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Repair Methodology for the Carrying Structure of the Rejecting Drum of the Bucket-Wheel Reclaimer Stacker Conveyor at Coal Landfill

Damaging of the carrying steel structure and embedding of the rejecting drum of the stacker conveyor occurred during the exploitation of the bucket-wheel reclaimer with the belonging stacker. The analysis of the cause and level of damaging led to the conclusion that damaged parts should be replaced by new ones and that methodology of repair should be based on the application of a suitable welding technology. This paper presents the methodology of repair welding performed during the replacement of the damaged carrying structure and embedding of the rejecting drum of the stacker conveyor which consist of steel sheets and profiles that's based on the conceptual solution for damage repair through the use of program package 'Catia' – V5 that enabled the creation of models and graphic documentation of structural parts that should be replaced by new ones. It should also be noted that geodetic survey of the lower belt of the stacker structure was performed after the substitution of damaged parts of the structure.

Keywords: *spreader, open pit surface mine, welded structure, damage, repair*

1. INTRODUCTION

At the coal landfill of the thermal power plant 'Nikola Tesla A' in Obrenovac (Serbia) two bucket-wheel reclaimers with internal designations DU1 and DU2, manufactured by french company 'Ameco', are in service. They are moving along the circular track (the so called polar track), and it should be noted that there are only 3 bucket-wheel reclaimers of that type in Eastern Europe. The third bucket-wheel reclaimer manufactured by 'Ameco' operates at the coal landfill that belongs to thermal power plant 'Nikola Tesla' in Obrenovac.

Bucket-wheel reclaimer with the belonging stacker [1] is presented in figure 1, while damages that occurred at the support steel structure and embedding of the stacker conveyor rejecting drum before repair are shown in figure 2. Figure 3 shows the condition of the support steel structure and embedding of the stacker conveyor rejecting drum after temporary repair has been carried out.

a) Bucket-wheel reclaimer (DU1);

b) Appearance of the bucket-wheel reclaimer (view from the side);

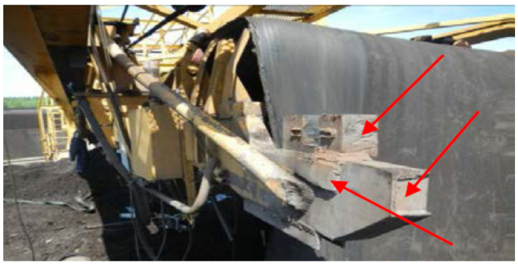
c) Appearance of the bucket-wheel reclaimer (view from behind)

Figure 1. Appearance of the bucket-wheel reclaimer with internal designation DU1 and of the boom of the belonging stacker at the coal landfill.

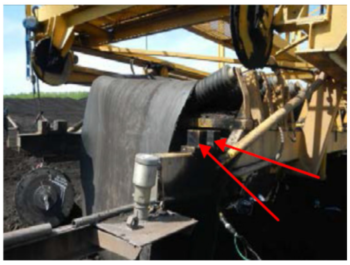
2. REPAIR TECHNOLOGY FOR THE CARRYING STRUCTURE OF THE REJECTING DRUM OF THE BUCKET-WHEEL RECLAIMER DU1 STACKER CONVEYOR

Through the analysis of damages and executed temporary repair of the support steel structure and embedding of the rejecting drum of the bucket-wheel reclaimer stacker conveyor, shown in figures 2 and 3, it can be concluded that temporary repair has not been successful, because figure 3 clearly shows that welded joints have not been executed properly, as well as that geodesic deviation between the carrying steel structure and embedding of the rejecting drum of the stacker conveyor occurred. Only by replacing the complete section of the damaged structure its integrity and service life could be maintained.

After the determination of the cause and amount of damage that occurred at the steel structure of the rejecting drum of the bucket-wheel reclaimer stacker conveyor during service it was concluded that repair methodology should be based on the application of adequate welding technology.



a) Damage that occurred on the carrying structure of the drum (right side);

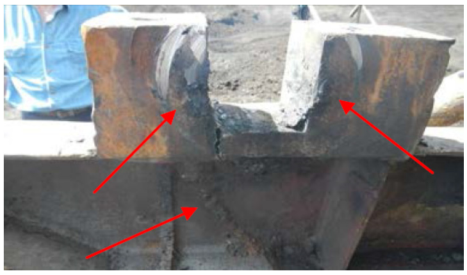


b) Damage that occurred on the carrying structure of the drum (left side);

c) Detail that indicates the cause of geodetic deviation of parent material during the repair of carrying structure;

d) Damage at the structure of an embedding of the stacker conveyor rejecting drum – detail;

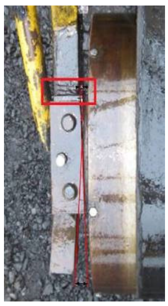
e) Damage at the carrying structure of an embedding of the stacker conveyor rejecting drum – side view;



f) Damage and a crack at the carrying structure of an embedding of the stacker conveyor rejecting drum

Figure 2. Appearance of damages that occurred at the carrying structure and embedding of the stacker conveyor rejecting drum.

