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Araştırma Makalesi / Research Article

Fatigue Life Estimation of Welded Joints in Mobile Cranes with Ultra High Strength Steels Using the Structural Stress Method

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ABSTRACT: In this study, static and dynamic finite element analysis (FEA) of a mobile crane design model were per-formed and stresses of welded joints were examined by the structural hot spot method. Especially in the welding of ultra-high strength steel (UHSS), choice of welding parameters affects mechanical properties. According to the FEA results, specimens containing different materials and welding parameters were prepared for investigated regions and an evaluation approach was proposed by performing destructive tests applied in this study. In this way, uncertainties in the production of welded joints are avoided by using destructive test results and FEA evaluations. As a result of the analysis, the hotspot value for maximum principal stress in critical regions of welded joints was found to be 527.54 MPa, and S960QL material was selected. As a result of these studies, UHSS materials were preferred and the minimum fatigue life estimate for welded joints was calculated as 13665 cycles and a mobile crane was produced.

Keywords: Fatigue life estimation, Finite element analysis, Mobile cranes, Ultra-high strength steels, Welded joints

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1. INTRODUCTION

Mobile cranes are work machines used to carry heavy loads to the desired location. The ability to meet the desired function and the safe operation of the crane depend on the designs before manufacturing. Analytical calculations in large structures can take a long time to be calculated due to hyper-static situations, and therefore, more practical and accurate evaluations can be made by performing analyzes using the finite element analysis (FEA). While evaluating the safe operation of cranes, fatigue life in terms of general structure is as important as working under static loads (Lu et al., 2014). Especially in mobile cranes, more occupational accidents and loss of life can be experienced compared to other crane types (Al-Humaidi and Tan 2009, Im and Park 2020). Many studies have been conducted on the most important causes of these accidents and loss of life (Cheng and Teizer 2014, Shin 2015, Raviv et al., 2017, Sadeghi et al., 2021). As stated in many studies, the design, analysis and calculations of mobile cranes are important for manufacturers due to the high number of work accidents and the effects of crane manufacturers. For this reason, it is especially important to make correct fatigue life calculations of welded joints.

The use of high-strength steels with high yield strength can be preferred both for obtaining a more reliable structure and for obtaining lighter structures. With the development of material technology, steels up to 1500 MPa yield strength can be used (Esterl et al., 2019). Steels with very high yield strength, called ultra-high strength fine grained structural steels, can also provide sufficient material toughness (Berg and Stranghöner 2016). With the selection of ultra-high-strength materials, greater load carrying capacity can be achieved with smaller and lower weights. Currently, studies are ongoing to evaluate the fatigue life of welded joints in ultra-high strength steels such as S960 material and to develop IIW recommendations (Ahola et al., 2024, Ahola et al., 2025, Xu et al., 2025).

Generally, the structures with the lowest fatigue life are the welded joints. In welded joints, many parameters such as voltage, current, feed rate, shielding gas, filler wire, environment conditions and weld geometry can affect the microstructure of the heat affected zone (HAZ). These parameters also can affect the phase formed in that area with the weld cooling (Gáspár 2019, Moravec et al., 2019, Mičian et al., 2020). Therefore, the selected parameters can affect the safety of the structure under static and dynamic loads (Tsutsumi et al., 2022).

In this study, destructive tests were carried out for welded joints and the selected welding parameters and the mechanical properties of the material were determined for evaluation as a result of FEA. As a result of a mobile crane design, the welded joints with the lowest fatigue life were examined using the structural hotspot stress approach, under the scenario created by performing FEA. Suggestions have been made for the evaluation of welded connections, especially in complex structures. By evaluating the studies conducted in the literature, fatigue life estimations have been made according to the recommended FAT classes in critical regions in complex structures. In addition, hardness measurement tests have been carried out to emphasize the importance of the hardness of the HAZ regions in welded structures. Although similar methodologies exist, the integration of hotspot stress analysis and destructive validation in mobile crane structures using UHSS materials remains underrepresented in literature.

2. MATERIALS AND METHODS

2.1 Creating a Finite Element Model

Having too many parameters that can affect the life of the structure in welded joints can cause many uncertainties during the evaluation phase. While estimating fatigue life in welded joints according to IIW (Hobbacher 2016) and Eurocode 3 standards, it is assumed that appropriate selections are made for welding parameters, selections are made according to fatigue strength class (FAT) tables according to weld type, shape and shapes, and life cycles are calculated according to S-N curves (Berg and Stranghöner 2014, Fuštar et al., 2018, Pamuk and Durgutlu 2018, Akyıldız et al., 2021, Gök and Baltacı 2021). While evaluating the results of FEA, there are approaches such as nominal stress method, structural hotspot stress method, effective notch method (effective notch) and fracture mechanics method (Paris law) (Sonsino et al., 2012, Niemi et al., 2018). As shown in Figure 1, according to the complexity of the structure, the method chosen and the accuracy rate and effort vary.

