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VIBRATION TREATMENT — EFFECTIVE METHOD OF IMPROVING THE DIMENSIONAL STABILITY OF WELDED STRUCTURES: INVESTIGATION AND PRACTICE

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The size of the fabricating structures is one of the most important parameters in the machine-building industry that defines their service properties. In structure fabrication by using joining, shaping and treatment the weldment acquires the shape predetermined by the dimensions. The stability of the dimensions attained during the weldment treatment, i.e. their preserving in the limits of deviations in the industrial process and service is necessary to realize the requirements to the structure properties.

As a result of the welding processes in a welded structure a complex state of preliminary stresses and complex structural transformations in the metal occur. These factors are a source of deformations which appear in the welding process, as well as after this process. The strain occurring after the welding process, called the delayed strain, can change in value over time and, it is possible that even after appropriate treatment the size or shape of the welded structures become changed. These are a number of causes of these changes. The delayed strain in a steel with an unstable structure, especially with a residual austenite content ccurs as a result of two phenomena: stress relaxation in creep and increase in volume due to the transformation of the residual austenite into martensite at the ambient temperature [I], The strains in low-carbon steels with stable structures take place as a result of relaxation [2]. In steels with a mean carbon content where the quenched structure occurs in the HAZ the martensite structure may appear, the strain can be caused by the relaxation of stresses, creep, as well as carbon diffusion and martensite net restructuring at room temperature. The restructuring consists of a transformation of the quenching martensite into tempering martensite by a change in the net tetragonality. This transformation is due to the change in specific volume and can be a source of strain after welding [3]. It is established that about 80% of the final strain appears in the first 60 days, while the other 20% appears over 9 months. It is considered that during the period that the delayed strain is occurring, i.e. in the period of natural ageing, the preliminary stresses should be decreased. The tests carried out indicate, however, that the link between the stability of the size, delayed strain and preliminary stresses is more complicated than it appears. The welded plate samples made of St3S steel were subjected to testing. The measuring bases were prepared on these plates to serve for the strain measurement. The strains were measured over 800 days. The plate samples during ageing were subjected to the thermal cycles akin to those which could be caused by changes in the weather. Figure 1 illustrates the delayed strains which were observed during testing. Figure 2 shows the distribution of preliminary stresses in the plates after ageing and the distribution of preliminary stresses determined in the same plates directly after welding. By comparing the preliminary stresses in both plates it is difficult to find clear differiencies which could indicate any stress reduction during the natural ageing. Thus, it can be stated that the delayed strains occurring as a result of relaxation will also influence the stabilization of the welded structure sizes without the preliminary stress reduction.

To increase the size stability the treatment is more often used after welding. Annealing to remove inner stress is a very effective procedure, but too energy-consuming. Attention should be paid to the cost of the heat treatment, in addition to the cost of energy, this also includes the furnace amortization and the high

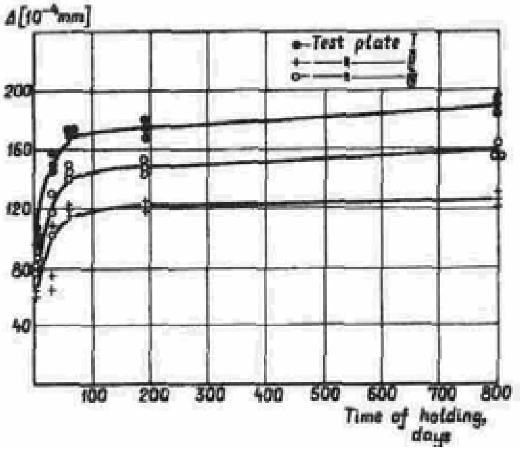

Figure 1 Curve of delayed strains in experimental plates subjected to a natural ageing.

