TESTING OF ELEMENTS AND JOINTS AT MECHANICAL CONSTRUCTIONS

Andreja Ilić[1], Lozica Ivanović[2], Danica Josifović[3], Vukić Lazić[4], Boris Rakić[5]

Summary: *Testing of elements and joints at mechanical constructions under static load are presented in this paper. The mechanical properties of elements and joints at mechanical constructions are significant factors that influent to its answer to load. Those properties are determined in this paper by experimental testing on models with same geometries as related zones of commonly used elements and joints at mechanical constructions. Models are made of general purpose structural low carbon steel with different geometries in order to analyze the influence of stress concentration. Also, different joining methodologies, welded ones and ones that require holes at zones of joints, are considered in the paper by testing of related models.*

Evaluation of obtained results implicate that construction answer to load is highly related to stress concentration that is provoked by geometry, so as joining methodology. The results can be used to evaluate construction mathematical model in order to analyze its efficiency. Furthermore, it is implicated that, as mechanical properties of elements and joints highly influent to mechanical constructions answer to load, numeric simulations of those constructions, also must consider those mechanical properties as key factors. Design solutions of mechanical constructions are based on stress-strain state and mechanical properties of its elements and joints under projected exploitative condition. But, real stress-strain state at elements and joints in exploitation, so as its mechanical properties, resulted from very complex, timely dependent, set of factors besides of design solution, such as construction fitness for use, so testing of those elements and joints come in the focus.
Keywords: *mechanical properties, joints, stress concentration, static load*

1. INTRODUCTION

Modern demands that are put at present mechanical constructions are far more complex than ever before. Demands for improving energy efficiency, reduce

[1]PhD student, University of Kragujevac, Faculty of Engineering, Kragujevac, Serbia, (gilic9@sbb.rs)
[2]PhD, associated professor, University of Kragujevac, Faculty of Engineering, Kragujevac, Serbia, (lozica@kg.ac.rs)
[3]PhD, full professor, University of Kragujevac, Faculty of Engineering, Kragujevac, Serbia, (danaj@kg.ac.rs)
[4]PhD, full professor, University of Kragujevac, Faculty of Engineering, Kragujevac, Serbia, (vlazic@kg.ac.rs)
[5]Master student, University of Kragujevac, Faculty of Engineering, Kragujevac, Serbia, (borismfkg@gmail.com)

environmental effects and constant increase of prices of basic materials cause constructions masses reductions. Construction solutions of reduced mass are not of the same shapes and dimensions as the constructions that change functionally, therefore the stress state within are more complex. Besides the tendency to mass reduction, there is a general tendency for reduction of geometric dimensions that automatically causes increase of stress levels and stress state becomes additionally more complex, and thus increases the risk of initiation, formation and development of cracks as well as fracture, which are, to the highest degree, caused by stress concentration. The stresses within mechanical constructions are of variable character with low or high number of changes which further increases the danger. Increasing the number of changes of stresses and increasing stress levels cause the increased risks of initiation and development of fatigue cracks and fracture. Reason for increase of stress level in modern mechanical structures is, also, reduction of classical degree of safety. The lower degree of safety is used consequently by reducing weight and reducing costs without increasing safety risks [1, 2 and 3].

Different joining methodologies are used at present mechanical constructions. Joining methodologies can be classified by different criteria. The two general groups of joining methodologies can be formed: one that allow rejoining of elements and one that do not. Welded joints are analyzed in this paper as represent of joining methodology that not allow rejoining of elements. The joining methodologies that allow rejoining usually require holes at joining zones are analyzed and obtained results are put in correlation with related results obtained for welded joints.