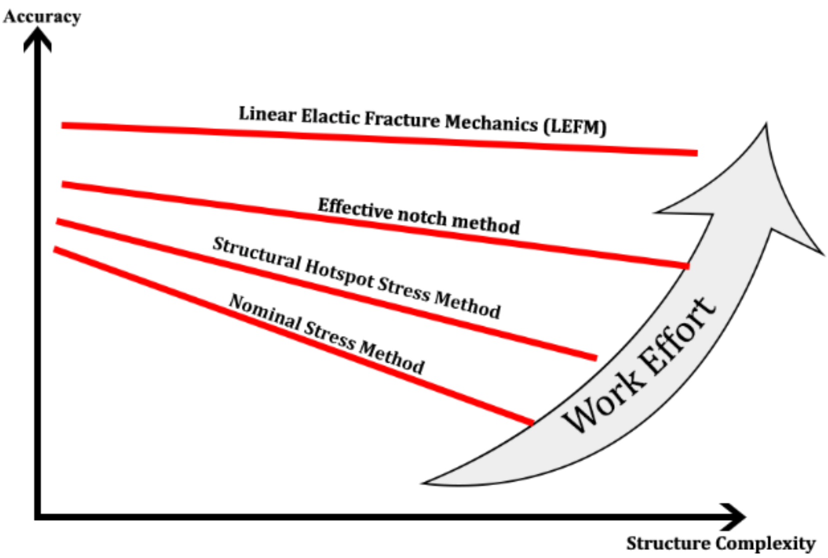

Figure 1. Accuracy-structure complexity according to fatigue evaluation approaches (Özden et al., 2022)

Solidworks, the computer-aided design software for the mobile crane, and Ansys, the FEA software, were used for the design and analysis processes. After all processes are completed, the production phase begins. Figure 2 shows the mobile crane, whose final design has been completed after analysis and improvements. In this study, the structures on the truck chassis were examined.

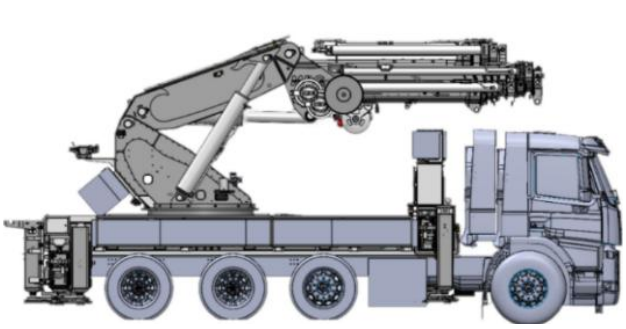

Figure 2. Mobile crane design

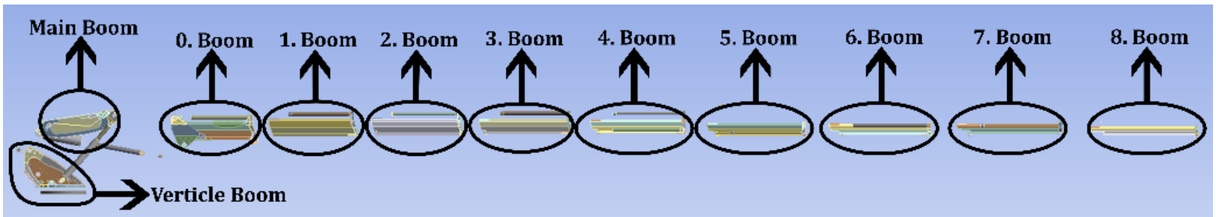

Figure 3. Analysis model classifications

For the analysis made for the upper group of the vehicle chassis, it is divided into groups as vertical boom, main boom and booms. Extension booms are classified as 1st, 2nd, 3rd..., 8th boom. With these classifications indicated in Figure 3, evaluations were made according to the results of the analysis.

Analyzes were made according to the specified scenarios and the results were evaluated according to the criteria described under the heading of design criteria in the DIN EN 1993-1-8 standard. For the stresses occurring in the weld seam, the static load and fatigue calculations according to the scenario applied depending on the static load were made according to IIW and EN 1993 standards.

In the finite element network of the analyzed model, 452775 elements and 689069 nodes were used. Quadratic mesh types are preferred in order not to cause shear locking and hexagonal mesh types are preferred in order to obtain more accurate results. While preparing the finite element mesh, the quality of the mesh structure was increased by making necessary corrections according to the skewness values. The skewness criteria refer to the deviation from the ideal element shape (equilateral triangle and square in 2 dimensions). The skewness quality value for the analyzed model is 0.25 on average and the skewness standard deviation value is 0.20. According to the element quality evaluation criterion, an average value of 0.85 was determined.

Since the model consists of more than one part, the contact definitions of the parts are made. Among these definitions, there are bonded and no separation contact definitions, and as stated in the introduction, they are linear contact definitions. In joint definitions, fixed, cylindrical, revolute joint properties are defined according to the degree of freedom. Flexible is defined instead of rigid in joint definitions and definitions closer to reality are obtained. All definitions are defined linearly and since the material properties are below the yield strength, they are defined linearly. As a scenario, analyses were performed in the horizontal position of the crane where maximum stresses occur. Other kinematic configurations were not examined because they were less stressed. Boundary conditions were defined from the feet in contact with the ground. If there are forces in the sliding direction, definitions were performed with remote displacement instead of fixed joint. In addition, joint definitions are used to model the behavior of the structure in various regions. Elastic properties of materials are considered important because linear analysis is performed in the analysis. While preparing the analysis model, sheet metal parts were converted into shell parts. Radius, chamfer, hole, tooth, wedge, etc., which will not be used as a reference in the analysis model, which has no effect on the analysis of sheet metal and solid parts. geometry has been removed from the model. Machine elements, hydraulic, electrical, electronic, etc., which will not be examined structurally. hardware has been removed from the model. The effects of the components that will affect the results of the analysis in terms of mass properties, although they will not be examined structurally, are included in the analysis with various definitions.

