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SURFACE QUALITY OF STEEL TUBES AND THEIR BEHAVIOR DURING SERVICING IN BOILERS

Abstract: *The quality of seamless steel tubes usually is concerned on geometrical measurements, mechanical testing and rarely on checking the chemical composition. After a years in service, many kinds of damages on steel boiler tubes are available. The servicing conditions at a boiler plant (temperature, pressure, water quality, etc.) certainly have an important influence on the behavior of seamless tubes, so many parameters have to be controled, but the surface state of used tubes does not is concerned on an adequate manner. It is registered that frequently the surface of boiler tubes are responsible for metal degradation, it means that boiler is failed, and production process is stopped.*

Here are shown and discussed some examples of surface quality of steel boiler tubes before the damage has happened, when the smooth surface is changed into rough one, with a lot of striations. An increasing of surface roughness means that damage will occured pretty soon. The investigation of surface changes is provided by using a metallographic analysis. Thermal fatigue of boiler tubes also shows an influence on increasing the surface roughness of used steel boiler tubes.

Keywords: *surface roughness, boiler tubes, steel degradation, metallographic analysis*

1. INTRODUCTION

Boiler tube in power-generation are used to generate steam for electricity production. Boiler tubes are a part of tubing components of utility and industrial boilers. Operating temperatures and pressures of boiler tubes in this case are up to 530°C and 160 bar and higher. Boilers are used for different combustion systems, conventional coal (pulverized coal), oil and gas. Boilers for industrial applications produce steam or hot water for process applications for various industries - biomass firing (fluidized bed boilers), heating, pulp and paper industry (recovery boilers), waste to energy plants, various chemical processes, etc. [1,2].

The most popular steel grades, commonly used for boiler seamless tubes, according to SRPS C.B5.022, are: Č1214; Č1215; Č7100, Č7400 and Č7401. Almost steels for boiler tubes are covered by standards EN 10216-2 and 3; EN 10204 3.1; DIN 10216; 10315-1,4; 17175 etc. Carbon steel is ordinary steel which contain other alloying metals in their common percentages, while austenitic boiler tubes are made from low carbon and high chromium content [2÷4]. Despite its relatively limited corrosion resistance, carbon steel pipes and tubes are used in marine applications, nuclear power and fossil fuel power plants, transportation, petroleum plants and construction. Two examples for using the boiler tubes in power equipments are shown in Figure 1.

Figure 1 – An conemporary example of power generating equipment

All tubes are checked according to the relevant standards. Longitudinal and transverse flaws on the outside/inside surface, wall thickness, laminations, are available by special NTD test [3,6].

2. LONGITUDINAL CRACKING OF BOILER TUBES

The failure of boiler tube(s) [2,3,7] represents pretty serious problem, because the whole plant should be stopped. One example of tube cracking and its microstructure is given in Figure 2.

Metallographic view shows that the initial structure is composed from ferrite and pearlite, and finely dispersed carbides, and it is commonly and expected structure in this kind of steel grade, 15 Mo 3 (Č 7100). All around on the outer diameter of tube were visible a lot of smaller striations, but just one has lead to the cracking. The crack is started from the surface, and propagate through the tube wall. The reasons for such crack should be search in: a) tube manufacturing process and b) servicing conditions [3,6].

It′s really impossible to explain the nature of longitudinal crack from. Fig. 2, only by servicing conditions or chemical inhomogeneous of steel.

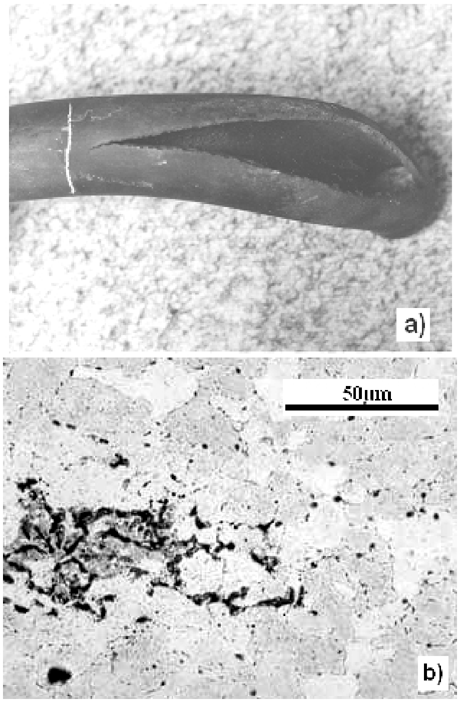

Figure 2 – Longitudinal crack at 15 Mo 3 boiler tube a) and microstructure in cross section b)

So, the nature and origin of longitudinal crack should be search in a manufacturing process.

3. BOILER STEEL PIPES MANUFACTURING PROCESS

Seamless pipes are those which do not have a welded seam. They were first made by drilling a hole through the center of a solid cylinder [8,9]. This method was developed during the late 1800s. These types of pipes were perfect for bicycle frames because they have thin walls, are lightweight but are strong. In 1895, the first plant to produce seamless tubes was built.
Boiler tubes are mainly heavy-wall tubes, to sustain high pressure, Figure 3.

