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ISSN 0543-5846
METABK 54(2) 399-402 (2015)
UDC – UDK 621.791:052:669.15:669.182=111

THE POSSIBILITY OF TRIBOPAIR LIFETIME EXTENDING BY WELDING OF QUENCHED AND TEMPERED STAINLESS STEEL WITH QUENCHED AND TEMPERED CARBON STEEL

Received – Primljeno: 2014-02-18
Accepted – Prihvaćeno: 2014-09-30
Preliminary Note – Prethodno priopćenje

In the conditions of tribocorrosion wear, extending of parts lifetime could be achieved by using stainless steel, which is hardened to sufficiently high hardness. In the tribosystem bolt/ bushing shell/link plate of the bucket elevator transporter conveyor machine, the previously quenched and tempered martensitic stainless steel for bolts is hardened at ≈47 HRC and welded with the quenched and tempered high yield carbon steel for bolts. Additional material, based on Cr-Ni-Mo (18/8/6) is used. The microstructure and hardness of welded samples are tested. On the tensile tester, resistance of the welded joint is tested with a simulated experiment. Dimensional control of worn tribosystem elements was performed after six months of service.

Key words: welded joint, martensitic stainless steel, tribopair, carbon steel, life time

INTRODUCTION

Need for choosing of proper material type, technological and construction parameters is especially evident in the cases of complex wear mechanisms [1,2]. In terms of tribocorrosion wear, material of basic element of tribosystem should be resistant to aggressive media, with sufficiently high hardness and satisfying conditions of tribological compatibility [3]. Tribopair with damage of elements caused by corrosion, due to abrasive and adhesion wear, is selected for research of specifics that appears in tribocorrosion wear. A bright example of such wear is a tribosystem of bucket elevators for transport of oil cake [4]. They consist of a chain in which each third connecting link carries bucket. Elevators capacity is approx..mately 250 t per day. Degumming sediment formed in the process of degumming of crude oil, is added to the cake as ballast. That residue contains phosp-hatides. The inspection found that pH of the sediment is approx. 5,2. According to the original documentation, breaking force of elevator chain is approx. 2 500 N and declared lifetime of a chain is two years.

CONDITION ASSESMENT

Previous visual control of original elevator parts is performed [4]. It was found that parts are exposed to wear and corrosive and aggressive media. In addition, there is contact between internal and external link plates, internal and external link shoes, bushing shell, bolt, and buckets that are bolted on link shoes. Link shoes are every third connecting link of the chain. The measured sprocket surface hardness was between 56 and 59 HRC. Figure 1 shows the parts of the original elevator chain after approx. six months of work. It should be noted that original bolts are welded for external link plates and internal link plates are attached with bushing shell by pressing. On several connections of internal link plates there are several loose connections.

Values measured during the dimensional control are wear of a bolt ≈ 3 mm (Only the surface of bolt which is in contact with bushing shell is worn), and ear

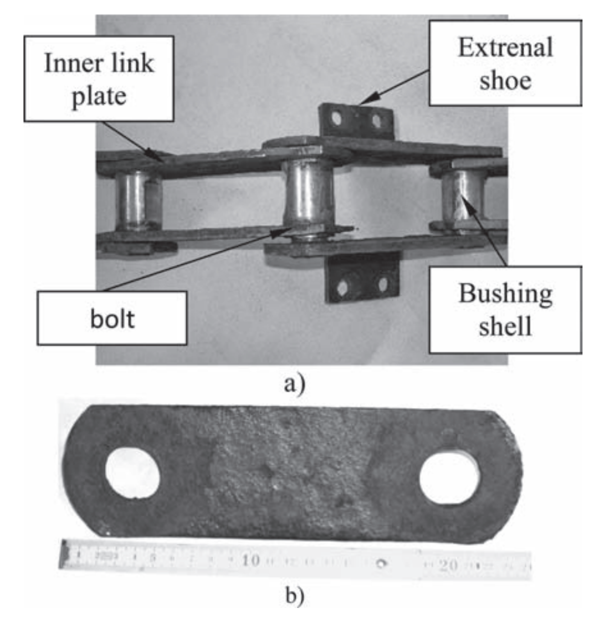

Figure 1 The appearance of damaged chain (a), and original damaged link plate (b)

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of a bushing shell on the outside ≈ 2,2 mm and on the inside to ≈ 1 mm, with emergence of upsetting compund bushing layer of bushing shell/link plate and increasing the gap at about 0,8 mm by evry loose connection. Chain pitch is 160 mm and a total length is 32 m. Estimated total elongation at that chain length is 1 600 mm.

