UNIVERSITY OF NIŠ
FACULTY OF MECHANICAL ENGINEERING
Department for Production, IT and Management

34th INTERNATIONAL CONFERENCE ON PRODUCTION ENGINEERING

PROCEEDINGS

Sponsor General

Ministry of Education and Science, Republic of Serbia

September 28-30 2011,
Niš
Serbia

34th INTERNATIONAL CONFERENCE ON PRODUCTION ENGINEERING
28. - 30. September 2011, Niš, Serbia
University of Niš, Faculty of Mechanical Engineering

MECHANICAL PROPERTIES OF WELDED JOINTS AT STEEL TUBES WITH SQUARE CROSS SECTION

Andreja ILIĆ[1], Danica JOSIFOVIĆ[1], Vukić LAZIĆ[1], Lozica IVANOVIĆ[1]
Faculty of Mechanical Engineering, University of Kragujevac, Sestre Janjić 6, 34000 Kragujevac, Serbia,
Phone: +381-34-335990, Fax: +381-34-333192
gilic9@sbb.rs , danaj@kg.ac.rs , vlazic@kg.ac.rs , lozica@kg.ac.rs

Abstract: *Welded construction working properties are highly influenced by the stress and strain distribution in welded joints zones. Stress and strain distributions are determined by stress concentration provoked by geometrical discontinuities and heterogeneous of material. Stress concentration changed the stress distribution, position of maximal stresses and, by that, the position of danger cross section zone which act as damage and integrity safety risk.*
This paper deals with experimental determination of stress concentration influence on welded constructions integrity. The experimental procedure was done on welded joints models in static load conditions on samples made of commonly used steel tube with square cross section. Experimental procedure was conducted on existing testing devices in Welding Laboratory and Material Testing Laboratory at Faculty of Mechanical Engineering in Kragujevac. The models of welded joints at steel tubes were loaded to bending and maximal bending force was determined. Additional stress concentrator was introduced to the models, as circular hole in axis, to determine the influence of multiple stress concentration to maximal obtained bending force.
The aim of this paper is to analyze influence of stress concentration to the resistance of welded structures. Stress concentration were analyzed by experimental approach objected to include as much influential factors as it is possible. The main objective of stress state distribution is creating the precise analytic model and to obtain the relevant data and information for constructions evaluating and optimizations, so as to perform integrity, safety and reliability analysis. This paper pointed out the necessity of analyzing the welded constructions on different dimension levels. Further investigations in this area have to be continued by development of numerical model of the welded construction which will, in involvement with adequate software, complete the experimentally obtained results.

Key words*: welded joint, multiple stress concentration, bending*

1. INTRODUCTION

Welding is most dominant method of forming permanent joints in mechanical constructions which provide essential role in fabrication of wide range components and structures. Welded joints due to other joining methods provide higher efficiency, lighter weight, smooth joint appearances, easy alteration and addition are possible, less expensive. The technology procedures of welding are continually developing due to application of the newly obtained results in fundamental scientific disciplines, as well as in the other disciplines to meet the modern demands. But, as consequence of applied technology processes, zones of welded joints are the zones of high level of residual stresses and high degree of material inhomogenity. The welding process is based on localized heating and cooling, which creates irregular temperature field. The process of welding provoked disrupted expansion and contraction during heating and cooling.

Welded joints zones are zones with high thermal and structural stresses, which derive from the process of welding and represent their own stresses which do not depend on the external load. Other structural discontinuities in those zones, such as stress concentrators additionally complicate the stress state. The indicated facts point out that properties of welded joints are key element of structural integrity of the welded constructions. Welded structure is a complex system that can be considered from many aspects. Safety and reliability requirements for welded construction point out that welded joint zones have to be considered adequately.

The essence of determining the present stress state in zones of welded joints is the formation of the more accurate analytical model of welded constructions. Capacity calculations analyze and prove mechanical resistance and stability of welded structures for the expected loads and exploitative conditions. The multiple stress concentrations at zones of welded joint and mechanical properties of welded joints are major dominant factor to precision of analytical models used for calculations. Data obtained from exploitation of welded constructions shoved that mechanical properties of welded joints due to is nature were not adequately take in consideration in present analytical models and capacity calculations.

