Nontouch experimental method for recording and measuring of fracture under high temperature

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Abstract. High-temperature tests are related to the great difficulty of their execution, as the sample is inside the closed furnace. In the process of high temperature tests deformation of the specimen becomes nonuniform due to the inhomogeneous microstructure of the sample and the variability of temperature in the furnace and in time. As a rule, during such tests a "neck" is formed in a weakened section. The proposed method of nontouch measurement can measure the shape of the specimen, which allows you to monitor the fracture and development of strain localization and currently receive up to five parameters. The tests demonstrated the effectiveness of the proposed system of high-temperature measurements in tension until fracture.

Introduction. The purpose of any experiment is to check theoretical model of the real process. During under high temperature experiments many problems arises because of the impossibility of direction measurements parameters. Also the count of available sensors is greatly reduced. Most of sensors couldn't work under high temperature. Usually, in such kind of experiments only a few parameters is measured that badly influence on the comparison with checking theory.

One axis tension creep tests under high temperature started in the early 20th century. In all this tests a specimen is located into the closed furnace, so tension of the specimen is the only parameter which can be measured. During the high temperature tests, deformation of the specimen becomes inhomogeneous due to the inhomogeneous microstructure of the specimen or different temperature in the furnace. As a rule, at such tests the "neck" appears in the some slowed section. The tension deformation is higher in this section than in others. The neck's size grows up till the fracture. Measurement of the neck presents a great interest. The data of such kind could not be obtained using standard tests. Some of furnaces is equipped with viewing holes for observation the specimen and the growing neck. However, for measurement these parameters must be observed special conditions: light into the furnace, creation of the non-touch (optical) recording device, development of the special application for processing recorded data. The development of a system, that could increase the number of measured parameters during the experiment, get characteristics of formation and development of the cervix, will significantly improve the reliability of the comparative analysis with theoretical calculations. The development of such system is presented in this article.

The main idea of measurements is non-touch approach. The offered method non-touch measurement is able to measure forms of specimens that allow to watch for the starting and growing of the localization deformation. Author obtained the same system in [1-2]. The developed system consists of three main parts:

- the modernization furnace,
- the recording device,
- the complex of computer programs.

Scheme of test. The device IMEH-5 is used in experiments, located in Institute of mechanics at Moscow State University. On Fig.1 is shown the one-axis tension scheme of this device. The device IMEH-5 is capable to support a given high temperature and set given strain in the working part of the furnace. Strain tension is set with loads, which is put on the platform at lower part of the device. - The strain depends on the count of loads you can set -.

The aluminum alloy was used in experiments with working temperature $400^0\mathrm{C}$. The initial length of the specimen was $l_0 = 21, 23, 28, 35\ \mathrm{mm}$, the initial diameter was $d_0 = 3.5, 4, 5, 6\ \mathrm{mm}$. The thicker specimens were chosen over a long working base to minimize edge effect.

Tests were carried out as follows. The specimen was mounted in the rods and placed in the furnace and heated to operating temperature. After the release of the temperature at a given level the camera with special period of work was turned on. A rapid loading of the specimen was produced to a specified level of axial stress. Further deformation was carried out at a constant tension force to the fracture. After destroying of the specimen the shooting was stopped. The temperature was gradually decreased to a room temperature. The sample was removed from the furnace.

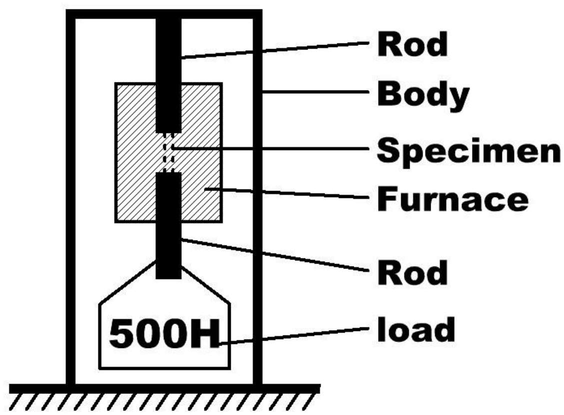

Fig. 1. Scheme of test.

