ABSTRACT

Many testing methods, which are customary used in verification during production processes of machine parts, tools or assemblies, simply could not be applied after years in servicing of an assembly or equipment. For testing of any equipment, the non-destructive method always is preferable. For topographic analysis of the metal surface characteristics are developed numerous methods, but for microstructural evaluation there are only a few. If such analysis has to be provided on situ than replica method is irreplaceable. The replica should retain the details from the inspected surface and in anyway represent the negative of the microstructure. When replica is taken in field, it can be metallographically inspected or photographed in laboratory at anytime. So, many processes which are present at inspected surface can be monitored by replica technique. The replica also is obtainable from the fractured surface and only by this technique is possible to asscess the reason(s) for damage. In this paper are presented some examples when replicas were taken from ferrous materials, steels, but also from a non-ferrous metals.

Key words: replica, preparation, surface analysis, kinds of damages

IZVOD

Mnoge metode ispitivanja, koje se obično koriste u ispitivanju tokom proizvodnih procesa mašinskih delova, alata ili sklopa, jednostavno se ne mogu primeniti nakon više godina rada takvog sklopa ili opreme. Za ispitivanje bilo koje opreme, metode ispitivanja bez razaranja uvek imaju prednost. Za topografsku analizu karakteristika površine metala razvijene su brojne metode, ali za otkrivanje strukture postoje samo nekoliko. Ako takvu analizu treba izvršiti na licu mesta onda je metoda replika nezamenljiva. Replika treba da zadrži detalje sa ispitivane površine i ona svakako predstavlja negativ mikrostrukture. Kada je replika uzeta na terenu, ona se može metalografski ispitivati i fotografisati u laboratoriji u bilo koje vreme. Tako, mnogi procesi koji su prisutni na ispitanoj površini mogu se ispitivati primenom tehnike replika. Replika je, takođe, primenljiva na površinama lomova i samo ovom tehnikom je moguće dati ocenu razloga pojave loma. U ovom radu su prikazani primjeri kada su replike uzete sa železnih materijala, čelika, ali i sa obojenih metala.

Ključne reči: replika, priprema, analiza površine, vrste oštećenja

1. INTRODUCTION

For metal surface analysis of machine, tool part or construction, the replica method as a non-destructive method could be used for microstructural examination(s). The surface condition as well as various surface damages, occurring frequently due to overheating or overloading, even crack(s) appearance, are able for metallographic analysis in situ. The surface preparation of monitored component/assembly for replica metallography should be in fact done on the same way as for the usual surface preparation when the optical (light) microscopy is used [1,8÷12]. The area of the inspected machine part/construction first is mechanically grinded, polished, if it’s possible an electropolishing also could be used, and than etched
for revealing the microstructure of material. The replica does not damage the inspected machine part/construction, and the monitored component can further operate.

In thermopower generator, petrochemical plants, bridges, etc., there are numerous machine parts which are exposed to both high temperature and high stresses [1,4÷6]. Production of electric current or petrol/gas both for citizens and industry constantly has a rising level. In condition monitoring or certification of those plants the testing of components preferably should be non destructive. If in common metallographic practice is obvious to cut off a specimen for further microscopic evaluation, either for light or electron microscopy, than in named plants taking a sample by cutting is just forbidden [11÷13]. Any thermopower generation plant really represents a complex structure, as can be seen from Fig. 1.

1. firebox;
2. boiler drum;
3. vapor overheating;
4. economizer;
5. air heater;
6. fan;
7. filter for gases;
8. chimney;
9. ash remover;
10. coal mill;
11. mill’s fan;
12. coal stock

Using the replica technique, as a non destructive method, has developed originally from preparation the samples for transmission electron microscope monitoring. Now, the non destructive metallography using replicas is a quite indispensable technique for monitoring the metal (material) conditioning during (thermo)mechanical loading either of machine parts or construction [8÷15].

The monitoring of inspected surface can be made on-site, but in such circumstances frequently is made just an overview. Full judgement often is more efficient when the replicas were brought to the laboratory and can be examined later under the more favorable conditions [11÷16]. One of the great advantage of the replica method lies in fact that replicas can be taken on site by skilled personal but the evaluation of microstructure can be done in the laboratory by qualified metallurgist. Further, it means that results can be photographed and stored. This is of crucial importance for the future periodic retesting, particularly for comparison of obtained results.