2. OBJECT AND METHODOLOGY OF EXPERIMENTAL TESTING

In order to test the mechanical properties of welded joints at steel tubes with square cross section due to its wide usage and significance, the experimental testing in two stages was done. The experimental testing of mechanical properties was done on welded joints models in static load conditions on mechanical loading device with automatic registering the force dependence on elongation, firstly without additional stress concentrator in welded joints zones, and after that, with introducing it as circular holes in axis. The samples were made, by defined welding procedure, of commonly used steel tube with square cross section. Experimental procedure was done using testing devices in Welding Laboratory and Material Testing Laboratory at Faculty of Mechanical Engineering in Kragujevac. The joint models of steel tubes were loaded to bending and maximal bending force was determined. The operation of mechanical loading machine was achieved through the worm transmission and the winding spindle. Winding spindle is in relation to moving jaws of the machine. The machine is equipped with a device for registering force dependence on elongation. Mechanical loading machine was loaded in the range up to 5 *kN* with a force increase speed adequate for static tests l0 *mm/min* during testing (Fig.1.).

Fig.1. Loading principle during testing

For preparation of models, steel tubes of commonly used structural steel with square cross section were welded with wire electrode ESAB AUTROD 12:51, d = 1 mm, the specification EN 440, from ESAB producers, Sweden using welding device VARMIG 400 D 42 in protective atmosphere of CO_2 with flow rate 9 l / min. Welding parameters were: welding current I = 105 A, welding voltage U = 21 V and welding speed v_z = 28 m/h. Circular holes in axis were introduced to the models as additional stress concentrators to determine the influence of multiple stress concentration to maximal bending force. Tested models were prepared with proper geometrical similarity to real welded constructions. Testing was done according to pre-defined procedure on a series of five specimens. Firstly, models of welded joints at steel tubes with square cross section loaded to bending were tested. The shapes and dimensions of tested models, are shown in Fig.2.

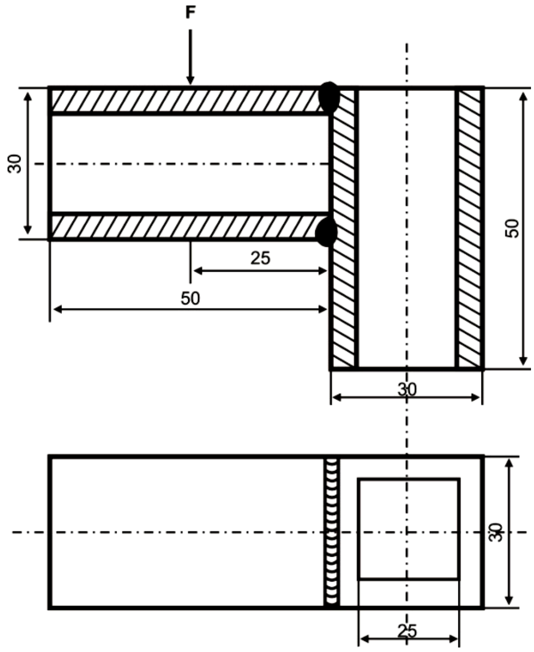

Fig.2. Shape and dimensions of tested specimens

Force dependence on elongation were register and maximal bending force were determined (Fig.3.). The obtained results show small relative variations and can be taken as relevant for further analysis.

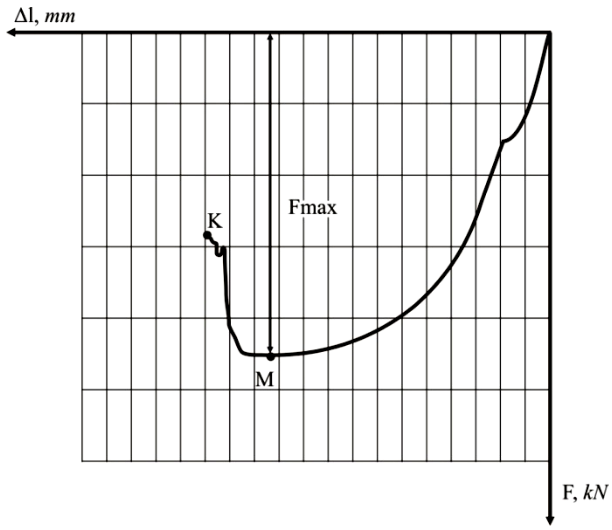

Fig. 3. Force dependence on elongation for tested specimens

Second stage of experimental testing ware done on the models with additional stress concentrators in zones of welded joints for qvalitative determination of multiple stress concentration to mechanical properties. Testing was done according to pre-defined procedure on a series of five models of welded joints at steel tubes with square cross section and circular holes in axis loaded to bending. The shapes and dimensions of tested models during the second stage of testing are shown in Fig.4. Force dependence on elongation were registrated automaticly on testing device and maximal bending force were determined. The obtained resultus are shown at Fig.5. and show very small relative variations, so can be taken as relevant for further analysis.