2. MODEL TESTING

Model tests were carried out on specimens bars made of a strip profiles of material Č0361 according to Serbian National Standard, chemical composition 0.17% C, 0.05% S, 0.05% P, 0.007% N, which is used for responsible welded structures in which there is no risk of brittle fracture. This is the carbon steel of required quality with the following characteristics: tensile strength Rm = 370-450 MPa; yield strength $R_{p0.2}$ = 240 MPa (thickness s < 16 mm), that is $R_{p0.2}$ = 230 MPa (at 16 < s <40 mm) and allowed elongation $A_{5,65\%}$ = 23 %. For model preparation, specimens bars are welded in protective atmosphere of CO_2 with flow rate 9 l / min, welding device VARMIG 400 D 42 producer Gorenje and wire electrode ESAB AUTROD 12:51, d = 1 mm, the specification EN 440, from ESAB producers, Sweden. Welding parameters are: welding current I = 105 A, welding voltage U = 21 V and welding speed v_z = 28 m/h. Specimen bars were tested on mechanical loading machine which operation 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 (Fig. 1).

During the testing, mechanical loading machine was loaded in the range up to 5 kN with a force increase speed adequate for static tests; l0 mm/min. Experimental testing was performed at the Laboratory for welding and Laboratory for machining materials using existing equipment for testing at Faculty of Engineering in Kragujevac.

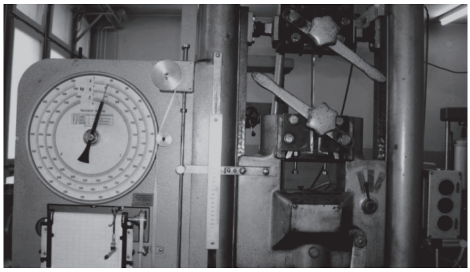

Fig. 1 *Mechanical loading machine with measuring device*

The shape and dimensions of specimen bars examined, with the flat sides and concave sides are shown at Fig.2. Testing was conducted using a pre-defined procedure on a series of five specimen bars for each configuration of stress concentrator. Force at yield and tensile strength were measured. Elongation to breaking was also determined. The obtained results show very small relative exceptions and can be taken as relevant for further analysis

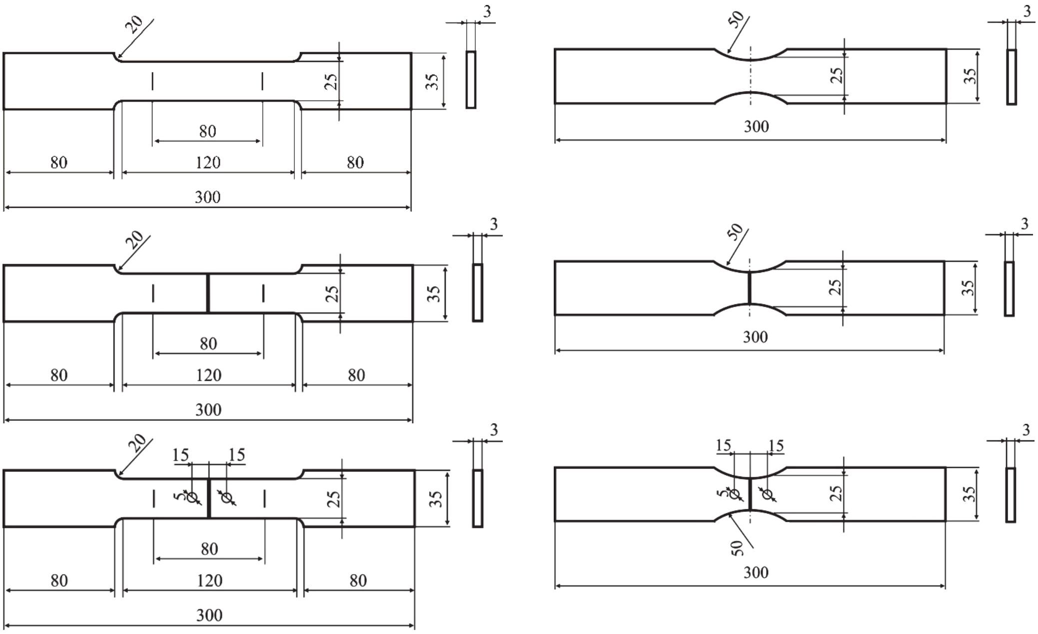

Fig. 2 *Shapes and dimensions of tested specimen bars with flat and concave sides*

Average obtained values for every series of mechanical properties made of base material, with the weldment and weldment and holes on the axis and with flat and concave sides are shown at Fig. 3, 4 and 5.

