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Aluminum Replicas for Optical Metallography

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The opportunity to make metallographic replicas from aluminum foil by means of knurling is investigated. The force to be applied to a roller for the contact surface of foil to adequately replicate a steel metallographic specimen microstructure is determined. The device for making aluminum replicas for non-destructive testing of a steam pipeline microstructure is made and tested under the thermal power plant conditions.

Keywords Creep, Extruding, Force, Knurling, Metallographic specimen, Microstructure, Non-destructive testing, Replica, Revolving power, Roller, Specific force, Technical diagnostics

Long-term operation of thermal power station equipment under the conditions of creep rupture is accompanied by irreversible changes of metal microstructure that worsens strength properties of metal and results in catastrophic failure. Therefore the control of microstructure is obligatory during the thermal power equipment technical diagnostics (Ref 1).

The most reliable method of metal microstructure monitoring is the optical metallography (Ref 2). The classical optical metallography requires destructive evaluation that requires the replacement of the equipment and consequently is unacceptable for economic reasons. The non-destructive examination of a microstructure is expedient in this case. For this purpose a metallographic specimen is made directly on equipment, for example, on a steam pipeline. The investigation of a microstructure is made on this metallographic specimen by means of a portable microscope or replicas. However, the use of portable microscopes is not always acceptable because of dust content of boiler shop atmosphere and vibration of the equipment. Therefore the most widespread method of non-destructive control of a microstructure in power system is a method of replicas.

Polymeric replicas have been used for these purposes (Ref 3, 4), but polymeric materials have low reflective ability (Ref 5). That is why the development of a technique of metal replicas making is expedient. The development of a technical to make metal replicas is expedient.

From the electron microscopy practice, the way of making aluminum replica by the method of pressing (Ref 6) is well-known. For this purpose a feed (an aluminum plate or foil) is pressed to a surface of a steel metallographic specimen with the help of a hydropress. It is necessary to create a specific force of 294 N/mm^2 for contacting with the surface of a steel metallographic specimen in order for the surface of aluminum to adequately replicate the investigated microstructure. If a replica has the size of 20×20 mm, it is necessary to apply to the initial feed the general force of pressing of 117,600 N. It is clear that such a press is difficult to place and fix on equipment, for example on a steam pipeline, especially on vertical or overhead location of a metallographic specimen.

We have considered the possibility of making aluminum replica by means of roller knurling. Thus, we proceeded from the assumption that the force for producing replica by means of knurling should be less, since not all the area of a feed is exposed to deformation simultaneously, but only the area covered with the arch of contact of a roller with a feed. Besides, knurling is the simpler process than pressing to use in such a situation.

At the first stage of the investigation, the basic possibility of producing aluminum replica by means of knurling is explored. For this purpose under the laboratory conditions a device (Fig. 1) like the lever 1 was used. One end of the lever was fixed in the hinge 2, on the other end the platform 3 for placing of weight was hanged. The roller 4 (diameter 22 mm, width 7 mm) had a possibility to rotate on an axis in the rack 5 attached to the lever. The foil 6 was placed under the roller and on a flat metallographic specimen 7 (chromium-molybdenum-vanadium alloy steel, after the operating time of 220 thousand hours at temperature 540 °C). The metallographic specimen was placed on the mobile little table 8 set on the rigid basis. The pressure of the roller upon foil was increased from experiment to experiment, by adding weight onto the platform. In each experiment, i.e. for every value of the weight, a new sample of foil was used. The process of knurling proper was carried out by the movement of a little table. After each experiment the contacting surface of foil was examined on a stationary

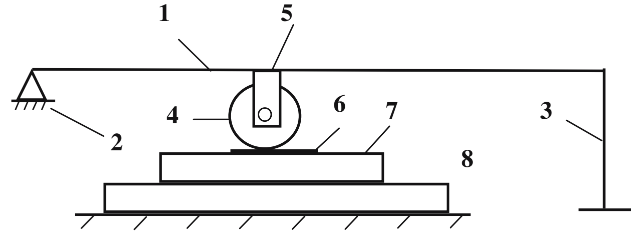

Fig. 1 The drawing of the laboratory device for the replica knurling. Explanations are in the text

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metallographic microscope and compared with the known microstructure of the original steel metallographic specimen.

