THE ULTRASONIC MECHANICAL TEST FACILITY FOR RESEARCH OF IMPACT ULTRASONIC VIBRATIONS ON MECHANICAL PROPERTIES OF MATERIALS

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The communication is devoted to description of a test facility for research of ultrasonic vibrations impact on physical and mechanical properties of constructional materials in course of the plastic deformation at various deformation rates in vacuum. Principal scheme and description of created ultrasonic mechanical test facility (UMTF) are presented. Results of pilot tests obtained in course of the technique adjustment are included and discussed.

1. INTRODUCTION

For many reasons it is very important to study impact of different types of external high-energy influence on constructional material properties. First of all, this matter should be considered from the point of view of specifying opportunity of using certain material in those conditions where it can appear during its operation. It is well known that severe working conditions of many nuclear power plants being under impact of different types of high-energy irradiation are the cause of their premature partial or full failure.

On the other hand, this matter can be considered from the point of view of opportunity of preliminary use of various types of high-energy impact on structure formation process and material properties at different stages of their production and processing in order to improve needed properties. One of the possible types of such impact is the ultrasonic irradiation. Many experimental research results of ultrasonic impact on metal and alloy properties are stored. The significant part of these results is submitted in the well known monograph [1]. Microscopic mechanisms of ultrasonic impact on diffusion in solid materials are investigated in theoretical works [2, 3]. Nevertheless this field of researches is still interesting and promising for fundamentals and applications.

A number of technological techniques widely used in various branches of industry is developed on the basis of the created database. For example, ultrasound is used during thermal processing of materials. In this case, ultrasound initiates segregation of hardening phases, facilitates martensite transformations which is accompanied by increase of strength of the constructional materials [4-7]. There are many examples of ultrasound impact on material properties, however, it is not the high time to speak that this matter is thoroughly investigated.

Modern technologies using has allowed to develop and create a number of new, prospective materials during last years. Family of Hastelloys, multicomponent metalllic glasses and others are regarded as advanced materials. An investigation of ultrasound impact on physical and mechanical properties of these materials has not been carried out so far.

2. THE GOAL OF THE WORK

The goal of the done work was to create the UMTF intended to investigate the impact of ultrasonic vibrations on physical and mechanical properties of constructional materials in a wide temperature – deformation rate range in vacuum. In particular, in order to investigate role of the ultrasound on properties of the Hastelloys which are candidates to be used in the molten salt nuclear reactors. To some extend, ultrasound can imitate the so-called “radiating shaking” [8] which is influence on diffusion of short-wave phonons generated at relaxation of unstable Frankel pairs and replacements of atoms under irradiation [8].

3. EQUIPMENT AND EXPERIMENTAL TECHNIQUE

The created UMTF for deformation of constructional materials at ultrasonic vibrations impact includes:

- loading device equipped with electric motor, converter of rotation frequency of electric motor, reduction system, dynamometer system and captures;
- vacuum system consisting of vacuum chamber, forevacuum and diffusion pumps;
- ultrasonic system consisting of ultrasonic generator, magnetostriction transformer and concentrator of ultrasound;
- system of material samples heating in vacuum;
- general cooling system;
- recording system;
- instrument stand with control panel.

It is possible to carry out material research on UMTF:

- in atmosphere and vacuum conditions;
- in conditions of compression and tension deformation (reverser is provided for compression);

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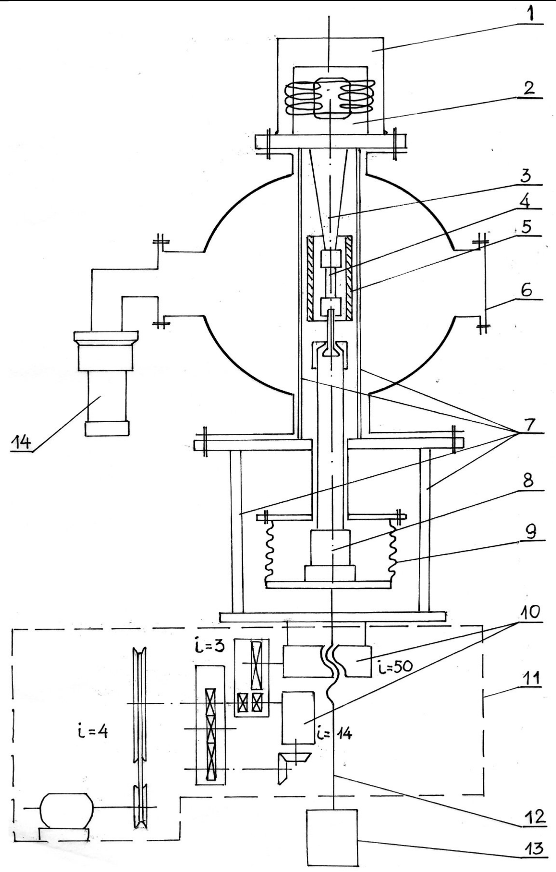
– in a temperature range from ~77 up to ~1500 K;

– in a wide temperature range of deformation from 0,01 up to 4 mm/min.



