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Research Article

Fatigue analysis of Welded Joint with and without Shot Peening

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Abstract

This paper summarizes fatigue test on high strength steel specimens in the as-welded condition and specimens treated by Shot peening. Results indicate that material strength has effect, to a certain extent, on the fatigue performance of Shot peening welded joints. High tensile weld residual stress is one important factor contributing to fatigue crack development even under reversal or compressive cyclic loadings. A compressive stress induced by Shot peening is beneficial by eliminating the tensile residual stresses and generating compressive residual stresses, which improves fatigue strength of welded structures. Internal stresses were investigated on five base metal samples treated by shot peening. The induced compressive residual stresses benefit to increase the threshold value of stress intensity factor range, for fatigue crack initiation and early propagation. Shot peening was successfully applied for increasing the fatigue life and corrosion resistance of welded elements, elimination of distortions caused by welding and other technological processes, residual stress relieving, increasing of the hardness of the surface of materials. Shot peening could be effectively applied for fatigue life improvement during manufacturing, rehabilitation and repair of welded elements and structures. It is shown that Shot peening is the most effective and economic technique for increasing of fatigue strength of welded elements in materials of different strength.

Keywords: *Fatigue analysis, shot peening, welded joint analysis, Residual Stresses, Fatigue Failure, Axial Loading.*

Introduction

Fatigue fracture is the main failure type of welded structures, and the fatigue strength is primarily decided by welded joints. One remarkable characteristic of as-welded joints is that the fatigue strength is almost independent of the material strength, which results in the impossibility of using higher strength steel to meet the requirements of high dynamic load projects. At present, all the fatigue design criteria of welded joints are established based on this point. Besides, there are two other principles: as for as welded joints, stress range is used as the design load because the high welding residual stress makes the average stress load (characterized by stress ratio R) have no effect on fatigue performance; all the slopes of fatigue design S–N curves for steel and aluminum welded joints are recommended as 3.0 by IIW.

Until now, fatigue designs of welded structures treated by kinds of post-weld improvement techniques, such as hammer, TIG dressing and ultrasonic peening treatment (UPT), are consistent with the above principles. However, large numbers of fatigue tests indicate that after improving treatments, fatigue performances of welded joints are quite different from the as-welded ones, especially for those treatments that can eliminate tensile residual stress and induce compressive residual stress. In this project, fatigue design differences between as-welded joints and Shot peening joints are discussed based on numbers of testing results, and some suggestions are given.

Fatigue resistance of welded joints, defined as a function of detail type and stress range in most of the current structural codes, can affect the serviceability limit state and prevent effective utilization of high performance steels. Post-weld enhancement of the fatigue resistance of common attachment details such as transverse stiffeners, cover plates, gusset plates, bulkheads and other welded details that experience crack growth from a weld toe and have their resistance defined by Categories C, D, E or E_s is therefore essential for efficient use of both magnetic and non-magnetic steels. Enhancing fatigue resistance of welded joints by conventional improvement techniques such as grinding, shot peening, air hammer peening, tungsten inert gas (TIG) arc remelting and welding consumables, that involve plastic deformation of the surface and/or improvement of weld toe characteristics, is well established. However, these procedures are manpower intensive, not always efficient and less environment friendly.

The presence of high tensile weld residual stress is an important factor contributing to fatigue crack

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development even under reversal or compressive cyclic loadings. This may cause fatigue failure earlier than non-pre stressed materials. A compressive stress induced by post weld treatment may be beneficial by eliminating the tensile residual stresses and introducing compression residual stresses which improve fatigue strength of welded structures. Stresses in a welded structure are a combination of applied stress due to load and the locked-in weld residual stresses which are independent of the load. When the applied stress is superimposed on the residual stress at a point in the material, the tensile component of the internal stress (internal stress = ϭapplied + ϭresidual) will contribute to fatigue crack development and is defined as effective stress range, sr,eff. The stress ratio, R, is defined as the ratio of the minimum internal stress to the maximum internal stress and is normally different from the externally applied stress ratio, Rapplied. High tensile residual stress makes the entire applied stress reversal cycles contribute to fatigue. Most fatigue design codes for steel structures are based on full-scale fatigue test data of as-welded details where high residual stresses exist.

