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STUDY OF THE KINETICS OF THE STEAM-ZIRCONIUM REACTION USING A ONE ROD ASSEMBLY MODEL

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Abstract

The results of the investigation of steam-zirconium reaction kinetics at the HPE simulator surface are presented in the paper. The dynamic characteristics of the hydrogen production resulted from the heated surface dryout are determined.

INTRODUCTION

The necessity of the knowledge of the laws of hydrogen generation during the interaction between the HPE shells made of the zirconium alloy and water coolant is highly increased when the problem of severe out-of-project accident was initiated, so their evolution is determined by the hidrogen discharge.

In [1] on the base of publications available the analisis was made of the hidrogen generation processes under severe accidents resulted from the circulation break off. From the estimations presented there regarding the amount of generated hydrogen during some first hours after the accident, it follows that the general source of the hydrogen is the reaction of zirconium with steam-water mixture. For example, the velocity of hydrogen generation may reach the value of 726 kg/h for the ordinery commercial APP USA.

Among the latter publications dealing with this problem the paper of the Japan authors [2] is remarcable. In this paper the results of the in-pile experiments are presented devoted to the study of hydrogen generation during the steam-zirconium reaction when the accidant situation was initiated by reactivity. The HPE was cooled by subsaturated water in the film boiling regime. The amount of the hydrogen generated was determined by the void fraction gauge at the channel exit and from the metallografic examinations also. In spite of the significant discrepancy between the results obtained by these two methods, the data allow to make conclusions about the strong temperature influence upon the hydrogen production.