Other applications of the replica technique are used for analyzing the different damages, failure analyses and other microstructural changes caused by welding, heat-treating, etc.

2. REPLICA’S METALLOGRAPHY

A variety of non-destructive testing methods were developed in past for detecting the imperfections, cracks or similar irregularities in a material from which were made different machine parts, device or construction [1÷7]. One of the useful non destructive method for micro-structural observations of the metal (surface) state is the replica technique, also referred as field metallography. Replica is real copy of the microstructure from the inspected surface. By taking a replica from the machine part, tool or construction, the surface shall not be damaged and can farther operates, as earlier does.

2.1. Surface preparation for replica taking

The inspected area must be prepared for replicating on the same way as for optical microscopy. For surface analyzing of a machine/construction
part, the tested area firstly should be cleaned-up and degreased by one of the chemical treatments. After that, the inspected surface must be mechanically (rough and moderate) grinded, than high polished, and finally this area needs etching as for microstructural analysis by light microscopy [11÷16].

Grinding and polishing are provided by high-powered hand drills, with attachments of small disks. Those disks are fitted with grinding papers: firstly with rough one and further with disk of fine grains, for example 360 grits at the begging up to 1000 (1200) grits at the end of mechanical treating. SiC is a common grinding material. Polishing is provided by using diamond pastes or alumina powder mixed with water. Instead of pastes another shapes of polishing materials can be used as spray or suspension.

Etching is usually carried out with a cotton swab saturated with the etchant. For the most structural steels as etchant also is used a nitral (solution of nitric acid into the alcohol). For etching on situ usually little more concentrated solution (3–6% of nitric acid) has to be used than in a laboratory (1 to 3%).

When working with such chemicals, the safety precautions must be provided. The surrounding area of inspected machine part or construction has to be protected, indeed, especially from the acid solution influence.

2.2. Replica techniques

Replicating today represents a job, which has never been so easy [11÷13]. In modern field metallography are used three different replica techniques:

- Foil
- Two-component polymer
- Drops of lacquer

1) In this technique a softened foil is placed onto the prepared (grinded, polished and electro-polished) sample surface. The foil is made of an ethyl acetate basis, with thickness less than 0,1 mm. The sensuation of the foil is achieved by immersion into the acetone for couple of seconds. The time of replicating at a surface usually is about 15–20 s. After removing from the inspected surface, the foil is put on the flat glass slide (plate).

It seems that metal-coated plastic foils are now dominant for replicating of different samples. The back-metal provides a higher quality of the surface image, and easier or safer handling. For improving the contrast, the plastic foil is sputtered (by plasma technique) with aluminium or gold metal.

As a standard dimensions of transparent or metal coated foils could be regarded 20x30 mm, while in the second type of replica the dimensions may be greater, depending from the occasions [11÷13,16].

2) Another technique uses a two-component cold-setting polymer. The polymer is squeezed from gun with a piston to the area to be examined. Compounds are supplied in cartridges and are dispensed using a hand-operating gun, as it was shown in Fig. 2a). The cartridges contain both polymer and curing agent, which are mixed in a disposable nozzle during the application to the surface [11,16].

Removing the polymer from the sampled surface is done after it has hardened (cold-setting is over), Fig. 2b), without leaving any residues on the inspected surface. The curing time is about 5 min. or less. Than, a highly accurate and stable replica will be obtained. The cured replica is tough and dimensionaly stable. The thickness of such replica is about a few millimetres. This replica technique allows an inspection at locations where access is difficult, such as inside the pipes. In comparison
with previous technique, this technique with polymer enables the replicating the pitting: such obtained replica further can be examined by scanning electron microscope, see Fig. 3.

Example from Fig. 3. offers many advantages in using of this technique [16]. Usually, no significant health risk is present when working with such polymer. This type of replica is useful for applications under different conditions (as slightly increased temperature) and on horizontal as well as vertical or overhead surfaces.

3) The third technique uses a lacquer: only a few drops of such substance onto the inspected surface is enough [12]. After reinforcing, when the curing process of polymer is finished at room temperature, the replica is ready for microscopical analyzing. But, this kind of replica is exposed to bend during peels of from the surface. Generally, this technique has not found a wide application but for rounded samples such replicating might has an advantage.

