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MODEL ACHIEVEMENT FOR IGNITION AND DEVELOPMENT OF STOCHASTIC DISCHARGE CHANNELS IN CONCRETE AND REINFORCED CONCRETE TAKING INTO ACCOUNT THE PROPERTIES OF THE MEDIUM AND THE GEOMETRY OF THE REINFORCING FRAME

The article develops a generalized model of electrodischarge action on concrete, which allows consistently describing phases of electro-explosion in condensed media: initiation and development of discharge channels, expansion, generation of shock waves, interaction of waves with the material being processed, deformation and destruction of solid materials. The model is based on a stochastic deterministic approach to the development of instability. processes associated with the distribution of the electric field, when mechanical stresses break. The flow of the process is considered deterministically on the basis of nonlinear integro-differential equations, local processes leading to the growth of the channel and cracks - stochastically. Equations describing the nature of the discharge development, the change of the channel resistance and its expansion are concordantly solved with the transition equations in the scheme of the real pulse generator. Expansion of the channel in the liquid is based on the law of conservation of energy, mass, pulse, equations of wave dynamics and allows to calculate the temporal and amplitude impact of shock waves from the channel on the barriers.

The process of electrical breakdown of condensed dielectrics occurs with the development of a stochastically discharge structure, mainly *determined by the emergence of highly conductive plasma channels. The development of the channel structure begins in the area of maximum field tension. In this case, the processes of phase transitions of a material directly determine the quantitative and qualitative processes of image of channels. As part of the study of the model, an analysis of the influence of the movement of electro-discharges on the redistribution of the electrostatic field, conditions leading to the direct formation of discharge channels, fracture formation and complete deformation was conducted.*

Keywords: model, electro-discharge device, stochastic-deterministic approach, electric field, mechanical voltage, shock wave, channel resistance, dielectric, pulse generator, differential equations.

Introduction

The construction of discrete growth models under numerical methods is the most promising method of studying electrodischarge channels. However, due to non-stationary and unsustainable growth and nonlinearity of processes, there is a phase transition of dielectric plasma in which only certain aspects of growth can be studied by analytical methods. At the same time, numerical methods allow to study complex models of development of discharge at all stages of formation of discharge structure with consideration of conditions of breakdown. Taking into account interconnected and non-linear processes of electro-discharge transfer and in agreement with the physically reactive fields, a stochastic-deterministic approach is proposed for constructing a model of the development of the proposed channel [1 - 3]. The study of dynamic processes in an electric field at macroscopic level is proposed using stochastic methods illustrating the processes of growth instability and microperturbation intensity, directly determined by fluctuations and microbundle of the medium.

Materials and methods

It seems that locality of electric field intensity Ep determines the main directions of instability of processes in the model, they have a direct influence on deformation relations when the aggregate state changes during the process of chemical reactions of media and the mechanical state of concrete and reinforced concrete body. The stochastic law in the present case describes the direct integral effect of the development of discharge channels. At the same time, the dependence of the development of microscopic processes in the channel, taking into account the probability of their growth from Ep, can be determined both experimentally and by modeling these processes. For modelling, a step-by-step dependency is proposed, determined by the amount of energy released in the process of canal development. At the same time, the local nature of the density of energy released at a given stage can clearly reflect the threshold of instability, at which the formation and development of the channel begins. This task allows analogy of experimental results and model results.

It is obvious that the quadratic projection of local stress Es will always determine directly proportional growth of probability density of development of the discharge channel wn, with the projection value dominating the critical value Es, Ek> Es. In the event that the probability density of the bit channel is wd is zero, for Es< Ek:

$$\omega_d = \alpha \cdot \theta\left(E_s - E_k\right) \cdot E_s^2 \tag{1}$$

where a - factor which takes into account the speed of development;

θ (x) – function step by step (θ (x)=1 at x>0 and θ (x)=0 at x≤ 0).

Microheterogeneity of the material and instability of its structure and processes that determine the development of the channel can be based on stochastic choice. At the same time, it is proposed to calculate the limit intensity by using optics for the development of high-speed discharge channels [4].