Fatigue design S–N curves are categorized as a function of the welded detail type and the applied stress range regardless of the type of cyclic stress and strength of the steel materials. When compressive residual stress is induced by post treatment, tensile weld residual stress and applied tensile stresses may be eliminated or partially reduced. The beneficial effect by post-weld treatment is more significant when applied stress amplitude is smaller and less effective when applied stress amplitude is greater. However, tensile residual stresses remain due to the heat produced in the treatment operation. Peening techniques can both improve the weld toe profile and induce beneficial compressive stresses at weld toes. Post-weld treatments have been used for in-service bridge structures to repair slightly cracked welded details and to retrofit the details without detectable cracks by improving weld toe conditions and improving the fatigue strength. Post-weld treatment is not often used for new structures because of fabrication cost and the ability to design fatigue resistant details.

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.

Literature Review

Henri-Paul Lieurade, Cetim, Senlis, France, fatigue improvement of welded components by shot peening, as we know that Cold laps, undercuts (even when shallow), beads that are too convex and incomplete penetration all lead to the creation and subsequent propagation of fatigue cracks whose initiation phase can be very short and even non-existent. After shot peening the transversal gradients shows that the greatest compressive residual stresses are observed in the weld seam. The analysis concerns the four improvement techniques which have given rise to the greatest number of studies: burr grinding, TIG dressing, hammer peening ad shot peening. ln this study, different parameters have been analysed such as the type and thickness of the welded joint, the yield strength 230 <ϭy <800 MPa) and the stress ratio R (-1 < R <0.5). That is the case with high ALMEN intensities, which are obtained with large shot. So far shot peening of welded joints must meet two requirements 1.maximum affected depth by doing a large ALMEN intensity. 2.Treatment of all the defects by using small shot. An improvement from 50 to 150 % is found, with respect of the initial quality of the welded joint. An undesirable residual stress relaxation can appear only for high stress ratio or high stress peaks in compression. The application of load sequences, even with R = -1 emphasizes the large improvement induced by shot peening.

Arshad Mehmood and M. M. I. Hammouda, Effect of shot peening on the fatigue life of 2024 aluminum alloy, In this experimental study of the effect of shot peening parameters such as shot size, nozzle pressure, nozzle distance, impingement angle and exposure time on high strength aluminium alloy ASTM 2024 mostly used in air craft industries for cyclic loading applications has been presented. The effect of shot peening on fatigue life of the 2024 Aluminium alloy was studied under constant amplitude loading condition .The results showed that shot peening can be applied to increase the fatigue life of the aluminium alloy under optimum conditions otherwise we may not get the appropriate results and even it may cause adverse effects. Higher intensities can be obtained at lower pressure for large size shots. Nozzle angle had the greatest effect on intensity. Changes in nozzle/impingement angles have a pronounced effect at low angles and very little effect at angles greater than 55º for small shots and 65º for large diameter shots. Larger size shots produce more residual stresses in the surface layers of the specimen as compared to smaller size shots and smaller shots are more effective than the larger shots. Optimum value of the peening intensity exists between 8A to 13A for aluminum alloys.

Uros Zupanc, Janez Grum, Surface integrity of shot peened aluminium alloy 7075-T651, The paper describes the effects of SP treatment by presenting analyses of surface roughness measurement, microhardness profiles, microstructure changes, residual stresses and material bending fatigue resistance. The fatigue limit of the SP-treated specimens increased to 218 MPa at 107 cycles. The experimental data confirmed an increase of fatigue strength after SP treatment due to the compressive residual stress ability to influence fatigue crack nucleation. Based on the study of the influence of the SP treatment they have given following conclusion after SP treatment the increase of surface roughness should be expected. Possible surface cracks and SP medium residual introduced into the surface may occur and represent a potential risk of fatigue crack initiation under dynamic loads. a favorable influence of SP treatment on material increased fatigue resistance was found. SP treatment nearly doubled the cycles to failure at the higher applied stresses when compared to the untreated specimens. The fatigue limit of the SP-treated specimens increased to 218 MPa at 107 cycles.

