Problems of assessing the effectiveness of CAE-complexes in the design of offshore structures

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Abstract. The article analyzes the effectiveness of the application when designing offshore engineering analysis systems, which are collectively called CAE. Currently, the production of offshore oil and gas resources, which are extracted using offshore hydraulic structures, is actively developing. These structures are offshore stationary platforms (SMEs) of pile type for various purposes. Offshore platforms are subject to various loads and are in a difficult stress state. The calculation of their real stress state is a difficult task. A solution to this complex problem can be found by building a computer model in a specialized CAE software package. To date, a large number of CAE systems with various functionalities have been developed. In this regard, a technique is needed to evaluate the effectiveness of a specific CAE software package to solve the problem of assessing the stress state of a stationary marine platform. The author offers his own methodology for assessing the effectiveness of CAE packets and gives an example of its practical application.

1. Introduction

Russia has a considerable marine oil and gas reserves located on sea and ocean shelves. Oil and gas fields are actively developed on the shelf of the Caspian Sea, the Baltic sea, Sakhalin and other regions, the production of which is using offshore structures, which are also known as offshore oil and gas structures (OOGS). These structures are fixed offshore platforms (FOPs) pile type for various purposes. Fixed offshore platforms are used extensively for oil and gas on offshore fields in the world. For example, in the Gulf of Mexico used approximately 4,500 such facilities. Active marine stationary platforms are used by Norway, Azerbaijan, Iran, several countries of the Persian Gulf, China, Brazil, USA and many other countries. It means that we can confidently say that these structures are widespread and play a key role in the extraction of offshore oil and gas resources.

The extraction of oil and gas resources in the world is carried out in difficult conditions and is accompanied by extreme environmental influences [1-20]. Most of the elements of fixed offshore platforms are located in difficult-stress state, are often subjected to combined action of bending, stretching, compression and torsion. Therefore, the evaluation of the actual stress state with account of interference of elements is a complex and tedious task, effective solution which can be found by constructing computer models using specialized software. To solve this problem, there is a separate class of computer-aided design, which are known under the name CAE (Computer Aided Engineering). These complexes are intended for solution of various engineering problems: calculation, analysis, simulation of physical processes, optimization of structures. Design of the packages is often based on numerical
methods of solving differential equations (finite element method, finite volume method, finite difference method, etc.)

The most common and effective calculation methods used in CAE-systems is the finite element method (FEM). System using numerical analysis technical of structures the finite element method are called FEA-systems (Finite Element Analysis).

Assessment of stress state of offshore platforms is a challenging task related to the interference of elements and wide range of operating loads, such as wind, ice, wave, seismic, etc., which need to be considered in various combinations, using the so-called load combination factors.

Most systems CAE in the evaluation of the stress state use the finite element method. The basic idea of this method is that any continuous in a certain field value (for example, internal stress or displacement in the elements of the offshore platform) can be approximated by a discrete model, which is created from the set of piecewise continuous functions defined in a finite number of subregions. Usually such functions are polynomials – linear, quadratic, cubic, etc. Piecewise continuous functions are constructed using the values of the continuous quantities at the points of connection of elements (nodes).

It means that you can say that most of the systems CAE uses similar approaches to solving the problem of evaluating the stress state of FOPs. However, the question arises, what is the software package to choose, to evaluate the stress state of the platform? Indeed, at present, various companies are offered a variety of solutions in this area. In this connection, you need a method that allows to evaluate the effectiveness of a program complex for the solution of the problem of estimation of the considered problem of estimation of the stress state of a marine platform. The author offers his own method, which consists in the following.

It is well known that the packages CAE are multifunctional and capable of solving wide range of problems. However, most of these complexes have functions that are not used in the evaluation of the stress state of the marine platform. Thus, due to these "unnecessary" functions increases the cost of the package CY. There is a task on the classification of functions and identify all unnecessary to evaluate the stress state of the marine platform functionality (EF).

2. Method

To resolve this problem, it is reasonable to use the method of functional-cost the analysis (FSA). Its purpose is in classification of the PV software products and determining the ratio of the number of useful features and costs of their implementation.

