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EXPERIMENTAL INVESTIGATION OF FILM BOILING ON SPHERES USING HIGH-SPEED VIDEO

Andrey AGALTSOV, Ivan FEDOSEENKO•

Abstract: *The experimental investigation of saturated Freon-113 film boiling on spheres with different diameters at atmospheric pressure under conditions of free convection is executed. It was found that with increasing diameter of the sphere and the temperature difference is changing the wave motion of the vapor film with two-dimensional to three-dimensional mode. Also, found that in a range of regime parameters at which observed a three-dimensional interface motion, the destruction method of two-dimensional wave is similar to a series of three or more waves. I.e. was some system memory. When the temperature difference close to critical after the passage of a wave are possible the local contacts of liquid with a heated surface of the sphere. However, these contacts do not lead to degradation of the wave motion of the interface, and the film boiling crisis of saturated Freon-113 occurs smoothly in contrast to the crisis at boiling of saturated and subcooled water.*

1. INTRODUCTION

One of the insufficiently studied sides of film boiling is the movement of the liquid-vapor interface and the accompanying wave processes. Now there are very limited theoretical and experimental studies covering this aspect. However, finding the characteristics of motion of the interface will allow more appropriate to construct a model of the process and can greatly help in explanation of such phenomena as the crisis of film boiling and vapor explosion.

In [1,2,3] it was noted that in film boiling on a vertical flat plate in conditions of forced and free convection, the wave at the interface always had a three-dimensional structure. On the other hand, we know [4] that depending on regime parameters and at other properties of the liquid in the film boiling can occur with a wave of almost regular two-dimensional structure. Such a transition from one type of wave motion to the wave motion of another type can significantly affects the heat transfer coefficient and the parameters at which the film boiling crisis, and also on the characteristics of the crisis. For this reason, it makes sense to define the ranges of regime parameters in which the existence of one or another kinds of waves.

2. EXPERIMENTAL FACILITY AND METHOD

Investigations were made on the experimental installation which scheme is shown on fig. 1. Tank with test liquid (1) was a horizontal cylindrical vessel with an inner diameter of 90 mm, supplied with two viewing windows for visual, video and photography

• Agaltsov Andrey, Institute of High Temperature RAS, Russia, Moscow, agaltsovam@gmail.com; Fedoseenko Ivan, Moscow Power Engineering Institute, Russia, Moscow, n1ce_91@bk.ru

observations, on the outer wall of which electric heater was wound for providing the liquid temperature necessary in each experiment. On the top part of the vessel was mounted vertical condenser (2) type of pipe in a pipe and the tap water was used as coolant. Over the condenser was installed the chamber (3) for heating of the sample.
The sphere (4) rigidly fixed on a special tubular probe, by which was lifted to a heating zone, and then submerged into a liquid at synchronous inclusion of system of data gathering from temperature sensors.
To measure the temperature of the sphere was used a Chromel-Alumel thermocouple with diameter of thermo electrodes of 0.2 mm, embedded with the help heat resistant glue VS-10T in a blind hole with a diameter of 0.8 mm and depth of 15 mm drilled at an angle 45° to a vertical axis. To measure the temperature of the liquid in the bulk tank and a heating device also was used a Chromel-Alumel thermocouple.

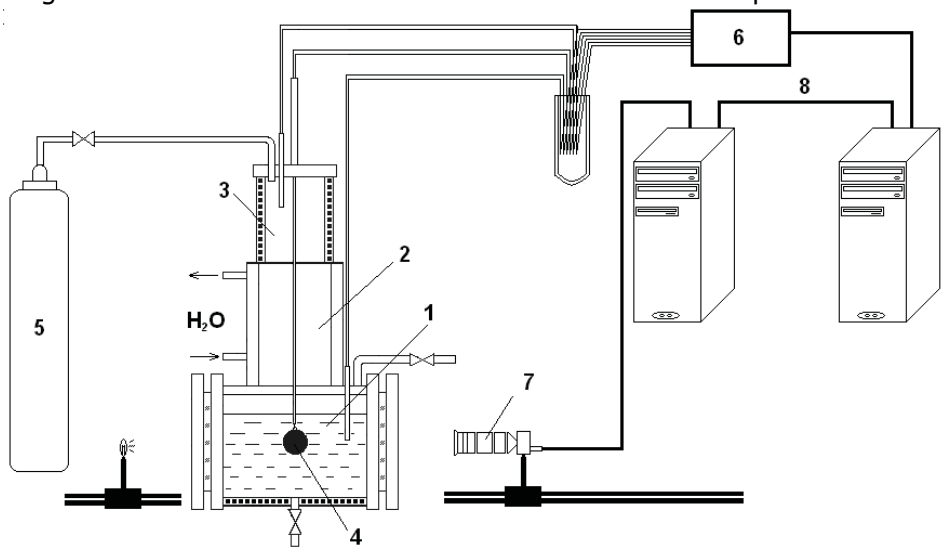


Figure 1: Experimental facility.
1 – tank with an investigated liquid, 2 – the condenser, 3 – the chamber for heating of the sample, 4 – sphere, 5 – argon cylinder , 6 – ADC, 7 – a high-speed video camera, 8 – a synchronization line.