Figure 3 – Semi/finished heavy-wall tubes

Seamed tubes are heavier and more rigid. Typical schedule of steel boiler tube production consists of: forging/piercing, rolling and sometimes drawing. Forging/piercing is providing only in hot state, while rolling is available in hot, but also in cold state, and finally the drawing is always done in cold state [4,8],. The rolling of tubes, either from steel or any other metal [9], successfuly is provided by so called pilger process, Figure 4.

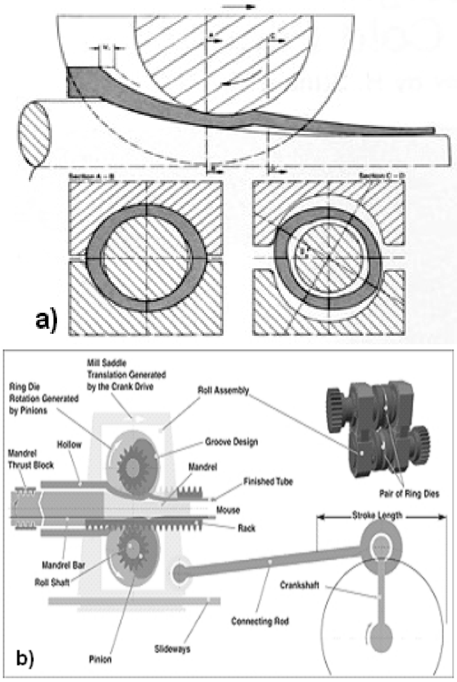

Figure 4 – Principle of tube rolling in pilger process: a) at rolling moment and b) scheme of machine

The pilgering process relies on next way: the tube moves forward and it rotates while the ring dies move back (this action is similar to a crankshaft driving a piston in an automotive engine) and rotate for 900. Pair of ring dies are fixed to a machine housing, weight from 1-2 tones [8]. The oscilation motions of such mass reach about 45-120 cycles/min. The obtained tubes are nearly to circular, so they should be further fabricated by drawing [9].

4. QUALITY OF STEEL TUBULAR PRODUCTS

Certain pipe characteristics can be controlled during production. For example, the diameter of the pipe is often modified depending how it will be used. The diameter can range from tiny pipes used to make hypodermic needles, to large pipes used to transport gas throughout a city. The wall thickness of the pipe can also be controlled. Often the type of steel will also have an impact on pipe's the strength, hardness and flexibility. Other controllable characteristics include length, coating material, and end finish.

Before the fabrication of a boiler, the tube material is undergoes to detail testing, including geomerical measurements, mechanical testing, rarely technological, hydraulical testing, or similar. Microstructural examinations of new tubes, impurity&slag contest, etc., are far away to be practice in everyday works in Serbia, it is just autor′s opinion [3,10,13].

5. SURFACE QUALITY OF CRACKED BOILER TUBE AND DISCUSSION

The surface quality of boiler tubes, either from steel or brass, usually are not studiously monitored in the stage of boiler production, except the dimensional control. But, after a years in service, many damage mechanisms have appeared, both at the surface or in the bulk of material. The monitored crack was originated at the surface, so that problem should be a matter of consideration.

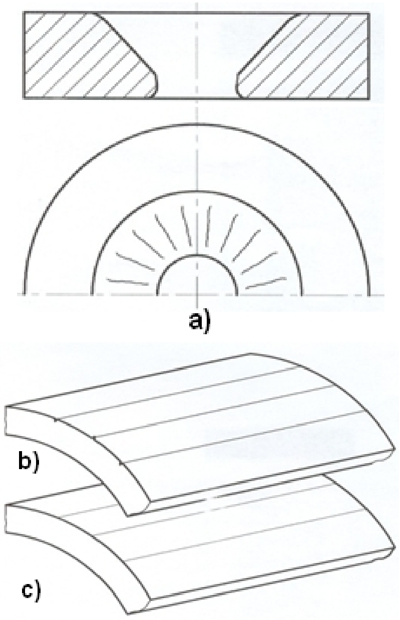

Figure 5 – Striations at die surface a), striations at tube surface b) and squeezed iregularities into surface c)

The corrosion products were present in those boiler tubes, but the main reason for tube failure could not be notified only as a consequence of a corrosion process: if the corrosion failure is happened than the straight longitudinal crack simply could not be appeared. The straight lines at outer surface of a tube became visible usually after a long period, but here they were registered after shorter time, about 15000 h. For such surface irregularities the response lies in drawing die, Figure 5a). The drawing die during working cycles is undergoing to wear. Sometimes the wear at the die diameter is not uniform distributed, rather is localized making striations. Striations from the drawing die will be copied on the outer diameter of tube, Figure 5b). After final, calibrating, drawing the smooth surface will be obtained but the striations were squeezed onto the surface. After a while, during working of such produced tube in boiler (hot) conditions, such irregularity will be open and this will be a real place for crack appearance, as registered in Figure 2.

6. CONCLUSION

In the moment of tube production all consequences whish would arise from the servicing conditions simply are not predictable or clearly visible. Here is given an example of tube cracking when all parameters about mechanical or chemical requirements are satisfied, but in spite of this the boiler tube is failure.

The failure is oriented in longitudinal direction. Such crack could not be explained by regular working conditions in boiler plant, but the quality of tube surface. For obtaining of squeezed surface is responsible the drawing die with partially damaged working surface, it means that frequently re-grindings are missed.

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