BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LXII No. 2/2010	163 – 176	Seria Tehnică

Structural and Dimensional Rehabilitation of Earthmoving Machines (Loaders, Excavators, Backhoe Excavators etc.)

Dumitru Gogu*, Doru Fulga **,Virgil Tudosescu***,
Vasile Ţaga*, Cornel Rădulescu

* S.C. WELDCONS SRL, Bucharest
e-mail: weldcons@gmail.com

** S.C. TŰV AUSTRIA România SRL Bucharest
e-mail: ro-ful@tuv.at

*** S.C. Doosan IMGB SA, Bucharest
e-mail: virgil.tudosescu@doosan.com

Abstract

We want to present our attempt using some practical solutions for reabilitation of earthmoving equipments, after long service in ballast stations and which presents many failures. The nature of this failures could be different and we try to classify in three categories, as follows: structural failures which affect strenght capacity of elemments (cracks); mechanical wear failures in joints (bores, bushes, bolts, etc.); wear and impact failures on buckets.

The main percent of reabilitation works, since more than two years, occured by the WELDCONS SRL specialists are regarding KOMATSU equipments which are using WELDOX 700 – structural steel and HARDOX 400 – wear steel, products of SSAB OXELÖSUND – Sweden.

The welding technologies are based on procedure qualification records, tested and verified, using different fillers and welding processes, technologies adapted for a large number of base materials, so for other brands in service in Romania.

The reabilitation jobs are carried out more than 90% on site, which reduce costs opposite factory repairing.

General Presentation

The paper presents the summary of repair activities of earthmoving machinery made by the experts of WELDCONS SRL since 2008. The repair activities performed at the rate of over 90% on site, on the earthmoving equipment such as front loaders, excavators or backhoe loaders are based on technologies that may be applicable for all the brands in use in quarries, gravel pits, construction sites etc. using equivalent basic materials and having a similar type of defects while in service.

Earthmoving machines are complex working equipments required in severe operating conditions (high loads, variable stress, mechanical shocks, abrasion, wet environment, etc.). Due to these conditions and reduced or mostly ignored opportunities for maintenance/service, there are more frequent instances of wear/faults than the usual ones, with serious consequences on the reliability of the equipment, which can cause heavy losses to the companies that own it by restraining the equipment for considerable periods of time.

Welding repairs of earthmoving machinery components are required because the costs are much lower than the costs of new parts, as repairs may be performed on a common basis without disassembling the components and the technologies used for the repairs can improve the reliability of components.

Welding repairs have been performed on cracked arms, bearing supports, bearings, bolts, buckets, wear plates, teeth, etc.

The main beneficiaries of the repair works carried out by SC WELDCONS SRL so far have been:

- SC Lafarge Agregate Betoane SA – Grădinari gravel pit, Giurgiu ;
- SC Lafarge Arcom Gips SA – Nucsoara quarry, Prahova ;
- SC Agregate Minerale Construct SRL – Grădinari gravel pit, Giurgiu ;
- SC Tehnologica Radion SA – Potlogi gravel pit, Dâmbovita ;
- SC Marcom RMC 94 SRL – earthmoving machinery dealer, Otopeni, Ilfov ;
- SC SandCompany SRL – Râfov gravel pit, Prahova ;
- SC UniMineral SRL – Piatra Olt gravel pit, Olt ;
- SC SOROCAM SRL – Revărsarea quarry, Tulcea.

Fault/Wear Typology, Classification, Causes

Following the interventions performed and after the analysis of the various types of wears and faults arising from the operation there have been established the main types of faults which can be classified as following:

- faults affecting the structural frame of arms (cracks);
- mechanical wears of joints that affect the bearing support - bearing (wear bush) – bolt assembly;
- mechanical wears by abrasion and impact of the stressed elements belonging to the buckets (wear plates, teeth, front blades, etc..).

The causes of these faults/wears are due to the overloading of mechanical nature, the faulty execution and inadequate maintenance while in service. The main element overloading instances can be classified as following:

- overloading of the structural frame (arms) which exceed the limits set by the rules of operation set for the equipment (overload due to inadequate operation conditions);
- overloading of joints along with the lack of or improper lubrication of components, non-observance of the service schedule, use in other work environments and for other purposes than those which they are intended for, use of low quality parts, interventions performed by unqualified personnel or with inadequate technical equipment;
- mechanical wear of the elements that are subject to wear and that exceed the level prescribed by the manufacturer.