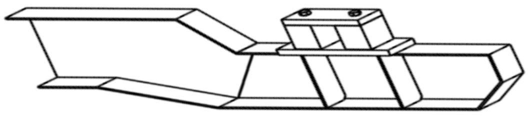
a) Appearance of the rejecting component of the stacker and of the last repair carried out in the area of the damage that occurred at the carrying structure of the drum;



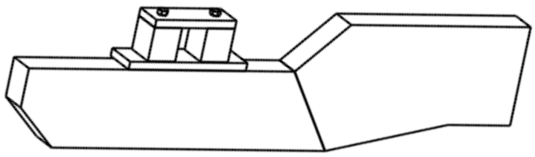
b) Badly executed welded joint and repair carried out in the area of the damage that occurred at the carrying structure of the stacker conveyor rejecting drum

Figure 3. Appearance of the carrying steel structure of the stacker conveyor rejecting drum after temporary repair.

On the basis of the design solution for the repair which relied on program 'CATIA' – V5 the models and graphic documentation which refer to components that should be replaced were created, figure 4.



a) Model of the structure section (view from the side of the drum);



b) Model of the structure section (view from the outside)

Figure 4. Model of components that should be replaced by new ones at the carrying structure of the rejecting drum of the bucket-wheel reclaimer stacker conveyor.

3. TECHNOLOGY OF WELDING OF NEW COMPONENTS AT THE CARRYING STRUCTURE OF THE REJECTING DRUM OF THE BUCKET WHEEL RECLAIMER DU1 STACKER CONVEYOR

Complete welding of new components at the carrying structure of the rejecting drum of the bucket-wheel reclaimer stacker conveyor at the coal landfill located near thermal power plant 'Nikola Tesla A' in Obrenovac which were joined by butt and/or fillet welds formed between steel sheets and profiles made of structural steel should be carried out in accordance with technology presented in reference [2].

Taking into account the fact that the user of equipment does not possess project and technical documentation, creators of the welding technology assumed that structural steels S235J2G3 and S355J2G3 (in accordance with standard EN 10025-2 [3] were used, which are often being applied for the making of steel structures of bucket-wheel reclaimers and stackers.

3.1 Introductory considerations

Properties of parent material and profiles made of structural non-alloyed steels S235J2G3 and S355J2G3 (in accordance with standard SRPS EN 10025-2:2011) [3] are presented in tables 1 and 2.

Table 1. Chemical composition in accordance with [3]

Steel	C (%)	Si (%)	Mn (%)	P (%)	S (%)	Cu (%)
S235J2G3	≤ 0.19	-	≤ 1.50	≤ 0.045	≤ 0.045	≤ 0.60
S355J2G3	≤ 0.23	≤ 0.60	≤ 1.70	≤ 0.045	≤ 0.045	≤ 0.60

Table 2. Mechanical properties in accordance with [3]

Steel	Yield strength YS (N/mm^2)	Tensile strength TS (N/mm^2)	Elongation A5 (%)
S235J2G3	235	360 - 510	24
S355J2G3	355	470 - 630	22

3.2 Weldability of parent material (sheets and profiles)

Weldability of sheet and profile material can be operative, metallurgical and structural. Ability of material to be joined by welding (technological process of material joining) is being determined by material equivalent CEV, which is being calculated on the basis of chemical composition. Equations from which the CEV could be obtained are as follows:

According to the International Institute of Welding (IIW)

$$CEV = C + \frac{M_n}{6} + \frac{C_r + M_o + V}{5} + \frac{N_i + C_u}{15} (\%) > 0.45 \quad (1)$$

According to Ito-Bessyo

$$CEV = C + \frac{S_i}{30} + \frac{M_n + C_u + C_r}{20} + \frac{N_i}{60} + \frac{M_o + V}{15} + \cdots \cdots + 5B(\%) > 0.45 \quad (2)$$

