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EFFECT OF LOCAL CRITICALITY IN DYNAMICS OF STEAM-WATER GEOTHERMAL MIXTURE

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ABSTRACT

The development of basis of dynamics of a steam-water mixture is presented. This development is based on usage of effect of local criticality. The examples of the solution of concrete problems of dynamics of a geothermal mixture are shown. The explanation to existence of stages of the critical efflux is given. The guidelines for calculation of a flow, estimation of hydraulic shocks and pressure oscillations are submitted.

INTRODUCTION

The development of geothermal fields is characterized by a broad spectrum of problems of dynamics of a steam-water mixture. The tendency to an effective utilization of resources demands increase of accuracy of computational methods. However in some problems the perfecting of computational methods restrains by absence of indispensable scientific basis.

In the present paper the effect of local criticality as development of the scientific basis for problem solving of dynamics of steam-water geothermal mixture is esteemed. The concrete examples of usage of the given effect are submitted.

EFFECT OF LOCAL CRITICALITY

In single-phase hydrodynamics the critical flow associates with flow with a speed of sound. In heterogenous medium the speed of sound depends on a wavelength. Therefore indicated phenomenon for heterogenous mediums demands more fundamental definition. Generally critical flow corresponds to independence of flow parameters of a pressure gradient (criticality on a pressure gradient). In practice in a critical flow a module of a pressure gradient aspires to perpetuity.

In nonuniform mediums it is necessary to expect non-uniformity on cross-section of achievement of a condition of criticality of a flow. The release of pressure downstream can be interpreted as macroscopic increase of a module of a pressure gradient. Let's remark, that the given decrease can be connected to non-steady processes or simply with movement to a low-pressure area. This disturbance cannot change a pressure gradient in the field of a critical flow. The pressure gradient is equal to perpetuity. But in adjacent areas the pressure gradient will change. In outcome there should be irregularity of pressure in cross-section of a flow. Also there should be local mass flows from area of a critical flow in adjacent areas. The originating of local transverse gradients of pressure and mass flows at a macroscopic longitudinal disturbance is essence of effect of local criticality.

STAGES OF THE CRITICAL EFFLUX

The critical efflux of a steam-water mixture in a practical geothermics meets in technologies of measurement of parameters of mixture (Shulyupin A.N. and Alekseev V.I., 1995). Availability of several stages of the efflux is established experimentally. The effect of local criticality can be used to explain these stages.

Let's consider the efflux of a mixture during release of pressure of ambient environment (downstream). The first stage is characterized by a constancy of the mass flow-rate. Thus the pressure of the efflux is equal to ambient pressure. The given stage can be connected with distribution of area of a critical flow on a considerable proportion of exit section. Thus the release of pressure of environment results in reallocating mass on cross-section.

The second stage is characterized by excess of pressure of the efflux above ambient pressure. Thus the pressure variation of environment still has an effect for pressure of the efflux. The second stage can be connected with unstable implementation of a condition of criticality in all exit section. Also it is possible to explain this stage by implementation of a condition of criticality in a tapping point of pressure.

The third stage is characterized by independence of all parameters of the efflux of ambient pressure. This stage takes place in technologies of measurement of parameters of a mixture. It is possible to explain third stage by stable availability of a critical flow in all exit section. The relevant practical consequent of development of the efflux up to thirds of stage is the hypothesis about a homogeneous flow. The flow becomes homogeneous due to fissile stirring at the first and second stages.

SIMULATION OF ANNULAR-MIST REGIME

The annular-mist regime is relevant at flow in wells and pipelines for the transport of a steam-water mixture. There are basis to consider, that capabilities of a conventional integral method of the description of two-phase flows (Wallis G.B., 1972) for the given regime are depleted. The stable structure in this regime gives chance to use of the structural approach. It is in this case recommended to esteem separately dynamics of a water film and dispersed core of a flow.

Usage of the structural approach is characterized by complexity of definition of conditions on border of different members of structure. Apparently, speed of water on border the film - core can not exceed critical speed of motion of saturated water. Differently effect of local criticality will put to runaway of water in core of flow. The analysis demonstrates, that speeds of water and steam in a core considerably surpass critical speed of motion of saturated water. Therefore for speed of water on border the film - core is expedient to use value of critical speed of motion of saturated water (Shulyupin A.N., 1996)

$$v_c = \left(\frac{d\rho'}{dp} + \frac{(\rho' - \rho'')\rho'}{\rho'' r}\left(\frac{di'}{dp} - \frac{1}{\rho'}\right)\right)^{-0.5}, \qquad (1)$$

where v_c is critical speed of motion of saturated water, ρ’ and ρ” are densities of water and steam, p is pressure, r is specific heat of phase change, i’ is specific enthalpy of water.

