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IMPROVING THE METHOD OF SEALING THREADED CASING JOINTS BY USING ANAEROBIC SEALANTS

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УДОСКОНАЛЕННЯ МЕТОДУ ГЕРМЕТИЗАЦІЇ РІЗЬБОВИХ З'ЄДНАНЬ ОБСАДНИХ ТРУБ ІЗ ВИКОРИСТАННЯМ АНАЕРОБНОГО ГЕРМЕТИКА

Purpose. The purpose of this study is to improve the sealing method of threaded casing joints by applying anaerobic sealants and to evaluate their effectiveness under the operating conditions of oil and gas wells using numerical simulation and comparative analysis.

Methods. The study was based on a comprehensive literature review, comparative analysis of modern sealing materials, and numerical simulation of a threaded casing joint using ANSYS Mechanical. The stress–strain behaviour of the joint was investigated under an axial load of 250 kN and an internal pressure of 10 MPa, taking into account the mechanical properties of both the anaerobic sealant and the casing steel.

Findings. The results demonstrate that the application of an anaerobic sealant ensures reliable sealing of the threaded joint under operational loading conditions. The maximum equivalent stress reached 210.11 MPa, which is below the yield strength of the casing steel, while the maximum total deformation did not exceed 0.0706 mm, confirming the structural integrity and elastic behaviour of the connection.

Originality. A numerical assessment of the effect of a polymerized anaerobic sealant layer on the stress-strain state of a casing threaded connection was performed. In the model, the sealant was represented as a deformable intermediate layer interacting with the mating thread surfaces. Three calculation cases were compared: without sealant and with sealant having Young's moduli of $3 \cdot 10^6$ and $5 \cdot 10^6$ Pa and Poisson's ratios of 0.40 and 0.45, respectively. A relationship was established between the mechanical properties of the sealant and the stress-strain state of the connection. The maximum equivalent stress was 210.11 MPa, while the total deformation was 0.0706 mm. Local stresses in the sealant may exceed its tensile strength of 25-30 MPa and adhesive strength of up to 20 MPa, indicating the possibility of local damage to the sealant layer.

Practical implementation. The approach can be applied in oil and gas well construction, repair, and operation to improve casing joint sealing, reduce leakage and integrity risks, lower maintenance costs, and extend casing life under high-pressure and aggressive conditions.

Keywords: *casing string, threaded joint, anaerobic sealant, sealing performance, finite element analysis, ANSYS Mechanical.*

Introduction. The reliability and safe operation of oil and gas wells largely depend on the integrity of casing strings and, in particular, on the tightness of their threaded connections. Loss of tightness may lead to complications during well construction and operation, additional repair works, increased downtime, and significant economic losses [1–3]. Therefore, improving the reliability of threaded casing joints remains an important engineering task in modern well construction.

The quality of casing pipes, their mechanical properties, testing procedures, and operating requirements are regulated by international and national standards. In particular, API Specification 5CT establishes requirements for casing and tubing used in oil and gas wells [4], while relevant Ukrainian regulatory documents define requirements for the operation of casing strings [5]. However, compliance with these requirements alone does not completely eliminate the possibility of leakage in threaded joints, especially under the combined action of axial loads, internal pressure, temperature changes, and aggressive wellbore environments.

Various sealing materials and thread compounds are used to improve the tightness of casing connections. Their effectiveness depends on the thread geometry, mechanical loading, pressure, temperature, and the properties of the sealing material [6–8]. Conventional sealing compounds can provide the required sealing performance only within certain operating limits, which creates the need to investigate alternative sealing methods. In this context, anaerobic sealants are of particular interest because, after polymerization in the confined space between metallic surfaces, they can form a continuous sealing layer in the threaded connection. Therefore, it is important to evaluate not only their sealing potential but also their influence on the stress–strain state of threaded casing joints under operational loading.

Ensuring the tightness of threaded casing joints is an important condition for the reliable and safe operation of oil and gas wells. The sealing performance of such connections depends on the geometry of the thread, the quality of manufacturing and assembly, the applied tightening torque, the mechanical loading conditions, and the properties of the sealing material used [9–12].

Conventional sealing materials and thread compounds are widely used to reduce leakage through the gaps between mating thread surfaces. However, their effectiveness may decrease under elevated pressure, temperature variations, cyclic loading, and exposure to aggressive wellbore fluids. Therefore, modern studies are focused on improving both the design of threaded connections and the properties of sealing materials used in the contact zone [26, 28, 29].