The following units are designated on the scheme:

1. Water jacket.
2. Magnetostrictive converter.
3. Ultrasound concentration.
4. Specimen of investigated material rigidly adjusted to ultrasound concentrator.
5. Vacuum furnace; refrigerator installation is provided to carry out low-temperature tests.
6. Flange with input lead.
7. Power arresting device.
8. Dynamometer with piezosensors of power.
9. Sylphon.
10. Warm reduction gearbox.
11. Kinematic scheme of reduction system.
12. Feed spindle.
13. Dynamometer with piezosensors of deformation.
14. Diffusion vacuum pump.

Fig. 1. Scheme of the UMTF for mechanical tests under ultrasonic impact

The mechanical part of the facility consists of active capture drive of poses 10 which is a warm reduction gearbox of speed with step of feed spindle pos. 12 - 3 mm that is situated in the tower of the facility. Loading is carried out within the limits of two ranges of fixed speed each one representing a number of lowering steps with big transfer number. Besides, in each range there is an opportunity of smooth adjustment of specimen loading by changing industrial frequency of voltage driving the engine with the help of the frequency converter.

Switching of speed ranges of active capture is carried out manually by moving pinion installed on the top socle plane. The drive feed spindle is connected to the facility capture chain via (through) vacuum condensation of sylphon type pos. 9. Deformation gage pos. 13, feed spindle pos. 12 and power gage pos. 8 (dynamometer with piezosensor installed on it) are installed in succession from the bottom upwards on the socle of the facility. Power piezosensor, installed on a dynamometer, perceives test loading and transfers data on its dimension to a recording equipment installed outside the facility.

The power piezosensor is shielded by screens located on capture chain in order to prevent its heating.

The sample pos. 4 fixed in captures is located inside the heating electric furnace pos. 5. The top capture is rigidly fixed to the ultrasound converter pos. 3. In cases of uniaxial compression the sample is installed in a reverse that provides compression. Ultrasonic vibrations of the magnetostrictive converter pos. 2, that is in a circuit with ultrasonic generator UZG 2-4M, are transferred on a specimen by means of the concentrator pos. 3.

Magnetostrective converter cooling is carried out by a water-jacket pos. 1.

UZG 2-4M generator is capable to create vibrations in a range from 18 up to 22 kHz, change of power is possible in a range from 2 up to 4±0.5 kW.

Vacuum conditions in the chamber are created by diffusion pump pos. 14 situated in a circuit with the forevacuum pump.

The UMTF operation principle is reduced to the following: power load is created by active capture at test on tensile or compression, short-term creep and relaxation. Strain rate can vary with the help of reduction system together with rotation frequency converter of the electromotor ATV-28. The rotation frequency converter provides changes of rotation frequency of the electromotor from 2.5 up to 75 Hz. Loading control is carried out by strain sensor.

Control and operation of specimen heating is carried out from the control panel by instrument complex RIF-101 and vacuum availability in system is controlled by ionization-thermocouple vacuummeter situated on the instrument stand.

Heat control of the electric furnace transfers to a self-acting mode reaching the required temperature and then the given heating temperature is kept by constant.

The deformation specimen control is carried out transfer of a feed spindle of active capture by a dynamometer with strain sensors pos.13. The sensor signal is transferred to the inlet of the tensometric booster situated on the instrument stand.

The facility cooling is carried out autonomously by closed system consisting of circulation three-speed pump, metal tank with volume of 300 liters, set of hoses connected by valves in system joints.

4. MEASUREMENT RESULTS AND DISCUSSION

Such a constructional material as stainless steel X18H10T (Cr – 18%, Ni – 10%, Ti – 0.45%) was chosen as a material to perform pilot tests of the system. Tests were carried out at room temperature at various rates of strain rate. Fig. 2 shows deformation curves 1 and 2 obtained at tensile rate ($d\varepsilon/dt = 0.15\ min^{-1}$) without ultrasound impact and at ultrasound impact during deformation, correspondingly. The output signal power from generator was 3.5±0.5 kW. Resonance frequency of using magnetostriction converter is ~21 kHz.