According to HCS (Hot Cracking Sensitivity)

$$HCS = \frac{100C \cdot \left(S + P + \frac{S_i}{25} + \frac{N_i}{100}\right)}{3M_n + C_r + M_o + V} (\%) \leq 4.5 \quad (3)$$

- Through the use of HCS equation (Hot Cracking Sensitivity) it was determined that the material is not prone to hot cracking, due to the fact that obtained result is smaller than 4.5 (boundary value for the occurrence of hot cracks in steels with tensile strength TS < 700 (N/mm^2))
- For chemical compositions of materials presented in table 1 and in the case of the least favourable content of hydrogen in weld metal (H = 6 ml/100 grams) preheating at temperatures up to 100 ºC is required;
- Maximum hardness in heat-affected zone (HAZ) for shown chemical compositions of parent material can not be higher than 350 HV, which means that materials are not prone to cold cracking;
- Critical cooling rate at which purely martensitic structure which would cause cold cracking occurs should be lower than 32 °C/sec, which means that no delayed cooling is necessary;
- Taking into account the fact that tensile strength of profile material is TS < 700 N/mm^2, hot cracking is not likely to occur.

3.3 Selection of the process and filler material for repair welding of new components

By the analysis of parameters on which the selection of the process of repair welding depends (weldability of material, energetic possibilities of welding processes, geometric complexity of the structure, economic indicators) it was determined that process 111 is the most appropriate process for application. Due to limited possibilities of execution of preheating and heat treatment after repair welding, the most optimal solution was to use Mo alloyed basic electrodes EVB Mo (Jesenice), classified in accordance with standard [4]. Chemical composition of pure weld metal is shown in table 3, while mechanical properties are presented in table 4.

Table 3. Chemical composition

Electrode	C (%)	Si (%)	Mn (%)	Mo (%)
EVB Mo	0.10	0.50	0.80	0.50

Table 4. Mechanical properties of pure weld metal

Electrode	Yield strength YS0.2% (N/mm^2)	Tensile strength Rm (N/mm^2)	Elongation A5 (%)	Impact energy $KV_{300/2}$ (J/cm^2)
EVB Mo	> 450	530 - 630	> 22	> 47 (- 20 ^{0}C)

3.4 Rules that should be abided during the execution of welding

Rules that should be abided during the execution of welding are presented due to the fact that no welding technology qualification for sheets and profiles was predicted:

- Preparation of grooves and surfaces for welding should be performed by grinding. All requirements defined in the specification of welding technology have to be met;
- Allowed deviation regarding the parallelness of surfaces and constituting elements with respect to the welding axis is 1-2 mm;
- Allowed deviation of verticality of the position of constituting elements with respect to the welding axis is 1^o;
- Allowed deviation of the position of constituting elements with respect to the welding axis is 1 mm;
- Edges of segments of constituting elements should be thoroughly cleaned from the outside at a length of 15 mm from the edge of the segment;
- Prior to processing edges of constituting elements have to be degreased and clean;
- Number of passes n (including the roots) for welding is the constituting part of the welding technology specification;

Butt welds (depending on the thickness of parent material):

$$n = \frac{A_{ov} - A_r}{A_f} - 1 \quad \text{- for one-sided welding} \qquad (4)$$

where:

n	-	number of welding passes (including the root)
A_{ov} (mm^2)	-	overall area of the weld defined with respect to the groove shape
A_r (mm^2)	-	area of the root weld $A_r = (4 \div 6) \cdot d_e$
A_f (mm^2)	-	surface of the weld fill $A_f = (6 \div 9) \cdot d_e$
d_e (mm)	-	diameter of the electrode

Fillet welds (depending on the cathetus of the 'k' weld)

$$n = \frac{A_{ov}}{A_f} \qquad A_{ov} = (0.6 \div 0.65) \cdot k^2 \qquad (5)$$

for grooves with area smaller than 20 mm^2 value 0.65 is being adopted, while value 0.6 is being adopted for grooves wih area higher than 20 mm^2.