2.2 Criteria for Finite Element Analysis Results

For the designs made, the geometric and loading conditions specified for the scenarios and the analysis results were evaluated, and the regions with a safety factor above 1.5 were determined as safe zones. Analyzes were made according to different scenarios and the results were evaluated according to the normal stress and shear stress criteria in the DIN EN 1993-1-8 standard. For unsafe areas, the design in that area has been improved and more efficient designs have been obtained for resistance to load. In Equation 1,2,3, the criteria for shear stress, normal stress and equivalent stress according to EN 1993-1-8 were evaluated as a result of FEA, and design or material changes were made.

$$f_{vw,d} \leq \frac{f_u / \sqrt{3}}{\beta_w \gamma_{m2}} \tag{1}$$

$$\sigma_1 \leq \frac{0.9 f_u}{\gamma_{m2}} \tag{2}$$

$$\sigma_{vonmises} \leq \frac{f_u}{\beta_w \gamma_{m2}} \tag{3}$$

While evaluating the structural stress method, stress values can be taken from 2 or 3 points and hotspot stresses can be determined (Hobbacher 2016). The hotspot stress is calculated with Equation 4 by taking the stress values from 2 points according to the maximum 0.5.t (thickness) fine mesh size value and applying extrapolation. In Equation 5, hotspot stress is calculated by quadratic extrapolation from 3 points. The calculated hotspot stress values are calculated by determining the FAT class, and the fatigue life (N) is calculated by finding the maximum and minimum hotspot stress difference (Δσhs) with the formulation created according to the S-N curve in Equation 6.

$$\sigma_{hs} = 1.67\sigma_{0.4t} - 0.67\sigma_{1t} \tag{4}$$

$$\sigma_{hs} = 2.52\sigma_{0.4t} - 2.24\sigma_{0.9t} + 0.72\sigma_{1.4t} \tag{5}$$

$$\Delta\sigma_{hs}^{m} = N.C \tag{6}$$

2.3 Materials Used in Welded Joint Production

For welded joints, there are many factors that can affect the mechanical properties after processing during production and may cause discontinuity in the weld pool. Preheating, interpass temperature, shielding gas selection, voltage, current etc. These choices greatly affect the mechanical properties of the welded joint. Destructive tests should be performed in order to determine the mechanical properties according to the selection of these parameters. Finite element analysis results should be evaluated according to the mechanical properties of the structure to be produced, determined as a result of the tests.

S960QL and S690QL ultra high strength steels are preferred for base material and workpiece in welded joints. For the welding filler material, filler material-1 (FM-1) in S960QL steel and filler material-2 (FM-2) in S690QL steel was preferred. Destructive tests were performed to verify the parameters. The chemical compositions of the materials used are indicated in Table 1.

Table 1. Chemical compositions of used materials, wt %

	C	Si	Mn	Cr	Ni	Mo	Ceq
S960QL	0.17	0.22	1.24	0.2	0.06	0.599	0.54
S690QL	0.13	0.27	1.19	0.25	0.05	0.151	0.41
FM-1	0.081	0.8	1.75	0.41	2.22	0.533	
FM-2	0.089	0.53	1.54	0.26	1.23	0.24	

In order to determine the preheating values of the materials used in welded joints, Ceq (Carbon Equivalent) values were calculated according to the chemical composition values. Preheating value was preferred for t8/5 time, in which bainitic phase formation was preferred after welding. This process affects the hardness of the weld bead, the heat affected zone (HAZ) and the base material. Hardness and mechanical properties are checked for compliance with tests performed according to the selected welding parameters. At the end of the tests, it was concluded that it is suitable if the hardness values are less than 350 HV and the yield strength value is at least 960 MPa.

2.4 Proposed Method

In finite element analysis, the solution time of large and complex structures can take a very long time. While preparing the analysis model, geometries that will affect the results at a very low level and negatively affect the mesh structure should be removed. Depending on the number of nodes and elements of the network structure, solution time can take a long time. The use of shell modeling instead of solid modeling also affects the solution time, as it will cause great changes in the number of nodes and elements in the network structure. Therefore, in finite element analyzes of machines with large and complex structures such as mobile cranes, geometries that will affect the results should be simplified, and linear definitions should be preferred in shell modeling and material, connection, geometry settings.

Before performing the FEA of the structure, preference should be made for welded joints according to the 4 different approaches indicated in Figure 1. The most accurate results can be achieved with the linear elastic fracture mechanics approach, but it can take a very long time in large and complex structures. For large and complex structures such as mobile cranes, the structural hotspot stress approach may be preferred as in this study. In this way, works that may take a long time before production can be completed in a shorter time with the choices made.

The mechanical properties evaluated for the critical weld regions determined as a result of FEA and the welding parameter can change after production. It was recommended to prepare welded joint specimens according to the specified parameters, perform destructive tests, and evaluate them according to the determined mechanical properties, especially for FEA in the welding of ultra-high strength steels.

The studies in the literature for weld T joints, the study called ID Ped1 (Pedersen et al., 2010), the study called ID Gal2 and ID Gal1 (Galtier and Statnikov 2004), the study called ID Sta1 (Statnikov et al., 2004), and the IIW recommendation (Hobbacher 2016) results are shown in Figure 4. In these studies, the material of the welded joints was not taken as a basis and the results were shared in general. In addition, there are many studies that were developed by comparing according to IIW recommendations (Zhu et al., 2022, Fass et al., 2023, Baumgartner et al., 2024).