Laboratory tests on the damaged original parts of chain

Chemical analysis showed that the link plates and link shoes are made of quenched and tempered steel, C45E [5]. The measured surface hardness of link plates and link shoes, mean is approx. 210 HB. The thickness of these parts of the chain before the installation was 8 mm. Dimensional control was found that the corrosion caused local reducing of thickness on max. 6,8 mm. Chemical analysis showed that the bolts (Ø 30 x 83 mm) and bushing shells (Ø 42 / Ø 30 x 65 mm) are made of austenitic corrosion steel X5 CrNiMo 17-12-2 [6]. The characteristic appearance of damaged bolts and bushing shells are shown in Figure 2 and Figure 3. Hardness about 300 HV1, with continuously decrease to approx. 200 HV1, is measured in the surface area, at the cross-section of the bushing shell and bolt, in the middle of the tested parts.

TEST RESULTS

By analysing of measured results, it follows:

- Link plates and link shoes are made from steel for quenching and tempering, and the cause of their damage is corrosion due to the presence of fatty acids in the cake,
- Bushing shells and bolts are made of austenitic stainless steel and were damaged by abrasion particles of crust but also by adhesion in the area of mutual contact,
- Because of a corrosion impact of aggressive media on link plates and link shoes, damaging of their connecting spots with pressed bushing shells has been observed.

A final result of all wear processes is increasing of a chain step and „upon contact“ of the sprocket.

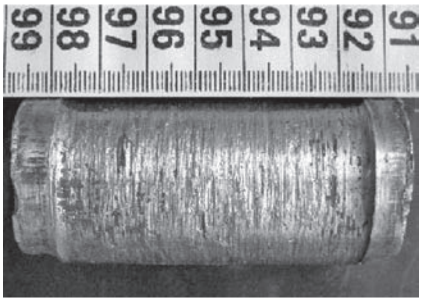
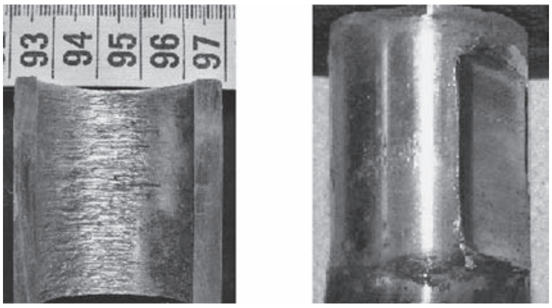


Figure 2 The appearance of the original bolts "worn place"



a) b)

Figure 3 The appearance of the original bushing shell on spot „worn place" (a), macro recording of cross-sectional sample (b)

The choice of own variant materials for wear resistance research

Based on the results of the measuring, it was concluded that the most critical elements in tribosystem are bolts and bushing shells. The dominant mechanism of wear is abrasion with particles of grind and adhesion in area of mutual contact, and bushing shell contact with sprocket. Another critical spot is contact of bushing shell and bolt with link plates and link shoes. Considering the fact that the bolts emphasize the size of the dimensional wear, they were selected as the parts, which will be performed for research by using our own variant materials.

