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Fatigue Life Improvement of Welded Elements by Ultrasonic Peening

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ABSTRACT

The development of the Ultrasonic Peening (UP) technology was a logical continuation of the work done before directed on the investigation and further development of known techniques for surface plastic deformation such as shot peening, hammer peening, needle peening. The UP technique is based on the combined effect of the high frequency impacts of the special strikers and ultrasonic oscillations in treated material. The UP was applied successfully for the increasing of the fatigue life of parts and welded elements, eliminating of distortions caused by welding and other technological processes, residual stress relieving, increasing of the hardness of materials. The results of fatigue testing showed that UP is the most efficient technique for increasing the fatigue life of welded elements as compared to such existing improvement treatments as grinding, TIG-dressing, shot peening, hammer peening etc. The historical review, description of the technology and modern equipment for fatigue life improvement of welded elements by UP are presented in this document.

KEYWORDS: Ultrasonic peening, welded elements, fatigue, improvement treatments

1. Introduction.

Ultrasonic Peening of parts and welded elements is a comparatively recent and promising technology that has emerged from extensive development by engineers mostly from Ukrainian and Russian research institutes. The Ultrasonic Peening (UP) produces a number of beneficial effects in metals and alloys. Foremost among these is increasing the resistance of materials to surface-related failures, such as fatigue and stress corrosion cracking. One of the promising ways of industrial application of UP is the post-weld treatment of welded elements and structures. The results of fatigue testing showed that the UP is the most efficient and economical technique for fatigue life improvement of welded elements and structures as compared to the existing improvement treatments such as grinding, TIG-dressing, shot peening, hammer peening etc.

The development of the UP technology was a logical continuation of the work done before directed on the investigation and further development of known before techniques for surface plastic deformation such as shot peening and hammer peening [1]. During the different stages of its development the UP process was also known as "ultrasonic treatment", "ultrasonic impact technique/technology/treatment/peening".

The modern equipment for UP is based on known technical solutions of working heads for hammer peening known from 40's of last century. At that time and later a number of different multi-strikers working heads were developed for impact treatments of parts and welded elements by using mostly pneumatic driven equipment. In order to perform more effectively the improvement treatment of parts and welded elements by using pneumatic and other types of equipment, the special strikers made of high-strength materials are used. The effective impact treatment is provided when the strikers are not connected to the tip of actuator but are located between the actuator and treated material.

In parallel to the development of different impact techniques for surface treatment of materials and welds such as hammer peening and shot peening, the intensive R&D directed on using of high power ultrasound for the impact treatment of the materials, parts and welded elements were conducted mainly in USSR and USA at the second half of the last century. Only in former USSR there were more than ten independent research and scientific centers that worked in the above-mentioned field of activity. As a result of the efforts of these centers the different tools were developed based on using of ultrasonic impact technique for surface plastic deformation of materials and welded elements.

Until now, there is an intensive research and development activity in industrial application of high power ultrasonics worldwide. Significant number of publications and patents on application of ultrasound for improvement treatments of materials, parts, welded elements and structures are known. This document describes the historical aspect, technology and advanced equipment for fatigue life improvement of welded elements by UP.

2. Historical Review of Ultrasonic Peening

Intense levels of high frequency acoustic energy, or high power ultrasonics have found practical use in many industrial processes, of which cleaning, welding and drilling are well-known examples. Other applications include metal forming, treatment of molten metals, chemical processing, and even therapeutic and surgical uses in medicine. In most industrial applications, high power ultrasonics involves power levels of hundreds to thousands of watts, and ultrasonic systems operating in the frequency ranges from 15 kHz to 100 kHz. Typical amplitudes range from about 10 to 40 microns. Such ultrasonic system operating, for instance, at 20 kHz is creating a cyclic acceleration of around 40,000 g (force of gravity).

Much of the early research on high power ultrasonics was largely theoretical and concentrated on apparent changes to the material properties under the action of the ultrasonics. Blaha and Langenecker [2] strain tested monocrystalline metal samples immersed in tetrachloromethane irradiated with ultrasound over a wide frequency range up to 800 kHz. The ultrasound led to increased strain to fracture and increased ultimate tensile strength. Finding that ultrasonic energy was more effective than thermal energy, they suggested that ultrasound might be more readily absorbed at the dislocation sites that gave rise to plastic flow.

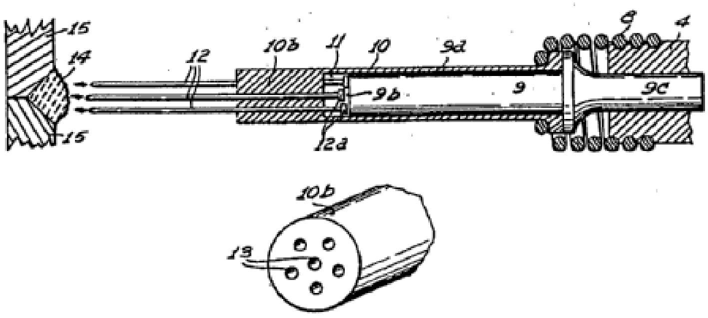
Nevill and Brotzen [3] suggested that a reduction in plastic flow stress under the action of ultrasound could be attributed simply to superposition of stresses from applied load and ultrasonic oscillations in material. Severdenko and Klubovich [4] suggested that the effect of that ultrasound was simply analogous to the effect of increased temperature, causing a reduction in the rate of work hardening. In early work on forging aluminum with ultrasound, they reported dramatic results, including reduction of forging force to zero, virtual elimination of "barrelling" and reversal of the residual stress distribution. It was suggested that these benefits were a result of reduced friction, elasto-plastic wave formation and thermal softening effects.

