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STRESSES DISTRIBUTION IN CASING SUPPORT UNDER THE INFLUENCE OF LOCAL COMPACTING PRESSURE

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ABSTRACT

The article represents methods of evaluation of stress distributions in casing supports of wells and elements of foundation caused by local loads and compacting in soil base. Conditions of load's origin were identified. Main methods and equations are given and proved by conducted experiments. Model of stress-strain state in casing support as an applicable result is created and shown. Impact of compression on absolute value of durability is presented.

Keywords: local pressure, concrete, stress distribution, Western Siberia, Arctic, civil engineering.

1. INTRODUCTION

The majority of oil and gas field's are locate in permafrost regions such as the Kama River region, Western and Eastern Siberia. The permafrost zones are runs from the Kola Peninsula to Ural where it coincides with latitude of the Arctic Circle. Then the permafrost area's border deviated to south. It runs up to river Ob latitude, crosses the river Enisey and goes of the limits of Russia. The great part of cryolithozone based in eastward of Ural mountain. The square of this zone is about 9 million square kilometers and its south border reaches to latitude of 58-59^0.

The first prospecting wells in permafrost regions were drilled in the 1930s. Then this process has been continued in the Western Siberian Lowland in 1954. As a result was discovering of a new giant gas fields and gas condensate fields such as Medvezhye, Urengoyskoye, Yamburgskoye, Kharasaveiskoye, Bovanenkovskoye etc. In addition, has been discovered gas and oil fields in Eastern Siberia.

Some specific complications has a connection with the permafrost rocks in geological cross-section namely the breaching of the integrity in casing strings and its deformation. Many scientists such as A.V. Maramzin, G.S. Griznov, I.V. Belov e.t.c. made their research about an explanation mechanism of deformation in casing strings. The most fully reasons of deformation in casing strings in cryolithozone were marked in listed points [1, 2, 3]. According to the above-mentioned source the main reason of deformation is a formation of a liquid(e.g. the drill mud, cement slurry and other technical water-based liquors) in tubing-casing annulus. After freezing, this liquid has change of state from a liquid to a solid. Then the pressure has destroyed the casing support parts of casing string and cement sheath. In general, this opinion is correct. However, this research does not include the analysis of shear and normal stresses propagation in a solid of casing, in cement sheath, deflection of casing as well as impact of having (or not having) adhesion between the cement sheath and casing string and an effect of these elements on a whole construction's strength.

The above-mentioned facts and emergence of operating problems has becoming the occasion of research.

As it was mentioned above the refreezing pressure in permafrost rocks and underground pressure in the zone of rock flowage (salt deposition, clay e.t.c.) are the main reasons in formation of compacting external pressure. As the rule, this pressure is local, so it follows the continuum mechanics [4, 5].

2. MATERIALS AND METHODS

The limit state of casing support can be characterized with the plastic flow in inside pipecasing that comes before the deformation. In addition, it saves the load-carrying ability Ifother pipes casing and cement sheath that binding together will be in the elastoplastic area or plastic area. With the volumetric compression of cement sheath that's became an elastoplastic material. So casing support's reliability improved by conversion the whole system of brittle-to-ductile transition. Proceeding Griffith's theory of fracture breakage is knows that material's destruction begins with the microcracks. Moreover, the one material's layer in plastic consistence does not convert in the second layer before it does not attain a limiting value of stress. In case if any layer in the casing support will change toplastic stage then the completely pressure completelypropagate through this layer to the next layer [6, 7, 8].

There are many assignment options of elastic and plastic ranges of well casings and cement sheath and it depends on the pressure quantity, well casings construction's features and physical and mechanical characteristics of its layers. As the rule, the pipes of external casing string are the first in transition of elastic-plastic deformations area and then the other parts of casing. The pressure's value in the elastoplastic area and plastic area of well casing and cement sheath base on system of equation's solution.

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$$\left.\begin{aligned} \sigma_{rej} &= -\sigma_{rjj} + \frac{2\cdot\sigma_{Sj}}{\sqrt{3}}\cdot\ln\frac{r}{r_j}; \\ \sigma_{\theta ej} &= -\sigma_{rjj} + \frac{2\cdot\sigma_{Sj}}{\sqrt{3}}\cdot\left(1+\ln\frac{r}{r_j}\right); \end{aligned}\right\} \quad (1)$$

It is equivalent for all layers of well casing in conjugation of layer's boundaries and at elastic to ductile transition of layers. ($r_j \le r \le \rho_j$) [7].

For ρ_j -radiuses of plasticity; for σ_{rjj} - value of radial pressures in inside areas of external tube and the cement; σ_{rj+1} - value of radial pressures in the next external tube area and cement; σ_{rjj} - for limits of material's yield in j-layer.

As an example in the table 1arerepresent some calculated values of *external pressure.* At exactly these values in well casings of three-string well will form different sizes areas of plasticity. Two variants of results are represented in Table-1. The first one has an elastic modulus E_1=1*10^3 MPa for the cement between the casing supports. The second one has E_2=1*10^4 MPa.