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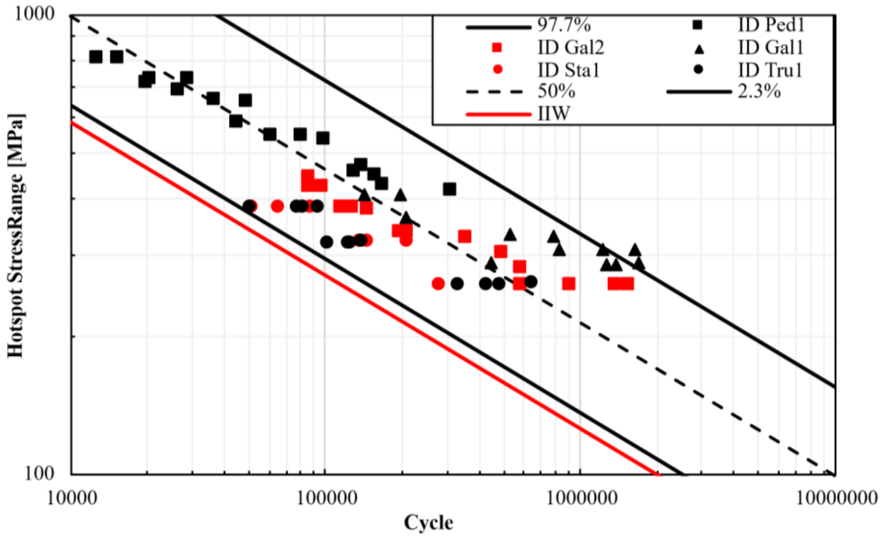


Figure 4. Hotspot stress method fatigue test results for T joints in the literature

63 test results were taken from the studies in the literature and curves were created according to 50%, 97.7% and 2.3% probability distributions as shown in Figure 4. FAT 109 was determined according to 97.7% probability distribution, FAT 265 was determined according to 2.3% probability distribution and FAT 170 was determined according to 50% probability distribution. Standard deviation was determined as 147.01 according to stress range values. Since FAT 109 class will obtain higher conversion values than FAT 100 class, which is one of the IIW recommendations, according to 97.7% probability distribution, FAT 100 or lower classes are recommended for more conservative results.

3. RESULTS AND DISCUSSION

FEA of the structure was carried out and critical points were examined. The most critical regions were evaluated from the extension booms, vertical boom and main boom groupings. They were named region under investigation (RUI), and critical areas were named RUI-1 in the vertical boom group, RUI-2 in the main boom group, and RUI-3,4,5 in the extension boom group. The analysis results of the general structure and these regions are shown in Figure 5.

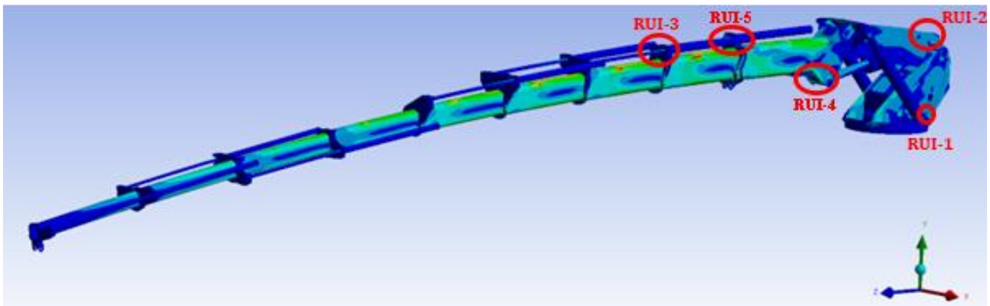
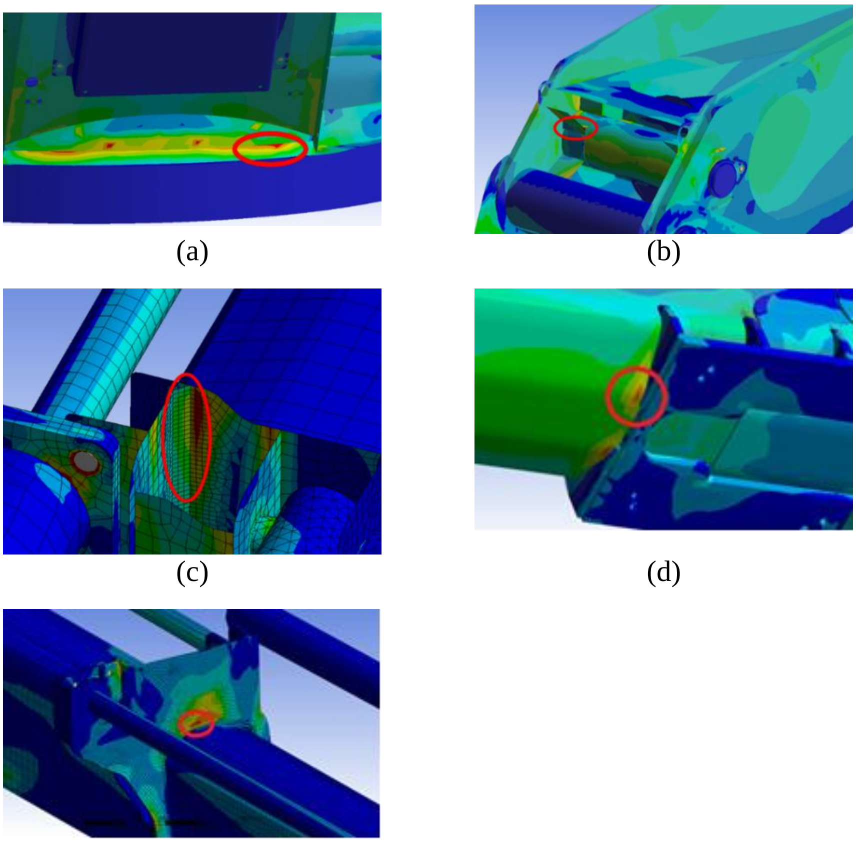