P. S. Prevéy, J.T. Cammett, The effect of shot peening coverage on residual stress, cold work and fatigue in a Ni-Cr-Mo low alloy steel, Significant surface and near surface compressive residual stresses were associated with the low stress ground condition. Hence, fatigue life for this condition was intermediate between lives for peened specimens and the electro-polished specimen, which had no residual stresses. The results suggest further that, for R > 0 loading, the full benefit from peening can be realized at less than 100% coverage, although the limited number of initial tests did not permit assessment of an optimum coverage level, if any. Full S-N curves for a range of coverage were prepared to test the unexpected finding of uniform fatigue strength, independent of coverage. The compressive surface then yields in the first few cycles of testing resulting in rapid relaxation of the compressive surface layer. Residual stress measurements on failed samples in the current work showed no significant change in surface compression after 130 and 220 x 103 cycles at R = 0.1 and Smax of 1240 MPA (180 ksi) for either the 100% or 20% coverage samples, respectively. Most of the prior studies of the effect of coverage on fatigue have employed fully reversed bending (R = -1) fatigue tests. It is well known that fully reversed bending of the highly compressive shot peened surface can drive the surface beyond yield in compression, causing rapid loss of compression in the initial cycles of the test. The observed fatigue improvement with increased coverage may be due to increasing yield strength with work hardening of the surface with higher coverage.

J A Akbar, S kyriacou, M El-Zafrany, Effect of shot peening on the fatigue life of auxially loaded notched component , this investigation examines the effect shot peening upon the fatigue life of notched laboratory samples subjected to axial cyclic loading. The test involved assessing the fatigue life of the material in the as- machined and peened conditions at room temperature. The experimental data provides strong evidence of the beneficial effect of the shot peening treatment upon the fatigue life of component subjected to tension- tension loading. The extend of life improvement has been found to be a function of the stress concentration factor. The beneficial effect of the process is greater at long fatigue lives than at short fatigue lives, and further the beneficial effect of peening are far greater on notched parts with high stress concentration than on parts with lower stress concentration. This improvement was achieved by giving a light edge finish at the notch corners before the peening treatment in order to eliminate the chipping of the edge, which was identified to be responsible for premature failures. Evidently, the shot peening has produced repeatable result indicating improvement in the fatigue life over the range of loads and geometric configurations utilized.

CAD Model

CADD software, or environments, provides the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CATIA V5 is mainly used for detailed engineering of 3D models and/or 2D drawings of physical components, but it is also used throughout the engineering process from conceptual design and layout of products.

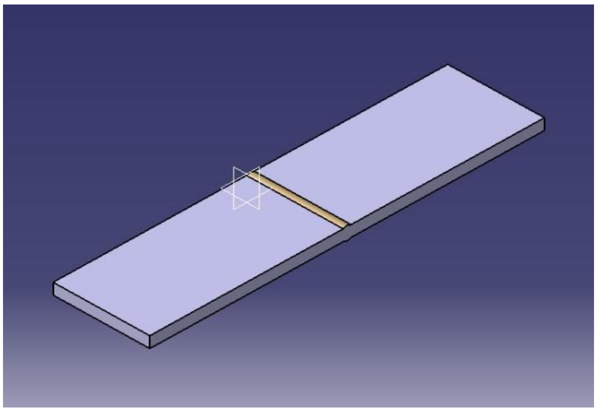

Fig. 1 Isomeric View of Welded Plates (CATIA V5)

Meshing

A structure or component consists of infinite number of particles or points hence they must be divided in to some finite number of parts.

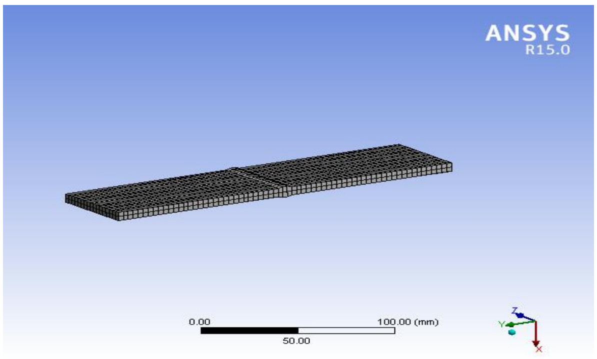

Fig 2 Hexahedral Meshing on Welded Plates

In meshing we divide these components into finite numbers. Dividing helps us to carry out calculations on the meshed part. We divide the component by nodes and elements. We are going to mesh the components using 3D elements. As all dimension of welded plates are in proportion we use the Hexahedral elements for meshing.

While meshing mesh size of an element is to be taken into consideration because all software's have some limits for the number of elements. Less the mesh size more will be the number of elements and coarse the mesh size less will be the number of elements. As the number of elements increases the run time increases. After meshing elements are to be checked for Quality i.e. elements have some definite quality criteria which should be met by all elements. A quality criterion consists of minimum and maximum angles of the elements, jacobian, warpage etc.