The material used for preparation of samples used in testing is commonly used structural steel of commercial quality that fully meets the required mechanical properties, both in terms of mechanical strength and plasticity, which was experimentally confirmed.

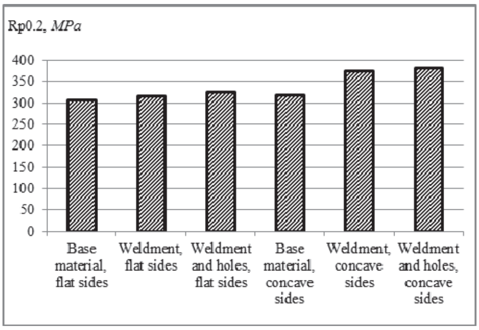

Fig. 3 *Average yield strength of tested specimens*

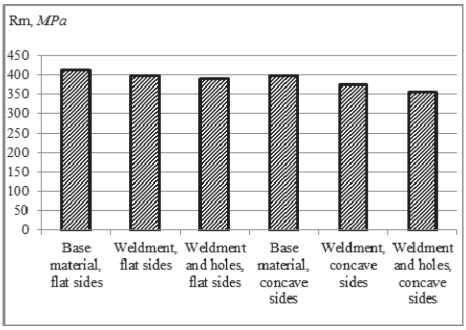

Fig. 4 *Average tensile strength of tested specimens*

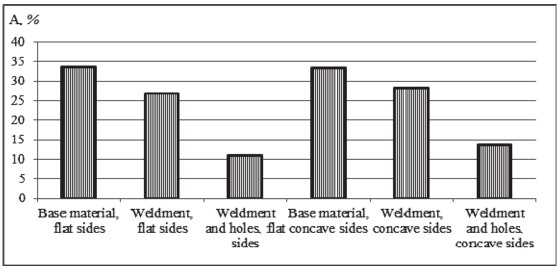

Fig. 5 *Average elongation of tested specimens*

Mechanical properties of welded joint, during tests, remain within the limits of base material, so that by the appropriate choice of parameters for technological welding process, good utilization of the mechanical characteristics of the used base material can be achieved. By testing the specimen bars with flat sides, welded joint and circular holes in the axis, tensile strength values are reached, which show a clear tendency of descent of mechanical properties due to stress concentration. The appearance of specimen bar with flat sides, welded joint and the circular holes in the axis after testing is shown at Fig. 6.

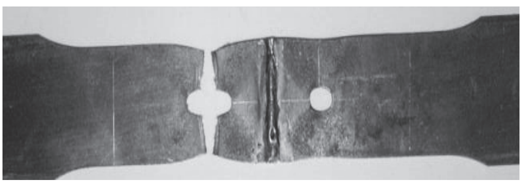

Fig. 6 *Specimen with flat sides after testing*

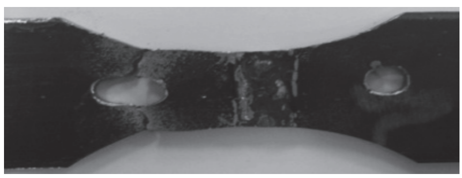

Fig. 7 *Specimen with concave sides after testing*

Welded joints plasticity is lower than the plasticity of the base material which is proven experimentally (Fig. 6), in accordance with current literature sources related to this area [4, 5 and 6]. The stress distributions at the considered zones are obtained by numerical simulation by AutoDesk Inventor Professional 2012 software [10]. Visualization of the stress distribution at considered zones are presented at Fig. 8 and Fig. 9.