The possibility of using ultrasound for improving the service properties of welded structures was described in 1959 by A.V. Mordvintseva [5]. She analyzed the using of ultrasonic treatment for relieving of welding residual stresses.

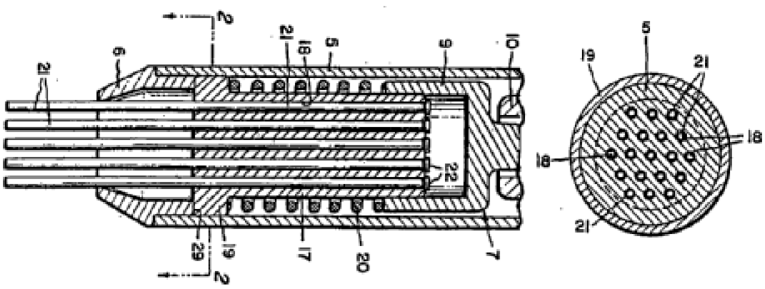
Initially in the equipment for ultrasonic treatment the deforming elements-strikers were attached to the tip of the ultrasonic transducer [6,7]. In this case the ultrasonic contact with the metal surface is provided by a whole instrument with the force of 100 - 500 N. Such ultrasonic systems could be used, for example, for finishing treatment of metal surfaces.

More effective surface deformation by using of the energy of ultrasound is achieved when the strikers are not connected with ultrasonic transducer but are located near the transformer's tip. The modern equipment for UP is based on known technical solutions of working heads for hammer peening known from 40's of last century. At that time and later a number of different multi-strikers working heads were developed for impact treatments of parts and welded elements by using mostly pneumatic driven equipment. The effective impact treatment is provided when the strikers are not connected to the tip of actuator but are located between the actuator and treated material [8,9]. The tools with the freely movable strikers (12 on Figure 1a and 21 on Figure 1b) mounted in holder for impact treatment of materials and welded elements are shown on Figure 1.

In 60's and 70's in former Soviet Union and USA the different types of ultrasonic equipment with so-called intermidiate element(s) were developed based on the idea of using of freely movable strikers for impact treatment [10-17]. For example, an ultrasonic tool (Figure 2) with the sphere as an intermidiate element – striker for improvement treatment of materials that is based on the combined effect of impacts and ultrasonic oscilations induced in treated material was decribed in 1970 [11]. In the case of so-called intermediate element-striker(s) the force of only 30 - 50 N is required for treatment of materials.



a)



b)

Figure 1. Sectional view through tools with freely movable strikers
(12 on Figure 1a and 21 on Figure 1b) for surface impact treatment:
a – described in [8],
b – described in [9].

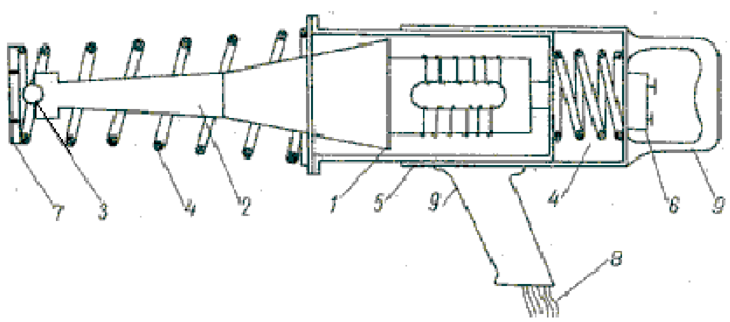


Figure 2. Ultrasonic tool with intermediate element (3) for treatment of materials [11]:
1 – magnetostrictive transducer, 2 – waveguide, 3 – intermediate element.

Some specific features of the ultrasonic impact treatment of metals are described in [13]. It is shown that the operational frequency of the transducer and the frequency of the intermediate element-striker are not the same (Figure 3). Also it is suggested that during such ultrasonic impact treatment the dinamic force replaces the static force that is characteristic to the other forms of energy normally used in metal working processes is described.

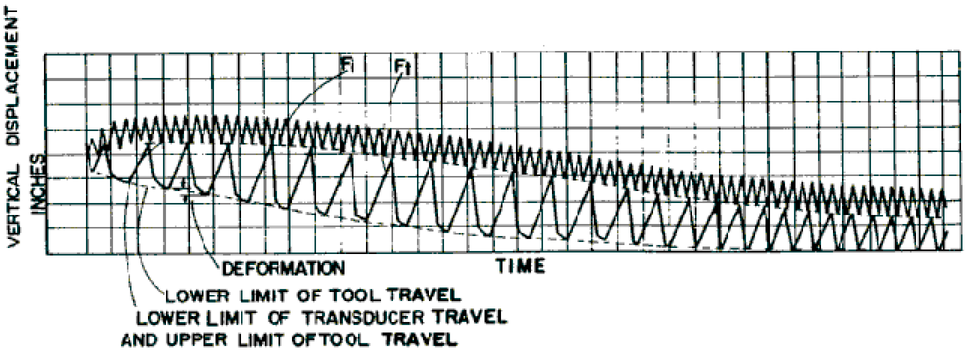


Figure 3. Graphical illustration of the ultrasonic impact technique showing the difference in the frequency of transducer and intermediate element motions [13].