For creating samples/bolts on which experiments will be performed, martensitic stainless steel in a quenched and tempered condition X20Cr13 is selected [7]. Samples of bolts are made according to technical documentation for making elevator chain. These bolts are then induction hardened. It was measured that the surface hardness of the bolt is in the range of 45 ÷ 48 HRC. Ten bolts in total, or five articles, of chain are embedded in elevator chain. Test bolts are welded to link plate with MMA procedure. Electrode based on Cr-Ni- Mn (18/8/6), classified by EN 1600 [8], is used as an filler material. Electrode diameter is Ø 3,25 mm, intensity of current is I ≈ 80 A. Material of link plates is C45E. Samples/bolts are incorporated in new original elevator chain at the beginning of sunflower processing. In this chain bushing shells are made from steel for cementation, 16MnCr5. Effective hardness depth of bushing shell was ≈ 0,8 mm from inside and outside. Surface hardness of bushing shell is in range from 55 to 58 HRC. It is important to point out that the quarrying of test bolts is previously agreed after approx. six months of use. So will ensure comparability of the wear resistance of parts that have been tested within the previous recording conditions.

Test results of own variant samples/parts

In order to verify welded joint of bolt/link plate, static tensile tests, were conducted on the testing machine, Figure 4a. The load is added until the termination of welded joint, and broken places served for metallo-

a) b)

Figure 4 Testing of welded joint of bolt/link plate (a); External link plate after breaking (b)

a) b)

Figure 5 Characteristic wear traces of bolts, macro (a); micro, magn. 50 x (b)

graphic examination and hardness control. The appearance of the welded compound link plate/bolt after testing is shown on Figure 4b. Welded joint of external link plate was broken at 170 kN force.

Typical wear traces of bolts are shown at Figure 5a and 5b.

Dimensional control was conducted on test sample of bolts with calibrated calliper. Conclusion was based on measurements on dozen positions. On the most spent part, a diameter is 29,7mm. Compared to the measurement of a new bolt, that is wearing of ≈ 0,3 mm. Wear traces of the towing part of the stud, are characterized by radial furrows caused by abrasive action of tiny particles of sunflower and bushing shell. These particles, came in contact with bolt/bushing shell, during the work and considering the hardness of micro abrasives of ≈ 6 Mohs „furrows“ are interrupted at the point of encountering on harder carbides. Microstructures and hardness of bolts, plates, weld and HAZ are shown in Figure 6.

Diagram in Figure 7 shows the flow of hardness HV1 from the edge to the core of the bolts (curve ***a***) and on bushing shell (curve ***b***). Results of bushing shell dimensional control shows that there is an intensive wear in contact area with the bolt, and wall thickness is reduced from 6 to ≈ 3 mm.

Figure 8 a shows characteristic wear traces of external surface of bushing shell, and Figure 8 b shows wear traces of bushing shell from the inside in contact with bolt.