Number of nodes: 13206
Number of elements: 2278
Element size = default

After meshing is completed we apply boundary conditions. These boundary conditions are the reference points for calculating the results of analysis. Elements are defined by their properties. Material properties are assigned to the elements. Here proper arrangements are made so that we can run the analysis in solver software. After the completion of process model is exported to the solver.

Application of Load

For this study we have taken two different loading conditions to obtain stress ratio 0.5. For tensile loading we apply 50000N and Compressive load of 25000N. These loading conditions are used for with and without shot peening analysis.

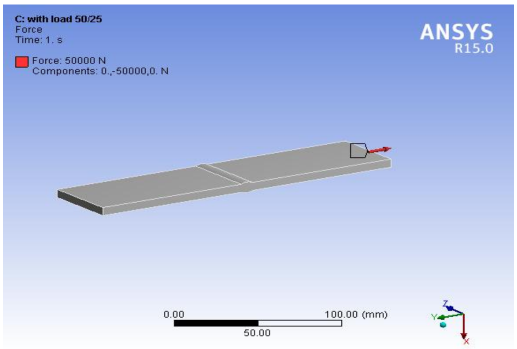

Fig. 3 Tensile load of 50000 N

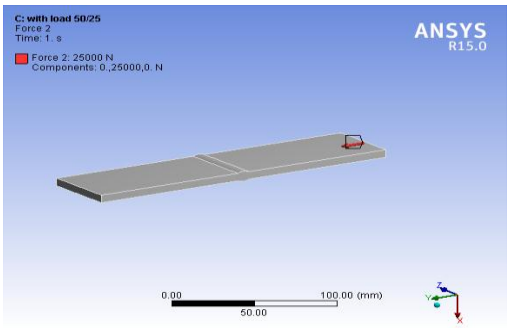

Fig. 4 Compressive load of 25000N

Static Analysis

Results (Without Shot Peening)

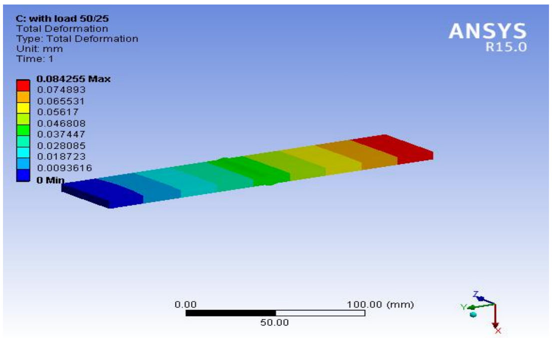

Fig. 5 Deformation is found to be 8.4255e-002 mm

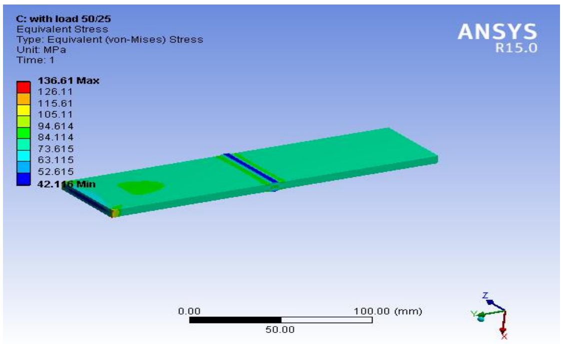

Fig. 6 Maximum stresses are found to be 136.61 MPa

Results (With Shot Peening)

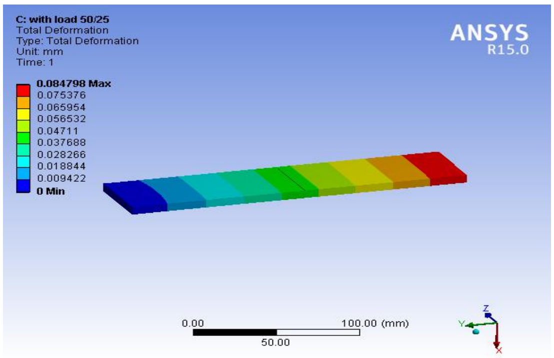

Fig. 7 Deformation is found to be 8.4798e-002 mm

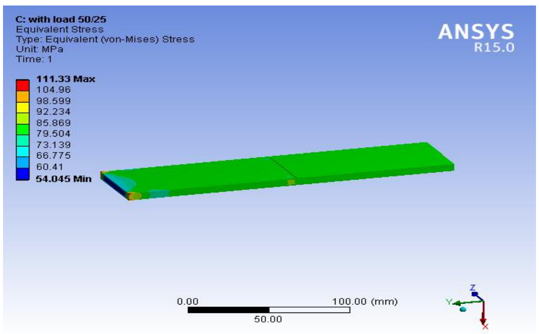

Fig. 8 Maximum stresses are found to be 111.33 MPa

Fatigue Analysis (Without Shot Peening)