The surface of aluminum foil in the initial condition has well-defined scratch marks and stains from a roll (Fig. 2a). With increasing force on the roller during contact the surface of foil burnishes. The effect of burnishing manifests itself in gradual disappearing of scratch marks and stains, and the microstructure of metallographic specimen 205 N (Fig. 2b) begins to appear on the foil. The absolute adequacy of replicating of a microstructure of steel on the contacting surface of foil is achieved at the force of 411 N to a roller (Fig. 2c).

So, the basic opportunity of replica making by means of knurling was shown and the necessary force with which the roller should press on foil for its contacting surface to adequately replicate the microstructure of the metallographic specimen was determined.

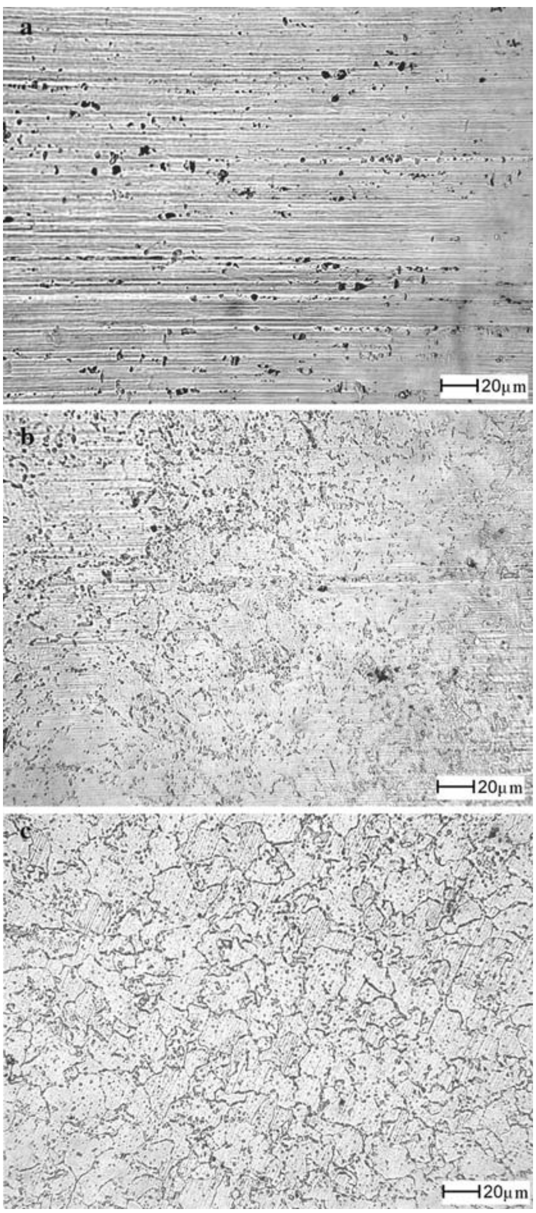

Fig. 2 The change of a microstructure of aluminum foil depending on the pressure upon a roller: (a) the pressure upon a roller is zero, (b) pressure is 205 N, (c) the pressure is 411 N

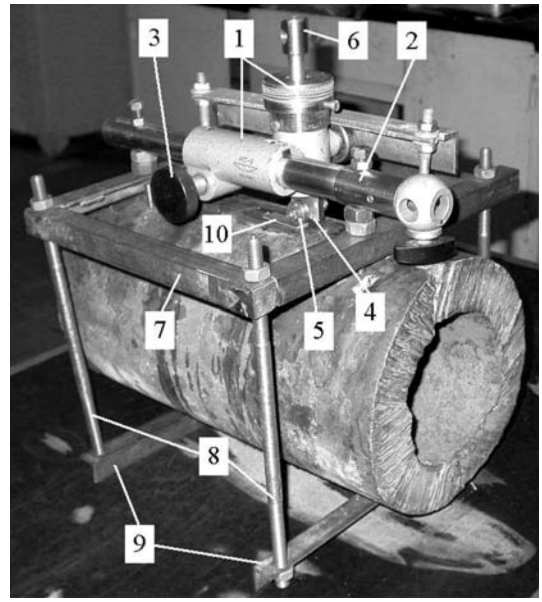

Fig. 3 The device for making aluminum replicas by means of knurling. Explanations are in the text