2.3. Metallographic examination

The application of those systems offers superior and fast results. For applying the replica technique an expensive operator experience is not necessary, so one can be sure to return to the laboratory with good replicas every time. The replica will reflect light as like a polished metal. This fact makes replica well suited for microstructural examination with a conventional microscope, by using bright or dark field. The replica can be examined up to a magnification of 500 x times by using a light microscope or up to 5000 x with a scanning electron microscope. In metallographic analysis by replica technique a high resolution may be achieved: down to 0.1 μm.

2.4. Disadvantage of replica technique

Although there are numerous advantages there are just a few limitations in using of replica technique. All replica techniques are not adequate means for inspection of the cavities or inner holes. If such measurements have to be provided, then 3D examination can be carried out by using a non-contact measuring instruments, such as laser measuring equipment or measuring projectors with 2D or 3D facilities [13÷16].

Image of the surface obtained by replica is referred only at the examined layer. It means that the bulk material may has quite different structure. Than, the replicating must be repeated after regrinding and repolishing.

If the residuals from etching process are not fully removed than a kind of the corrosion process may takes place in the future, which represents a disadvantage in the hole replicating technique.

3. SOME ENGINEERING INSPECTION APPLICATIONS & DISCUSSION

The replicating represent very versatile system for non-destructive testing of machine parts, components or constructions [11÷13]. In Fig. 1. is represented one boiler plant. In this paper a part of it will be shortly described for replicating. The boiler drum, pos. 2. at Fig. 1, is closed cylindrical vessel. In this case, boiler drum has outer diameter about Ø1800 mm, length 17500 mm.

The boiler drum belongs to a structures with a heavy wall thickness, sometimes over 80mm. The importance of boiler drum function demands periodically inspection of material state, and for that purpose usually the replica method is used. The distribution of places where replicas were taken is shown in Fig. 4.
Typical microstructures are shown in figures as follows. The slightly different microstructure is found at the cylinder part and the bottom side of the boiler drum, as is shown in Fig. 5). A pores, dark areas in Fig. 5a), easily could be registered by using this technique. Any kind of ferritization in structure, Fig. 5b), can be also discovered by this technique.

The initial structure, represented in Fig. 6a), might be changed during welding process, see Fig. 6b). Those weldments should be the matter of periodical inspection, indeed [14,15]. Instead of changes into the weldments another types of changes (creep or crack damage) in material could be distinguished, see Fig. 6c), d).

Monitoring the microstructure by using a replica method could give us more informations about the diffusion along the grain boundaries, corrosion, precipitation or enlarging the grain size. So, using replica method for monitoring the microstructure will make sense only by periodical investigation and comparison of obtained with previous results. Coalescence of micropores also could be registered by replica method [11,15].

It's far away that only components from a thermopower station are able for replicating. One example, pretty known from a common life, is a crankshaft from a vehicle, in Fig. 7 is represented such examination.
Fig. 6. Microstructure of: a) base material near weldment, b) in weldment; c) beginning of creep, and d) appearing of one crack

The crankshafts generally are produced by casting, forging, machining and heat-treating. After replica is taken off, an analysis could be provided for discovering the reason(s) of cracking. But, the replica technique is available for monitoring the surface layer, for example the cracks at hard chromium layer obtained by electroplating [11], as it was shown in Fig. 8. This example certainly shows wider application of replica technique.

Fig. 7. View of crankshaft a) and cracks at the surface, registered by replica method b)
Non-ferrous metals rarely are examined by using the replica technique, but it is also possible, as could be seen from Fig. 9.

The slightly difference is evident when the structure is monitored by light microscope or by using the replica, but such difference in colour of the picture might be neglected.

Replica technique is available for monitoring the structure changes into the metal. For further discussion of findings, a solid knowledge about metallurgical reactions is needed.

For discovering the cracks or microcracks, the replica method may offer an overview on the damage character (brittle or ductile), dimension of crack, and at the same time a look to the microstructure change of inspected material/machine component.

After replica is taken off, an analysis could be provided for discovering the reason(s) of cracking at the surface. The replica technique is also available for monitoring the surface layer obtained by electroplating or any another method, especially when cracks were appeared.

Replica technique is available for monitoring the structure changes into the metal. For further discussion of findings, a solid knowledge about metallurgical reactions is needed. Monitoring the microstructure by using a replica method could give us more information about the diffusion along the grain boundaries, corrosion, precipitation or enlarging the grain size. So, the using replica method for monitoring the microstructure has the sense only by periodically investigation and comparison of obtained with previous results.

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REFERENCE