Furnace. For developed method of measurement it is necessary to have a direction viewing contact to testing specimen. Any furnaces are equipped with such windows. As a rule, these furnaces aren’t high temperature and don’t able to heat under 250°C. Big high temperature furnace IMEH-5 was used. It doesn’t have the hole , so the hole must be made.

The hole, sized 12x1.5 sm, was made through isolation material of the furnace. The additional mounting, which copy the outside form, was produced. It has a square hole in the center for watching. This hole is closed chunky by optical quartz glass. This construction exclude including cold air into the furnace during experiment.

Lighting by turbular electric heating elements isn’t enough for sharp shooting; therefore it’s necessary for additional lighting. The quartz lamp was mounted into the furnace on a ceramic holder. Electricity was supplied nichrome wire. The excellent quality of the lighting was achieved during experiment with adjustment brightness and deferent location of the lamp.

Recoding device. The special rules are required for the recording device. Resolution of measurement depends on quality of received images. Quality of the received images depends on the optical resolution of system. It takes place some reasons of optical distortion of images, which decrease resolution, such as geometrical distortions, caused not by an ideal optical system, non-alignment of the lens and the sensor, precision manufacturing of parts, and the distortion caused by the lack of the "force" of optics. This is optical luminosity and clarity achieved in the frame.

Application programs. Packet of the programs was written for converting given images of the specimen to the numerical geometry and for the next calculation of various parameters. The packet of the programs consists of two main parts – the solver and the postprocessor.

The solver converts images from graphic form (photo) to the numerical form (metrical dates) and calculates necessary parameters. Two actions are consistently made: recognizing edges of the specimen and solving parameters. It exists an automatic recognizing module for. If the result of working the automatic module isn't correct, than user must recognize the photo by himself. The module of the manual editing give ability to mark reference points on the image by the mouse, after that parameters can be calculated by development program.

The solver can calculate the next parameters (all solving parameters are calculated in the coordinate system associated with the specimen): $L(t)$ - length of the specimen, $p(t) = \ln\left(L(t)/L(0)\right)$ - creep deformation, $\dot{p}(t)$ - creep velocity deformation, $D(t, z)$ - the diameter of the specimen in the cross sections, $\sigma(t, z)$ - valid stress in the cross section, t - time, z - the longitudinal coordinate.

The postprocessor shows all solved dates in the two-dimension form. There is possibility to depict the function of various parameters on the time t and longitudinal coordinate of the specimen z by graphics. Changing of creep deformation is shown on the Fig. 2. Some parameters could be shown with the help of colors corresponding of the strain or stress in the cross section. for example, the diameter in the cross section is shown on the Fig. 3 and the stress in the cross section is shown on the Fig 4.

Results. Function $p(t)$ till the fracture is standard data given with one-axis tension. This function is shown in Fig. 2. According to this dependence it could be concluded that the time till the fracture $t^* = 1985$ sec, steady velocity of deformation $\dot{p} = 4\cdot 10^{-5}\,\text{sec}^{-1}$, limited deformation $p^* = 0.29$, elongation of the specimen in the moment of the fracture $\Delta l^* = 7\,\text{mm}$.

Developed system allows to have an optical access to the specimen, so the process of deformation could be watched and also written to a video-file of deformation process. The video-file could consist of common process of deformation and, additionally, supplementary reality, shown with the help of colors corresponding of the strain or stress valid. Example of same images is shown in Fig 3-4.

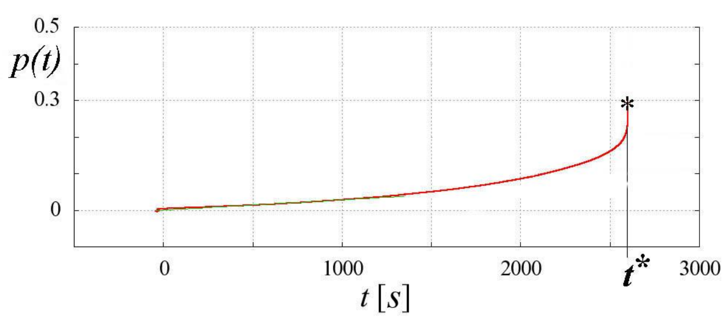

Fig. 2. Creep deformation.