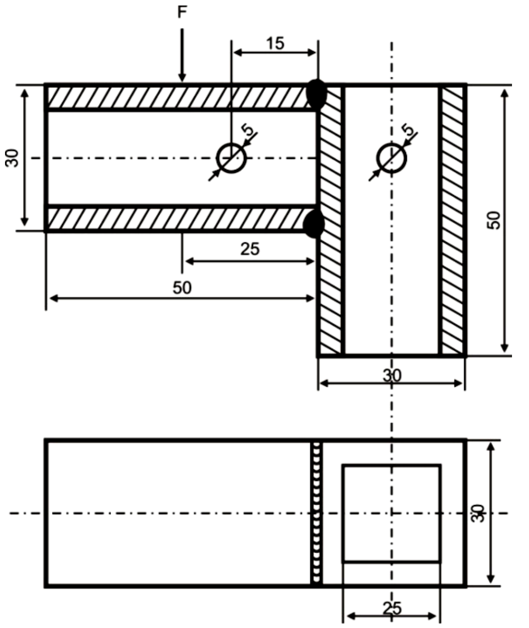

Fig.4. Shape and dimensions of tested specimens

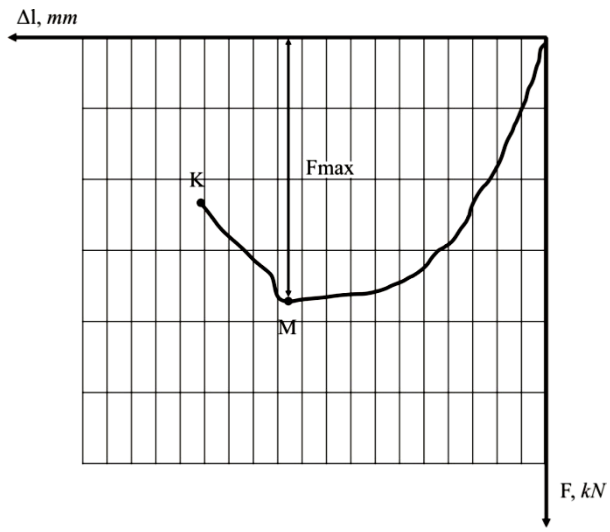

Fig. 5. Force dependence on elongation for specimens with holes

The presented diagrams (Fig.3 and Fig.5.) showed different material behavior due to different multiple stress concentration within tested samples. Complex stress state provoked by multiple stress concentration conditioned the different answers to loading. Furthermore, maximal bending forces obtained on two tested types of models were different. Mechanical properties comparisons of tested specimens are shown in Fig.6. The trend of decline in mechanical properties of tested models is obvious at Fig.6. The diameters of holes in tested models were a few times smaller than dimensions of cross section of square tubes, but provoked stress concentrations were significant to mechanical properties of models. It is important to note that provoked stress concentrations would be severally higher in dynamic load conditions.

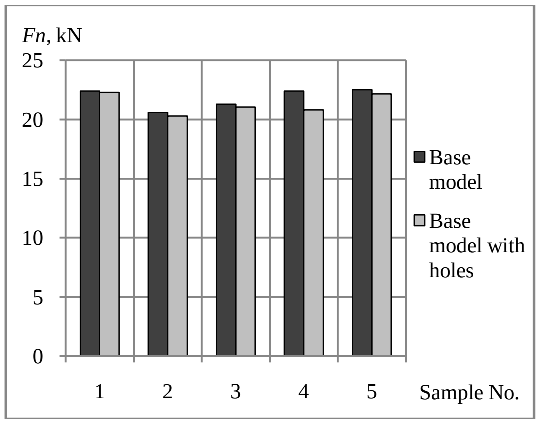

Fig.6. Mechanical properties comparisons of tested models

3. EVALUATIONS OF OBTAINED RESULTS

The material used for tested models preparation is widely used structural steel of commercial quality that fully meets the required mechanical properties, which was experimentally confirmed. Mechanical properties of welded joint, during testing, remain within the limits of base material. By that, it can be concluded that by the appropriate choice of parameters for technological welding process, good utilization of the base material can be achieved. The appearance of models made of steel tubes with square cross section and welded joints loaded to bending after testing is shown at Fig.7.

Fig. 7. Appearance of models with holes after testing

The position of breaking zone shows that the highest stress concentration occurred in the area welded joints. All tested models break at zones of highly loaded weldment. The obtained results are in agreement with other literature sources that analyze the stress concentration and stress-strain state of metallic materials in zones with high degree of inhomogenity.

The comparisons of maximal obtained bending force showed that multiple stress concentration provoke decline in mechanical properties of welded joints at steel tubes with square cross section. The self obtained experimental result is in accordance with relevant literature sources related to this area.

Different behavior of tested models during loading showed that mechanical properties of tested models were highly influenced by stress state distribution in zones of welded joints. Diagrams of dependence force on elongation for two types of models showed that stress concentration due to holes additionally complicate the stress state, but high levels of stresses were obtained in zones of weldments. The experimental results are in accordance with the results shown in the literature related to this area.