Figure 5. General structure analysis results and RUI regions

RUI regions and FAT classes were determined in detail and according to IIW. While making FAT classifications for the RUI-1 region, single-sided corner welding type was selected in the vertical boom group and FAT 90 class was selected according to the structural stress method. The same weld type is selected in the welded region in the RUI-2,3,4,5 regions. FAT 100 class was selected from the nominal stress structural stress method tables according to the double-sided beveled type called K butt weld. In Figure 6, the regions examined for FAT classifications are indicated with a red ellipse.



(a) (b) (c) (d) (e)

Figure 6. Analysis results for FAT classifications of welded joints (a) RUI-1, (b) RUI-2, (c) RUI-3, (d) RUI-4, (e) RUI-5

Stress values were taken up to 60 mm distance by taking the weld end of the examined critical welded joints as reference. The hotspot stresses of the regions were determined to estimate the fatigue life. Maximum principal, von-Misses and shear stress values are shown in Figure 7, and according to the results, the region with the highest maximum principal stress value is the RUI-3 region, and the hotspot stress was found to be 527.54 MPa. It can be seen that a horizontal graph is obtained in the RUI-2 region and the hotspot stress was found to be 246.28 MPa. The hotspot stress of the RUI-1 region was found to be 274.27 MPa. The hotspot stress of the RUI-4 region was found to be 250.43 MPa. The hotspot stress of the RUI-5 region was found to be 261.87 MPa.