At the end of 60's and beginning of 70's the intensive investigation into the influence of high power ultrasonics on the properties of materials and welded elements was initiated at the Institute for Metal Physics (Kiev, Ukraine) [15,17-20]. The intermediate element-striker was employed for surface strengthening and plastic deformation of materials. This striker oscillated in the gap between the end of the ultrasonic transducer and treated specimen. The changes in the mechanical properties of the materials and texture under the action of the ultrasonic treatment were analyzed [21,22]. The results of these studies initiated the development of the UP technology. Practically, at the same time the efficiency of the application of intermediate element during ultrasonic treatment for plastic deformation of materials was analyzed in the number of research centers in former USSR and USA [10-22].

At the very beginning of 70's the collaboration between the Paton Welding Institute (PWI) and the Institute for Metal Physics (IMP) in the application of high power ultrasonics and high frequency impacts for improvement treatment of welded elements and structures and relieving of welding residual stresses was started. The first results of this collaboration in the field of ultrasonic impact treatment of welded elements and structures were published in 1974 [15] and later [17, 22-26].

In 1982 the PWI intensifies its efforts in the development of the application of ultrasonic impact technology for increasing the fatigue life of welded elements and structures. For the first time the PWI proposed to use UP for treatment of only the transition zone from weld to base metal. The sphere as a striker was used for plastic deformation of weld toe creating the radius equals to the radius of sphere. This kind of UP treatment provided significant increase of the fatigue life of welded elements – from 15 to 20 times depending on the level of cyclic loading. The standard ultrasonic equipment USG-10 (power supply 10 kW) and vibrating sphere with the diameter 16 mm were used at that time for UP [27]. The formation of so-called "groove" in the weld toe zone for optimum fatigue life improvement of welded elements by UP was proposed by PWI [28,29].

Later, a number of industrial applications and other aspects of UP technology were developed at PWI. For example, the effectiveness of the UP application for the increase of the fatigue life of welded elements subjected to cyclic compression was analyzed by testing of large-scale welded elements of construction equipment as well as welded elements of bridges [28,30].

Beginning from 1983 the PWI started collaboration with the Northern Machine-Building Enterprise – SMP (Severodvinsk, Russia) in the development of ultrasonic treatment to increase the fatigue life of welded elements of high strength steel. The recommendations for the improvement treatment of welded elements made of high strength steel by UP were developed in the frame of this collaboration. The different aspects of the UP technology were developed and patented by PWI jointly with the SMP and GNPP "Kvant" (Severodvinsk, Russia) [31-34].

A comparison of the efficiency of UP of welded elements made from aluminum alloys by using magnetostrictive and peizoceramic ultrasonic transducers was performed at the PWI. The influence of different parameters of UP on the fatigue life of welded elements were analyzed. Better results for fatigue life improvement were received when the piezo-ceramic transducer with power consumption of 0,3 kW was used for UP [35]. The role of decreasing the stress concentration during the UP treatment on the fatigue strength of welded elements was also evaluated [36]. Based on the analysis of changes of the residual stresses, stress concentration and mechanical properties of the surface layers under the action of UP treatment, a predictive model was developed for evaluation of the effectiveness of UP without the need for costly fatigue testing of large-scale welded specimens [1,37]. One of the advantages of the developed predictive model is the possibility to optimize the parameters of UP treatment to increase the fatigue life of welded elements.

Starting from 1987 the results on the development of the UP technology were presented by PWI in some East European countries [38,39] and later to Western scientific and engineering communities [40-45].

The results of the development of the UP technology and fatigue assessment of welded specimens after application of the UP were presented for the first time in 1993 at the International Institute of Welding (IIW) by PWI scientists [46]. Later, additional results on the development of the UP technology and fatigue testing of welded specimens, specification for weld toe improvement by UP as well as the results on verification of the efficiency of the UP technology conducted in the frame of IIW test program were presented with participation of the PWI [47-50].

Presently, intensive research and development activity in industrial application of high power ultrasonics and particularly ultrasonic impact technique is under way in Ukraine, Russia, Canada, USA and China [51-58]. During such activity the principles of optimum UP application and corresponding software were developed. The technology and equipment for UP were adapted for different industrial applications. The Computerized Complex for UP of materials, parts and welded elements was developed recently based on using of the high efficient optimized piezoelectric transducers. The complex consists of the compact ultrasonic transducer, generator and laptop with expert system for UP optimum application: maximum possible increase in fatigue life of welded elements with minimum cost, labor and power consumption [59,60].

3. Technology, Eqipment and Software for Ultrasonic Peening

3.1. Technology

The surface plastic deformation is widely used as an effective method of strengthening of parts and welded elements. During plastic deformation of surface layers the density of defects is increased and compressive macroscopic stresses are formed. As a result, engineering properties of materials, parts and welded structures could be improved drastically. Different improvement treatments and techniques such as shot peening, hammer peening, laser shock processing, etc. are applied for this purpose.

One of the promising techniques for surface plastic deformation is the Ultrasonic Peening (UP) of materials, parts and welded elements. The UP technique is based on the combined effect of the high frequency impacts of the special strikers and ultrasonic oscillation in treated material.