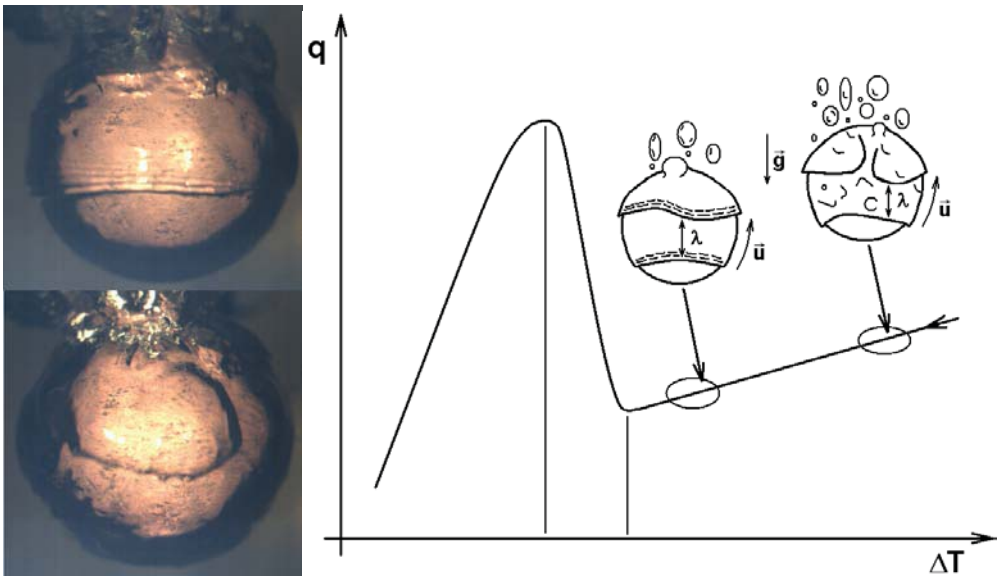
Also the high-speed video shooting by means of high-speed video camera VS-FAST of firm VIDEOSCAN was done. During experiment after indication of the thermocouple in the center of sphere achieved the demanded value the synchronizing signal including record of video shots in a computer memory was given to the video camera.

3. RESULTS

Analysis of high-speed video of saturated film boiling of Freon-113 under conditions of free convection on spheres with diameters 15, 20, 25 and 30 mm revealed a number of significant qualitative changes in the character of interface motion at varying the characteristic size of the heat transfer surface and at varying temperature difference.
On fig. 2a photos of real process of film boiling on spheres with diameter of 30 mm (at the bottom) and 20 mm (at the top) are represented. It is necessary to notice that for sphere with diameter of 20 mm wave has two-dimensional ring structure, and for sphere with diameter of 30 mm the behavior of interface has the developed three-dimensionality.

Besides increasing the temperature difference is changing the wave motion of the vapor film with two-dimensional to three-dimensional mode (fig. 2b). It is reasonable to assume that the effect of temperature difference on the stability of two-dimensional wave motion is primarily associated with an increase in its average amplitude with increasing temperature of the heat surface [4].

At small temperature differences when small amplitude of waves, in front of the trailing edge there is uniform ripple with geometry similar to the geometry of the wave itself. It should be noted that a similar ripple before going through waves on a thin film of liquid flowing down was observed in [5]. With increasing temperature of the sphere, this ripple is becoming increasingly insignificant and subsequently disappears at all, but it is becoming increasingly likely appearance of small irregular ripples at the interface between the two fronts of waves.



a) b)

Figure 2: Effect of sphere diameter (a) and the temperature difference (b).

If we follow the destruction of the two-dimensional wave, then we see that the reason for the initiation of this process is often macro-disturbance on vapor film, available in the way it goes. A curvature of the rear front and decay of the waves may in turn give rise to such macro-disturbance. Indeed in heat-transfer surface area, where a wave because of its curvature was somewhat earlier (fig. 3 Identification 1), formed by evaporation vapor will be greater (fig. 3 Identification 1) than on the area where the wave has passed later. The resulting unevenness, in turn, can cause decay or deformation of the subsequent wave. For example, a qualitative analysis of the video during boiling of saturated Freon-113 on a copper sphere 25 mm diameter showed that the way to the collapse of the wave, first initiated by some other reasons, and form of three-dimensional segments could be similar to a series of three or more waves. Indicated system memory (the memory available to the waves with respect to its predecessors) is gradually lost and, accordingly, subsequent waves pass into a state of two-dimensional or decay on a different principle, depending on regime parameters and random factors.

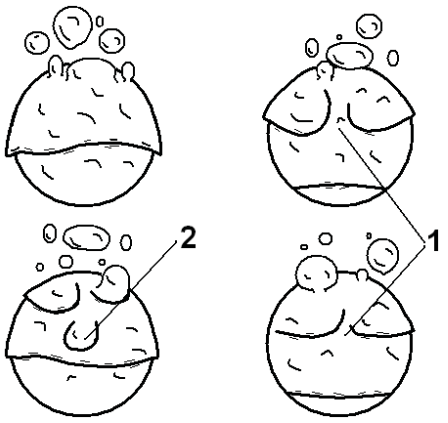


Figure 3: Collapse of the wave due to the disturbance created by the previous wave.

When the temperature difference close to critical after the passage of a wave are possible the local contacts of liquid with a heated surface of the sphere. However, these contacts do not lead to degradation of the wave motion of the interface.

Also on the received video frames we can see that the contacts are on the same sections of the spherical surface. This fact apparently is more heterogeneity of the heat transfer surface (corrosion, mechanical defects, etc.).

With the cooling surface of the sphere of contacts and the probability of their range is increasing and is continuous tuning with the film boiling regime to transition regime.

4. CONCLUSIONS

A study of film boiling of saturated Freon-113 on spheres of diameters 15, 20, 25 and 30 mm with high-speed video was done. It was found that increasing the diameter of the sphere and the temperature difference leads to a transition from two-dimensional structure of vapor movement to three-dimensional. Also, found that the disturbance caused by the destruction of the previous two-dimensional wave may be the reason destruction of the subsequent wave. In the case of possible contact liquid with heated surface of the sphere, these contacts do not lead to an instantaneous adjustment of the wave of film boiling to transition boiling, i.e. this transition occurs smoothly.

5. REFERENCES

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