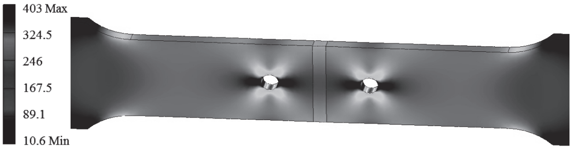

Fig. 8 *Visualization of the stress distribution at specimen with flat sides and holes*

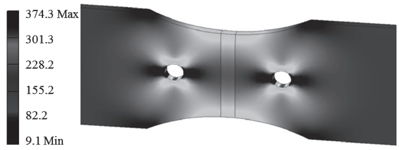

Fig. 9 *Visualization of the stress distribution at specimen with concave sides and holes*

The position of breaking zone shows that the highest stress concentration occurred in the area of holes for specimen bars with welded joints and holes in the axis under load to tension (Fig. 6). Stress distribution obtained by numerical simulation also implicate that maximal stress act at the zone of the holes (Fig. 8 and Fig. 9). The highest stress level on the yield limit and the highest plasticity are shown by the specimen bars with welded joints and holes in the axis [5, 6 and 7]. Due to stress concentration near the dominant sources – holes, formation of positive zones for material yield occurs, and from the view of plasticity, these concentration sources affect the increase of deformations that occur until the final breaking of specimen bar (Fig. 6). The obtained results are in agreement with other literature sources that analyze the stress concentration area and stress-strain state of metallic materials[5, 6, 7, 8 and 9]. When examining the mechanical properties of specimen bars with concave sides without weldment, achieved stresses on yield limit and tensile strength show the trend of slight decline, so that the stress concentration caused by the shape of tested specimen bars can be ignored. In testing of specimen bars with concave sides and welded joint, values on the yield limit and tensile strength of specimen bar show a trend of mechanical properties decline. At Fig. 7, the appearance of specimen bar with concave sides, welded joint and the circular holes in the axis after the executed testing is shown. Dominant stress concentration is caused by circular holes which show the position of the breaking zone (Fig. 7). The experimental results are in accordance with the results shown in the literature related to this area and also in agreement with stress distribution that is obtained by numerical simulation (Fig. 9) [5, 6, 7, 8, 9 and 10].

3. CONCLUSION

Testing of mechanical properties of elements and joints has become vital factor for adequate way of engineering and manufacturing, research and development of mechanical constructions. Only, by proper consideration mechanical properties, optimization of design solutions of mechanical constructions can be done. Present mechanical constructions as complex, heterogeneous systems from material aspects must be analyzed at different dimension levels. Development of mathematical models and computer added numerical simulations of mechanical constructions under virtual exploitation conditions provide higher degree of flexibility at its design, but experimental testing of mechanical are still essential. Experimental testing of mechanical properties of elements and joints is not only a verification tool for analytical and numerical models. Experimental testing is basic tool for establishing of phenomenological relationship especially at zones of joints. Stress concentration caused by characteristic shape of construction elements completely changed the stress state distribution, position of maximal stresses, and by that the position of danger cross section zone which act as safety risk for damage and integrity of the construction. Distribution of the stresses at considered zones are also changeable due to characteristic of load and exploitation conditions.

The application of present mechanical constructions and its functions become more and more complex due to modern demand in mechanical engineering. Furthermore, present safety and reliability demands become more and more strict. The modern mechanical structures must have lower weight, better performance and improved energy efficiency with out of simultaneous compromises in affordability. Those facts support the use of efficient and more advanced design methods. Those design methods must be based to safety, reliability and quality requirements, so as to energy efficiency and environmental concerns. But, most important factors that influent to design are mechanical properties of elements and joints that can be relevantly determined only by experimental testing.

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