The sealing performance of threaded casing joints depends on the accuracy of thread manufacturing, the quality of assembly, the applied make-up torque, and the properties of the sealing material. Various technological and design approaches have been proposed to improve the tightness of casing connections [13, 30]. These include filling the cavities of the final turns of the internal thread with a compliant sealing material [14], modifying the relationship between the pitch of the external and internal threads [15], and using casing pipes with increased wall thickness and improved threaded connection designs [16].

Although these approaches can improve the sealing performance of threaded joints, their effectiveness depends on the operating conditions and the mechanical behaviour of the connection. Therefore, the use of additional sealing materials capable of

interacting with the threaded surfaces and maintaining their properties under combined mechanical and pressure loading remains of practical interest.

Along with the classic thread profiles used in domestic practice, premium connection systems are becoming increasingly common [17]. In particular, VAM ® connections [18] are characterized by multi-circuit sealing according to the "metal-metal" principle, high resistance to bending loads, and proven reliability during long-term operation. Another modern development is the VAGT ® system [19], which combines an improved buttress profile of threads and a metal-metal seal, which ensures tightness even in environments with a high content of hydrogen sulfide and during offshore drilling.

Analysis of industrial material and literature sources on the issue of leakage of threaded joints of casing pipes made it possible to develop a classification of the causes [19] of these violations (Table 1) and a description of the leakage of casing columns in the fields of Shebelynka DD (Table 2).

Table 1

Classification of causes of leakage of threaded joints

Causes of leakage of threaded joints		
Incorrect strength calculation of the column	Violation of technology	Casing deterioration
1. Lack of maximum internal pressure when carrying out various works in the column.	1. Pipe runs with defects in threaded joints.	1 Deterioration of drill pipes and locks.
2. Failure to take into account the increase in axial loads when changing the temperature regime, abnormal external and internal pressures.	2. Mismatch of thread type and lubricant to well conditions.	2. Deterioration of bits and fishing tools.
3. Lack of simultaneous action of internal pressure and tensile load.	3. Creating internal pressure.	3. Corrosion.
	4. Poor connection of column sections.	4. Hydroabrasive deterioration.
	5. Lack of control over the torque values when screwing threaded joints.	
	6. Incorrect fitting of the pipe into the coupling when they are screwed.	
	7. Uncontrolled twisting speed.	
	8. Non-compliance with the temperature regime.	
	9. Thread damage.	
	10. Incorrect scheme of application of forces to the pipe.	
	11. No use of anaerobic sealants in threaded joints, including premium ones such as VAM®, VAGT®. As a result, the risk of tightness loss under cyclic loads and exposure to an aggressive environment increases.	

Table 2

Violation of the tightness of casing columns in the fields of Shebelynka DD

Area Field,	Well No.	Diameter Operating column, m	Purpose of the well	Causes of leakage violations
Yulivske	25	0.146	Exploration	Twisting of threaded joints with underestimated torque values
Muratovske	51	0.146 0.168	Development	Use of low-performance lubricants. Twisting of threaded joints with underestimated torque values
West Shebelynske	7	0.140 0.168	Development	Use of low-impact lubricants.
Lychkivske	52	0.140 0.168	Development	Twisting of threaded joints with underestimated torque values Use of low-impact lubricants.
Modern premium connections (VAM®, VAGT®)	-	0.140– 0.168	Development / offshore	The tightness is ensured by a metal-metal seal; however, the use of anaerobic sealants minimizes the risk of tightness losses under cyclic loads and aggressive environments

The following requirements apply to lubricants used in twisting threaded joints:

1. Good lubricating properties

2. The stability of the properties of the lubricant at intervals and when the temperature changes in a certain range.

3. The required consistency is sufficient to prevent the liquid or gas pressure from removing the grease from the thread gaps.

4. Prevention of seizures when screwing threaded joints.

The quality of the lubricant is assessed by the following indicators: friction coefficient, adhesion force, and tightness of the threaded joints [21]. For comparison of indicators, the research of USsA and R-2MVP lubricants can be provided as well.

The adhesion force was measured by a method, the essence of which was to determine the peeling forces of a metal disc that interacts with a metal plate through the lubricant, after contact for one minute. The change in the adhesive properties of lubricants over time was also measured.

To assess the quality of the lubricant, the shear resistance of the lubricant was determined.

To do this, the simplest method was used to move the lubricant through the hole in the container using C-2.

The device for determining the shear resistance of lubricants C-2 consists of a housing-1, matrix-2, punch-3, container-4, and time-a display matrix d. The thickness of the matrix 2 is selected based on the volume of lubricant in the container 4.

