14th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2010, Mediterranean Cruise, 11-18 September 2010

IMPACT OF THE CRACK IN THE ANGULAR WELDED JOINT ON THE EXPLOITING BEHAVIOUR OF THE CARRYING STRUCTURES MADE OF IMPROVED STRENGTH STEEL

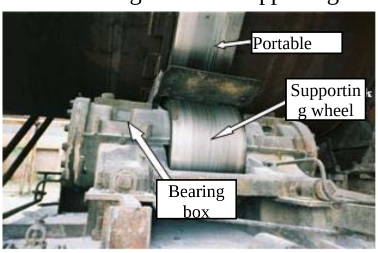
Milenko Perović
Chamber of Economy of Montenegro
Novaka Miloševa 29/II, Podgorica,
Montenegro

ABSTRACT
The technical systems are required to be reliable and work safely throughout all stages of the planned working cycle with the retention of the process parameters at the given level. The residual stresses, the possibility to occur the metallic discontinuity and the change of the geometric shape on the spot where the elements are joined by welding are very common causes for the loss of the integrity components and the system as a whole. This paper presents the procedure of sample analysis, which led to occurrence and development of the crack of elements with a big cross section as a consequence of badly chosen welding technology. The analysis are based on the morphological image of various crack areas, where the crack occurred as a result of fractography of the surface in the course of demolition, as well as on the microstructural characterization of several specific initiation areas and the crack development.

Keywords: welding, crack, fractography surface

1. INTRODUCTION

Torque transmission , regardless on applied structural solution, causes stress-deformation state of structural elements that is potentially critical to their failure. This is additionally complicated if system components are exposed to high specific pressures, higher temperatures and wearing processes. Such a case is with systems that perform rotational motion technologic parts for sintering industrial powder materials such as: alumina, cement, lime etc. Basic transmission friction-mechanic architecture in such kinds of production equipment comprised of rotating side with supporting wheel, which is presented in Figure 1.



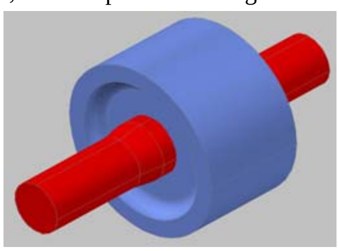


Figure 1.Appearance of carrying station in exploitation and 3D image of supporting system

2. ANALYSIS OF THE SUBJECT OF RESEARCH

According to the basic documentation, the axle is made of forged steel of quality Ck 45(DIN 17006;W.No 1.1725) , and supporting wheel is made of carbonic structural cast element for general purposes with quality St 50-2(DIN 17006, W.No 1.0050)[1]. Manufacturing sheets of the axle and supporting wheel are presented on Figures 2. i 3.

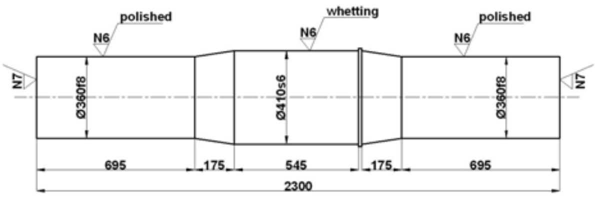


Figure 2. Axle scheme

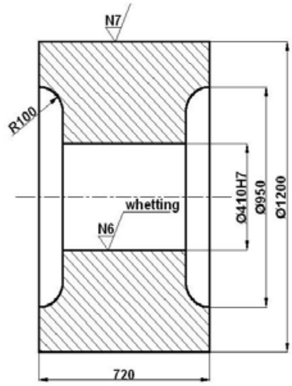


Figure 3. wheel scheme

Joint between the axle and supporting wheel is created by overlap in the tolerance field Ø410H7/s6. During long exploitation time, because of wearing on contact surface of the wheel and its movement on the axle in axial direction, user of the equipment decided to replace critically endangered assembly in supporting station. For that purpose, he engaged repairing company from neighborhood which he deemed appropriate in material, technological and professional sense, to be able to conveniently make new spare part. Repairer chose steel 42 CrMo4 instead of steel Ck45 (DIN 17006, W.N1.7225), treated it thermally up to tensile strength of Rm=850MPa and processed it without grinding of overlapping area, simultaneously retaining mentioned toleration measures. In order to prevent movement of wheel on the axle after the construction is cooled, he performed radial welding of wheel and the axle in several traverses of angular joint.