High frequency of impacts is one of the main differences and advantages of UP technology. The optimized equipment for UP consumes only 0,2 - 0,4 kW of the electric power. At the same time the quality of UP treatment allows providing the highest fatigue characteristics of welded elements in comparison with the application of known improvement treatments.

The ultrasonic transducer oscillates at a high frequency, with 20-30 kHz being typical. As was described earlier, the transducer may be based on either piezoelectric or magnetostrictive technology (Figure 4). Whichever technology is used, the output end of the transducer will be oscillating, typically at an amplitude of 20 – 40 µm. During the oscillations, the transducer tip will impact the striker at different stages in the oscillation cycle.

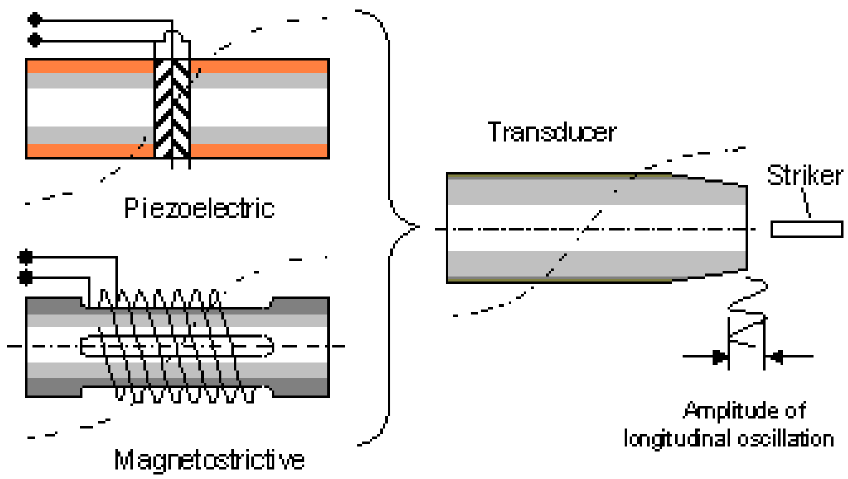


Figure 4. Schematic view of transducer for Ultrasonic Peening

A single striker arrangement is shown in Figure 4. In reality the different number of strikers are used for different industrial application. A few types of working heads with different number of strikers are used typically [60]:

- a single-row head with 3-5 strikers that is applied, for example, for treatment of weld toe zones,
- a head with one striker that is generally applied for treatment of difficult-to-access surfaces such as crossing welds etc,
- head with 7 or more strikers, which is mainly applied for treatment of planar surfaces or surfaces with a large radius of a curve.

The striker(s) impacts the treated surface. The impact results in plastic deformation of the surface layers of the material. These high stress impacts, repeated hundreds to thousands of times per second, results in the ultrasonic peening effect of this technique. The plastic deformation during UP is more intensive than under the action of traditional surface treatment processes [61]. The surface roughness is reduced and the wear resistance is increased as a result of the action of UP.

The UP is very effective for relieving of harmful tensile residual stresses and introducing of the beneficial compressive residual stresses in surface layer of parts and welded elements. The mechanism of residual stresses redistribution is connected mainly with two factors. At a high-frequency impact loading the oscillation with complex frequency mode spectrum propagates in a treated element. The nature of this spectrum depends on the frequency of ultrasonic transducer, mass, quantity and form of impact units (spheres, rods etc.), and also on the geometry of the treated element. These oscillations lead to lowering of residual welding stresses. The second and the more important factor, at least for fatigue improvement, is surface plastic deformation, which leads to introducing of the beneficial compressive residual stresses.

The features of high-frequency impact deformation explain the high efficiency of UP application for fatigue life improvement. A reological model explaining effect of essential lowering of the deforming force in high-frequency impact loading was developed [61]. It is known, that at the impulse loading even with the level of stresses lower than the yield strength, the inelastic behavior of material - mechanical hysteresis is observed. If the time of relaxation process exceeds the gap between two subsequent impacts, the mechanical system is in non-equilibrium state and each subsequent impact results in accumulation of deformation.

It was shown experimentally that in repeated static loading the size of the plastic impressions from a sphere does not practically change after first loading. If the sphere vibrates with high frequency, the impression grows during repeated impacts up to a certain extent. The dependence of accumulation of a plastic deformation depending on the frequency of impacts could be analyzed by using the developed reological model [62].

During the UP process the strikers oscillate creating a small gap (~ 0.01 - 0,1 mm) between the ultrasonic transducer, striker and the treated material. These oscillations have an aperiodic character with the frequency lower than the frequency of ultrasonic transducer. It was found, that at different oscillation amplitudes there is an optimum gap at which the highest plastic deformation is observed. The deforming element(s) oscillates with lower frequency than the tip of ultrasonic transducer alternately hitting the tip of transformer and treated surface. The generation of the intensive quazi-resonance vibrations of the striker(s) in the gap between the ultrasonic transducer tip and treated material is a specific feature of UP process.

In the fatigue improvement the beneficial effect is achieved mainly by introducing of the compressive residual stresses into surface layers of metals and alloys, decrease in stress concentration of weld toe zones and the enhancement of the mechanical properties of the surface layer of the material. The schematic view of the cross section of material/part improved by UP is shown on Figure 5. The description of the UP benefits is presented in Table 1.