The values of the efficiency coefficients for various lubricants obtained experimentally are given in Table 3

Table 3

Results of lubricants research

Name of the lubricant	Adhesion of the lubricant kN/m^2	Oil resistance for shear, MPa	Friction coefficient	Coefficient of the lubricant efficiency
USsA	4.65	0.122	0,058	0.38
R-2 MVP	2.40	0.133	0.09	0.68
US-OT	6.9	0.146	0.08	1.57

The data presented in Table 3 demonstrate noticeable differences in the performance characteristics of the investigated thread lubricants. Among the considered materials, US-OT shows the highest adhesion value of 6.9 kN/m² and the highest efficiency coefficient of 1.57, whereas R-2MVP is characterized by a higher friction coefficient compared with USsA. These differences confirm that the choice of sealing material can significantly influence the mechanical and sealing behaviour of threaded casing joints. Table 4 provides recommendations for the use of sealing lubricants for various types of threaded joints.

Table 4

Types of lubricants to ensure the tightness of threaded joints of casing pipes

Well	Temperature, ^{0}C	Pressure, MPa	Thread	Lubricant
Petroleum	100	12.7	Triangular	R-2 MVP
	120	12.7	-II-	US-1
	200	12.7	-II-	R-402
	200	12.7	-II-	FUM tape
Gas, condensate	100	12.7	OTTG, TBO	R-2 MVP
	120	12.7	Any	US-1
	200	12.7	OTTG, TBO	R-402
	200	19.6	Any	FUM tape
Gas, Condensate, offshore	200	70-80	Premium (VAM®, VAGT®)	Special thread compounds (NOV, Schlumberger)

The data presented in Table 4 show that the selection of sealing material depends strongly on the operating conditions of the well, particularly temperature, pressure, and the type of threaded connection. Conventional thread compounds and PTFE-based

sealing materials are mainly used for standard threaded joints, whereas premium connections such as VAM® and VAGT® require specialized thread compounds under high-pressure operating conditions. This confirms that no single conventional sealing material is universally applicable over the entire range of casing operating conditions and supports the need to investigate alternative sealing technologies.

E-2075 lubricants are known as foreign polymer-based sealing lubricants [22]. E-2075 is an epoxy resin with an inorganic thickener. This lubricant is resistant to long-term operation at temperatures up to 2000°C. SHELL silicone threaded lubricants are used to seal threaded joints [23]. These lubricants are a mixture of metal and graphite powders, evenly distributed in a silicone base, the mass fraction of which is 36%. Solid components of the lubricant, the mass fraction of which is 25%

Current research on sealing materials for threaded connections is focused on improving their mechanical stability, adhesion to metallic surfaces, resistance to aggressive environments, and ability to maintain sealing performance under elevated pressure and temperature. Particular attention is given to polymer-based materials, including anaerobic sealants, which can form a solid sealing layer directly within the threaded interface. Such materials are promising for casing applications because their properties may influence not only the sealing performance but also the stress–strain state of the threaded connection [20, 31].

Identification of previously unresolved aspects of the general problem. Despite the considerable number of studies devoted to improving the sealing performance of threaded casing joints [32], most existing approaches are based on conventional thread compounds, premium threaded connections, or improvements in thread geometry. However, the influence of anaerobic sealants on the stress–strain state of threaded casing joints and their ability to improve sealing reliability under high-pressure operating conditions have not been sufficiently investigated. Comprehensive numerical studies of anaerobic sealants in threaded casing joints under combined mechanical loading remain limited.

Presentation of the main research material. The implementation of this research involves the development of its program [21], which includes four consecutive stages. The first stage involved the study of information on the principle of anaerobic sealant operation. At the second stage, a concept of a stand was developed to check the properties of anaerobic sealant and the physical justification of its work. At the third stage, in accordance with the data obtained and the proposed design, a model of the device was manufactured. The fourth stage involved conducting experiments and analyzing data.

We hypothesized that contact with the metal promotes the formation of active radicals responsible for oxygen depletion and polymerization of the anaerobic composition, transforming it from a stable liquid into a solid polymer [22].

Since metals differ from each other in electronic structure, they also have different abilities to interact with the components of the initiating system. According to this property, they can be divided into "active" – copper, iron, cobalt, copper alloys (brass, bronze), iron alloys (cast iron, steel), and "passive" – zinc, aluminum, cadmium, silver, chromium, alloy steel. Active surfaces accelerate polymerization due to the presence of metal ions involved in redox processes. On active surfaces, hardening at room

temperature with a set of 50–70% of maximum strength occurs in 1–3 hours. On a passive surface, it takes 5–7 hours to harden. Full strength is achieved within 5–24 hours. Inhibitory surfaces include surfaces of porous materials containing oxygen. Passivation of the metal surface also gives the surface an inactive character. At elevated temperatures of 60–120°C, as well as when treating the surface with an activator, the curing time is sharply reduced.