The development of velocity fields in the dynamics of electric charges in the context of electric field redistribution is proposed to describe deterministically, taking into account the principle of superposition fields or Gauss theorem, as applied to electric fields in diaelectrics:

$$\nabla(\varepsilon\varepsilon_0\vec{E}) = \rho \tag{2}$$

where ε and ε_0 – relative and absolute dielectric permeability;

ρ – charge density.

To describe the movement of charges in the development of channels in dielectric materials apply the fundamental law of ohm and the law of charge retention. As a consequence, the change in specific conductivityσ and charge density ρV will be described by the continuity equation:

$$\frac{d\rho_V}{dt} = -\nabla\left(\sigma \cdot \vec{E}\right) \tag{3}$$

According to which the dynamic dependence of linear density of linear charge density ρL:

$$\frac{d\rho_{\perp}}{dt} = -\frac{d}{dl}\left(\gamma \cdot E_l\right) \tag{4}$$

where γ – linear conductivity of the channel;

l – coordinate level.

According to the Kirchhoff equation, the zero-sum condition of the sum of all directional movements will be fulfilled at the channel branching points.

Undoubtedly, the change in the conductivity of the discharge channels will occur as a result of changes in their mechanical, thermal and electrostatic geometries at the macro and micromolecular levels. The intensity of these processes will be determined by the rate at which energy is released in the channels and dispersed into the environment. The conductivity change in this case can be determined according to the Rompe-Vezel formula specified for the spark channel itself:

$$\frac{d\gamma}{dt} = \chi \cdot \gamma \cdot E_l^2 - \xi \cdot \gamma \tag{4}$$

where χ и ξ – factors of drop and rise in conductivity;

The equation shows an immediate increase in conductivity with a power output in a destructive channel.

The physical properties of dielectrics and the development of the breakdown channel will directly determine the mutual response of charge carriers and atoms, taking into account structural defects and irregularities. In addition, any changes in polarization directly responsible for the formation of the S-shaped BAC and the development of unstable fields of velocities and stresses will also be determined by the type of material and the nature of the canal development.

The thermal instability of materials with a direct proportional dependence of conductivity on the field temperature (T), as well as the active feedback between these values in this case, will be a universal characteristic.

The electrical instability model is directly dependent on the temperature of the charge carrier in a highly conductive dielectric body [5, 6].

In the simulation of the deformation process in solid material, the II Law of Newton was used for elementary volume:

$$\rho \frac{d^2 u_i}{dt^2} = \sum_k \frac{\partial \sigma_{ik}}{\partial x_k} \tag{5}$$

where ρ – density;

u_i – displacements vector components;

σ_{ij} – voltage tensor components;

x_k – coordinates.

At the same time, Hooke law for homogeneous and isotropic materials clearly defines the relationship between stress tensor e_{ij} and strain tensor σ_{ij} in the elastic strain field [7]:

$$\sigma_{ij} = 2\mu e_{ij} + \lambda(\sum_k e_{kk})\delta_{ij} \tag{6}$$

$$e_{ij} = \frac{1}{2}\left(\frac{\partial u_j}{\partial x_i} + \frac{\partial u_i}{\partial x_j}\right) \tag{7}$$

where δ_{ij} – symbol Kronekera;

λ, μ – constants Lame.

Conditions of formation of macro fractures in dynamics require taking into account the time of preliminary loading stage, which determines the cumulative accumulation of cracks. Such a model should include the fracture criterion as the Touler-Boucher damage integral [8 - 10]:

$$K = \int_{t_c}^{t} \theta(\sigma(t) - \sigma_c) \cdot \left[\sigma(t) - \sigma_c\right]^2 dt \tag{8}$$

where θ – function of step by step immersion;

$\sigma(t)$ – instantaneous value of voltage tensor component towards crack formation.

