INFLUENCE OF DESIGN FEATURES OF RELOADER WELDED ASSEMBLIES ON ITS PERFORMANCE

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Improvement of reliability and safety of structures of machines and mechanisms in long-term operation under cyclic loading is becoming ever more urgent. Welded assemblies of a reloader were taken as an example for analysis of design solutions for the above assemblies allowing for their load level. Special attention is given to questions of decreasing structural stress raisers of weldments. An improved design of reloader diaphragm assembly, as well as geometry of electrotrolley edge preparation were proposed, ensuring the high quality of welded joints and, therefore, the required fatigue life. 8 Ref., 1 Table, 8 Figures.

Keywords: *stress raisers, welded assembly, analysis procedure, stress-strain state, welded assembly embodiment*

Ensuring reliable and safe operation of the structures of machines exposed to cyclic loads in service is becoming ever more urgent, as physical wear of machines in enterprises occurs much faster than the tempos of their technical re-equipment. A metal structure, most often welded, is the basis for all the machines and mechanisms, so that their further operation is influenced mainly by reliability and safety of its service. In Ukraine not every enterprise has enough funds for technical re-equipment. Therefore, timely detection of damage and upgrading of metal structures allow counterbalancing the problems of machine ageing and of their reliable and safe service [1]. Analysis of item embodiment is performed after its examination. Assessment of technical condition is one of the routine procedures performed to check the level of reliability (operational safety) and service life of structures, as well as determine their fitness-for-purpose under the conditions envisaged by the project and during specified service life [2].

The objective of special examinations, which are performed usually by specialized organizations, is obtaining factual data on the structure technical condition. The procedure of analysis of metal structure embodiment is applied to develop recommendations on their further operation. The scope and degree of examination detailing depend on availability of technical and maintenance documentation, state and degree of structure damage, and eventually, determine the package of reconstruction and repair operations.

Lowering of the level of welded assembly performance is observed with the following structure damage [3]:

- residual deformations of metal structure;
- local element damage;
- failure or reduction of element cross-sectional area due to corrosion;
- failure, buckling of closed section elements or element bulging due to water freezing in them.

Repair and upgrading of welded assemblies of metal structures should be performed so as to eliminate their design shortcomings as much as possible.

Analysis of design deficiencies of embodiment of reloader welded assemblies and examples of their improvement. The case of geometrical features of manufacturing welded assemblies of TAKRAF Company reloader was taken as an example to study their influence on crane service life [4–6].

Mounting longitudinal stiffeners in the reloader inner compartments increases the section moment of inertia and reduces the cyclic load range (Figure 1). Such a design of reloader main beams, however, can lead to negative consequences in lifting construction service, as welding of the lower longitudinal stiffener near the diaphragm creates a structural stress raiser [2].

Figure 2 shows the structure of reloader welded assembly.

Its service life is determined by the following features [5, 6]:

- stress concentration near the angle ends;
- residual welding stresses caused by metal heating by a concentrated heat source;
- weld location at not less than 10–20 mm distance;