Let's make a comparative description of the currently existing sealants that are actively used in the construction of wells and anaerobic mixture:

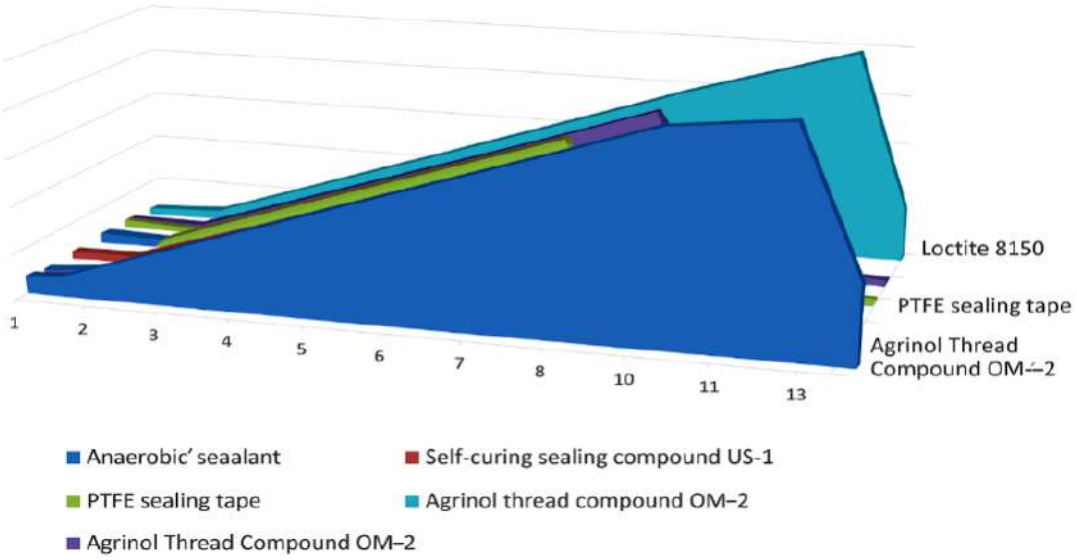


Fig. 1. Dependence of modern sealants on temperature

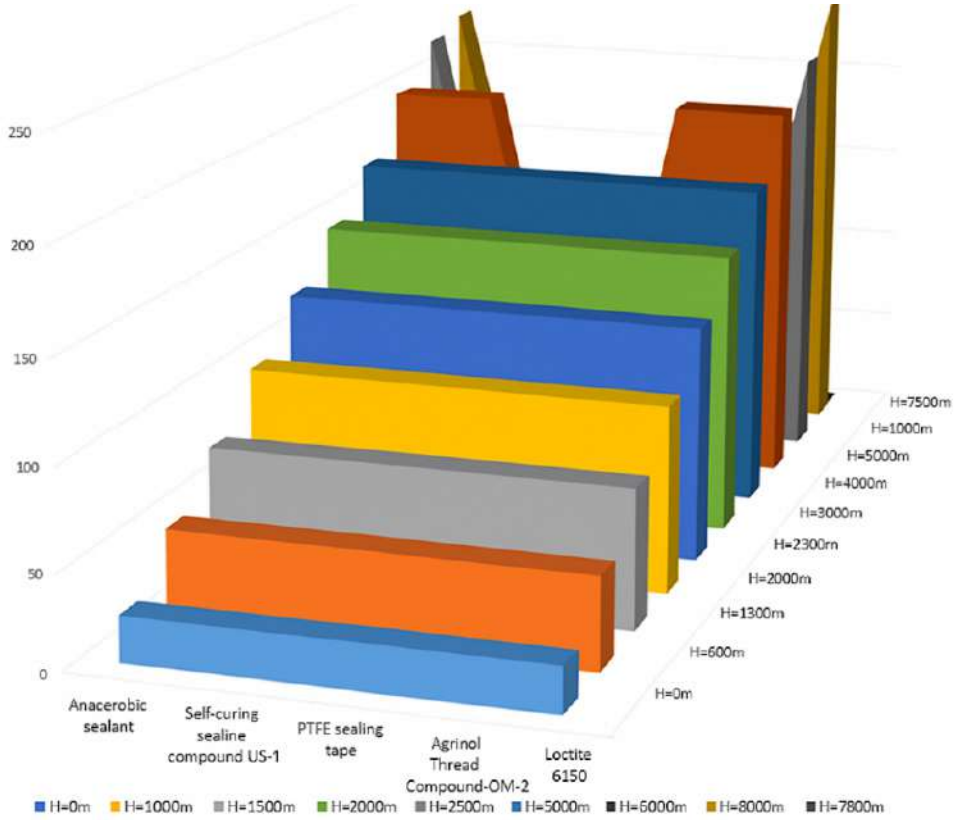


Fig. 2. Dependence of temperature on depth

The above graphs show the effectiveness of the use of anaerobic sealant even in the operation of ultra-deep wells with a depth of more than 7000 m, which is a significant advantage of their use in contrast to other proposed analogues. If we consider the graph of dependence (P_{add}) from (H), it will look as follows:

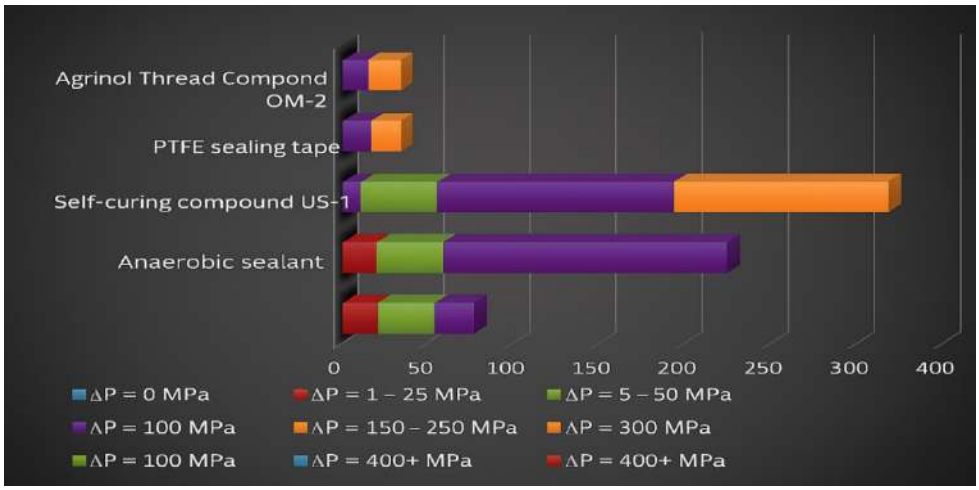


Fig. 3. Dependence Padd on H

The comparative data presented in Figures 1–3 demonstrate that the considered sealing materials differ substantially in their operating ranges and functional characteristics. PTFE sealing tape and conventional thread compounds are applicable within certain pressure and temperature limitations, whereas anaerobic sealants retain their sealing capability over a wider range of operating conditions. At the same time, the comparison does not indicate the absolute superiority of one material under all conditions; for example, some self-curing compounds may withstand higher pressure ranges under specific operating conditions.

The principal advantage of anaerobic sealants considered in this study is associated with their ability to polymerize within the confined space between metallic threaded surfaces and form a continuous sealing layer. Therefore, unlike conventional compounds that primarily provide lubrication