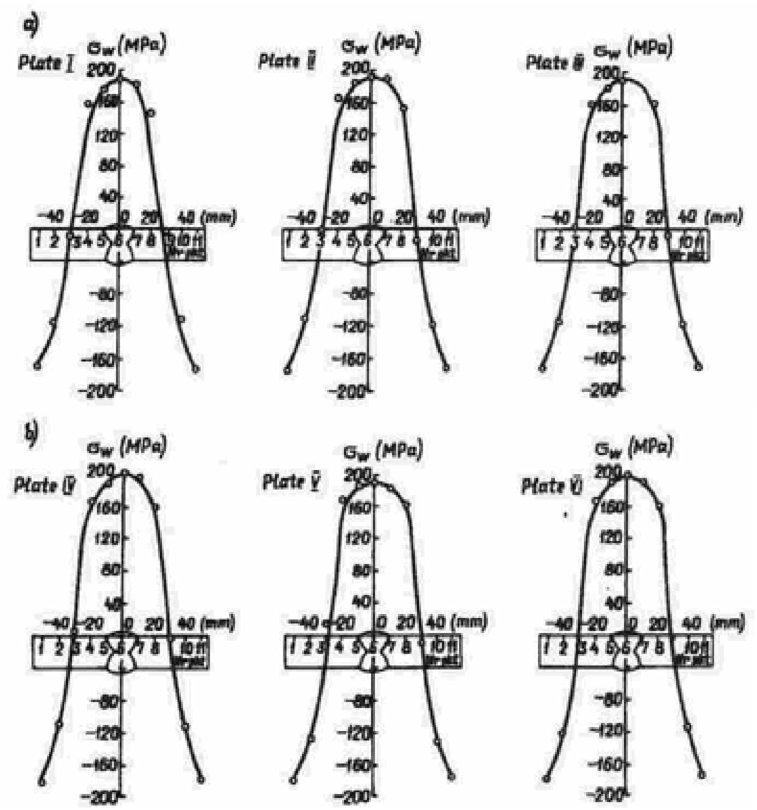

Figure 2 Distribution of preliminary stresses in experimental plates: (a) after natural ageing;
(b) after welding.

cost of transport when the heat treatment is applied in a cooperative. The elements after treatment should also be subjected to cleaning, shot or sand blasting, thus causing extra expenses. Natural ageing, due the time it takesy, is very rarely used.

Vibrations for reducing the preliminary stresses began to be used at the beginning of the 20th century in foundry production. At the beginning of the 1960s it began to be used not only in cast structures, but also in welded ones in industrialized countries, such as the USA, UK, West Germany and the USSR. A number of published articles show that during the loading of welded or hardfaced elements by negligible alternative forces of the order of 0.1-0.2 σ_y a considerable reduction in preliminary stresses is begun [4]. It follows from other literature sources that the reduction of the preliminary stresses occurs at higher alternative stresses of the order of 0.6 σ_Y .

At the Institute of Welding, tests were carried out to determine the effect of alternative stresses with a different amplitude on the preliminary stresses and the stability of sizes [2]. Experimental carbon steel plates with welds were subjected to alternative loads along the weld axis, thus causing stresses with a different amplitude (σ_{max} from 30 to 180 MPa at constant σ_{min}, = 15 MPa). After loading strain measurements were taken and the preliminary stress distribution was established. Figure 3 shows the results of the strain measurement. It follows from the figure that the strain is even occurred because of the action of small alternate forces. In turn it follows from the preliminary stress measurements that the reduction of these stresses takes place only after the alternate loading at $\sigma_{max} = 0.5\ \sigma_Y$. So, the following conclusion can be made: loading of a welded structure with a dynamic force, whose stress amplitude is within the limit of the material elasticity (up to 0.2 σ_y) will not influence the considerable reduction of the preliminary stresses. This loading causes negligible strains, as a result of which the stability of sizes is comparable to that obtained with natural ageing.

The above-mentioned conclusion was proved by the results of testing an experimental welded structure made of St3S steel (Figure 4) [2]. 12 mm diameter bearing balls, being the measuring base, were welded into the holes. Three samples were prepared for testing, one of them was subjected to the vibration stabilization, the second one was subjected to annealing to relieve the inner stresses at 650°C for two hours, while the third one remained in the

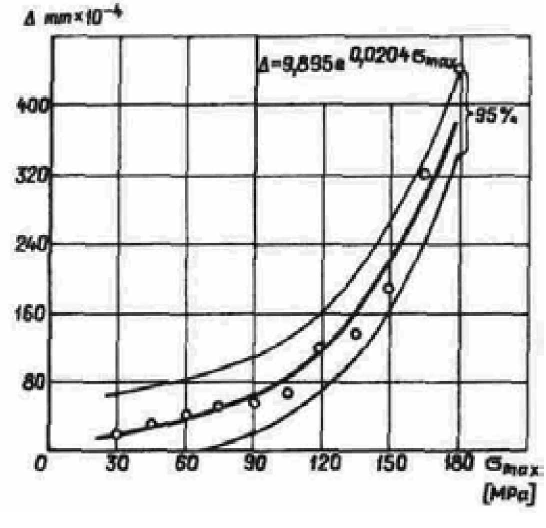

Figure 3 Curve of relationship between the strains and alternate stresses.