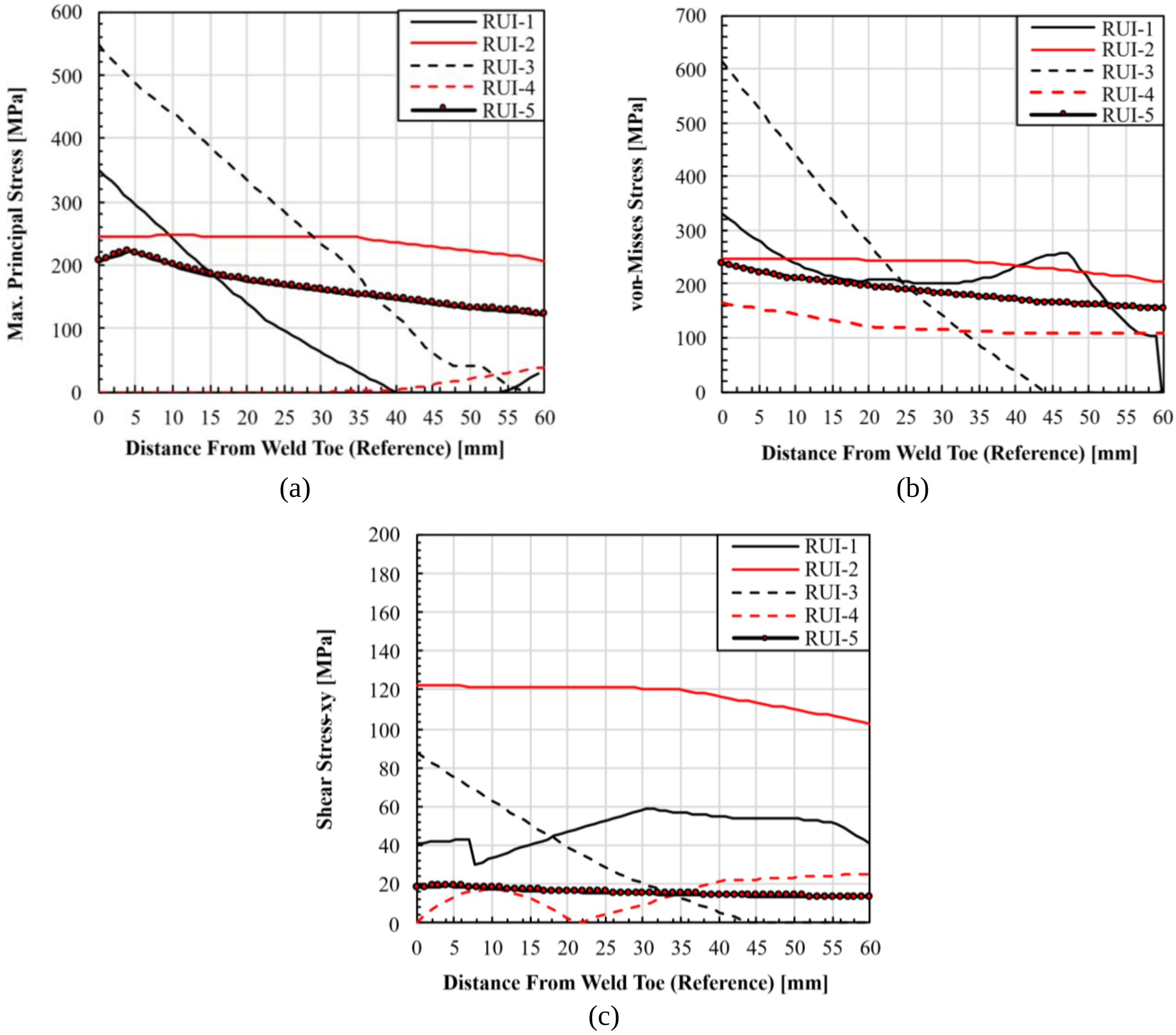


Figure 7. RUI regions stress results (a) Maximum principal stress (b) Equivalent (von-Misses) stress (c) Shear Stress

The hotspot stress values for the maximum principal stress determined by the structural stress method are used for fatigue life estimation. While estimating the fatigue life, the minimum stress is assumed to be 0 MPa and harmonic loads are assumed. In this case, the stress range is equal to the hotspot stress. In Figure 8, the S-N curve is drawn for the FAT classes determined according to the RUI regions. These FAT S-N curves have a probability accuracy of 97.7% relative to IIW. According to the results, 70877 cycles were found for the RUI-1 region, 97938 cycles for the RUI-2 region and 13665 cycles for the RUI-3 region, 251647 cycles for the RUI-4 region, 82954 cycles for the RUI-5 region. Since the results were above 10000 cycles, it was accepted in terms of fatigue life. In the production of RUI welded joint zones, for which fatigue life was estimated according to the results of FEA, the selected welding parameters can affect the mechanical properties of this zone.

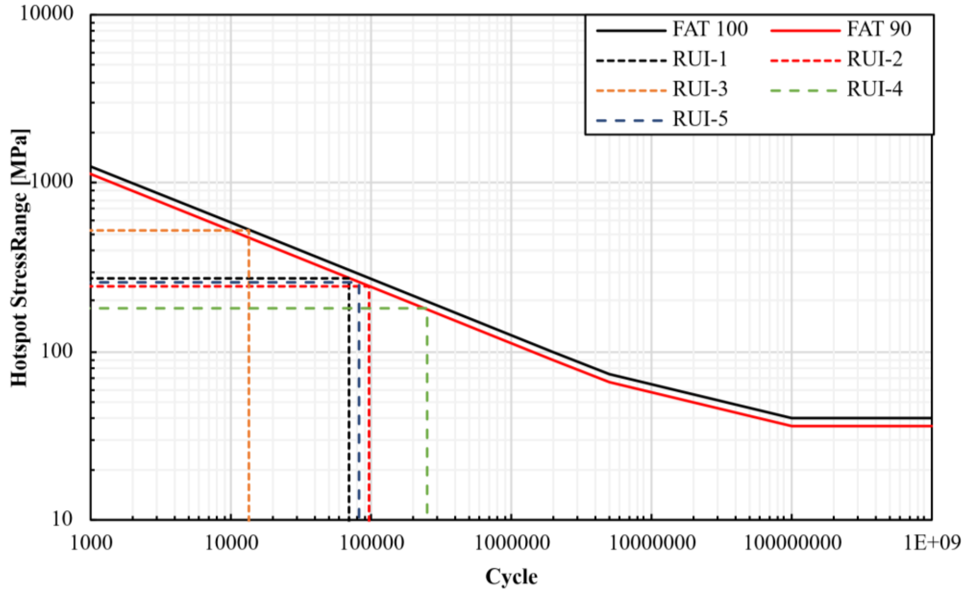


Figure 8. Fatigue life results according to S-N curves and hotspot stress range of RUI regions

Therefore, destructive tests were carried out according to the determined parameters in the critical welded joints examined by FEA and their mechanical properties were determined. In this study, welded joint design was carried out within the RUI-1,2,3,4,5 regions, specimens were prepared according to the parameters and destructive tests were carried out. S960QL, an ultra-high strength fine grain structural steel, was selected for RUI-1 zone materials and S690QL for RUI-2,3,4,5 zone materials. These selections were made according to the criteria that provide the safety criteria of EN 1993-1-8 for the equivalent stress values coming to that region. M21 (80% Ar + 20% CO_2) group shielding gas was selected with a flow rate of 12 lt/min for MAG welding in order to provide the penetration depth value and to protect it from the harmful effects of the atmosphere. For faults that may occur due to unforeseen reasons, ultrasonic, magnetic particle and penetration non-destructive tests (NDT) were performed after welding to prevent discontinuities that may occur in the weld seam. 1.2 mm filler material was used and welded according to 100 C° preheat and 200 C° interpass temperature. Table 2 specifies the welding parameters for the welded joint specimens prepared for destructive testing at the RUI sites.

Table 2. Chemical compositions of used materials, wt %

Specimen	I [A]	U [V]	V_{sp} [mm/s]	Heat Input [kJ/mm]
RUI-1–1. pass	250	26	5	1.04
RUI-1–2. and 3. pass	200	25	5	0.8
RUI-1–4. pass	200	25	5.83	0.69
RUI-2,3,4,5-1. pass	240	24	5.84	0.82
RUI-2,3,4,5-2. pass	240	24	5	0.96

Hardness measurements of base metal, HAZ and weld zones were made and evaluations were made. It was ensured that the hardness of 350 HV remained in all specimens. In Figure 9 weld seam design in images (a) and (b) for RUI-1, macro images in images (c) and (d) and ways for hardness measurement are indicated. In the RUI-2,3,4,5 regions, the base material and workpiece thicknesses are the same and are 10 mm. In Figure 9, weld seam design in images (e) and (f) of RUI-2,3,4,5 regions, macro images in images (g) and (h) and ways for hardness measurement are indicated.