Table-1. Lift effectiveness of the casing support in areas of elastoplastic and plastic deformations.

Elastoplastic area (%) in casing support with diameter and thickness of pipe wall, mm			**Pressure (external), MPa**	
168×12,0	**245×13,8**	**324×14,0**	$P(E_1)$	$P(E_2)$
0	0	0	44,80	88,24
0	0	50	57,89	241,10
0	0	100	66,04	277,72
0	50	100	146,51	555,33

As it appears from table 1 that external pressure for the casing support in elastoplastic area of deformation is higher than in area with only elastic deformation. However, the growth of the plastic areas in in casing support could lead to uneven load or loosing of stability in pitch. As a result, it could be a reason of serious accident in well. In this regard, the calculations of collapse resistance of casing string should be based on its test in elastic deformation area. The math model of bend for composite casing can represents as differential equations of monolayer construction [9].

$$D\left(\frac{d^4w}{dx^4} + 4w\beta\right) = q, \quad (2)$$

D is for integral characteristics of rigidity in bending of composite shell; w(x) - function of flexure, m; q –local strain on the presented area, MPa;

For monolayer, this expression can be transformed into the next equation:

$$D = \sum_{i=1}^{n} \frac{E^{(i)}h^{(i)^3}}{12(1-\nu^{(i)^2})} + \frac{2E^{(i)}\cdot h^{(i)}}{\left(1-\nu^{(i)^2}\right)}\cdot C^{(i)^2}\cdot\lambda, \quad (3)$$

The first summand is unit stiffness of monolayer and the second takes into account the interlaminar bond's strength. Here λ is for the modular ratio that can be taken from the next expression [8]:

$$\lambda = \frac{\frac{d^2w}{dx^2}\cdot\eta}{\frac{d^2w}{dx^2}\cdot\eta - \frac{E^{(i)}h^{(i)}}{(1-\nu)}\cdot\frac{d^4w}{dx^4}}, \quad (4)$$

C^i– the space between the median surfaces of adjacent layers,м; $E^{(i)}$ - modulus of elastic *i*-layer; ν^i - Poisson's ratio for material of i-layer; $h^{(i)}$ - thickness of the *i*-layer, m; *R* - the radius of curvature of the shell, m; η - stiffness coefficient of bond shearing in contact of the cement and casting pipe, N/mm^3.

$$\beta = \sum_{i=1}^{n} \frac{E^{(i)}h^{(i)}}{4R^2D}. \quad (5)$$

The calculation of the bend in composite cylindrical shell made on side faces of the construction for s swivel support condition. The function of deflection presented as a series of sines W(x) (6):

$$W(x) = \sum_{m=1}^{\infty} W_m \sin\frac{m\pi x}{\alpha}. \quad (6)$$

Strain in line's range (7):

$$q(x) = \sum_{m=1}^{\infty} q_m \sin\frac{m\pi x}{\alpha}. \quad (7)$$

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Then it is possible to calculate the radial strains (8);

$$\left.\begin{aligned}\sigma_x^{(1)} &= \frac{d^2W}{dx^2}\left(C^{(1)}\alpha + \frac{h^{(1)}}{2}\right)\frac{E^{(1)}}{\left(1-v^{(1)^2}\right)};\\ \sigma_x^{(2)} &= \frac{d^2W}{dx^2}\frac{h^{(2)}}{2}\frac{E^{(2)}}{\left(1-v^{(2)^2}\right)};\\ \sigma_x^{(3)} &= \frac{d^2W}{dx^2}\left(C^{(3)}\alpha + \frac{h^{(3)}}{2}\right)\frac{E^{(3)}}{\left(1-v^{(3)^2}\right)},\end{aligned}\right| \quad (8)$$

: α is for the length of the local strain area.

The tangential shearing stress in an adjacent layer's boundaries could be written as a next expression:

$$\left.\begin{aligned}\tau_{x(xy)}^{(1)} &= \eta_{x(xy)}\left[C^{(1)}\frac{\partial w}{\partial x} + \int_0^x \frac{\partial^2 w}{\partial x^2}\left(Z_x^0 - C_x^{(1)}\alpha_x^{(1)}\right)dx + \left(A_2 - A_1\right)\right]\\ \tau_{y(xy)}^{(1)} &= \eta_{y(xy)}\left[C^{(1)}\frac{\partial w}{\partial y} + \int_0^x \frac{\partial^2 w}{\partial y^2}\left(Z_y^0 - C_y^{(1)}\alpha_y^{(1)}\right)dy + \left(A_4 - A_3\right)\right]\end{aligned}\right\} \quad (9)$$

Am - constants that depend on borderline conditions of separate layers bracing.