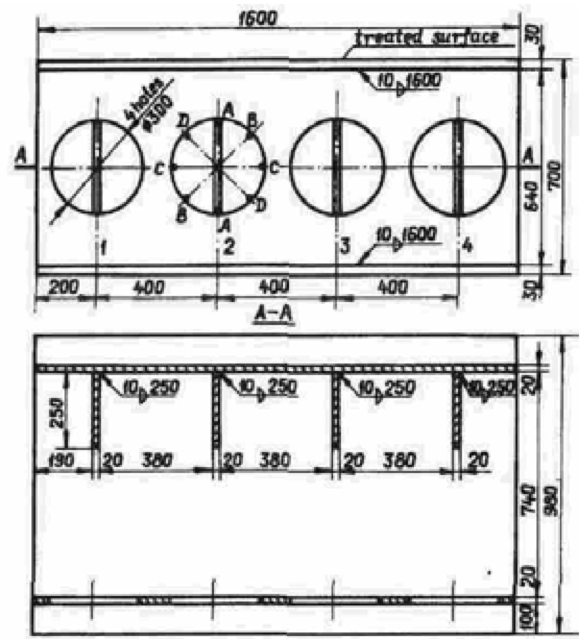

Figure 4 Shape and sizes of the experimental sample **for** testing the vibration stabilization effectiveness.

as-welded state without any additional treatment. During vibration of the experimental model of the structure the alternative stresses were measured using resistance strain gages. The strain gages were fixed in the upper girth, in its mid part. The highest stress amplitudes were observed in the middle of the girth and amounted to 36 MPa, which is considerably lower than the yield stress of St3S steel (σ_Y = 220 MPa).

All these three as-welded and extra-treated (by vibration stabilization and annealing) experimental samples were subjected to a mechanical treatment which consisted of a step-by-step milling of the upper girth surface in a gentry milling machine-tool. After each stage of milling the distances between the measuring bases which were arranged in the three experimental samples of the structure in all four holes was measured (Figure 4). The measurements in the bases were made with an internal micrometer with an accuracy 0.01 mm in the measurement direction A-A, B-B, C-C, D-D. Figure 5 shows the results of the diameter change after each stage of the cutting treatment.

The measure of the stability sizes was the variation in size and shape of the experimental sample after the cutting treatment. The variations in the distances

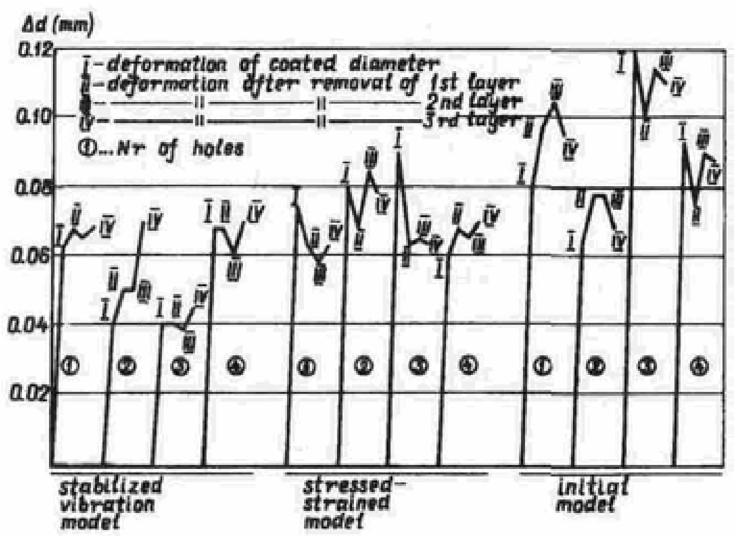

Figure 5 Curves of measuring hole diameters in experimental samples after successive phases
of cutting treatment.

between the measuring bases located in the holes met the requirements of the change in size, and so the degree of stabilization, though these holes after welding were not subjected to any treatment. It is seen in Figure 5 that in the experimental samples after vibration stabilization and annealing the size variation is considerably lower than in the as-welded sample.