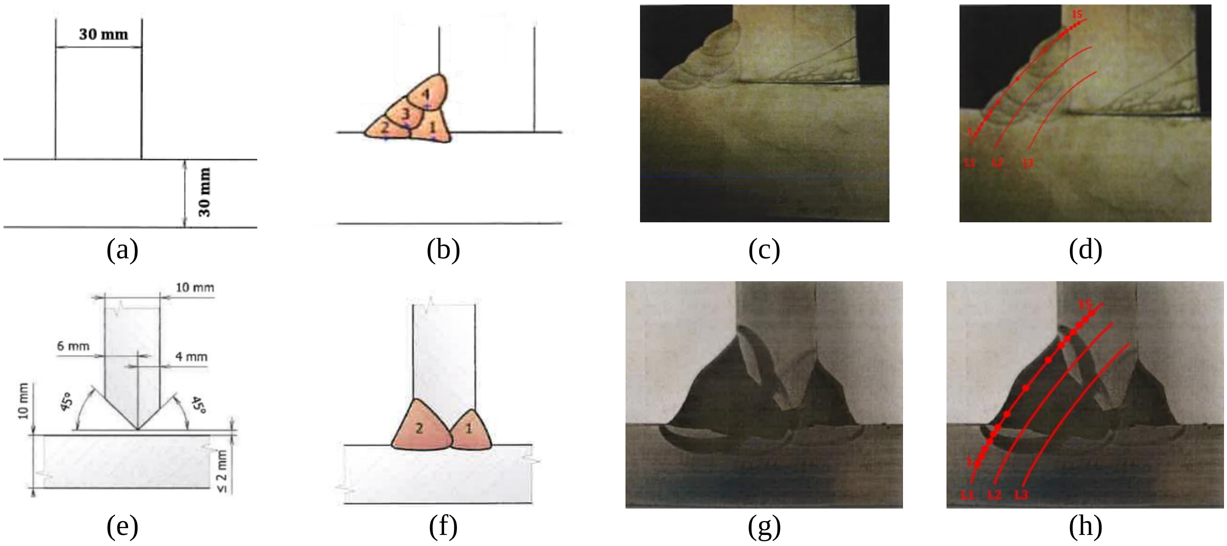


Figure 9. (a) RUI-1 base material and workpiece 30 mm, (b) RUI-1 weld seam number of passes, (c) RUI-1 weld seam macro view, (d) RUI-1 hardness measurement path, (e) RUI-2,3,4,5 base material and workpiece thicknesses, (f) RUI-2 and RUI-3 weld seam design, (g) RUI-2 and RUI-3 weld seam macro view, (h) RUI-2,3,4,5 path for hardness measurement

The hardness measurements taken from the base metal, HAZ and weld zones according to the paths in Figure 9 (d) and (h) are shown in Figure 10. The maximum hardness for RUI-1 was found to be 349 HV in the weld zone. In RUI-2,3,4,5, the maximum hardness was found to be 292 HV in the HAZ region. These hardness values realized in UHSS materials are found to be suitable because they are below 350 HV.

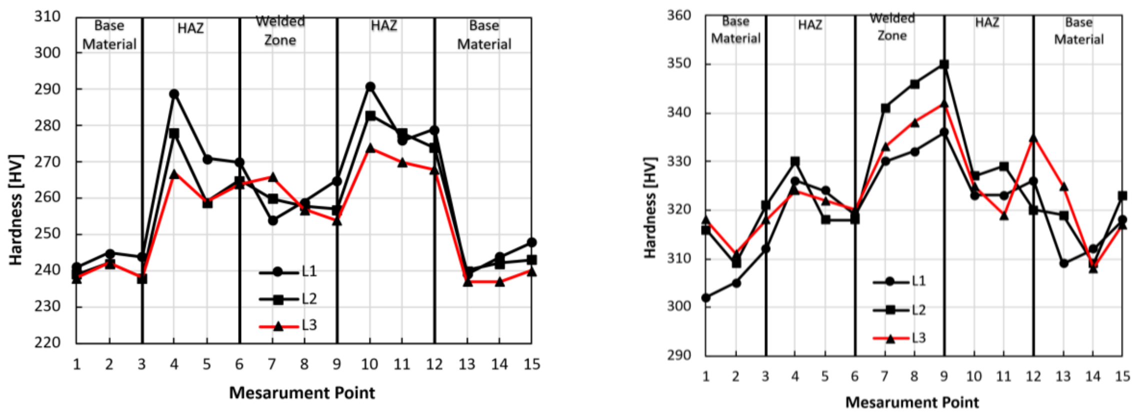


Figure 10. Hardness measurements for (a) RUI-1, (b) RUI-2,3,4,5 fatigue life results according to S-N curves and hotspot stress of RUI regions

Statistical results of hardness measurement tests performed for all critical regions are given in Table 3 and Table 4. While L1 measurement values were higher in RUI-1 tests, L1 measurement values were determined to be lower in other measurements. Standard deviations were determined to be 17.46 in RUI-1 measurements and 8.97 in L1 at the highest and 8.97 in other measurements. This situation was interpreted as being related to multiple passes and cooling times.