There is no doubt that the directional destruction of the material at a given point can occur only at the condition: Es< Ek

To account for material irregularities affecting cracking, a probability function of fracture formation is introduced. In this case, the density of the probability of growth of this crack, if the load value of the critical value is exceeded, will be directly proportional to the integral of damage.

$$\omega_{cr} = \beta\, \theta(K - K_c) \cdot K \tag{9}$$

where β – fracture probability.

Results and discussions

Simulation is provided at the discharge interval in the pulse generator circuit due to the coordination of current and voltage in the circuit. The potential electrode has a potential value equal to that of a given discharge region, whereas the assumed potential is zero S0.

In this case, the equality of the currents of offset and conduction during the discharge interval through the electrode is clearly visible:

$$\int_{S_P}\left(-\varepsilon\varepsilon_0\frac{d}{dt}\left(\vec{\nabla}\phi\right)-\sigma\vec{\nabla}\phi\right)d\vec{s}+\sum\gamma E_l=I_D \qquad (10)$$

$$\varphi\Big|_{S_P}=U_D\,,\ \varphi\Big|_{S_0}=0$$

The transfer of stored energy in the condenser into the internal energy of the ionization products and the mechanical work of shearing at the expansion of the flow occurs at the stage of channel breakdown. To reconcile the energy balance in the generator chain, it is proposed to assume direct proportionality between the specific conductivity of the channel and the specific internal energy of the channel:

$$\sigma=\eta\cdot\frac{W}{V}\,\gamma=\eta\frac{P(t)\,\pi r_k^2(t)}{\gamma_*-1} \qquad (11)$$

No doubt, this proves, that the increased conductivity parameter will always affect the connection between the linear conductivity of the breakdown channel and the internal energy of the plasma flowing in the channel.

The equation determining the interaction between the internal energy of the plasma flowing inside the channel, the joule energy and the mechanical work of the expansion is determined by the energy balance equation for the channel section, in this case, the radius of the channel will be determined from the conditions of equal pressures inside and outside:

$$P=\frac{\frac{1}{3}\int\limits_S\sum\limits_{k=1}^{3}\sigma_{kk}ds}{2\pi r_{ch}l} \qquad (12)$$

where $\frac{1}{3}\int\limits_S\sum\limits_{k=1}^{3}\sigma_{kk}ds$ – total force acting on the channel from the surrounding material.

Conclusion

Studies have shown the effectiveness of formation of discharge channels in the construction of discrete growth models. At the same time, numerical methods make it possible to study more complex models of development of the discharge and to consider all stages of formation of the discharge structure under different conditions of breakdown, taking into account the simulation at the interval of discharge in the generator chain. The conducted studies showed the possibility of using and developing pulse generators for the ignition process and the development of stochastic discharge channels in concrete and reinforced concrete, taking into account the properties of the medium and the geometry of the reinforcing framework.

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ҚОРШАҒАН ОРТАНЫҢ ҚАСИЕТТЕРІН ЖӘНЕ АРМАТУРАЛЫҚ ҚАҢҚАНЫҢ ГЕОМЕТРИЯСЫН ЕСКЕРЕ ОТЫРЫП, БЕТОН МЕН ТЕМІРБЕТОНДАҒЫ СТОХАСТИКАЛЫҚ РАЗРЯДТЫ АРНАЛАРДЫ ТҰТАТУ ЖӘНЕ ДАМЫТУ МОДЕЛІН ӘЗІРЛЕУ

Бетонга электр разрядының әсер етуінің жалпыланган моделі жасалды, ол конденсацияланган ортадағы электр жарылысының фазаларын дәйекті түрде сипаттауға мүмкіндік береді: разрядтық арналардың басталуы және дамуы, соққы толқындарының кеңеюі, пайда болуы, толқындардың өңделетін материалмен әрекеттесуі, қатты материалдардың деформациясы мен бұзылуы. Модель тұрақсыздықты дамытудың стохастикалық-детерминистік тәсіліне негізделген. механикалық кернеулердің бұзылуымен электр өрісінің таралуына байланысты процестер. Процестің барысы сызықты емес интегро-дифференциалдық теңдеулер негізінде детерминистік түрде қарастырылады, канал мен жарықтардың өсуіне әкелетін жергілікті процестер стохастикалық болып табылады. Разрядтың даму сипатын сипаттайтын теңдеулер, арнаның кедергісінің өзгеруі және оның кеңеюі нақты импульсті генератор тізбегіндегі өтпелі теңдеулермен келісілген түрде шешіледі.