3. RESULTS

The bracing is unified for all layers, so it possible to represent the difference as $A_{m+1} - A_1 = 0;$ for $Z^i \in \left(-h^i/2; h^i/2\right)$ is a coordinate of point в*i*-layer, in which formed the components of stress state. E.g. The stress state calculation, widely applied for overlapping of cryolithozone, compound for wells $168\times245\times324$ mm in case of freezing of water saturated zone of middle pipe (Figure-1).

The basic factors that were set: thickness of pipe walls $h^{(1)}$, $h^{(3)}$thickness of cement $h^{(2)}$; elasticity modulus of pipe material$E^{(1)}$, $E^{(3)}$and cement stone$E^{(2)}$. The lower and upper levels of the casing wall thicknesses were varied in accordance with the standard, the modulus of elasticity of the cement in accordance [4].

$h^{(1)}= h^{(3)}$=8,9*10^{-3}m; $h^{(2)}$=29,6*10^{-3}m; R=98.8*10^{-3} v; $E^{(1)}$= $E^{(3)}$= 2.1*10^{5}MPa; a=12,0 m; $C^{(1)}$= $C^{(2)}$=23.7*10^{-3}m; q=50 MPa; η = 0, 100, 10^{6}N/mm^3; $E^{(2)}$=10^3; 5*10^3;1*10^{6}MPa.

The result of calculation set in Table-2.

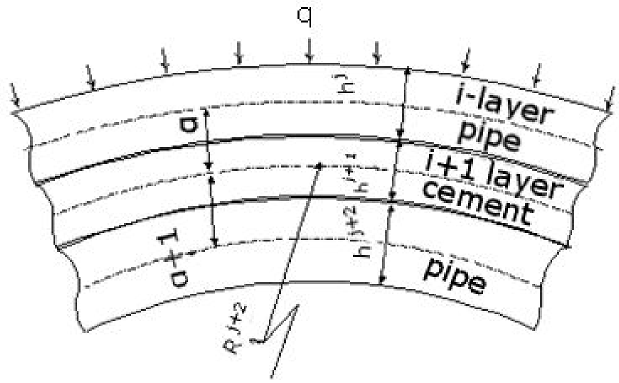

Figure-1. Calculation model of stress-strain state in casing support under the local axisymmetrical load.

In the Figure-1 represented graphs of the normal and tangent stress distribution in body of casing and cement, string deflection. It makes sense in case of presence and absence of contact between cement and casing string far forth for the place of compacting external pressure force.

4. DISCUSSIONS

Analysis of represented calculations suggests that the basic stress is in area of casing support on interval 0,4 $\div$0,6 x/a, i.e. it takes near the place of compacting pressure force(graph of load application in the point x/a=0,5).

It was noted that absolute value of developed stresses in casing are much higher than in cement. For the first case, it is 100MPa and there is almost no relation on cement durability and availability of adhesion between cement and casing. It is vice versa for the second case.

If cement has an adhesion with casing then the value of the normallines of compacting in cement will be much lower than without in casing. In addition, the higher cement durability, the higher value of lines of compacting. So, it means that the elements of casing react for the stress as apart. If cement has a adhesion with casing string then system will react for the stress as a monolith .In this way there is no any effect on the value of compacting stress by cement durability. The maximum value of normal (compacting) stresses along cement are 70 MPa (under the condition of absence of adhesion between cement and casing string).It seems that arised from compacting strain stresses are relaxing by casing string. If the casing string has an adhesion with cement, it will relax by casing string-cement system.

Table-2. The maximum value of stress-stain state of casing support.

E_c, MPa	η, N/mm^3	W, mm	τ, MPa	$\sigma^{(1)}$, MPa	$\sigma^{(2)}$, MPa
$1*10^3$	0,0	0,2345	0,0	-115,7	-8,5
	100	0,2344	0,5	-113,8	-6,6
	10^6	0,1162	14,1	-102,8	-1,9
$5*10^3$	0,0	0,2187	0,0	-107,1	-39,0
	100	0,2187	0,4	-105,3	-30,8
	10^6	0,109	13,0	-95,6	-8,7
$1*10^4$	0,0	0,1956	0,0	-97,5	-71,6
	100	0,1956	0,4	-96,3	-55,7
	10^6	0,098	11,8	-86,6	-15,8

The pattern of distribution of shearing (internal) stresses in area of contact between the casing string and cement is more complicated for a several reasons. Firstly, there is no any depends on cement durability. Secondly, the pattern is undulatory. This is because the directions of effect are different (in a clockwise direction, in a counterclockwise direction).

CONCLUSIONS

Finally, the effects of stresses appear on deflection of casing support. In this regard, the deflection was not note a whole interval, but only in a space about ± 0, 15 x/a from the compacting stress application point.

Therefore, by the results of made theoretical studies it follows that, operating problems arising from the external local compacting loads are connecting with generation of normal stresses in casing string and cement. It's the compression.

It can exceed the absolute value of durability of the casing string-cement system. In this regard, the most important value is existence of adhesion between these elements. This implies that the basic trend of development in cementation of the casing strings is conditioning of long-term contact that forming in casing annulus of cement with the casing string.

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