It is proposed to subdivide the functions performed by CAE on the principle of ABC is to: (A) major functions, which are indispensable for the execution of the considered problem; (B) sub - functions contributing to the core functions or their complements; (C) redundant features, which do not contribute to the evaluation of the stress state of offshore platforms, but increase the cost of the package CAE. In order to improve the accuracy of evaluating the effectiveness of CAE packages, class B functions were ranked as follows:

B3 is an auxiliary functional that allows solving the problems of assessing the stress state of SMEs especially effectively and is rated at 3 points;
B2 – an auxiliary functionality, often used in solving the problem under consideration, and is rated at 2 points;
B1 – an additional functionality that is potentially applicable, but not often used by engineers in assessing the stress state in the elements and welded joints of the platform and is rated at 1 point.

For the implementation of this methodology, a comparative table of PV packages of CAEs is created. It lists all the available functions of the considered software products and indicates the presence of a function (‘+’) or its absence (‘-’) for each specific package (table. 1). After this, the functions are grouped into main, auxiliary and redundant. The separation of functions is based on the method of expert assessments. The expert assessment method is a method of organizing work with expert experts and processing expert opinions expressed in quantitative or qualitative form.
Table 1. Comparative table of CAE package functionality.

| Function | Name of the CAE package |
|----------|--------------------------|
|          | CAE-1 | CAE-2 | … | CAE-n |
| 1        | +     | -     | … | +     |
| 2        | -     | -     | … | +     |
| …        | …     | …     | … | …     |
| n        | +     | +     | … | +     |

Then, a comparative table of the functionality of the CAE packages is compiled, in which all functions are grouped into groups (table 2).

Table 2. Comparative table of the functionality of the CAE packages

| Function | Name of the CAE package |
|----------|--------------------------|
|          | CAE-1 | CAE-2 | … | CAE-n |
| Functions of the group «A» |
| 1        | +     | -     | … | +     |
| 2        | -     | -     | … | +     |
| …        | …     | …     | … | …     |
| n        | +     | +     | … | +     |
| Functions of the group «B1» |
| 1        | -     | +     | … | +     |
| 2        | -     | -     | … | +     |
| …        | …     | …     | … | …     |
| n        | -     | +     | … | +     |
| Functions of the group «C» |
| 1        | +     | +     | … | +     |
| 2        | +     | -     | … | +     |
| …        | …     | …     | … | …     |
| n        | +     | -     | … | +     |

After classifying all functions according to the ABC method, all software products that do not have class A functions are excluded. Next, the costs of using a specific CAE complex were determined and the coefficient of efficiency of the CAE package is calculated by the formula:

\[
E = \frac{a \cdot B_1 + x \cdot B_2 + y \cdot B_3}{K},
\]

where:
- \( E \) – a coefficient of effectiveness of the CAE package;
- \( K \) – a cost of using the CAE package;
- \( a, x, y \) – the number of functions of class "B";
- \( B_1, B_2, B_3 \) – functions of class «B».

The CAE package for which the value of the efficiency coefficient is the highest is the most effective for assessing the stress state of the platform.
3. Result

For analysis, we selected both domestic and foreign software systems that are widely used in modern industrial and civil engineering. A comparative table of the functionality of each of the analyzed CAE packages has been compiled. Based on expert evaluation, all functionalities were classified according to the ABC method.

Table 3. Classification of the functional capabilities of CAE complexes for solving the problem of stress analysis of a fixed offshore platform.