Basic Materials of the Repaired Parts

For the execution of the elements submitted to resistance stress we use steel sheets with high resistance characteristics (Rp $_{0.2}$ = min. 690 MPa) and fine grain steels, quenched and tempered according to EN 10028-6, brands P 690 Q, P 690 P 690 QL1 and QL2.

The most common basic material used for this purpose is WELDOX 700, produced by the Swedish company SSAB Oxelösund, which has the following:

Mechanical characteristics: $R_{p0,2}$ = min. 690 MPa ; R_m = 780 – 930 MPa (for thicknesses between 4 – 100 mm) and R_m = 710 – 900 MPa (for thicknesses between 101 – 130 mm); A_5 = min. 14%.

Chemical composition: C = max. 0.20 %, Si = max. 0.60 %, Mn = 1.6 %, P = max. 0.020 %, S= max. 0.010 %, B= 0.005 %, Nb = 0.04 %, Cr = 0.70 %, V = 0.09 %, Cu = 0,3 %0, Ti = 0.04 %.

Resilience: WELDOX 700 D (equivalent P 690 Q) - min. 27 J at -20 °C;
WELDOX 700 E (equivalent P 690 QL1) - min. 27 J at -40 °C;
WELDOX 700 F (equivalent P 690 QL2) - min. 27 J at -60 °C.

Equivalent carbon: CeV = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15 > 0.43

Steel has a very good weldability, it can be welded using all methods that ensure the minimum resistance characteristics (111, 135, 136, 141, 121, etc..), and requires preheating for thicknesses of over 30 mm.

For the execution of elements that are subject to wear and impact (wear plates, front blades, etc..) we frequently use HARDOX steel plates manufactured by the same SSAB company. The steel brand has no correspondent according to the European standards.

The main brands used are HARDOX 400, HARDOX 450, and HARDOX 500, whose characteristic is a high value of hardness (400, 450, or 500 HBW measured according to EN ISO 6506-1), obtained after a hardening heat treatment applied to the sheets after lamination. These steels have good workability, high capabilities for plastic deformation and a good weldability.

Requirements Taken into Consideration when Establishing the Repairing Technologies

In order to establish the welding repair technologies, by also taking into consideration the indications of the steel manufacturer, you should take into account the following parameters:

The minimum preheating temperature and the maximum interpass temperature

Choosing the right preheating temperature is important for preventing the cracks caused by diffusible hydrogen. It is recommended to use for WELDOX 700 a minimum preheating of 75 °C from starting from the 30 mm thickness and a maximum interpass temperature of 300 °C and for HARDOX, a minimum preheating of 75 °C starting from the 20 mm thickness (HARDOX 400) up to 175 °C starting from the 12 mm thickness (HARDOX 500).

The maximum interpass temperature for HARDOX is limited to 225 °C in order to prevent the modification of the material structure, obtained after the hardening operation.

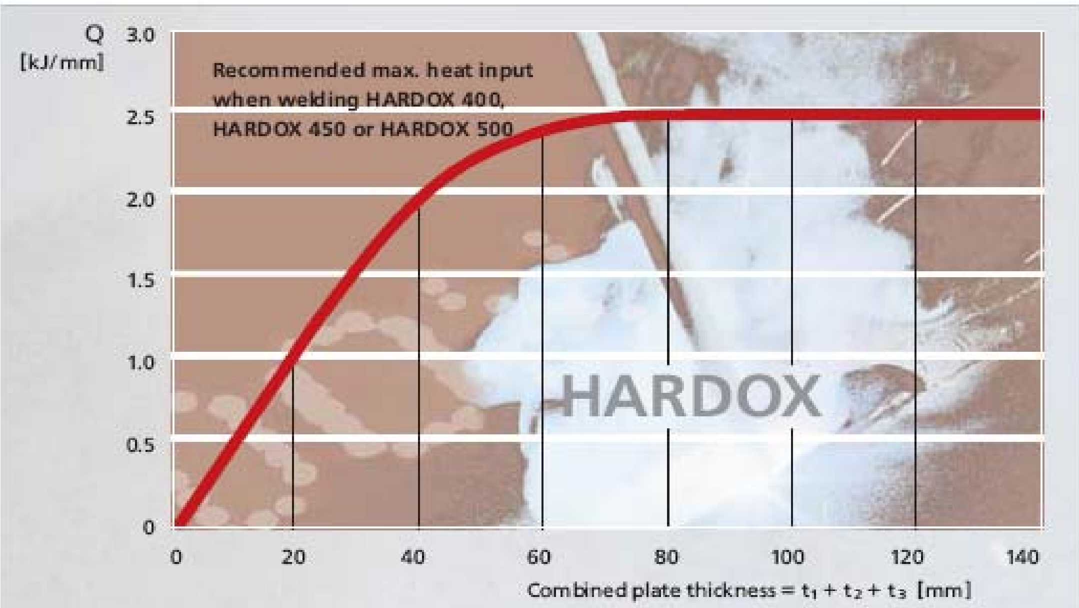
Preheating and interpass maximum temperature is measured according to EN ISO 13916.