Result (Life Cycle)

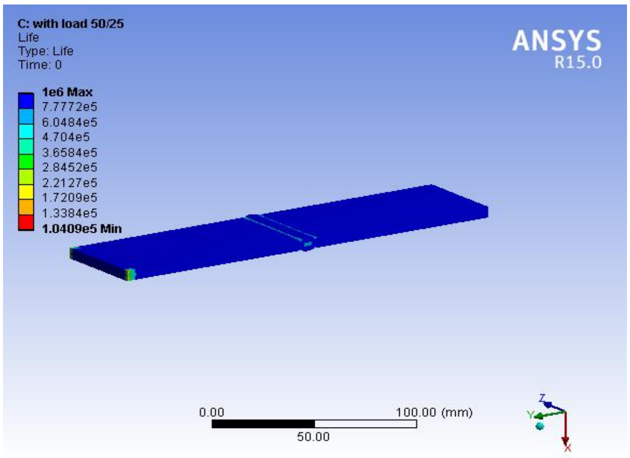

Fig. 9 Minimum no of cycles 1.0409e+005 cycles

Equivalent alternating stress

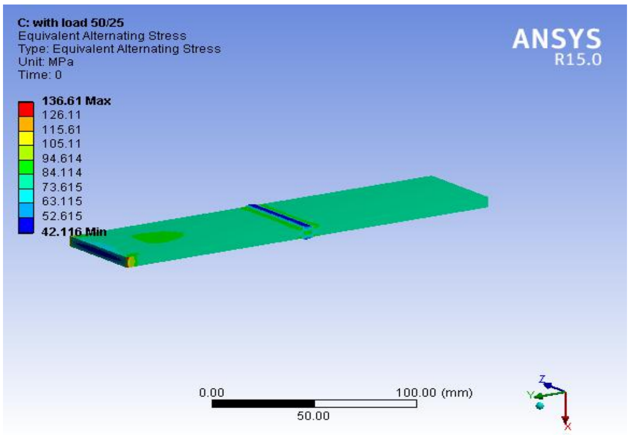

Fig. 10 Maximum equivalent alternating stress is 136.61 MPa

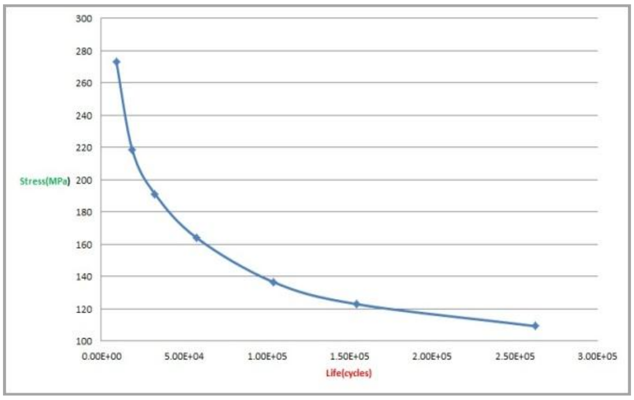

Fig. 11 S-N curve for without shot peening

Fatigue Analysis (Without Shot Peening)

Result (Life Cycle)