According to contractor's report , additional material that is used for welding belongs to group of low-carbon and non-alloying steels ISO 2560-E515B120262H [2].

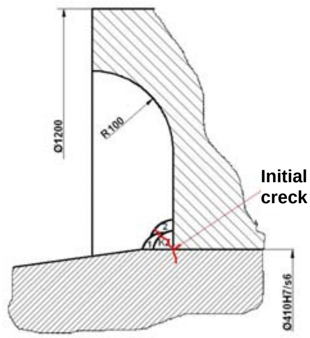


Figure 4. Crack position

3. IDENTIFYING OF CONSTRUCTION COLLAPSE

Only after a couple of days after completion of works, construction is mounted in place of mounting. After several working hours, they heard sound of the axle fracture in welding place to supporting wheel. Crack position in angular welded joint schematically is presented on Figure 4, and appearance of assembly after fracture is presented on Figure 5.

Figure 5. Assembly state after crack

3.1. Investigation of causes of fracture

The sample is taken immediately from region of welded joint and it served for metalographic researches and fractography of fracture surface, presented in Figure 6. In the zone of welded joint, from axle surface, a sample is cut off in order to analyse state of material. The sample is metalographically prepared on two sides, from external side (axle surface) and lateral (perpendicular to previous), in order to analyse possible impacts of weld on defect.

During metalographic and scanning analysis in this area we observed cracks that were filled with fresh oxide deposit what tells us that these cracks are initiated before final fracture and there were enough time for creation of corrosion products. Some cracks somewhere have penetrations up to 5mm in depth of parent material.

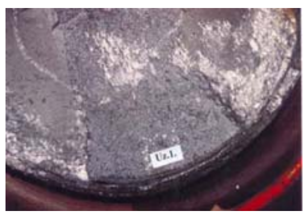


Figure 6. Sampling place

Microstructure of parent material in this region has been changed in relation to structure of parent material. High scope of microstructural ingredients is present, from ferrite-perlite to martensic and Widmanstatten, or their mixtures, Figure 7. a,b,c,d,e and f. This state of structure is characteristic for welded joints made by using additional material based on non-alloying steels.

3.2. Fractography analyze of fracture surface

Specimens for fractographic analyse fracture surface are taken from places presented in Figure 6. (immediately bellow material of angularly weleded joint). Analysis is conducted on scanning microscope type JEOL-JCXA-733. Due to presence of local corrosion products, samples are, after cleaning in alcohol and acetone, steamed with gold in order to provide their electrical conductivity. The samples are observed with magnifications of 40-3000x, [3]. Analysis of the external part of sample indicates that it is possible to observe presence of cracks occurred in various time intervals. Some of them are completely free of oxides and others have sticky skim which may indicate, inter alia, various time of their initiation. Figure 8. a, b, and c. By scan analysis of surface fracture, with bigger magnifications (up to 3000x) we can see that fracture appear to be in form of mixed fracture. There are forms of inter – crystalline and trans-crystalline fracture with observable development of secondary and tertiary cracks. Further inspection of the sample towards the core of axle, indicates that the structure is crystalline with big number of flat areas and stairs oriented towards the propagation of primary crack. This state is specific for trans-crystalline crack that begun with cutting or shear mechanism, Figure 9. a, b. These forms, in morphological sense, represent shapes similar to river networks and fish bones that have specific initiation mechanisms and are characteristic for trans-crystalline, Figure 9.c, d.