Figure 1. Stiffeners in reloader inner compartments

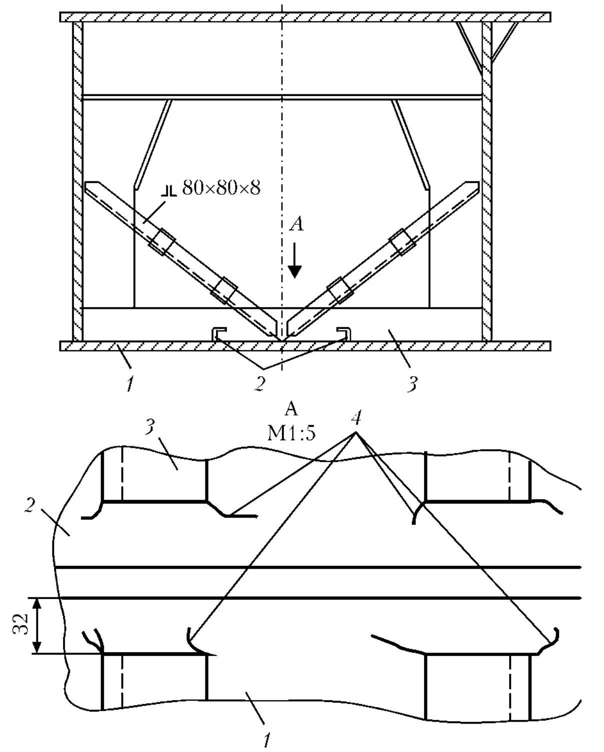

Figure 2. Schematic of lower welded girth of reloader girders: *1* — lower girth of reloader girder; *2* — diaphragm; *3* — angle stiffener; *4* — cracks

• nonuniformities of geometrical shape, composition, mechanical properties and microstructure;

• increased rigidity of the structure in points of welds coming closer to each other.

Reloader operation under the conditions of cyclic stresses leads to initiation of fatigue and lamellar fractures. Figure 2 shows cracks detected at angle ends. Ultrasonic examination revealed through-thickness cracks of lower girth. Strength analysis performed by finite element method showed the following stress values in reloader girder assemblies (Table).

Girder damage develops in reloader operation under cyclic loading. Analysis of conclusions of expert examinations of reloaders, operating in the Krym Soda Works for 30 years, showed that cracks are localized in under-rail zone of upper girth, points of force flow transfer (rigid or flexible support) of the lower girth, as well as in points of connection of wind brace to lower girth (Figure 3). As a rule, damage accumulates in girders in the rigid and flexible supports, in the span middle part, and for reloaders with a combined system — in point of connection of suspension elements to box girders. Crack initiation is the consequence of insufficient moment of inertia of reloader compartments, deficiencies of welded assembly design, unsound preparation of the edges for welding, and welding technology defects.

Experimental investigations of the level of alternating stresses in reloader operation were performed with application of strain gauges, which were combined into strain gauge rosettes and were mounted in the points of highest calculated stresses.

Processing of experimental investigation data allowed establishing the sites of defect initiation in the upper girth of girders: on flexible support, where tensile stresses vary in the range of $(0.2–0.7)\sigma_y$ at location of the loaded trolley in the carriage unloading section (flexible support arm); on rigid support, where tensile stresses vary in the range of $(0.1–0.5)\sigma_y$ at location of loaded trolley in the section of hopper charging (rigid support arm). It was established that tensile stresses vary in the range of $(0.2–0.6)\sigma_y$ at movement of loaded trolley in the span middle.

To lower the probability of cracking in the lower girth (diaphragm and angle stiffeners) the design of angle stiffener welded assembly was changed. Stress raisers were eliminated by

Dependence of calculated stresses (MPa) in reloader girder assemblies on load position

Calculated elements of reloader girders	Without load (dead weight)	On the arm on the left	In midspan	On the arm on the right
3-4	127	144	280	133
4-5	160	198	260	155
5-6	250	280	320	250
6-7	170	220	290	190
7-8	170	180	240	180
8-9	190	250	270	200
9-10	130	230	290	142
10-11	250	270	310	260
11-12	190	226	288	210