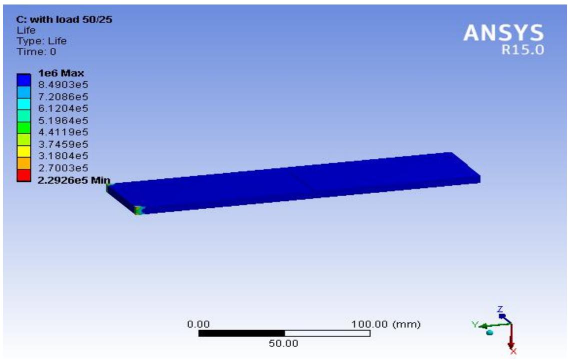

Fig. 12 Min no of cycles 2.2926e+005 cycles

Equivalent alternating stress

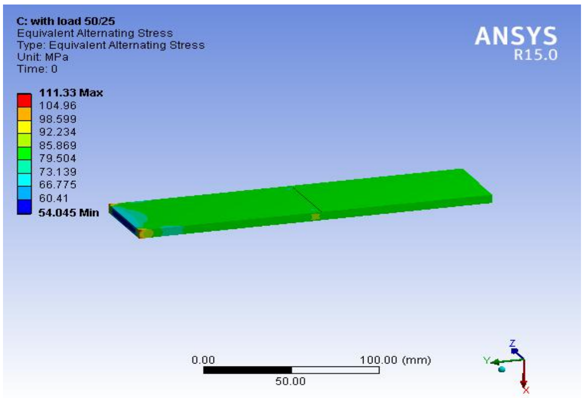

Fig. 13 Max equivalent alternating stress is 111.33 MPa

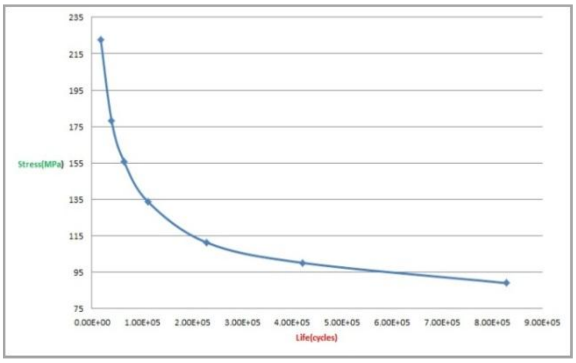

Fig. 14 S-N curve for without shot peening

Conclusions

1) From this study we got the different deformation between the Shot Peening and Without Shot Peening 8.4255e-002 mm and 8.4798e-002 mm respectively.
2) Stress level is reduced considerably from 136.61 Mpa to 111.33 Mpa.
3) Minimum No of cycle completed by welded joint without and with Shot Peening are 1.0409e+005 cycles and 2.2926e+005 cycles.
4) The surface finish of the welded joint is get finished due to shot peening.

5) There is considerable amount of compressive stress is induced in the material due to shot peening.

References

P.S. Prevéy, J.T. Cammett, (2002) The effect of shot peening coverage on residual stress, cold work and fatigue in a Ni-Cr-Mo low alloy steel, International Conference on Shot Peening, Garmisch-Partenkirchen, Germany, pp 16-20.

Sougata Roy, John W. Fister, Ben T. Yen, (2003) Fatigue resistance of welded details enhanced by ultrasonic impact treatment (UIT), Science Direct, Internation journal of Fatigue 25, pp 1239-1247.

Xiaohua Cheng, Sougata Roy, John W. Fister, Ben T. Yen, Henry J. Prask, Thomas Gnaupel-Herold, (2003) Residual stress modification by post-weld treatment and its beneficial effect on fatigue strength of welded structure, Science Direct, Internation journal of Fatigue 25, pp 1259-1269.

Henri-Paul Lieurade, Cetim, Senlis, France, (2005) Fatigue improvement of welded components by shot peening, ICSP9, pp 16-27.

Arshad Mehmood and M. M. I. Hammouda, (2007) Effect of shot peening on the fatigue life of 2024 aluminum alloy Failure of Engineering Materials & Structures, Code 02, pp 1-12.

Wang Ting, Wang Dongpo, Huo Lixing, Zhang Yufeng, (2009) Discussion on fatigue design of welded joints enhanced by ultrasonic peening treatment (UPT), International Journal of Fatigue 31 , pp 644–650.

A. Berg-Pollack, J. Voellmecke, C.M. Sonsino, (2009) Fatigue strength improvement by ultrasonic impact treatment of highly stressed spokes of cast aluminum wheels, International Journal of Fatigue 31, pp 644–650.

M.M. Pedersen, O. Mouritsen, M.R. Hansen, J.G. Andersen, J. Wenderby, (2010) Re analysis of fatigue data for welded joints using the notch stress approach, International Journal of Fatigue 32, pp 1620–1626.

Uros Zupanc, Janez Grum, (2011), Surface integrity of shot peened aluminium alloy 7075-T651 Journal of Mechanical Engineering 57-5, pp 379-384.

J A Akbar, S kyriacou, A M El-Zafrany, Effect of shot peening on the fatigue life of auxially loaded notched component , University of Bahrain, pp 349-358.