ON IMPACT INTERACTIONS OF THE DAMAGED MEDIUM WITH THE FLOW OF THE CAVITATING LIQUID

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Summary The detailed analysis of local processes impact interaction between deformable damageable medium and cavitating lliquid flow, caused erosion fracture is accomplished. This analysis is founded on results of researching local hydrodynamic flows in two- phases liquids, which have obtained authors recently. The complex phenomena in similar mediums require using separate processes method for investigation.

Problem review

The single steam bubble fracture leads to appearance swirl and cumulative stream of liquid. [1]. It was theoretically established and experimentally proved that limited value of speed wall single water steam (ρ_g^0 =0.562kg/m3) bubble with size R_0 =0.13410-3m under normal state P_g = 0.1MPa, T_g =373K under compressible triangular form pressure wave with amplitude P_b =30MPa and duration t_b =0.26e-03s is near 1300 m/s. The time of bubble degreasing from the initial size to ultimate size R*= 0.510-5m is tg=0.6-0.71e-06s. The steam temperature may be more than 1500 ºK, [2-4]. If these processes take place near construction surface, in accordingly with loss particularly possibilities to resistance of deformation erosion grooves appear.

Basic equiations

for deformable damageable medium (1) and liquid (2) with interface surface Sc fig.1, [5]

$$\rho_{,t} + \mathrm{div}(\rho * V) = 0; \qquad \rho(\rho * V)_{,t} + \mathrm{div}(\rho * V^2 + \sigma) - \rho * F = 0;$$

$$e_{,t} + \mathrm{div}(e + \sigma - q) * V + Q_{,t} = 0; \sigma = -p * I; \qquad e = \rho * \chi + \frac{1}{2}\rho\left(\nu^i\right)^2;$$

artificiality viscosity **q** Clausius - Duheme inequality.

$$p = A\left(\frac{\rho}{\rho_0} - 1\right) + B\left(\frac{\rho}{\rho_0} - 1\right)^2 + C\rho\varepsilon \qquad p = A\left(\frac{\rho}{\rho_0} - 1\right) \; p > -p^*$$

$$p = -p^* \qquad p \le p^*$$

$$\nu^1{}_n = \nu^2{}_n \qquad p_n^1 = p_n^2$$

$$\sigma_{jk} = -p\delta_{jk} + S_{jk} \; (j,k) = 1,2,3 \qquad S_{jk}^{\nabla} = \frac{\partial S_{jk}}{\partial t} - S_{jr}\omega_{rk} - S_{kr}\omega_{rj}$$

$$p(U,e) = p_-(U,e) + p_+(U,e) \qquad e = e_- + e_+$$

$$p_+(U,e) = \frac{\Gamma e_+}{U} \qquad p_-(U,e) = \frac{de}{dU}$$

A ductile behavior damageable structural material is similar process in viscous gas bubbles liquid, [1, 6].

Methods of numerical simulation

The numerical modeling of appreciably nonlinear behavior deformable damageable medium and liquid requires a using complex scheme numerical integration. The step time integration Δt is founded by use special criterions or CFL stability requirement, [7]. In respect to the modeled phenomena measure the shell – channel wall - can be represented as half medium to which is connected the corresponding part of liquid. The cumulative liquid stream can be represented as radius R* circle cylinder, variable velocity $V^*(r) = V_o^* \frac{(R^*)^2}{r^2}$ [2], along its length **r**, where V_0^* -bubble wall speed.

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COMPUTATION RESULTS

Dynamic half medium reaction for foregoing loading cases

It was considered two load cases: 1) *liquid is moistened damageable medium*. Propose that liquid velocity is zero on interface between them. It was found shock wave in liquid, located between destroyed bubble's wall R^* =2.510-5m and medium surface with distance r=9.810-5m, (r/ R^* =3.92). The medium surface was loaded by pressure vs time. 2*) liquid is not moistened damageable medium*. Propose that liquid pressure is zero on interface between them. It was found shock wave in water, located between b ubble's wall R*=5.0e-5m and medium surface with distance r=9.55e-5m, (r/ R^* =1.91). The medium surface was loaded by impact of moving with the constant velocity V_0^* =400m/s limited length stream. If steam bubble locates on medium surface (has the common part of wall) then the external loading can be represented as impact by unlimited length stream.

The liquid unlimited length stream impact. The stream liquid moves to the deformable half medium with the velocity $V^*(r)$, where R*= 5.0_{10}^{-5}m**,** V_0^* =1000m/s. As a result the complex wave processes arise in liquid stream and in liquid around it. The maximum deformation locates along boundary loading square (fig.1).

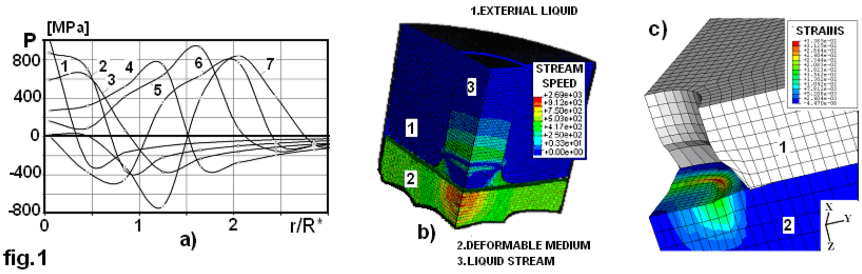

fig.1

Its quantity average ε~0.1, when material resistance to deformation do not depend from heating, and - ε~0.25 in opposite case at time moment t= 5.0_{10}^{-8}s. Thus, the combination mechanics and heat loading will be fractured of shell material by way of erosion grooves.

The Impulsive pressure action P(t). fig.2. When heating of material is omissible, then this loading do not leads to an appreciably variation of it state. The variation shell material resistance to deformation as a result of it local heating conduce to its tension located on loading square at a depth of ~3.0_{10}^{-5}m. There is plastic flow in term of all strained material volume. And as result of this its porosity increases. The maximum deflection, deformation and porosity locate in the centre of loading square. Its quantities average δ =$3.3._{10}^{-7}$m in direction of loading, ε ~0.018 at time t= 2.8_{10}^{-8}s, Vp≈ 6% at time t=1.0_{10}^{-6}s.

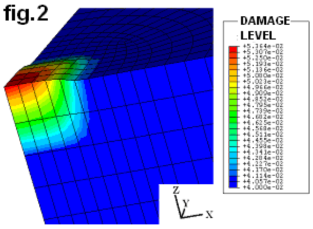

fig.2

The liquid limited length stream impact. It considers as the special case of the liquid with unlimited length. At beginning t=0 liquid stream with length L=5.0_{10}^{-5}m begin to move from bubble wall R*= 5.0_{10}^{-5}m to the deformable half medium with the constant velocity V_0^* =400m/s. This loading does not lead to fracture medium material. But if bubbles destroy are considered as association in unit of liquid volume in this case fractures may be.

CONCLUSION

The compression and destroy steam bubbles lead to the transitional wave processes in liquid. Its parameter average quantities are pressure is near 1.0 GPa, velocities are near 1300 m/s, temperature is near 1500 ºK. The character length and duration each of them are the ultimate bubble size and specific time it's variation. The combination mechanics and heat loading lead to fracture of shell material. An erosion grooves appear.

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