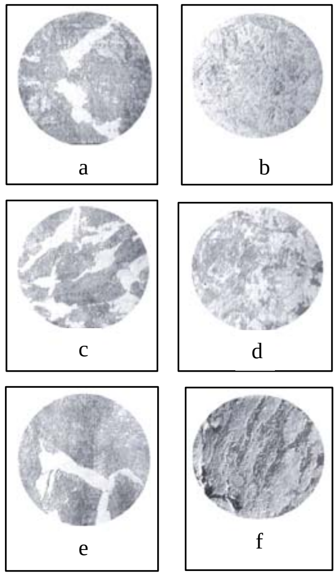
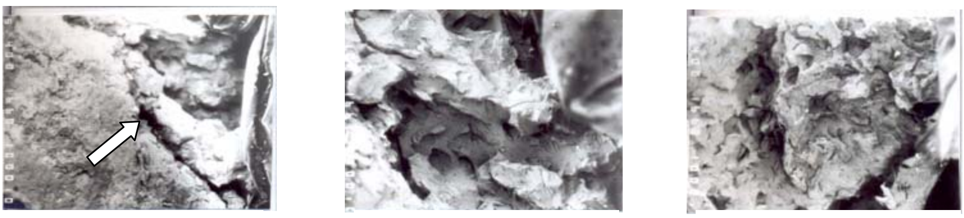
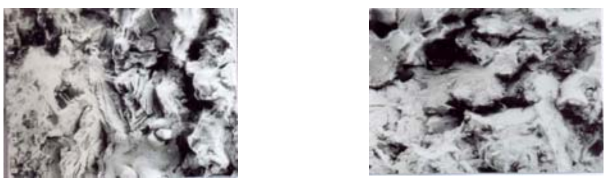


Figure 7. Welded joint microstructure.



a) micro-cracks on sample surface x40 *b) image up to previous x 100* *a) corrosion traces on crack x 240*

Figure 8. Micro-fractography of crack surface in in the sample located immediately to welded joint



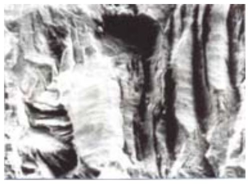
a) brittle crack x100 *b) lamella perlita x660*

c) second place-brittle crack x40 *d) secondary crack-detail x240*

Figure 9. Micro-fractography of crack surface in the sample located towards axle core.

Further inspection, towards the core of the axle, indicates that macro-feature of crack is typically brittle and micro-analysis of crack fractography indicates typical exclusive brittle crack. Microscopic properties of crack surface are in shapes of flat areas, river networks, staircases, fish bones etc. They are present in entire tested surface of the sample and are followed by tiny secondary cracks that are locally inter-crystalline , Figure 10. a,b,c,d.

a) brittle crack x100



b) brittle crack x60

c) detail x600
from Figure 10 a.

d) brittle crack x260
detail from Figure 10 b.

Figure 10. Micro-fractography of crack surface in axle core

None of three tested specimens shows elements of tough crack in any part. Here we have classic example of sound brittle crack, where trans-crystalline shape dominates.

4. ANALYSIS OF RESULTS AND CONCLUSION

The hypothesis in case of evaluation of possible causes for axle failure of supporting wheel has proved to be correct. Testing shows that use of non-alloying additional materials for welding of steels that are prone to incandescence, without applying of precaution measures, has catastrophic consequences. Therefore, special attention should be paid to the following [4]:

- Selection of material and thermal processing in every phase of making of elements being exposed to various load,
- Functionality of existing structural solution for prevention of unwanted movements of elements in pressed assemblies.
- Quality of processed surface in the contact area of axle and supporting wheal must be high in order to prevent occurrence of additional source of stress concentration caused by roughness.
- Welding technology of steels that are prone to initiation cold cracks for the case where other solutions of forming inseparable link are not feasible or impossible to attain.
- Size of overlap should be such that pressing stresses in contact area are not higher than stresses that are result of external load on elements.

6. REFERENCES

[1] Technical files of the Alumina Plant, Aluminim Plant Titotgrad, 1970.
[2] Additional welding materials, Product Catalogue, Electrode Production Plant, Montenegro, 2000.
[3] Expertise on causes of failure of supporting wheel axle of the calcining furnace, Institute of Ferrous Metallurgy, Montenegro, 2006.
[4] Perovic M: A Contribution to Identification of Causes for Fracture of Dynamically Loaded Tribomechanical Assembly Using Fractography Analysis of the Fracture Surface, International Symposium on Welding, Serbia, 2006.