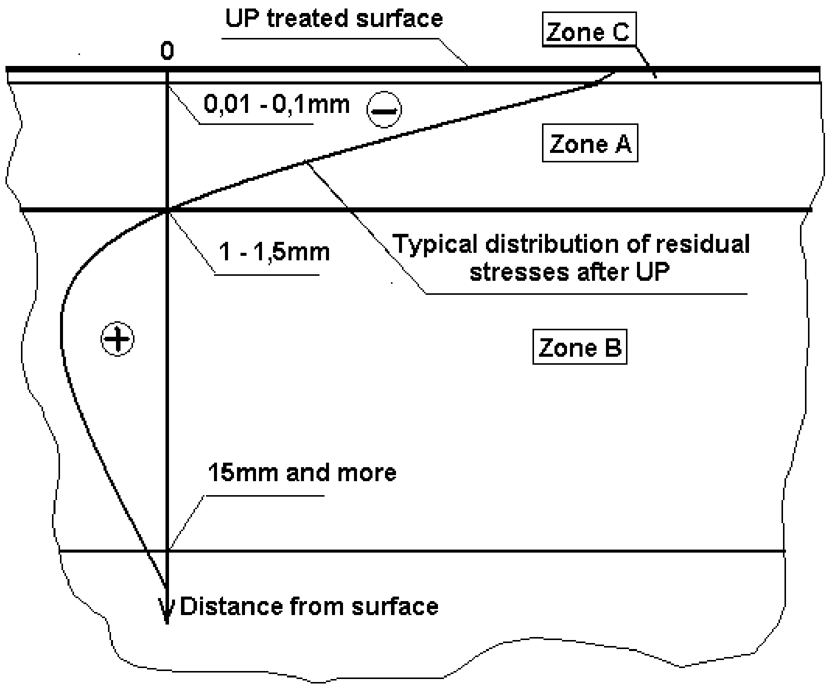


Figure 5. Schematic view of the cross section of material/part improved by Ultrasonic Peening

Table 1. Zones of Material/Part Improved by Ultrasonic Peening

Zone	Description of zone	Penetration (distance from surface), mm	Improved characteristics
A	Zone of plastic deformation and compressive residual stresses	1 –1,5 mm	Fatigue, corrosion, wear, distortion
B	Zone of relaxation of welding residual stresses	15 mm and more	Distortion, crack propagation
C	Zone of nanocrystallization (could be produced at certain conditions)	0,01 – 0,1 mm	Corrosion, wear, fatigue at elevated temperature

Figures 6 and 7 show the concept of the fatigue life improvement of welded elements by UP. In case of welded elements, it is enough to treat only the weld toe zone – the zone of transition from base metal to the weld, for a significant increase of fatigue life. The so-called groove characterized by certain geometrical parameters is produced by UP [28, 29].

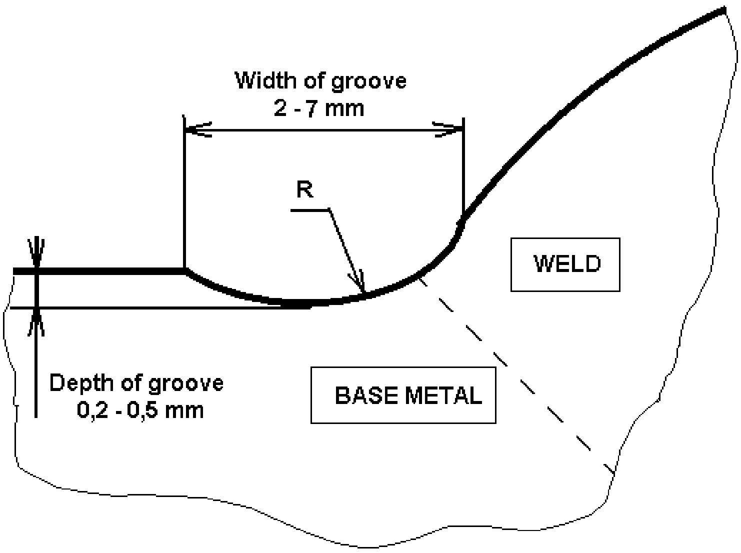


Figure 6. Profile of weld toe improved by Ultrasonic Peening

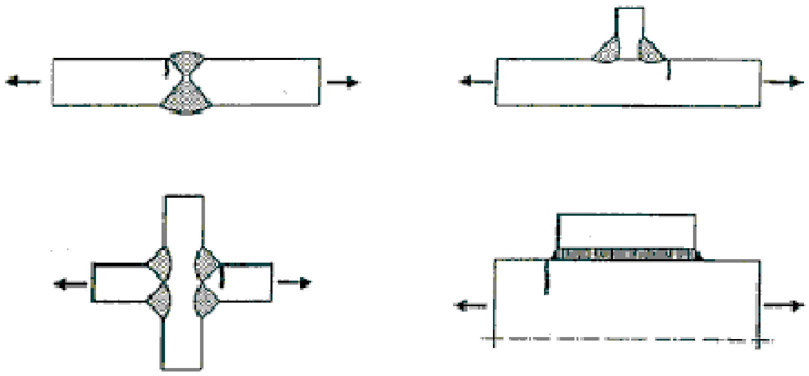


Figure 7. Examples of welded elements suitable for fatigue improvement
in accordance with IIW Doc. XIII-1815-00 [63]

3.2. Equipment for Ultrasonic Peening

There are two general types of ultrasonic transducers which can be used for UP: magnetostrictive and piezoelectric. Both accomplish the same task of converting alternating electrical energy to oscillating mechanical energy but do it in a different way (Figue 4). In magnetostrictive transducer the alternating electrical energy from the ultrasonic generator is first converted into an alternating magnetic field through the use of a wire coil. The alternating magnetic field is then used to induce mechanical vibrations at the ultrasonic frequency in resonant strips of magnetostrictive material.