Сұйықтықтағы арнаның кеңеюі энергияның, массаның, импульстің сақталу заңына және толқын динамикасының теңдеулеріне негізделеді және соғу толқындарының арна шуына уақытша және амплитудалық әсерін есептеуге мүмкіндік береді.

Конденсацияланған диэлектриктерді электрмен сынау процесі негізінен жоғары өткізгіш плазмалық арналардың пайда болуымен анықталатын стохастикалық разряд құрылымының дамуымен жүреді. Арналар құрылымының дамуы өрістің максималды күші аймағында пайда болады. Бұл жағдайда процестер материалдың фазалық ауысуы арналардың пайда болуының сандық және сапалық процестерін тікелей анықтайды. Модельді зерттеу аясында электр разрядтары қозғалысының электростатикалық өрісті қайта бөлуге әсері, разряд арналарының тікелей түзілуіне, жарықтың пайда болуына және толық деформацияға әкелетін жағдайлар және импульстік генератордың жұмысын үйлестіру шарттары талданды.

Кілтті сөздер: модель, электр разрядты құрылғы, стохастикалық-детерминистік тәсіл, электр өрісі, механикалық кернеу, соққы толқыны, канал кедергісі, диэлектрик, импульстік генератор, дифференциалдық теңдеулер.

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РАЗРАБОТКА МОДЕЛИ ЗАЖИГАНИЯ И РАЗВИТИЯ СТОХАСТИЧЕСКИХ РАЗРЯДНЫХ КАНАЛОВ В БЕТОНЕ И ЖЕЛЕЗОБЕТОНЕ С УЧЕТОМ СВОЙСТВ ОКРУЖАЮЩЕЙ СРЕДЫ И ГЕОМЕТРИИ АРМАТУРНОГО КАРКАСА

Аннотация. Разработана обобщенная модель воздействия электрического разряда на бетон, позволяющая последовательно характеризовать фазы электрического взрыва в конденсированной среде: начало и развитие разрядных каналов, расширение, *образование ударных волн, взаимодействие волн с обрабатываемым материалом, деформацию и разрушение твердых материалов. Модель основана на стохастико-детерминированном подходе к развитию нестабильности. процессы, связанные с распределением электрического поля с нарушением механических напряжений. Ход процесса рассматривается детерминированно на основе нелинейных интегро-дифференциальных уравнений, локальные процессы, приводящие к росту канала и трещин, стохастичны. Уравнения, характеризующие характер развития разряда, изменение сопротивления канала и его расширение решаются согласованно с переходными уравнениями в цепи генератора реальных импульсов. Расширение канала в жидкости основано на законе сохранения энергии, массы, импульса, уравнениях волновой динамики и позволяет рассчитать временное и амплитудное влияние ударных волн на помехи от канала.*

Процесс электроиспытания конденсированных диэлектриков происходит главным образом с развитием стохастической разрядной структуры, определяемой образованием высокопроницаемых плазменных каналов. Развитие структуры каналов происходит в области максимальной силы поля. При этом процессы непосредственно определяют количественные и качественные процессы образования каналов фазового перехода материала. В рамках исследования модели были проанализированы влияние движения электрических разрядов на перераспределение электростатического поля, условия, приводящие к прямому образованию разрядных каналов, образованию трещин и полной деформации, условия координации работы импульсного генератора.

Ключевые слова: модель, устройство электрического разряда, стохастико-детерминированный подход, электрическое поле, механическое напряжение, ударная волна, сопротивление канала, диэлектрик, генератор импульсов, дифференциальные уравнения

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