- Filler material has to respond to parent material regarding the chemical composition and mechanical properties;
- Quality and dimensions of filler material are listed in the welding technology specification for every single welded joint;
- Welding electrode has to be completely dry and devoid of dirt and grease;
- Designations and types of filler material are integral parts of of the welding technology specification, in accordance with the appropriate standard;
- Welding should be executed only by welders with an adequate certificate, in accordance with standard SRPS EN 287-1 [5];
- Tacking of profiles and sheets should be performed with length of 10 mm. Taking into account the fact that tacking edges remain integral parts of the root weld they have to be flawless;
- Electric arc used for tack welds is being generated by pulling in front of the starting point of the weld, in the section of the groove which would subsequently be welded. The establishment of the arc should not be executed on the surface of parent material;
- Welded joints should be executed without interruption, in the most convenient position;
- Welded joints need to have well penetrated roots and mild transition into parent material;
- Welding should be executed with reinforcement as low as possible.

3.5 Preparation of New Components for Welding and Appearance of the Carrying Structure of the Drum After Welding

Figure 5 shows the preparation of new components for welding, while figure 6 offers the appearance of the rejecting drum of the bucket-wheel reclaimer stacker conveyor after welding.

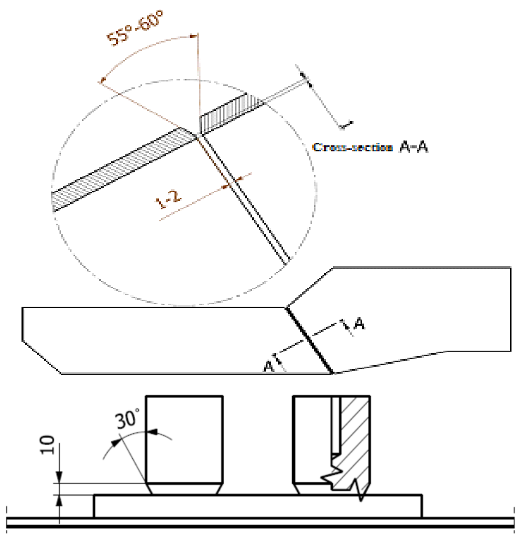


Figure 5. Appearance of the preparation of new components for welding at the carrying structure and embedding of the rejecting drum

During and after welding testing of welded joints by non-destructive methods was carried out (visual testing [5], magnetic particle testing [6], penetrant testing [7] and ultrasonic testing [8]). Geodetic survey was also performed in order to determine if the carrying steel structure and embedding of the rejecting drum were brought to an adequate position and therefore restored functionality.

Figure 6. Appearance of the rejecting drum after the installment of new components at the carrying structure

4. GEODETIC SURVEY OF THE LOWER BELT OF THE STACKER STRUCTURE AFTER THE REPAIR OF THE CARRYING STRUCTURE AND EMBEDDING OF THE REJECTING DRUM

Results of the geodetic survey of the condition of the welded carrying structure and embedding of the rejecting drum after the repair are presented in figures 7 and 8, as well as in tables 1 and 2.

Results of the geodetic survey carried out in order to establish the condition of the lower belt of the welded lattice structure of the stacker boom after the repair of the carrying structure and embeddings of the rejecting drum show that there is no significant deviation from predetermined geodetic values.

CONCLUSION

Integrity of structures is a relatively recent scientific and engineering discipline which in a broader sense comprises state analysis, behaviour and loosening diagnostics, service life evaluation and refurbishment of structures which means that, beside the usual situation in which it is necessary to evaluate the integrity of a structure when a flaw is detected by means of non-destructive tests, this discipline also comprises structural stress state analysis.

Calculation of the stress state and strength of the carrying structure of the stacker conveyor rejecting drum of the bucket-wheel excavator DU1 at the landfill of the thermal power plant 'Nikola Tesla A' in Obrenovac showed that the integrity of the lattice structure of the stacker as a whole was not jeopardized after the installation of new components.