Usually, the localization of deformation in the experiments is the explicit restriction of the specimen (marked eye), although the resolution of the eye is very weak. Time of the localization of the deformation could be found early and with high precision by developed system. Fig. 3 shows series of the photos for t = 0 sec, t = 960 sec, t = 1300 sec, t = 1560 sec. Fig 3c shows that localization don't mark by eye, but computer system has already found localization. In this example localization of the deformation is happened at time t = 1300 сек, that accords 80% of the time left. It is known, the most authors describe localization affirm that appears directly before time left and grown time of one is a few part of the all time deformation. The developed system shows incorrect this idea for the D16T alloy. There is a reason to believe that it would also be correct for other viscous materials.

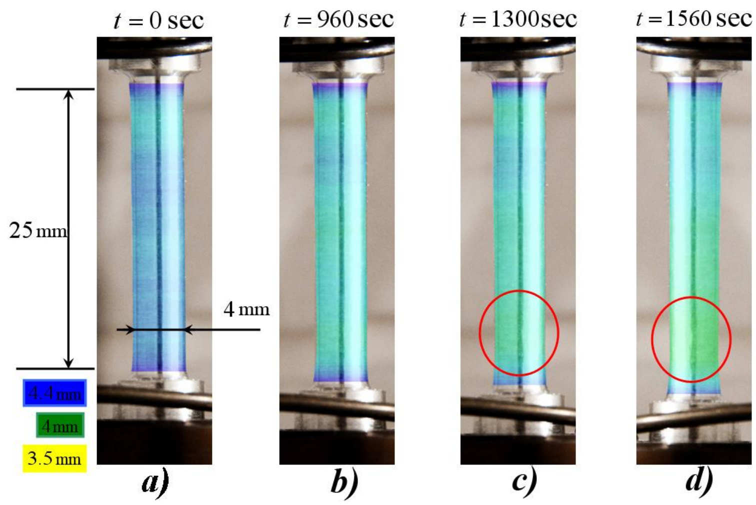

Fig. 3. Series of the photos of the specimen.

Localization of the deformation raise the tension stress near vicinity localization. Photos of the specimen are shown in Fig.4: with t = 0 sec – initial state, with t = 1981 sec – 4 seconds before the fracture of the specimen. These photos are shown with the help of different colors according to actual stress in the cross-section. The same stress is given near graphically. Increasing of actual stress in the specimen is light to watch at the place of localization, the development of which becomes the reason of destroying the specimen. The Increasing stress area is wide in comparison to the average measure of the specimen. Before destroying it corresponds to 30% of the specimen's length, so localization of deformation affects a large part of the specimen.

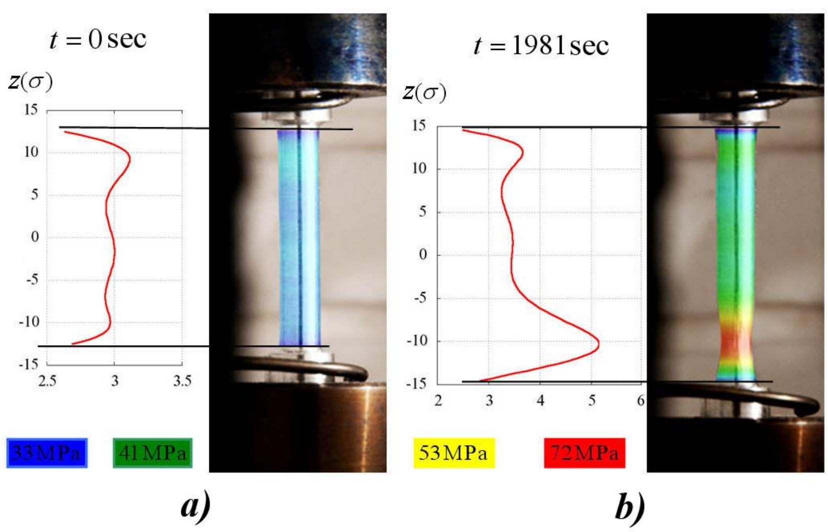

Fig. 4. Localization of the deformation.

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