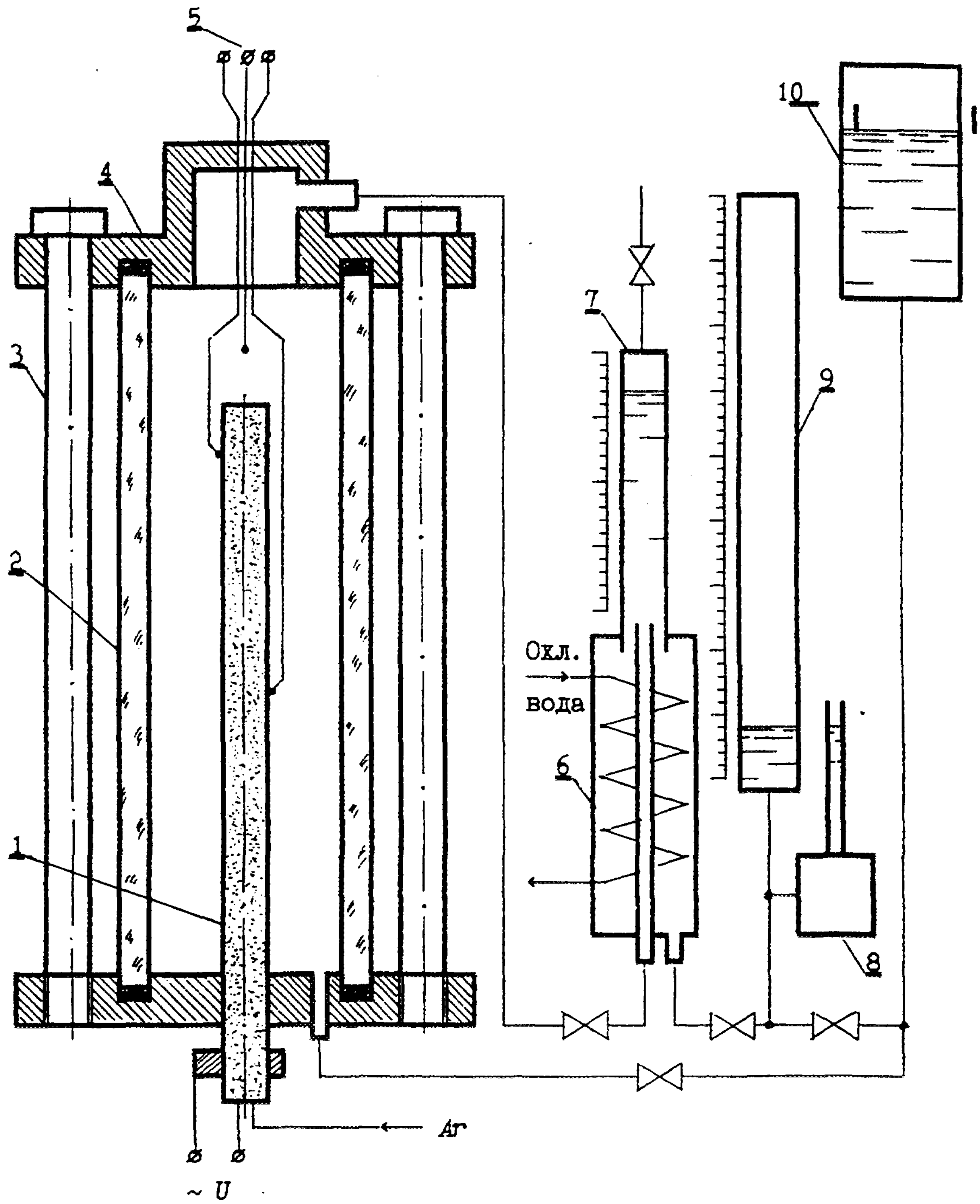

Fig. 1. Scheme of the Facility for Steam-Zirconium Reaction Investigation.

1 - Heating Element (HPE Simulator); *2* - Transparent Body; *3* - Bars; *4* - Фланец; *5* - Thermocouples; *6* - Refrigerator; *7* - Hydrogen Accumulator; *8* - Level Gauge SAPPHIRE-22DD Type; *9* - Replacing Tank; *10* - Water Feed Tank.

The aims of the present paper are as follows: experimental study of the hydrogen generation process as a result of the HPE zirconium shell oxigation in steam-water atmosphere under conditions of assembly dryout due to the circulation failure; using of the data obtained when developing the corresponding codes.

Presented in the paper are the results of first experiments having, in general, methodological purposes. At the one-rod assembly model the peculiarities of the hydrodynamic processes of its dry-out was visualised and the reliable method of hydrogen production measurement was veryfied.

EXPERIMENTAL FACILITY

The experimental facility is presented schematically in Fig. 1. Its basic elementa are the next:

- heating element: spiral or with internal heater *1*;
- assembly body made from the transparent quartz-glass tube for assembly dre-out process visualization *2*;
- bars *3*;
- flange *4*;
- thermocouples *5*;
- refrigerator *6*;
- calibrated measuring glass for hydrogen accumulation *7*;
- level gauge (volume) in *8*;
- expansion tank for collection of water replaced by steam and hydrogen *9*;
- water-provided tank *10*.

The collection and treatment of the information is fullfilled by the computer-controlled system.

During the process of the model dry-out a steam-water mixture is directed to the refrigerator where it is condenced, while hydrogen is led to the accumulator. Hydrogen replaces water to the calibrated replacing tank. The pressure difference gauge registers the change of water level in replacing tank vs. time what enables to identify the moment of the steam-zirconium reacton beginning and to measure the amount og the hydrogen produced. The thermocouples are used for measuring the temperatures of the simulator surface and that of steam. For the simulator to be vacuumed and and after that filled with argon serves a special system.

EXPERIMENTS

In the experiments carried out two types of heater were used: one of spiral type and another as a rod with internal heating.

The spiral type heater was fabricated of stainless steel capillary tube 4 mm in diameter. Inside this heater a small 60 × 5 mm plate zirconium was arranged. The chromel-alumel thermocouple was aranged at the plate centre.

The rod (HPE simulator) was made of the zirconium tube ∅9.1 × 0.5 mm. It was heated by molybdenum-made electric heater arranged inside which was insulated from the rod wall by pressed magnesium oxide. The total length of the simulator was 550 mm and that of the heated zone was 300 mm. The AC voltage was supplied to the simulator shell ahd heater from the transfomer. The internal part of the simulator was filled with argon.

The technique of the experiments carrying out was as follows. After the facility being filled with distilled deairated water one turned on simultaneously the simulator heating and the system recording in time the temperatures of the simulator surfase and exitingd steam and water level in accumulation tank. Once the electric power was turned on, the simulator surface reached the saturation temperature and the boiling took place. The beginning of boiling was accompanied by intensive dry-out of the model and consecutive increasing of the rod surface temperature. The front of temperature increase was spread down the rod following the water level in assembly. The experiment was finished when the volume gauge signal reached its extreme value.

