be equal to 5. Consequently, vibration processing is an effective way to reduce the level of residual stresses in welded parts and stabilize their geometry, and of the two methods studied, the method of vibration processing by pulsed unloading is preferable as it is more controllable, less energy-intensive and does not require noise protection.

REFERENCES:

1. Brittle fractures of welded structures / W.J. Hall, H. Kihara, V. Zut, A.A. Wells – Moscow: Mechanical Engineering, 1974. – 320 p.
2. Sagalevich V.M., Zavalishin M.N., Nashivochnikov V.V. Elimination of deformations of welded beam structures by vibration // Welding production. - 1979. - No. 9. - pp. 28-32.
3. Shpeer F.Z., Panov V.I. Vibration treatment of large-sized structures to reduce deformation and tendency to crack formation // Welding production. - 1983. - No. 5. - pp. 13-15.
4. Dryga A.I. Flexible automated section with vibration complex for processing body parts // Machine tools and tools. - 1992. - No. 3. - pp. 2-3.
5. A. c. No. 637232 USSR. Method of reducing residual stresses in parts / V. G. Aleshinsky, V. N. Kiselev, V. D. Penenko, V. A. Skazhenik, M. L. Turevsky, D. Ya. Furman. Publ. 1978, Bull. No. 46.
6. Stepnov M.N. Statistical methods for processing the results of mechanical tests: Handbook. - M.: Mechanical Engineering, 1985. - 232 p.