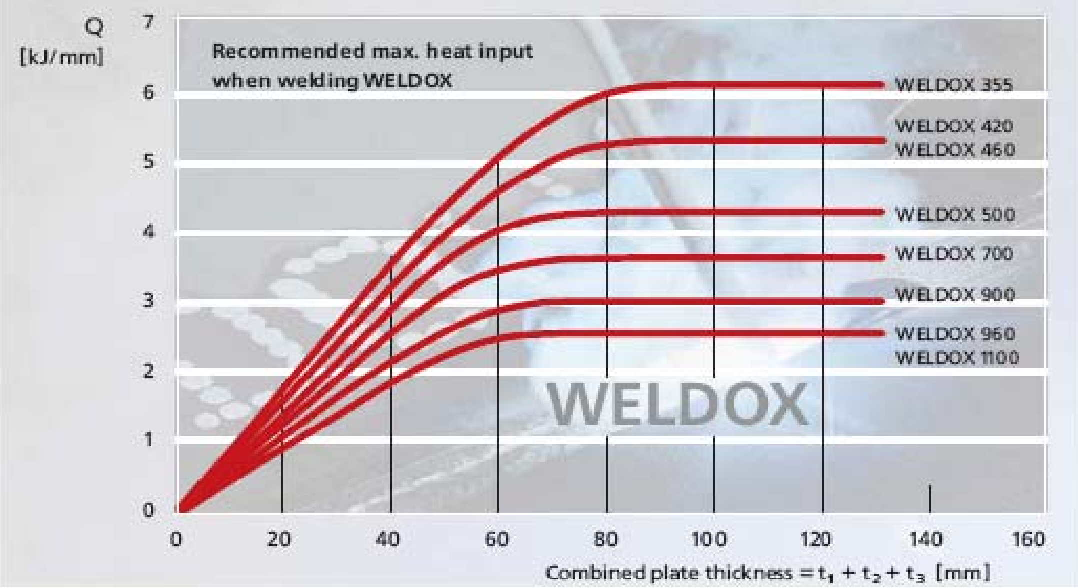
Linear energy

The use of a linear optimal energy in the welding process allows eliminating the risk of joint cracks, obtaining good mechanical properties for the joint and ensuring a proper productivity.

The minimum value of the linear energy, which prevents the cold cracking of the welded joint is determined by the brand of steel (value of the equivalent carbon), the thickness of the joint parts, the welding method, the diffusive hydrogen content in the joint, according to EN 1011-2.

The maximum of the linear energy, which provides the mechanical characteristics of the joint and the maximum productivity of the welding process are indicated by the steel manufacturer depending on the steel brand and on the thickness of the joint parts. The linear energy values recommended by the manufacturer are presented in the following diagrams:





Cracking caused by diffusible hydrogen

Cracking risk caused by diffusible hydrogen, in addition to compliance with the minimum preheating temperature and the minimum linear energy, can be reduced by applying the following measures: use of filler materials with low diffusible hydrogen content (HD $\leq$ 5 ml/100g MD), removal of any traces of impurities in the welding area, non-use of filler materials with superior characteristics compared to the basic material, weld layers deposit in a sequence that creates minimum stresses, setting minimum welding gaps, etc.

Choosing the welding consumables

According to each welding method applied, when choosing the filler materials the following rules will be observed:

For welding WELDOX 700, tack welds and root layers will be made of materials with low resistance characteristics compared to those of the basic material and the filling layers will be made of materials with a similar resistance to the basic material.

For welding the HARDOX type steel there shall be used only filler materials with low resistance characteristics ($Rp_{0.2}$ = max. 500 MPa).

In the case of severe loads, the filler materials will be applied after the deposit of a buffer layer made of stainless filler material, preferably of type 307 or 309.

Choosing the protection gas

When using the welding procedures 135 or 136, the protection gas will be chosen according to the arc stability, the reduction of drops percentage, the diminution or reduction of gas inclusions (pores), the insurance of sufficient penetration. The above described advantages can be achieved using a protection gas type M2.1, according to EN ISO 14175 (82% Ar + 18% CO_2).