At the second stage of the investigation, a portable device for the knurling of aluminum replicas for non-destructive control of microstructure of metal of steam pipelines was designed and made. For the presentation, the device was set on a segment of a pipe of 273 mm in diameter (Fig. 3). The device consists of the following main units. The cast case 1 has two cylindrical cavities placed in mutually perpendicular planes. Placed along the longitudinal axis of a steam pipeline, the cylindrical cavity of this case is fit on the cylindrical guide 2 with a toothed rack for moving the case 1 along the pipe by means of the toothed roller with the tube for manual feed 3. In the other cylindrical cavity of the case 1 placed perpendicular to a longitudinal axis of the pipe, the slider 4 is placed to which the roller 5 is attached by means of an axis. The slider 4 has the longitudinal thread channel in which the running screw 6 is placed. The guide 2 is rigidly fixed on the frame 7 by means of a screw connection. The case 1 is also strongly fixed on a frame. This is the device for making aluminum replicas by means of knurling.

The replica for non-destructive examination of microstructure is produced as follows. In the beginning, a metallographic specimen is made on a pipe by the procedure accepted in power system (Ref 3). Then the device is placed over metallographic specimen and fixed on a pipe by means of studs 8 and angles 9. The roller 5 is lifted above metallographic specimen by means of the running screw 6; foil 10 is placed on metallographic specimen under the roller. Then, by means of the running screw 6 the roller is pressed to the foil against the stop and moved along the pipe by rotating the tube 3. After the roller has passed all the length of the foil, it is lifted back above the foil by rotating the running screw in the opposite direction. A replica represents a strip of foil of 40-45 mm in length and 7 mm in width. A replica is taken off a metallographic specimen – it is ready for investigations on a stationary metallographic microscope in a laboratory of metals.

The device confirmed the possibility of making replicas by knurling under the laboratory conditions. Under the field conditions, the device was tested with the positive result during the non-destructive examination of microstructures of the metal bends of section IV of the main steam pipeline of the Pavlodar Thermal power station 1. For the confirmation of the adequacy of aluminum replicas the microstructure of the same metallographic specimens were investigated with a portable metallographic microscope, and with polymeric replicas as well. All the three methods gave identical results.

The position of the stretched zones of the bends of section IV of the main steam pipeline were not only horizontal, but also inclined and vertical. In all cases the device appeared to be efficient.

The weight of the device together with studs and angles for fixing is 4 kg. The time of the device fixing on a steam pipeline is 10-15 min. The time of knurling of one replica is 1-2 min. It is expedient to use one metallographic specimen for making 3-4 replicas.

The doubtless advantage of metal, namely aluminum, replicas is their high reflective ability.

References

1. RD 10-262-98. *Standard Instruction for Controlling and Extending the Service Life of the Metal of Basic Parts of Boilers, Turbines, and Pipelines of Thermal Power Plants* [in Russian], Izd. ORGRES, Moscow, 1999
2. V.V. Artamonov and V.P. Artamonov, Nondestructive testing of microstructure of metal of thermalenergetic equipment, *Defectoscopy*, 2002, **38**(2), p 34–41
3. *Recommendations on Control of Metal Microstructure by the Method of Replicas* [in Russian], Izd. ORGRES, Moscow, 1969
4. OST 34-70-690-96 Standard. *Metal of Steam-Power Equipment, Methods of Metallographic Analysis under Service Conditions* [in Russian], Izd. VTI, Moscow, 1997
5. V.V. Artamonov, A Study of the Process of Fabrication of Polymer Replicas, *Power Technol. Eng.*, 2003, **37**(2), p 114–119
6. E.V. Panchenko, Yu.A. Skakov, K.V. Popov et al., *Metallographic Laboratory* [in Russian], Metallurgizdat, Moscow, 1957