ANALYSIS OF STRESS AND STRAIN STATE OF PLATES AND SHELLS WITH DUE CONSIDERATION OF MATERIALS DAMAGEABILITY THANKS TO TIME-DEPENDENT DEFORMATION AND HIGH-TEMPERATURE HYDROGEN CORROSION

Belov A.V., Polivanov A.A., Popov A.G.
Kamyshin Technological Institute
Branch of Volgograd State Technical University
Kamyshin, Volgograd Region, Russia

The most important problem of energy and petrochemical as well as aircraft engineering development is the creation of new generation arrangement rendering possible realization of strict operating practice of exploitation (high temperature, pressure, speed, environmental aggressiveness, etc.) and providing high reliability and specified life. For designing such constructions the elaboration of design complexes rendering possible to carry out the investigation and behavior simulation of such constructions taking into account the attack of non-steady temperature, force field and degradation of mechanical-and-physical properties of their materials. The specified complexes including quite a number of basic intersystems should operate from mathematical models describing the evolution of stress and strain state of the constructions under the conditions of their near-real exploitation loading.

In this connection the elaboration of system concept of construction of such design complexes both from methodological point of view and from the position of construction of integrated functional design of interdependent models rendering possible to solve complex problems passing from their simple statement to a more complicated one becomes of the current interest.

System approach oriented integrated studies meant for a large variety of important engineering problems are carried out by the authors, among them:

- computing and valuation of loading capacity of non-uniform sandwich shell structures used in energy and petrochemical engineering, working in conditions of complex thermo-force loading, causing development of irreversible deformations, damageability of materials due to creeping and attack of aggressive media;
- design of optimal from the viewpoint of resistant durability, life duration and materials consumption of the structures as applied to concrete activities;
- valuation of wide class remaining life of highly stressed and dangerous from the after-effect viewpoint of failure of the structures (body frame of chemical reactors, parts of gas turbines and electric power installations, variators and other products of heavy-duty production) being at present time in use.

In the work presented here the concept of system approach to investigation method development and simulation of thermo-visco-elastic-plastic stress and strain state of non-uniform sandwich shell structures with account of materials damageability due to creeping and hydrogen corrosion.

At that the models determining the structures behavior and integrated into a complex are constructed with due consideration of present-day state of theoretical research and experimental data on fullness and adequacy of the considered physical and mechanical processes description. If necessary the models are complicated on account of their correlation. For this a hierarchic approach to the formation of model system realizing the principle “from simple to complex” is used, when the next difficulty level is reached after detailed enough study of a more simple model. Hence, a multilevel architecture of more and more complex models every one of which correlates the previous ones including them as special cases.

The developed in such a way method of solving a complex problem on valuation of durability, toughness and life time of quasistatically loaded sandwich envelopes of rotation according to the correspondent parameters’ predetermined values allows performing accounting in various statements. Let us consider every of the possible problem statements in a more detailed way.

1. Thermo-elastic statement of the problem. Here a linear dependence of stresses on strains is intended, the dependence of a material properties on temperature comes

into account by means of definition of mechanical properties of the material for different fixed values of temperatures. The construction failure is not intended.

2. Thermo-elastic-plastic statement of the problem. In this case the material behavior law is supposed to be linear only within the proportional limits, and for irreversible deformations development modeling the following things can be used:
   - simple straining process theory (theory of small elastoplastic deformations) – in case of steady thermo-force loading;
   - theory of nonisothermal processes of elastoplastic deformation of solid body elements in the path of flatness (theory of flow with isotropic hardening) – in case of non-steady thermo-force loading with the possibility of loading history investigation.

   Depending on loading conditions and mechanical properties of envelope materials for its bearing resistance valuation the use of one of the three sudden fracture criteria is possible: the Rankin, Tresca-Guest or Huber-MIses one.

Besides, stress and strain structures' calculations performing is possible also taking into account high-temperature hydrogen corrosion. To do it the methodology is enriched with a generalized model of hydrogen-containing medium attack to the construction.

3. Thermo-visco-elastic-plastic statement of the problem ignoring materials damageability at creeping. Here, in addition to the previous problem statement, the deformation adaptability in time due to the envelope materials' creeping is intended; it comes into account by means of introduction of creep strains into constitutive equations. At that, one of either prompt or long-term strength criteria can be used as the envelope fracture criterion.
4. Thermo-visco-elastic-plastic statement of the problem inclusive materials damageability at creeping. In the specified problem statement it is supposed that the creep strain development will be attended with damage accumulation in the envelope material that finally can lead to its fracture as well. At that, the scalar parameter of damageability ω_C is accepted as a measure of the material damageability in the process of creep strain development.

To describe the process of damage accumulation in a material due to creeping the kinetic damageability equation of Rabotnov Yu.N. is used.