4. CONCLUSION

Welding is widespread joining method in mechanical constructions. Due to applied technology, it introduced high level of residual stresses and high degree of material inhomogeneity. Mechanical properties of welded joints are dominant influential factor to properties, safety and reliability of whole welded structures.

Experimental testing of mechanical properties of welded joints has become vital factor in the successful way of engineering and manufacturing, research and development of welded structures. Only with appropriate consideration of nature of welded joints, the benefits of this joining method can be fully realized. On the other hand, welded construction must be analyzed on different dimension levels. Development of mathematical models and finite element methods in analysis of welded construction bring higher degree of flexibility in design, but experimental determinations of mechanical properties of welded joints are essential. Experimental determination of mechanical properties of welded joints is not only a verification tool for analytical and numerical models. It is a method to establish phenomenological relationship in zones of welded joints.

The application areas of welded constructions and its roles become more and more important according to the modern demand in mechanical engineering. Furthermore, present safety and reliability demands become more and more stricter. The modern welded structures must have lower weight, better performance and reduced energy consumption. This facts support the use of efficient and more accurate design methods. The design methods must be linked to safety, reliability and quality requirements which must be based on full understanding of nature of welded joints. Also, welding without any improvement gives rise to local stress concentration, residual stresses and different types of defects. These features combined with high level of load give rise danger of failure and loss of structural integrity. However, the stress distribution for a complex welded structure is usually not known, and conservative assumptions are made of the residual stress distribution and stress concentration when life predictions are assessed.

Finally, the challenge, in order to obtain design and manufacture of lightweight and effective welded structures with appropriate safety and reliability, may be recognized as applying local design methods with evaluating of residual stress fields and stress concentrations. Those design methods must be related to nature of welded joints zones in relation to its positions, load and real exploitation conditions.

REFERENCES

[1] JOSIFOVIĆ, D. (2000) *Examinations of mechanical construction I*, Faculty of Mechanical Engineering in Kragujevac (in Serbian).

[2] JOVANOVIĆ, M., ADAMOVIĆ, D., LAZIĆ, V. (1996) *Welding technology*, Faculty of Mechanical Engineering, Kragujevac (in Serbian).

[3] JOVANOVIĆ, M.,, LAZIĆ, V (2008) MMA, *MAG/MIG welding - manual*, Faculty of Mechanical Engineering in Kragujevac (in Serbian)

[4] ILIĆ, A. (2007) *Application of 3D photoelastic analysis for determination of stress state in mechanical constructions*, Master degree thesis, Faculty of Mechanical Engineering, Kragujevac (in Serbian).

[5] ILIĆ, A., JOSIFOVIĆ, D. (2008) *Design of the welded construction on the base of the photoelastic residual stress examinations*, 5th International Symposium „KOD 2008“, Proceedings of papers, pp. 359 – 364, Serbia.

[6] ILIĆ, A., JOSIFOVIĆ, D., LAZIĆ, V. (2009) *Experimental determination of the construction form influence on stress concentration in welded joints*, 8th Youth Symposium on Experimental Mechanics, Proceedings of extended abstracts, pp. 6 – 7, Hungary.

[7] ILIĆ, A. (2010) *Stress concentration and welded construction form influence on its durability*, PhD entrance thesis, Faculty of Mechanical Engineering, Kragujevac (in Serbian).

[8] ILIĆ, A., JOSIFOVIĆ, D., LAZIĆ, V., IVANOVIĆ, L. (2011) *Experimental determination of stress concentration influence on welded constructions stability*, The 7TH International Conference Research And Development Of Mechanical Elements And Systems IRMES 2011, Proceedings of papers, pp. 219 – 224, Serbia.

[9] DALLY, J. W., RILEY, W. F. (2008) *Experimental Stress Analysis*, McGraw-Hill Book Company, USA.

[10]JAMES, F. D. (2004) *MODERN EXPERIMENTAL STRESS ANALYSIS completing the solution of partially specified problems*, John Wiley & Sons Ltd, England.

[11]DAVIES, C. (2003) *The Science and Practice of Welding*, Vol. 2, Cambridge University Press, England.

[12]ENV 1993-1-1. Eurocode 3: *Design of steel structures* - Part 1-1. CEN 1992.

[13]LUDWIG, M. J. (2000) *Design of Welded Connections*, American Welding Society, USA.

[14]DAVID, S. A., DEBROY, T., DUPONT, J., KOSEKI, T., SMARTT, H. (2008) *Trends in Welding Research*, Proceedings of the 7th International Conference, American Welding Society, USA.

[15]GROTE, K. H., ANTONSSONM, E. K. (2009) *Springer Handbook of Mechanical Engineering*, Springer London, England.