Welding order and welding gaps

Welding seams will not be started and stopped on the corners of the parts. They will be moved from the corners with 10 to 15 mm. Welding gaps will not be bigger than 3 mm. When they are bigger, part edges will be built-up on both sides and will be grinded on the front, and if this is not possible, a permanent support will be permanently used for the root, and the two parts will be alternatively built-up until the proper achievement of the shape and the opening of joints. The welding technique with drawn arc, without oscillation, shall be exclusively used.

Choosing the welding methods

The choice of the welding method depends on the welding volume, the execution term of the repair, the accuracy of the load (in the case of wears), the technical possibilities of the performer.

WELDCONS SRL uses, depending on each case, the following welding methods (according to EN ISO 4063):

- 111 – manual electric welding with coated electrodes;
- 135 – MAG welding with solid wire;
- 136 – MAG welding with cored wire;

- 141 – WIG welding.

If it is necessary to remove the worn elements that require a large grinding volume the arc-air gauging method can be used.

Applied Technologies

Welding repairs of the cranks on the arms of the excavator

Causes: High stresses due to the non-observance of the operating conditions established by the manufacturer; hidden manufacturing defects.

Basic material: WELDOX 700 E, 15 mm thickness.

Operations:

Visual check and with penetrating liquids of the arm for highlighting the cracks and their extension;

Fig. 1. Visual testing showing a crack on excavator arm

Fig. 2. Penetrant testing after cracks removal

Fig. 3. Fit-up the permanent metalic support and preparing before welding

Method: 111

Electrodes: FRO Tenax 80 (classification E 69 4 Mn2NiCrMoB 42 H5, according to EN 757), Ø 3.2 and Ø 4, supplier SAF-FRO.

Permanent support: plate 5 x 50 x cord length (mm), material S 355 J2;

Welding parameters: Is = 130 - 180 A, Ua = 22 to 24 V, Q = 2.16 kJ / mm;

Welding technique: alternative load of the edges with basic material, welding with drawn electrode without oscillation;

Preheating: ambient temperature (about 25 °C).

Fig. 4. Welding on excavator arm

Fig.5. Arm repaired by welding after grinding the seams and penetrant testing examination

Fig. 6. The same comments as in figure 5.

Repair/renewal of the frontal loader by welding/mechanical treatment

Renewal of the bore of the main arm

Fig. 7. Renewall the bore of the main arm of a loader

Basic material: wrought carbon steel, minimum thickness 60 mm

Operations:

- preheating the loading area to approx. 150° C, using gas flame (propane);
- welding using the welding method 111, with ESAB electrodes, type OK 75.75 (classification E 69 4 Mn2NiCrMoB 42 H5, according to EN 757), Ø 3.2;
- welding technique: transversal loading with filiform rows; lateral completion at the end in order to achieve the thickness;
- roughing manual polishing; gauge use to verify the diameter (Dgauge = Dbore- 1mm);
- manual adjustment for achieving the bore diameter; check the buffering gauge by contact patch, precision for the realisation of the bore diameter: + / - 0.05 mm.

Fig. 8. Renewall after repairing by welding and adjusting

Rehabilitation of the joint holes in the bucket

Basic material: WELDOX 700 E, thicknesses: 25 - 60 mm.

Operations:

- cleaning by polishing, degreasing the holes and adjacent areas;
- loading using the welding method 141, ALTIG CrMo2 E wire (W CrMo2Si classification according to EN 12070), Ø 2.4, manufacturer SAF-FRO;
- parameters: WTH electrode, Ø 2.4, Is = 50 to 110 A, Ua = 15 to 18 V, Q = ca. 1.9 kJ / mm;
- welding technique: transversal, with multiple passes;
- roughing polishing by using the buffering gauge;
- manual adjustment for achieving the hole diameter; check the buffer size by contact patch, using the bolts.

Fig. 9. Rehabilitation by welding a ear bore of bucket

Fig. 10. Ear bores bucket inside TIG welded

Fig. 11. Rehabilitated bores by welding and adjusting

Loading by welding the wear plates of the excavator bucket

Basic material: HARDOX 400 plate.

Operations:

- polishing, removal of rust and dust (sand);
- loading using the welding method 136, SAF-FRO wire, type STEELCORED 54 (classification MSG5-GF-M21-40-P, according to DIN 8555), Ø 1.6 mm;
- gas type: M21 according to EN ISO 14175;
- welding technique: front, without oscillation, multilayer welding (thickness of the loaded layer = 7 to 12 mm);
- parameters: Is = 230 - 260 A, Ua = 24 to 28 V, Q = ca. 2.35 kJ / mm
- hardness obtained: approx. 40 HRC.