It undoubtedly follows from the test results that the stabilization of the welded structure sizes can be achieved by loading it with small alternate forces. The delayed strains occurring after the welding process can be effectively relieved by vibration stabilization. Bringing structure into the state of vibration with its resonance frequency causes a reaction in the form of small strains in it. These strains could appear later in the form ofelayed strains if we did not apply vibration stabilization. For this reason, vibration stabilization is often called 'accelerated ageing'.

Vibration stabilization, as a technological process, has already found a place in world industry, as well as in Poland. Considering the above- described experiments and test results it can be stated that the process of vibration stabilization consists in 'provoking' strains by applying alternate loading induced by putting the structure into a state of vibration.

The tests are performed in special vibration machines. It consists of a vibrator with an electric motor and a recording-controlling system. Such machines are manufactured in Poland and elsewhere.

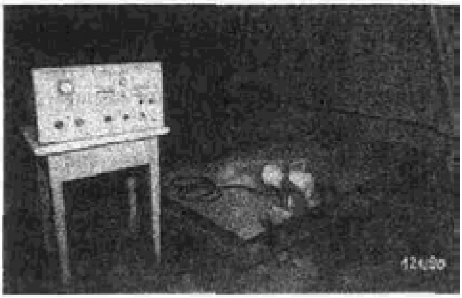

Figure 6 General view of the work station for vibration stabilization with a SW01 stabilizer.

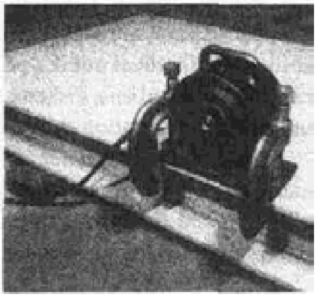

Figure 7 Motovibrator of the SW02 type vibration stabilizer.

In the mid 1980s the Institute of Welding in Gliwice developed, manufactured and used in industry the SW01 vibration stabilizer. This piece of equipment consisted of a control system and an eccentric vibrator with a d.c. electric motor. The motor rotation rate was controlled with the help of a thyristor d.c. converter, with a tachometric bridge and a loading current limiter (Figure 6). Installations of this type are now operating in 30 industrial enterprises.

At present the Institute of Welding has the type SW02A vibrator available. This is a new generation of installation with an automatic control system, a new drive system and vibrator (Figure 7). The driven a.c. unit (high current frequency converter) gives a high accuracy setting of the resonance frequency. In the automatic control system the amplitude measuring unit together with a sensor (Figure 8) is a feedback module. The process automatic control unit (ZASP) built-in into the control cabinet with a driven unit and amplitude measuring unit represents a recording-executing module which has a microcomputer, being also built-in into the control cabinet (Figure 9).

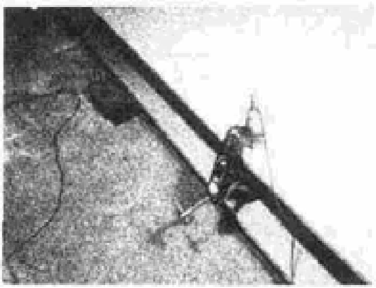

Figure 8 Amplitude sensor.

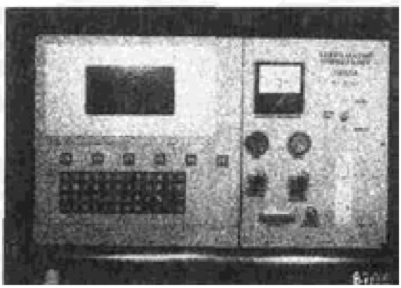

Figure 9 General view of the control cabinet of the SW02a type vibration stabilizer.

The process of vibration stabilization takes place in the following sequence: calibration, stabilization, control and recording of the results with ability to print them out if a printer is included in the work station. The results can also be saved on a diskette and then printed after the shift, for example, the process documentation in any PC with a printer.

Vibration stabilization is a low energy consuming process and finds increasingly wide application. The implementation of vibration stabilization in more than 30 enterprises in Poland proves that this method of treatment is an interesting technological process and attracts the attention of the industry.

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