RESULTS OF THE EXPERIMENTS

The experiments have shown that the noticeable hydrogen production due to the steam-zirconium reaction took place at the temperature about 650 °C. It was observed both visually as hydrogen bubbles in the accumulator and by record of the water level changes in the tank *9*. In the teats with spiral heater where the temperature didn't exceed 800 °C, it was marked also that the amount of hydrogen produced diminished with every consecutive turning on of the heater. It apparently may be explained by the

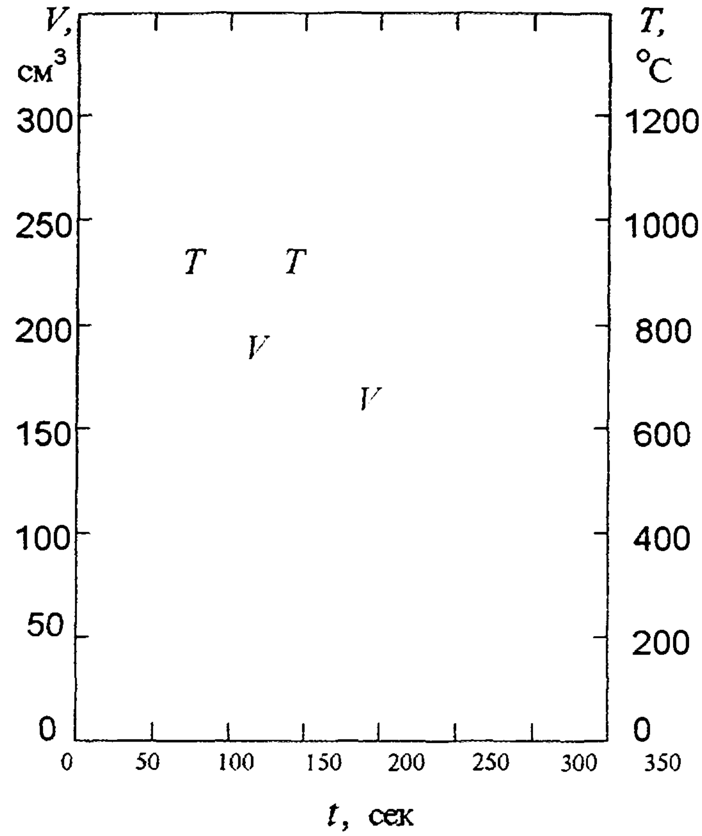

Fig. 2. Change of the water volume in accumulator tank and simulator surface temperature vs. time.
——— - Test N.1; — — — - Test N. 2.

influence of the zirconium oxide layer at the rod surface on the steam access to the clean ziconium surface and, finally on the hydrogen production. At the test with the rod simulator, however, at the temperature of 1000 °C there was a local break-off in oxide film. It may be resulted from both by the rod distorsion and by the hydrodynamic exerting of the steam-droplet mixture on its surface.

In Fig. 2 the results of two tests carried out at the identical initial conditions with the rod HPE simulator are shown. The electric power in both tests was 1.5 kW. Fig.2 illustrates evidently the dynamics of the assembly dryout and the hydrogen discharge during steam-zirconium reaction. The curves $V(t)$ and $T(t)$ are correlated with each other qwite well. So, the signal from the level gauge being initially constant begins to increase with the beginning of the steam-zirconium reaction. It's the moment when the rod temperature reaches its maximum value. At the meam temperature of 1000 °C the amount of the hydrogen produced during 170 s was as much as 143 cm³ in the test No.1 and 110 cm³ in the test No.2. The considerable rod deformation over the length was marked.

In [3] the measuring of the amount of hydrogen produced in the steam-zirconium reaction was carried out at the temperature of 1000 °C. The measuring technique was in determination the mass increase of small zirconium specimens in steam atmosphere during the definite time and consecutive calculation the amount of hydrogen. The mean value of the hydrogen volume produced by 1 cm^3 of the specimen surface per 1 s was about 0.0136 cm^3. In our tests this value was as much as 0.0125 cm^3. The agreement is quite satisfactory. It may be consider as a confirmation of the reliability of the dilatometric method used for the measuring the amount of hydrogen produced.

CONCLUSONS

Experimentally it has been shown that the dilatometric method of the amount of hydrogen produced during steam-zirconium reaction is a perspective one for carefull investigation of this reaction kynetics.

The visualization of the process of the one-rod assembly dry-out has been carried out.

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