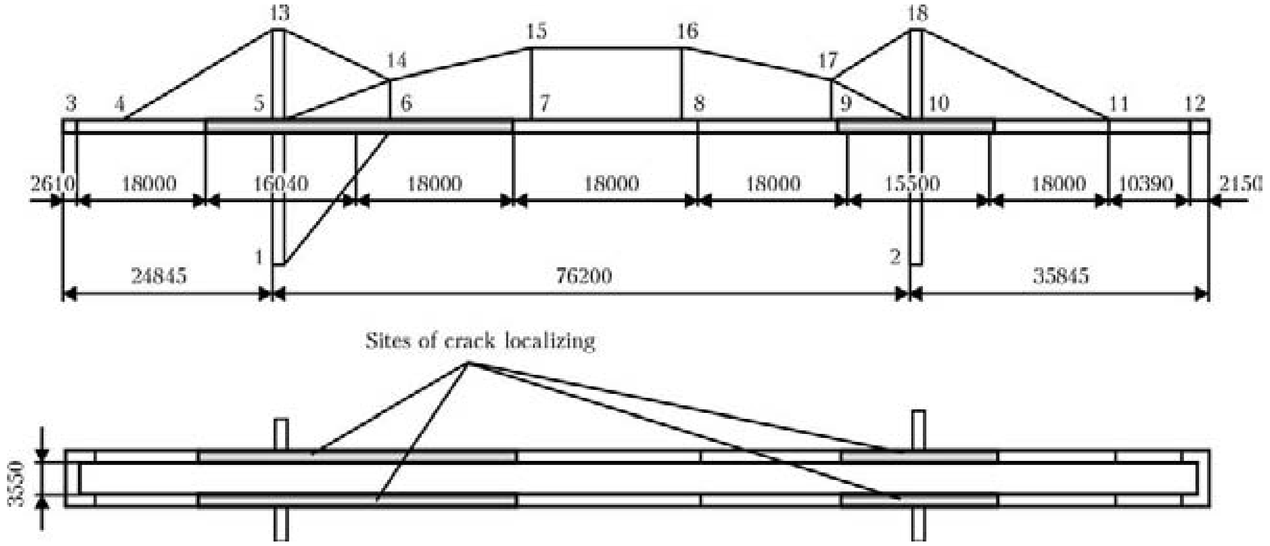

Figure 3. Sites of reloader crack localizing

smooth transition from base metal (lower girth) to the angle proper (Figure 4).

Smooth transition from base metal to angle metal reduced stress concentration. Such a change of the assembly design features eliminated crack initiation at angle ends (during 3 years of service). However, cracks appeared in the fusion zone of diaphragm weld (Figure 5) that is due to the impact of cyclic stresses on lower girth and absence of stiffener near the diaphragm. To eliminate this defect, a variant of welded assembly embodiment with angle stiffener continuation through holes in the diaphragm was selected (Figure 6).

After the welded assembly design has been modified, no cracks developed in the fusion zone of weld diaphragm.

It is shown that in welding and surfacing of reloader electrotrolleys, mounted along the main beam, the strength of copper-to-steel joint is in-

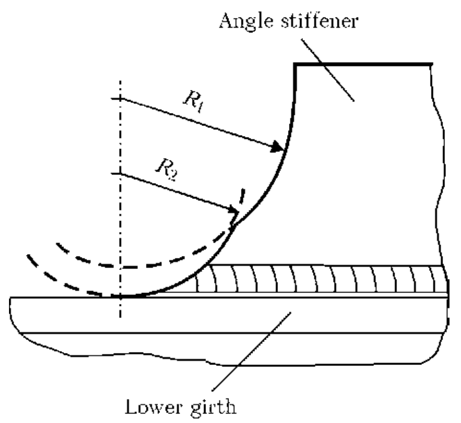

Figure 4. Change of angle stiffener welded assembly design

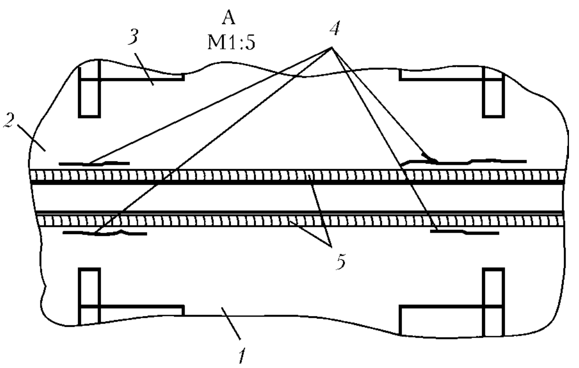

Figure 5. Cracks in the fusion zone of diaphragm weld: *1*–*4* — see Figure 2; *5* — diaphragm welds