ACKNOWLEDGMENT

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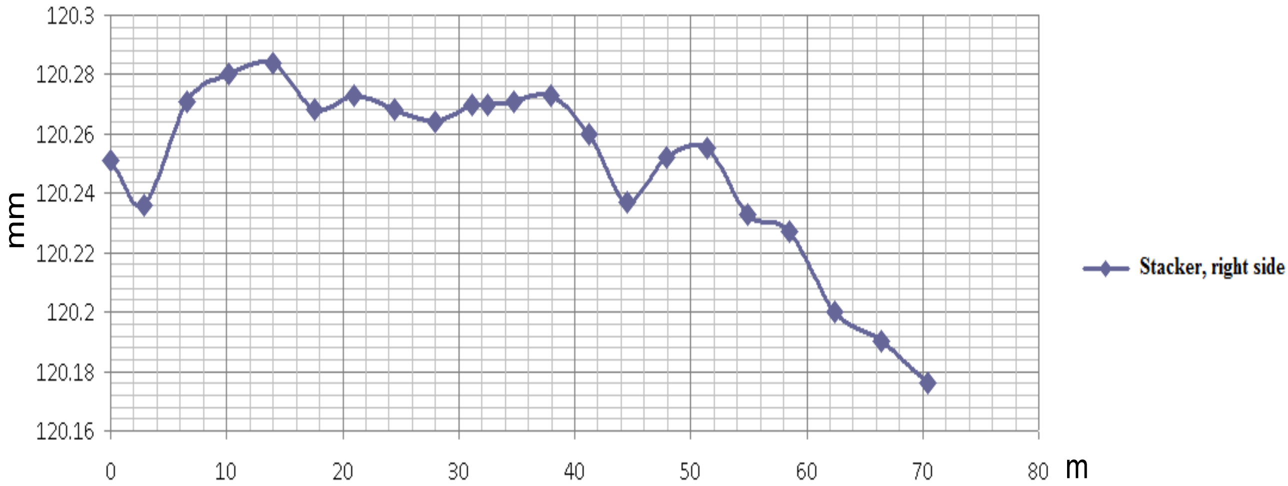

Figure 7. Appearance of results of geodetic survey that refer to the right side of the lower belt of the stacker structure

Table 1. Results of the geodetic survey of the condition of the right side of the lower belt of the stacker structure

Right side of the lower belt of the lattice structure of the stacker																						
RS	0	2.82	6.52	10.23	13.92	17.61	20.98	24.47	27.97	31.21	32.49	34.70	37.94	41.21	44.20	47.94	51.64	54.97	58.46	62.46	66.42	70.42
RGL	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.2	120.2	120.2	120.2	120.2	120.2	120.2	120.2

* RS – Right side of the stacker boom; ** RGL – Relative ground level of the stacker boom

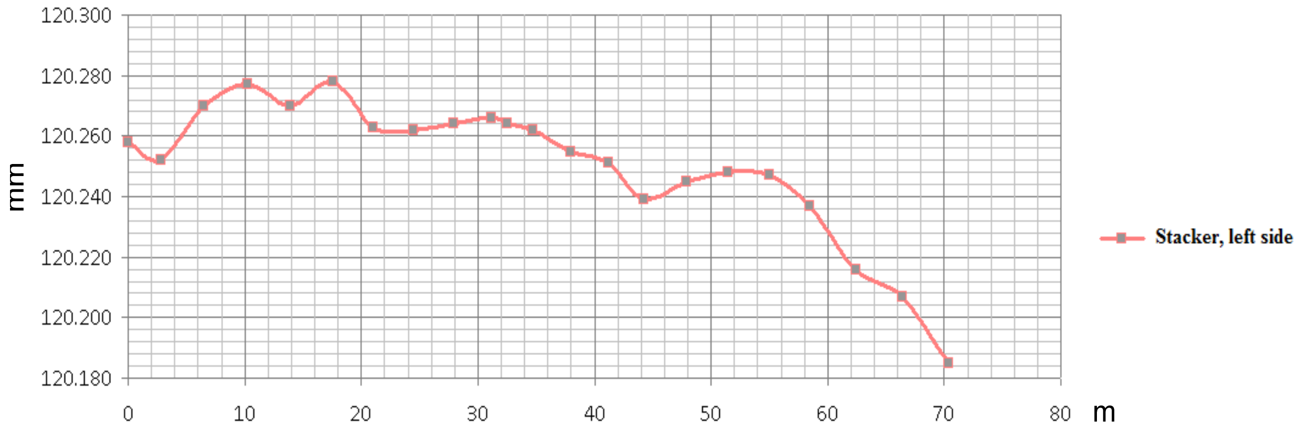

Figure 8. Appearance of results of geodetic survey that refer to the left side of the lower belt of the stacker structure

Table 2. Results of the geodetic survey of the condition of the left side of the lower belt of the stacker structure

Left side of the lower belt of the lattice structure of the stacker																						
LS	0	2.82	6.52	10.23	13.92	17.61	20.98	24.47	27.97	31.21	32.49	34.70	37.94	41.21	44.20	47.94	51.64	54.97	58.46	62.46	66.42	70.42
RGL	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.2	120.2	120.2	120.2	120.2	120.2	120.2	120.2

* LS – Left side of the stacker boom; ** RGL – Relative ground level of the stacker boom