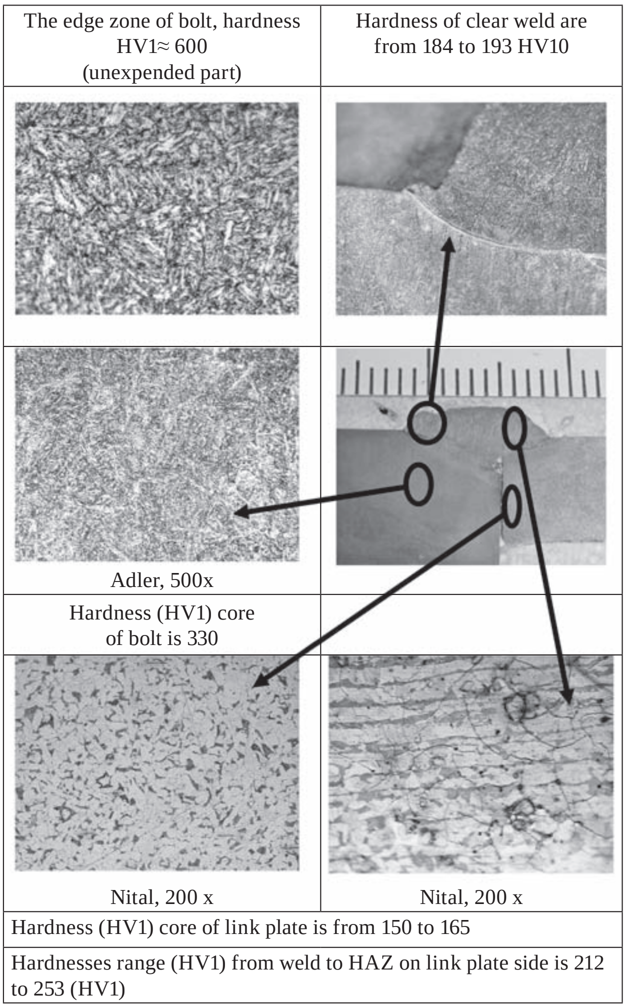


Figure 6 Microstructures and hardness of bolt and link plate

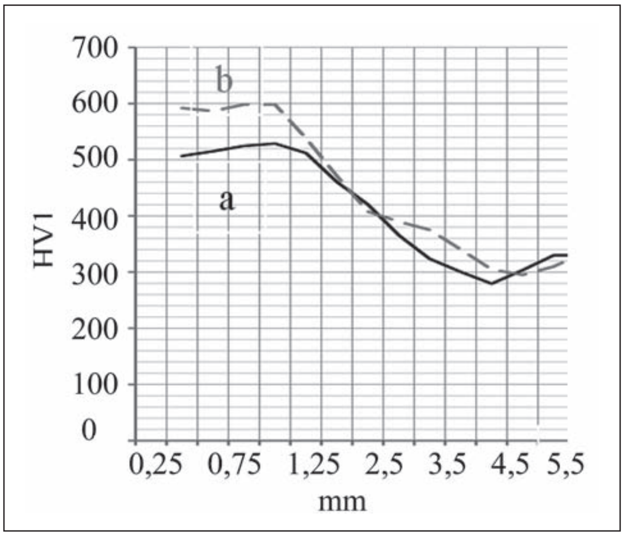
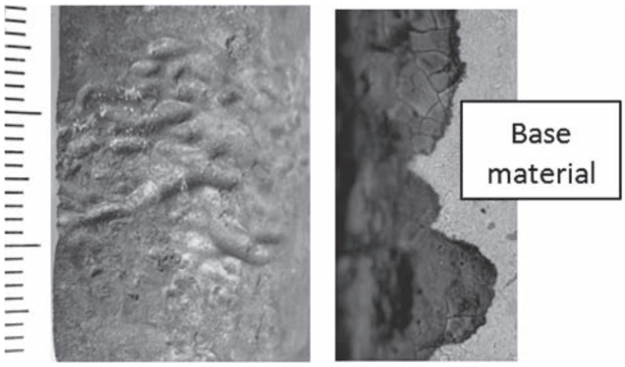


Figure 7 Hardness flow; bolt (a); and bushing shell (b)

ANALYZE OF RESULTS AND CONCLUSION

Based on the results of laboratory tests and comparisons of wear of original parts of chain elevator with variant bolts and bushing shells, conclusion is:

- the dominant wear mechanism of bolts made of martensitic corrosion-resistant steel is abrasion with tiny husk particles,



a) b)

Figure 8 A typical wear traces of external carburized surface of bushing shell (a); the outer surface (macro), inner surface (magn. 500 x) (b)

- carburized bushing shells are damaged by abrasion and corrosion due to action of acid media that has pH value ≈5,2,
- maximum measured breaking force of weld joint bolt/link plate is higher than the calculated breaking force of chain. Although, the main task of weld in this tribosystem is, to maintain a continuous connection between bolt and bushing shell during the use. It helps to avoiding unexpected damages noticed on original chain caused because of "riveting" of that joint and consequently jumping upon connecting links on the sprocket teeth.

Conducted analysis of results, research of microstructure and measured hardness of triboelements, shows that significant prolongation of lifetime could be achieved by this approach. Additionally, perhaps the most important, the risk of fracture could be avoided by welding of bushing shells and bolts to appropriate link plate. This is the most important thing for all structures, including this tribosystem. Wear intensity could be predicted, according to structure analysis, structure hardness and wear traces. These results are the basis for possible future research. Except for increasing of triboelement wear resistance, more analysis could go in direction of additional welding material impact, on bushing shells and bolts with link plates and the choice of other parameters of welding process.

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Note: For English language translation and editing responsible is prof. Martina Šuto, University of Osijek, Croatia.