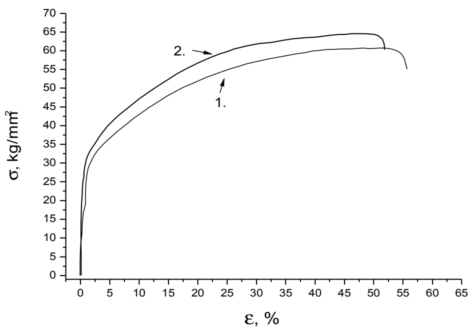


Fig. 2. Strain-stress curves of the stainless steel X18H10T (1) without and (2) with impact of ultrasound at room temperature. The strain rate was nearly 0.15 min^{-1}

From fig. 2 it is seen that steel strength increases due to the ultrasound impact and material plasticity, in its turn, decreases (from ~55 to 50 %). Yield stress and tensile strength values of the steel samples strained without sound (curve 1) were 27 and 60 kg/mm^2, correspondingly. Yield stress and tensile strength values of the steel samples strained at sound impact (curve 2) were 31 and 64 kg/mm^2, correspondingly.

Fig. 3 shows deformation curves 1, 2 and 3 obtained at tensile rate 0.15, 0.03 and 0.009 min^{-1} without ultrasound impact and at ultrasound impact during deformation, correspondingly. Output power of the signal from ultrasound generator was 2±0.5 kW. Resonance frequency of used magnetostricion converter is ~21 kHz.

Fig. 3 shows that sample strength increases and plasticity decreases under ultrasound impact during deformation, as it was in the first case. It is seen that values of the yield stress and tensile strength of the sample strained without sound with rate 0.15 min^{-1} (curve 1) were 27 and 60 kg/mm^2. Values of yield stress and tensile strength of the sample strained with rates 0.03 min^{-1} and 0.009 min^{-1} at ultrasound impact were 32 and 62 kg/mm^2 (curve 2), 27 and 69,5 kg/mm^2, correspondingly. It is obvious that strength and plasticity of material depend upon strain rate, i.e. duration of ultrasound impact.

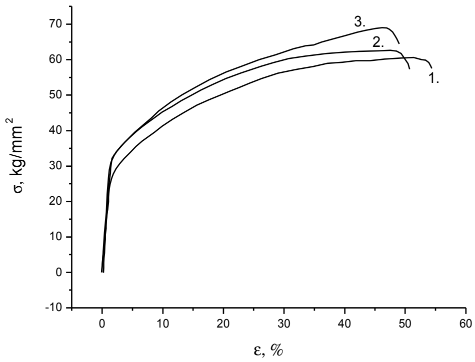


Fig. 3. Strain-stress curves (1) without and (2, 3) with impact of ultrasound at room temperature. The strain rate was nearly 0.15 min^{-1} in absence at the ultrasound, (curve 1). It was equal to 0.03 min^{-1} (curve 2) and 0.009 min^{-1} (curve 3) at ultrasound vibrations

Generally, strengthening of materials and alloys at external influence is usually connected with multiplication and pinning of dislocations and generation of vacancies. Vacancy generation happens at comparatively small sound amplitudes [2,3]. If, at the same time, dislocation multiplication is not essential, then the strengthening is connected with pinning of dislocations on vacancy complexes (for example, dislocation loops of vacancy type) generated under ultrasonic vibrations.

6. SUMMARY

1. UMTF has been constructed to study ultrasound impact on mechanical properties in a wide temperature-deformation rate range.
2. Strengthening of X18H10T steel specimens has been revealed as result of the ultrasound impact along with plasticity decrease. Probably it is caused by pinning of dislocations at vacancy complexes resulting during ultrasound processing of the material.

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УЛЬТРАЗВУКОВАЯ МЕХАНИЧЕСКАЯ ИСПЫТАТЕЛЬНАЯ УСТАНОВКА ДЛЯ ИССЛЕДОВАНИЯ ВЛИЯНИЯ УЛЬТРАЗВУКОВЫХ ВИБРАЦИЙ НА МЕХАНИЧЕСКИЕ СВОЙСТВА МАТЕРИАЛОВ

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Настоящее сообщение посвящено описанию метода исследования ультразвукового воздействия на физико-механические свойства конструкционных материалов в ходе пластической деформации при различных температурно-скоростных режимах в вакууме. Приводится принципиальная схема и описание вновь созданной экспериментальной установки позволяющей проводить исследования материалов этим методом. Представлены результаты тестирующих испытаний, полученные в ходе отработки методики.

УЛЬТРАЗВУКОВА МЕХАНІЧНА ВИПРОБУВАЛЬНА УСТАНОВКА ДЛЯ ДОСЛІДЖЕННЯ ВПЛИВУ УЛЬТРАЗВУКОВИХ ВІБРАЦІЙ НА МЕХАНІЧНІ ВЛАСТИВОСТІ МАТЕРІАЛІВ

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Це повідомлення присвячене опису засобу дослідження ультразвукового впливу на фізико-механічні властивості конструкційних матеріалів в ході пластичної деформації при різноманітних температурно-швидкісних режимах в вакуумі. Приводиться принципова схема та опис новітньо створеної експериментальної установки, що дозволить проводити дослідження матеріалів цим засобом. Подані результати тестових випробувань, які отримані в ході відпрацювання методики.