SIZE OF DRIP IN CORE OF ANNULAR-MIST FLOW

For definition of a slip velocity of phases in a core it is necessary to know the size of drips. Let's remark, that the speed of drips considerably exceeds critical speed of motion of saturated water. For this purpose it is necessary to constrain phase change in a drip. Differently effect of local criticality will call decay of a drip. Constrains boiling surface tension creating accessory pressure inside a drip (Grigoriev V.A. and Zorin V.M., 1988)

$$\Delta p = \frac{4\sigma}{a}, \qquad (2)$$

where Δp is accessory pressure, σ is factor of surface tension, a is radius of a drip.

The accessory pressure transfers water in underheated condition. It constrains boiling. After coalescence of two drips there is their decay and phase change. The release of pressure in a carrying flow up to the moment of coalescence of drips is determined by the formula

$$\Delta p = \left(-\frac{\partial p}{\partial z}\right) v_d t_c, \qquad (3)$$

where $\frac{\partial p}{\partial z}$ is module of a pressure gradient, v_d is speed of drips, t_c is time before coalescence.

Having equated right members (2) and (3) and using principles of a statistical physics (Reif F., 1977) for definition of time before coalescence of drips, we receive the formula for radius of a drip

$$a = \left(\frac{12\sqrt{2}\sigma v_h (1 - \varphi_c)}{\left(-\frac{\partial p}{\partial z}\right) v_d}\right)^{\frac{1}{2}} \qquad (4)$$

where v_h is speed of random motion of a drip, φ_c is void fraction in a core.

The formula (4) leave outs a capability of interplay of a drip with a film. Therefore this formula is applicable, when radius of a core is more a landing run of a drip before interplay. This length is determined by the formula

$$l = \frac{a}{3\sqrt{2}(1 - \varphi_c)} \qquad (5)$$

In a case, when radius of a core is less than value (5), as a mean landing run of a drip before interplay it is necessary to consider radius of a core. In this case

$$a = \frac{4\sigma v_h}{\left(-\frac{\partial p}{\partial z}\right) v_d R_c} \qquad (6)$$

where R_c is radius of a core.

MAXIMUM PRESSURE OSCILLATIONS AND HYDRAULIC SHOCKS

At designing of pipelines for the transport of a steam-water mixture it is important to know possible limiting recompression. The recompression takes place at hydraulic shocks on local resistances at transit of fluid plugs. The pressure oscillations are a consequent of modification of a flow structure. Idea of the solution of this problem is the thesis about influencing effect of local criticality on a flow structure. This thesis limits speed of a fluid fuse to critical speed of motion of saturated water. Pursuant to the Joukovski's formula (Grigoriev V.A. and Zorin V.M., 1988) for a limiting hydraulic shock on local resistance we have

$$\Delta p_r = \rho' v_c c' , \qquad (7)$$

where Δp_r is recompression, c' is speed of sound in liquid.

The maximum pressure variation, bound with modify structure of a flow, are determined by inhibition of water and boost of a fluid fuse up to limiting value. Therefore for pressure oscillations, according to a Bernoulli's relation, we have

$$\Delta p_o = \frac{\rho' v_c^2}{2} , \qquad (8)$$

where p_o is pressure oscillations.

TRANSITIONAL REGIME

The transitional regime takes place in wells. This regime is characterized by a randomness of a flow structure. The randomness of structure can be connected with effect of local criticality. Then the beginning of the given structure should be connected with originating of local criticality. The local criticality arises in a frontal part of steam slugs or bubbles at achievement of speed a steam by critical speed of motion of saturated water. At calculation of transitional regime it is recommended to esteem two stages (Shulyupin A.N., 2000). Speed the steam is necessary to receive by equal critical speed of motion of saturated water at the first stage. The speed of water should be received by equal critical speed of motion of saturated water at the second stage. For calculation v_c (m/s) it is possible to use not the formula (1) with necessity of usage of composite condition equations, and simple approximating of calculations under the indicated formula in pressure range $10^6 < p < 10^7$ (Pa)

$$v_c = 2.5 + 6.25p10^{-6} \qquad (9)$$

CONCLUSION

The significance of any idealized thesis is determined by the significance of practical outcomes obtained with usage of this thesis. The reviewed examples indicate availability of good chances of application of effect of local criticality in dynamics of steam-water geothermal mixture.

The effect of local criticality also can be applied to dynamics of homogeneous mediums. The conditions of existence of criticality are determined by flow velocity. If the flow is characterized by a non-uniformity of speed in cross-section, it is possible to expect originating of local criticality. However local criticality does not allow to using condition equations of a classic thermodynamics. In this case for the characteristic of a condition it is necessary to use equations such as a diffusion equation. Then the local criticality of a homogeneous flow is criticality of a diffusive flow. Thus the turbulence is represented by a consequent of effect of local criticality.

Let's mark, that the concept of criticality does not limit by criticality on a pressure gradient. The reviewed effect describes originating chaos at the ordered exposure. Generally it is possible to formulate the law - if the system component is not capable to perceive definite effect the given effect above the system will call relative chaos.

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