| Functional capabilities | Name of the CAE package |
|-------------------------|-------------------------|
|                         | SCAD Office | Dassault Systemes Solid Works | Ansys | Sofistik AG | Lira Abaqus |
| Functions of the group «А» |                        |                                 |       |            |            |
| Ability to import 3D models from CAD systems | + | + | + | + | + |
| Integrated Graphical Modeling Environment | + | + | + | - | + |
| Export of the geometry to neutral formats | + | + | + | + | + |
| Editing of the imported geometry and preparing it for calculation | + | + | + | + | + |
| Strength calculation (linear static) | + | + | + | + | + |
| Strength calculation (non-linear static) | + | + | + | + | + |
| Stability (linear) | + | + | + | + | + |
| Stability (non-linear), analysis of strength after loss of stability | + | + | + | + | + |
| Functions of the group «В» |                        |                                 |       |            |            |
| Using non-linear material models | + | + | + | + | + |
| Geometric nonlinearity | - | + | + | + | + |
| Functional capabilities                                                                 | Name of the CAE package |
|----------------------------------------------------------------------------------------|------------------------|
|                                                                                        | SCAD Office | Dassault Systemes Solid Works | Ansys | Sofistik AG | Lira Abaqus |
| Functions of the group «B₂»                                                           |             |                                |       |             |             |
| Elastic elements                                                                       | +          | +                               | +     | +           | +           |
| Point masses                                                                           | +          | +                               | +     | +           | +           |
| Damping elements                                                                       | +          | +                               | +     | +           | +           |
| Rods                                    | +          | +                               | +     | +           | +           |
| Beams                                   | +          | +                               | +     | +           | +           |
| Pipes/bends                             | +          | +                               | +     | +           | +           |
| The presence of an extensive database of training materials in Russian                   | +          | +                               | +     | -           | +           |
| Intuitive interface for a beginner                                                  | +          | +                               | -     | -           | -           |
| Technical support in Russia                                                                 | +          | +                               | +     | -           | +           |
| Large model libraries                                                                   | +          | +                               | -     | +           | -           |
| Thin shells                                                                            | +          | +                               | +     | +           | +           |
| Functions of the group «B₃»                                                           |             |                                |       |             |             |
| Preloading                                                                             | +          | +                               | +     | +           | +           |
4. Conclusion
Next, we will conduct a comparative analysis of the effectiveness of CAE complexes to solve the problem of analyzing the stress state of an offshore stationary platform. As a result, we obtain the following efficiency factors (see table 4).

Table 4. Comparative analysis of the effectiveness of CAE complexes for solving the problem of analysis of the stress state of a marine stationary platform.

| Functional capabilities | SCAD Office | Dassault Systemes Solid Works | Ansys | Sofistik AG | Lira | Abaqus |
|-------------------------|-------------|-------------------------------|------|-------------|-----|-------|
| Fatigue/Durability Calculation | - | + | + | + | + | + |
| Weld analysis (seam, spot welding) | - | + | + | - | - | - |
| Thermomechanical fatigue | - | + | + | - | - | + |
| Vibration resistance | - | + | + | - | - | - |
| Diffraction and radiation | - | - | + (with AQWA module) | - | - | - |
| Calculations in the frequency and time domain | - | - | + (with AQWA module) | - | - | - |
| Mooring, articulation, cables | - | - | AQWA module) | - | - | - |
| Transfer of loads to strength calculations | - | - | + (with AQWA module) | - | - | - |
| Calculation of safety factors | + | + | + | + | + | + |

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Table 4. Comparative analysis of the effectiveness of CAE complexes for solving the problem of analysis of the stress state of a marine stationary platform.

| Functional Points | SCAD Office | Dassault Systemes Solid Works | Ansys | Sofistik AG | Lira | Abaqus |
|-------------------|-------------|-------------------------------|------|-------------|-----|-------|
| Price for 1 version rub. * | 100 000 | 1 289 000 | 3 567 200 | 538 000 | 525 000 | 710 000 |

| Functional capabilities | SCAD Office | Dassault Systemes Solid Works | Ansys | Sofistik AG | Lira | Abaqus |
|-------------------------|-------------|-------------------------------|------|-------------|-----|-------|
| Fatigue/Durability Calculation | - | + | + | + | + | + |
| Weld analysis (seam, spot welding) | - | + | + | - | - | - |
| Thermomechanical fatigue | - | + | + | - | - | + |
| Vibration resistance | - | + | + | - | - | - |
| Diffraction and radiation | - | - | + (with AQWA module) | - | - | - |
| Calculations in the frequency and time domain | - | - | + (with AQWA module) | - | - | - |
| Mooring, articulation, cables | - | - | AQWA module) | - | - | - |
| Transfer of loads to strength calculations | - | - | + (with AQWA module) | - | - | - |
| Calculation of safety factors | + | + | + | + | + | + |
Ratio coefficient
(Point/price)  0.72*10^{-3}  0.07*10^{-3}  0.03*10^{-3}  0.13*10^{-3}  0.13*10^{-3}  0.*10^{-3}

* – prices are approximate, based on open data on the cost of PC from the manufacturer or official distributors

Thus, as a result of the study, it was found that the SCAD software package has the greatest efficiency for solving the stress state assessment problem from the “functionality-cost” ratio. This result was obtained primarily due to the lowest price and sufficient functionality for the problem considered in the article. It should also be noted the high accuracy of the calculations of other CAE software systems considered in this article, which, with more functionality, have a higher price.

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