As the equivalent stress one of the criteria of long-term strength - Johnson, Kats, Sdobyrev, Trunin or Lebedev-Pisarenko – can be used. The choice of a creep rupture strength criterion describing the material's damageability process at creeping most adequately depends on the kind of stress state, stress level and availability of enough test data.

The process of damage accumulation in the material of the studied shell is calculated by means of successive solutions of the kinetic damageability equation in every loading step. The investigation of the damage accumulation process in the shell element lasts until achieving a preset limit value close to the unit by the ω_C^* parameter. It is the condition of the shell's local fracture (i.e. fracture process beginning).

5. Thermo-visco-elastic-plastic statement of the problem inclusive materials damageability at creeping with fracture propagation stage investigation. The problem solution in such a statement supposes the shell's fracture propagation stage investigation. To do it for a first approximation the method offered by Kachanov L.M. and based on fracture front edge (the surface demarking the destroyed and yet undestroyed areas of the material) stroke study is used. The moment, at which the front edge stroke speed increases sharply (ten and more times as much) or when in separate most loaded points intolerably large deformations exceeding 5% are accumulated, is accepted as the total fracture time. The fracture front edge stroke speed is defined as the ratio of fracture front edge stroke to the period of time during which this stroke takes place.

Thus, the authors have developed the sandwich envelope structures' behavior modeling and research methodology which allows describing the following kinds of its stress and strain state:

- thermo-elastic;
- thermo-elastic-plastic inclusive and exclusive hydrogen corrosion;
- thermo-visco-elastic-plastic ignoring materials damageability at creeping;
- thermo-visco-elastic-plastic inclusive materials damageability at creeping;

- thermo-visco-elastic-plastic inclusive materials damageability at creeping and hydrogen corrosion;
- thermo-visco-elastic-plastic inclusive materials damageability at creeping and hydrogen corrosion with damageability areas propagation kinetics.

At developing this methodology the following was used: the linearized by the method of additional strains correlations of the theory of nonisothermal processes of elastic-plastic straining of solid body's elements in the path of flatness; kinetic equations of materials' damageability at creeping and hydrogen corrosion.

Using the developed methodology a range of applied problems on stress-strain analysis of single- and multilayer envelopes of rotation at various loading conditions, and that is:

- uniformly heated up three-layer cone shell rotating with constant angular velocity;
- double-layer spherical shell with various banding and loaded with intrinsic pressure;
- thin double-layer envelope of rotation with an irregular shape of meridian in the form of a vessel at its internal pressure loading;
- double-layer rotation shell representing an axial compensator loaded simultaneously with intrinsic pressure and shifting motion of its end faces;
- uniformly heated up cyclic plane dependent upon high-temperature hydrogen from one of the sides.

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SECONDARY POWER SOURCES WITH CAPACITORS IN POWER CIRCUIT

Magazinnink L.T.
Ulyanovsk State Technical University
Ulyanovsk, Russia

Single-phase secondary power sources (SPS), due to their little specific gravity (kg/kW) and quick response, got wide spread occurrence within the limits of power from tens of W (household audio- and video facilities) to some kW (electronic voltage stabilizers, plasmatron ion source feed elements of moderate capacity, electric arc welding devices, etc.) [1].

One of significant disadvantages of a "classical" SPS is a low phase factor (F_p) equal to 0,3…0,4 and conditioned by impulse character of the consumed current from the system.

For the purpose of the F_p increase an active filter on the input of the invert circuit is used, which is sometimes called the F_p adjuster. For the filter power key control a range of well known firms ("Micro Linear", "Simens", "Motorolla") have developed special electronic chips providing quasi-continuous character of the line current and F_p increase up to 0,86 with simultaneous invert circuit constant-voltage regulation [2].

In [1,3] a modified algorithm of active filter control and the scheme of the algorithm realization are offered, that provides the F_p increase up to 0,95 and more meeting the hardest demands of the IEC (IEC-1000-3-2).

Notice that the SPS power part complication connected with the active filter application is made up with the fact that together with the F_p increase and invert circuit out voltage stabilizing treatment the filter condenser capacity value decreases by about 60 %.

Further SPS updating in terms of specific gravity decrease and loss enhancement, for example, has the following limitations:

- because of the invert circuit out voltage unbalance the power isolating transformer is performed gapped in the heart and is used only in the incremental hysteresis loop, that makes the bicyclic invert circuit bridge network be non-effective compared to a single-pulse one, and, finally, leads to the transformer mass-volume showings increase;
- the invert circuit out voltage line-locked frequency increase allows reducing the transformer and smoothing inductor frames, however, the power transistors' losses increase at that. The last especially matters for powerful SPS.

The switching on the capacitors in series into the power transformation primary circuit allows excluding the invert circuit out voltage continuous component, and also, in some cases, reducing commutative losses in power transistors.