Fig.12: Built-up welding on bucket wear plates

Fig. 13. Hardness testing after built-up welding

Loading by welding the wear teeth of the bucket

Operations:

- rust removal by polishing;
- preheating by gas flame at approx. 100 °C;
- loading by welding with SAF-FRO electrodes, type EI 16Mn (classification E7-UM-200/50-KP, according to DIN 8555), Ø 3.2;
- hardness approx. 20 HRC, after welding and exposure to violent shocks (cold hardening) is hardened at min. 50 HRC (according to the indications of the manufacturer);
- welding technique: filiform drawn wires;- Parameters: Is = 85 to 110 A, Ua = 21 to 23 V.

Fig. 14. Bucket tooth repaired by welding (hardfacing)

Coating the wear elements of the buckets

Material : HARDOX 450 plate , thickness 20 mm

Operations:

- grinding worn plates to remove oxides;
- assembling new wear plate, clamping in hafts;
- contour welding with Supercito electrodes (classification E 42 4 B 42 H5, according to EN 499), Ø 3.2 and Ø 4, producer SAF-FRO;
- welding technique: drawn wires, thin layers;
- parameters: Is = 90 to 160 A, Ua = 21-24 V, Q = 1.9 to 2.2 KJ / mm.

Fig. 15. Excavator bucket rehabilitated using HARDOX wear plates

Economic Advantages of Welding Repairs

The big parts can be repaired by welding, at more reduced costs compared to their replacement with new parts.

ON SITE repairs performed by our company provide the following advantages:

- considerably reduced execution time, intervention is made without dismantling from the equipment the part to be repaired;
- reduced time of activity interruption for the equipment (as it is necessary for the intervention);
- boring / finishing costs much reduced compared to the classical variant (processing in the plant).

References

1. EN 499 – *Welding consumables. Covered electrodes for manual metal arc welding of non alloy and fine grain steels. Classification* ;
2. EN 757 – *Welding consumables. Covered electrodes for manual metal arc welding of high strength steels. Classification* ;
3. EN 1011-2 – *Welding. Recommendations for welding of metallic materials. Part 2: Arc welding of ferritic steels* ;
4. EN 10028-6 – *Flat products made of steels for pressure purposes. Part 6: Weldable fine grain steels, quenched and tempered* ;
5. EN 12070 – *Rods, wires and deposits for tungsten inert gas welding of non alloy and fine grain steels. Classification* ;
6. EN ISO 4063 – *Welding and allied processes – Nomenclature of processes and reference numbers* ;
7. EN ISO 6506-1 – *Metallic materials. Brinell hardness test. Test method* ;
8. EN ISO 13916 – *Welding. Guidance on the measurement of preheating temperature, interposes temperature and preheat maintenance temperature* ;
9. EN ISO 14175 – *Shielded gases for arc welding and cutting* ;
10. DIN 8555 – *Welding consumables for hard facing* ;
11. *HARDOX Wear Plate, WELDOX Structural Steel Plate – Welding*, SSAB Oxelösund, Sweden

Reabilitarea structurală şi dimensională a utilajelor terasiere (încărcătoare, excavatoare, buldoexcavatoare etc.)

Rezumat

Lucrarea prezintă rezumatul activităților de reparație a utilajelor terasiere efectuate de specialiştii firmei WELDCONS S.R.L. începând cu anul 2008. Activitățile de reparații, efectuate în procent de peste 90% pe şantier, pe utilaje terasiere precum încărcătoare frontale, excavatoare sau buldoexcavatoare au la bază tehnologii ce pot fi aplicabile pentru toate mărcile aflate în exploatare în cariere, balastiere, şantiere de construcții etc. care folosesc materiale de bază echivalente şi prezintă o tipologie similară a defecțiunilor în exploatare.

Utilajele terasiere sunt echipamente complexe de lucru solicitate în condiții severe de exploatare (sarcini mari, solicitări variabile, şocuri mecanice, abraziune, mediu umed etc.). Datorită acestor condiții cât şi a posibilitaților de întreținere/service reduse sau de cele mai multe ori ignorate, apar frecvent situații de uzuri/defecțiuni peste cele normale, cu consecințe grave asupra fiabilității utilajului, ce pot provoca pierderi mari companiilor deținătoare prin imobilizarea utilajelor respective pe perioade de timp considerabile.