Table 3. RUI-1 statistical results

Measure	Mean	Standard Deviation	Variance	Minimum	Maximum	RMSE
L1	261.07	17.46	304.91	239.00	291.00	7.82
L2	257.13	15.41	237.54	238.00	283.00	5.88
L3	252.20	13.12	172.20	237.00	274.00	5.46

Table 4. RUI-2,3,4,5 statistical results

Measure	Mean	Standard Deviation	Variance	Minimum	Maximum	RMSE
L1	319.87	8.97	80.51	302.00	336.00	7.99
L2	324.53	11.81	139.41	309.00	350.00	5.85
L3	324.13	10.36	107.35	308.00	342.00	6.08

While evaluating the welded joint area in the FEA, the yield strengths were taken as 960 MPa for RUI-1 and 690 MPa for RUI-2,3,4,5. As a result of the destructive tests, the mechanical properties and yield strengths were found to be 1050 MPa for RUI-1 and 730 MPa for RUI-2,3,4,5. Tensile strengths were found to be 1080 MPa for RUI-1 and 800 MPa for RUI-2,3,4,5. According to the destructive test results, it was found to be more positive than the mechanical properties evaluated in the FEA, and the welding parameter selections were deemed appropriate for production. Weld seam design was made for the critical welded connection areas determined by FEA and it was found to be suitable for the production of mobile cranes as a result of destructive tests. As a result of the calculations, destructive tests and FEA evaluations, ultra-high strength steel was selected and the mobile crane machine was produced. With the calculations made according to IIW and EN 1993 in welding joints, it was concluded that the structure is safe. It is predicted the discontinuities that may occur in the weld seam due to such as cold cracks, porosity and slag inclusions will be detected by NDT tests and a smooth weld seam will be provided.

4. CONCLUSION

UHSS steels can provide high strength of the structure and reduce their weight by improving them with FEA of the structure in which they were used. Parameters such as voltage, current, preheating, interpass temperature and shielding gas determined in the welded joints of UHSS steels affect the mechanical properties after welding. Since there is no analytical formulation of the parameters, they are examined by experimental studies. In this study, after evaluating the FEA, destructive tests of the critical welded regions were carried out and their mechanical properties were checked. With this evaluation approach, the effects of welding parameters for production after the design process were determined.

In this study, UHSS steels were preferred in critical welded areas of the crane. The critical welded junction sites were investigated with FEA and were named as RUI-1, RUI-2, RUI-3, RUI-4, and RUI-5 as a result. RUI regions were investigated using the structural hotspot stress method approach. Static and dynamic FEA were performed and improvements were made to meet the safety criteria according to Equation 1, Equation 2 and Equation 3. Due to the high axial force and moment in the RUI-1 region, 30 mm thickness was selected and S960QL material was chosen. For RUI-2 and RUI-3 regions, evaluations were made by choosing S690QL steel. By determining the design that provides the safety, the hotspot stresses were calculated according to the maximum principal stress values in the final design, 274.27 MPa for the RUI-1 region, 246.8 MPa for the RUI-2 region, and 527.54 MPa for the RUI-3 region, 250.43 MPa for the RUI-4 region, 261.87 MPa for the RUI-5 region. It was made according to the hotspot stresses in the S-N curves of the FAT class selected while estimating the fatigue life. According to IIW recommendations documents, FAT 90 class was chosen for RUI-1 and FAT 100 class was selected for RUI-2 and RUI-3. For dynamic stresses, the hotspot stress range was calculated by assuming harmonic loads and determining the minimum hotspot stress of 0 MPa.

Fatigue life was estimated according to the hotspot stress range in the S-N curves of the FAT classes and it was found 70877 cycles for RUI-1, 97938 cycles for RUI-2 and 13665 cycles for RUI-3, 251647 cycles for RUI-4, 82954 cycles for RUI-5. Since it was above 10000 cycle value, a mid-cycle structure was obtained and the design was considered suitable for FEA.

After the final design was evaluated, welding parameters were determined according to the weld seam designs and UHSS materials, and destructive tests were carried out with the prepared specimens. In the welding of UHSS materials, it has been observed that the mechanical properties of the post-production welded joints have improved as a result of the tests. Furthermore, it was decided that the selection of welding parameters was correct and the production of the mobile crane was carried out. In this study, especially if UHSS materials are used in the designed structures, FEA and destructive tests should be evaluated together, since the selected welding parameters affect the mechanical properties. Although similar methodologies exist, the integration of hotspot stress analysis and destructive validation in mobile crane structures using UHSS materials remains underrepresented in literature.

5. ACKNOWLEDGEMENTS

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6. CONFLICT OF INTEREST

Authors approve that to the best of their knowledge, there is not any conflict of interest or common interest with an institution/organization or a person that may affect the review process of the paper.

7. AUTHOR CONTRIBUTION

Osman Bahadır ÖZDEN contributed to determining the concept and/or design process of the research, managing the concept and/or design process, data collection, data analysis and interpretation of the results, preparation of the manuscript, critical analysis of the intellectual content, and final approval and full responsibility. Barış GÖKÇE contributed to data analysis and interpretation of the results, critical analysis of the intellectual content. Abdullah ERDEMİR contributed to data analysis and interpretation of the results, critical analysis of the intellectual content.

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