Figure 6. Welded assembly of modified design

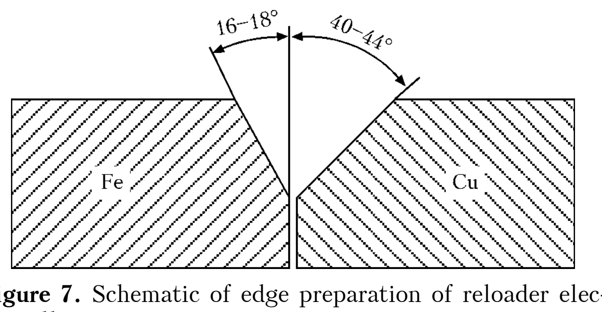

Figure 7. Schematic of edge preparation of reloader electrotrolley parts

Figure 8. Sound welded joint of copper to steel

sufficient. Frequent failures of electrotrolleys lead to crane outage. Shape of edge preparation in welding copper to steel was symmetrical that did not correspond to different thermophysical properties of copper and steel. Analysis of edge preparation geometry allowing for physico-chemical properties of copper and steel showed that edge preparation design should be asymmetrical to ensure equivalent strength of welded joint and sound weld [7, 8]. Figure 7 shows the schematic of edge preparation of electrotrolley parts for welding.

Welding of electrotrolley parts and their operation showed the rationality of application of the proposed geometry of edge preparation. Figure 8 illustrates a sound welded joint of copper to steel.

The proposed design of welded assemblies from dissimilar metals essentially improved welded joint quality and its service life.

Conclusions

1. Calculated and experimental investigation of the locations of damage initiation in reloader girders and their loading conditions showed the need for improvement of welded assembly design.

2. An improved design of diaphragm assembly of reloader main beams was proposed which demonstrated its high performance.

3. A new geometry of edge preparation in dissimilar metal welded assembly of reloader electrotrolleys was proposed which ensures high quality of welded joint and required service life.

1. Grote, K.-G., Postnikov, Yu.E., Makarenko, N.A. et al. (2012) Procedure of analysis of welded metal structure embodiment. In: *Abstr. of Int. Sci.-Techn. Conf. on University Science*. Mariupol: PGTU, Vol. 2, 303.
2. Gavrish, P.A., Shepotko, V.P., Kassov, V.D. (2012) *Damage of crane metal structures. Diagnostics. Repair*: Manual. Kramatorsk: Donbass DMBA.
3. Emelianov, O.A., Shepotko, V.P., Pikhota, Yu.V. et al. (2004) Fatigue damages of welded crane bridges. *The Paton Welding J.*, **5**, 29–35.
4. Shepotko, V.P., Gavrish, P.A. (2012) Analysis of embodiment of welded assemblies in repair of crane metal structures. *Podjomnye Sooruzh. i Spets. Tekhnika*, **4**, 10–11.
5. Shepotko, V.P., Gavrish, P.A. (2012) Adaptability-to-fabrication of repair welding of crane metal structures. *Ibid.*, **5**, 12–13.
6. Grote, K.-G., Postnikov, J., Makarenko, N. et al. (2012) Die Bewertungsmethodik der bauausfuehrung der untergleiszone der haupttrager der verladebrucke. *Visnyk Donbass DMBA*, 28(**3**), 110–113.
7. Gavrish, P.A., Tulupov, V.I. (2010) Preliminary heating at welding of copper with steel. In: *Proc. of 10th Int. Conf. on Research and Development in Mechanical Industry* (Donji Milanovac, Serbia, 16–17 Sept. 2010). Donji Milanovac: RaDMI, 156–158.
8. Gavrish, P.A., Tulupov, V.I. *Method of welding of dissimilar metals*. Pat. 75036 Ukraine. Int. Cl. B 23 K 13/00. Fil. 12.03.2012. Publ. 26.11.2012.

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