Magnetostrictive transducers are generally less efficient than the piezoelectric ones. This is due primarily to the fact that the magnetostrictive transducer requires a dual energy conversion from electrical to magnetic and then from magnetic to mechanical. Some efficiency is lost in each conversion. Magnetic hysteresis effects also detract from the efficiency of the magnetostrictive transducer. In addition, the magnetostrictive transducer for UP needs forced water-cooling. The equipment in this case is relatively heavy and expensive.

Piezoelectric transducers convert the alternating electrical energy directly to mechanical energy through the piezoelectric effect. Today's piezoelectric transducers incorporate stronger, more efficient and highly stable ceramic piezoelectric materials, which can operate under the temperature and stress condition. Piezoelectric transducers are reliable today and can reduce the energy costs for operation by as much as 60%.

Due to the high energy efficiency of peiezoelectric treansdusers the effect in fatigue life improvement by UP is practically the same by using of the magnetostrictive transducer with power consumption of 1000 Watts and peiezoceramic treansdusers with power consumption of only 250 Watts (Figure 8).

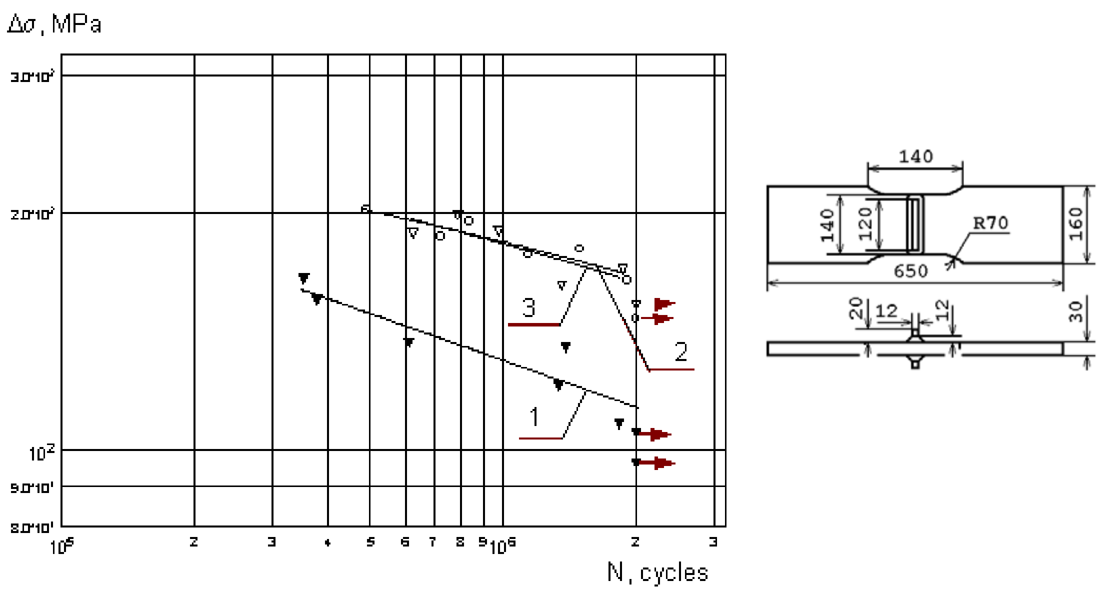
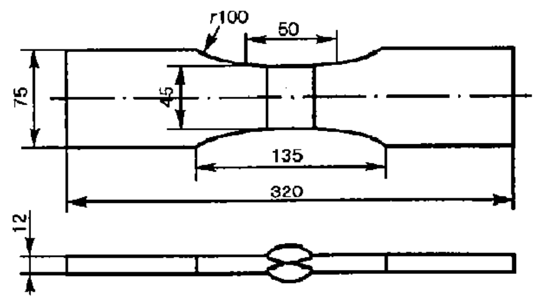


Figure 8. Fatigue curves of non-load carrying fillet welded joint (steel) :
1 - in as-welded condition;
2 and 3 - after application of UP by using magnetostrictive transducer (P = 1 kW) and piezoelectric transducer (P = 0,25 kW)

The fatigue testing of aluminium welded specimens in as-welded condition and after UP demonstrated that using the ultrasonic equipment based on piezoelectric transducer

(P = 0,25 kW) showed even higher increase in fatigue strength in comparison with the application of magnetostrictive transducer (P = 1 kW) (Figure 9).



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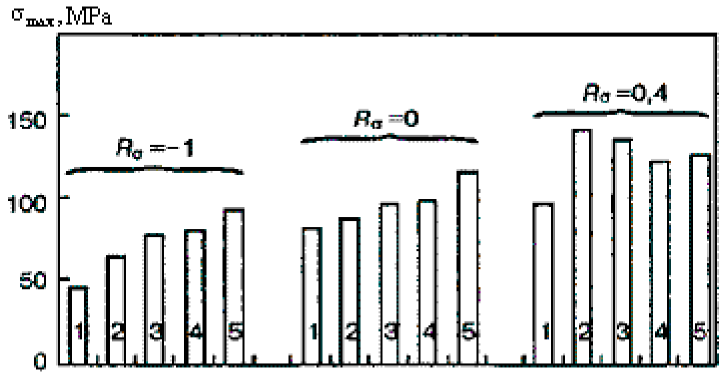

b)

Figure 9. Sketch of the aluminium welded specimen (a) and a comparison of the limit maximum stresses σ_{max} at N = 10^6 cycles at stress ratio R = -1, 0 and 0.4 (b) [35]:
1 – in as-welded condition, 2 – after grinding
3 and 5 – after application of UP by using piezoelectric transducer (P = 0,25 kW)
4 – after application of UP by using magnetostrictive transducer (P = 1 kW)

A Computerized Complex for UP treatment of materials, parts and welded elements was developed recently based on on highly efficient and reliable piezoelectric transducers. The Complex consists of a compact ultrasonic transducer, generator and a laptop with Expert System for UP optimum application (Fig. 10).

The new optimized UP system (total weight - 6 kg) includes:

1. The hand tool which is based on a piezoelectric transducer. Weight of the tool is ~3 kg and it is convenient for use. A number of working head types were designed for different industrial application.
2. Ultrasonic generator. Weight of the generator is ~ 2 kg with power consumption of only 250 watts. Output frequency ~ 22 kHz.
3. Laptop with software package for Optimum Application of Ultrasonic Peening designed for maximum possible increase in fatigue life of welded elements with minimum cost, labour and power consumption. The software was developed based on original predictive model.

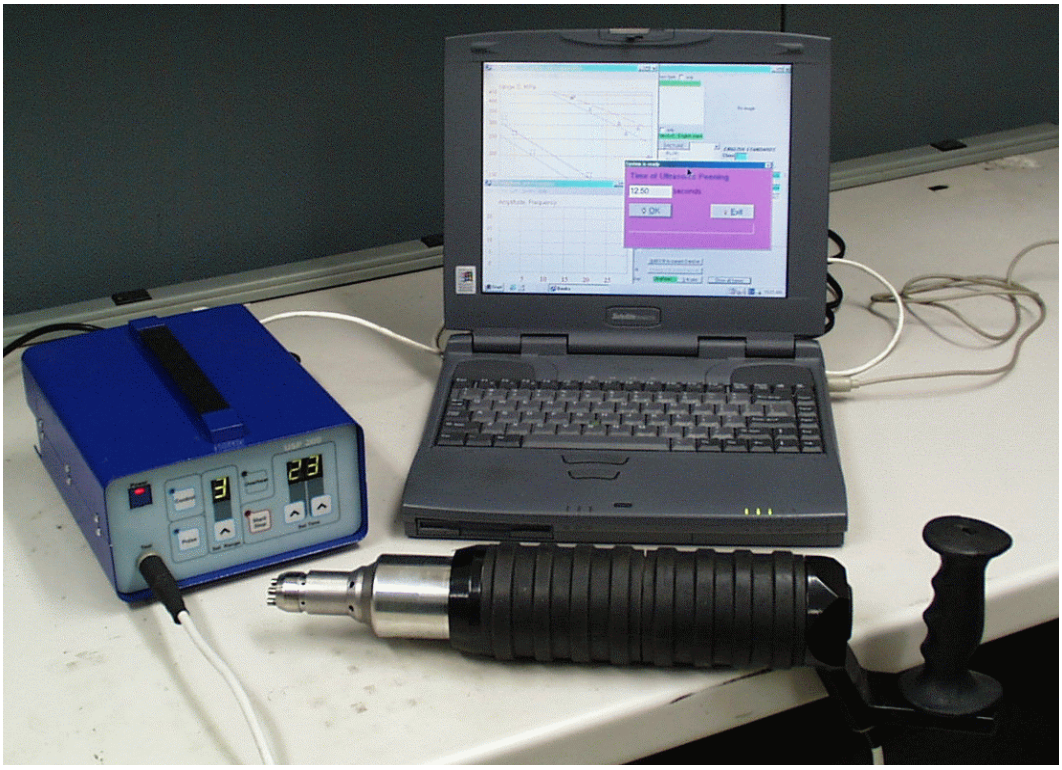

Figure 10. Computerized Complex for Ultrasonic Peening of parts and welded elements

3.3. Software for Optimum UP Application

The effects of improvement treatments, particularly UP, on the fatigue life of welded elements depend greatly on the level of induced residual stresses, mechanical properties of used material, the type of welded joints, parameters of cyclic loading and other factors. Presently, elaborate, time- and labor-consuming fatigue tests of large-scale specimens are required for this type of analysis.

For the effective application of UP, depending on the above-mentioned factors, a software package for Optimum Application of Ultrasonic Peening was developed that is based on an original predictive model. In the optimum application, a maximum possible increase in fatigue life of welded elements with minimum labor- and power-consumption is thought. The main functions of the developed software are:

- Determination of the maximum possible increase in fatigue life of welded elements by UP, depending on the mechanical properties of used material, the type of welded element, the parameters of cyclic loading and other factors;

- Determination of the optimum technological parameters of UP (maximum possible effect with minimum labor- and power-consumption) for every considered welded element;

- Quality monitoring of UP process;

- Final fatigue assessment of welded elements or structures after UP, based on detailed inspection of UP treated zones and computation.

The developed software allows assessing, through calculations, the influence of residual stress redistribution by UP on the service life of welded elements without having to perform the time- and labor-consuming fatigue tests and comparing the results of calculations with the effectiveness of other improvement treatments such as heat-treatment, vibration treatment, overloading etc.

The results of computation presented in Figure 11 show the effect of application of UP to increase the fatigue life of welded joints in steels of different strength. The data of fatigue testing of non-load-carrying fillet weld specimens in as-welded condition (with high tensile residual stresses) were used as initial fatigue data for calculating the effect of the UP. These results are in agreement with the existing statement that the fatigue strength of certain welded element in steels of different strength in as-welded condition is represented by a unique fatigue curve [1,64].

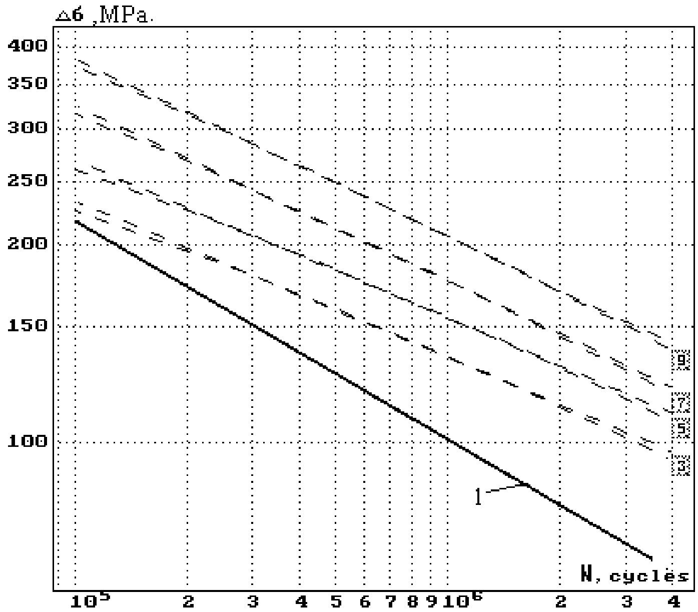

Figure 11. Fatigue curves of non-load-carrying fillet welded joint:
1 - in as-welded condition for all types of steel; 3, 5, 7 and 9 - after application of the UP to Steel 1,Steel 2, Steel 3, and Steel 4

Four types of steels were considered for fatigue analysis: Steel 1 - (σ_y = 270 MPa, σ_u = 410 MPa); Steel 2 - (σ_y = 370 MPa, σ_u = 470 MPa); Steel 3 - (σ_y = 615 MPa, σ_u = 747 MPa) and Steel 4 - (σ_y = 864 MPa, σ_u = 897 MPa). Line 1 in Figure 11 is the unique fatigue curve of considered welded joint for all types of steel in as-welded condition, determined experimentally. Lines 3, 5, 7 and 9 are the calculated fatigue curves for the welded joint after application of the UP to Steel 1, Steel 2, Steel 3 and Steel 4, respectively.

As can be seen from Figure 11, the higher the mechanical properties of the material - the higher the fatigue strength of welded joints after application of the UP. The increase in the limit stress range at $N=2\times10^6$ cycles under the influence of UP for welded joint in Steel 1 is 42%, for Steel 2 - 64%, for Steel 3 - 83% and for Steel 4 - 112%. These results show a strong tendency of increasing the fatigue strength of welded connections after application of UP with the increase in mechanical properties of the material used. In cases of high strength steels, the application of UP caused a two-fold increase in the limit stress range and over 10 times increase in the fatigue life of the welded elements.

Summary

1. One of the promising directions in using of the high power ultrasonics for industrial applications is the Ultrasonic Peening (UP) of materials, parts and welded elements. The UP technique is based on the combined effect of the high frequency impacts of the special strikers and ultrasonic oscillations in treated material. The unique mechanism of UP and developed compact equipment provide the highest increase in fatigue life of welded elements as compared with the application of existing improvement treatments such as grinding, TIG-dressing, shot peening, hammer peening.

2. An advanced computerized complex for UP of parts and welded elements based on piezoelectric transducer was developed recently. The complex consists of a compact ultrasonic transducer, an ultrasonic generator and a laptop with the Expert System for UP optimum application: maximum possible increase in fatigue life of welded elements with minimum time, cost, labor and power consumption.

3. The UP relieves harmful tensile residual stresses and induces beneficial compressive residual stresses to a depth of 1.0 -1.5 mm (depth of the zone of plastic deformation and compressive residual stresses).

4. The developed software allows analyzing with sufficient for practical purpose accuracy the effects of Ultrasonic Peening on the fatigue life of welded elements, depending on the level of residual stresses, mechanical properties of material used, type of joint and parameters of cyclic loading.

5. The developed computerized complex for UP could be used in different applications for increasing of the fatigue life of parts and welded elementsr, elimination of distortions caused by welding and other technological processes, residual stress relieving, increasing of the hardness of the materials and surface nanocrystallization.

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