and filling of thread clearances, the polymerized anaerobic layer can also participate in the mechanical interaction between the mating surfaces. This feature provides the basis for the subsequent numerical analysis of its influence on the stress–strain state of the threaded casing joint.

Thus, the comparison with conventional sealing materials presented in Figures 1–3 should be regarded as a comparative assessment of their operating characteristics, while the quantitative evaluation of the mechanical effect of the anaerobic sealant is performed below using finite-element modelling.

To assess the effectiveness of sealing a threaded casing joint using an anaerobic sealant, numerical modelling was carried out in ANSYS Mechanical [22]. All numerical results presented in this section were obtained using ANSYS Mechanical. The purpose of the calculation was to determine the stress–strain state of the connection under loads corresponding to typical operating conditions of gas wells at depths of more than 2000–3000 m.

The model takes into account the real geometry of the threaded connection of the casing pipe with a standard profile. As an object of modeling, pipes of standard size 7" (177.8 mm outer diameter, 164.0 mm inner diameter), with a wall thickness of 6.5 mm, were used. The material of the pipe is steel 20 or a similar alloy with a yield strength of about 245–250 MPa.

Anaerobic sealant was accounted for as a thin layer in the contact area between thread turns. It had the following characteristics: modulus of elasticity up to 1 GPa, Poisson's ratio 0.3, resistance to the action of the medium (oil, gas, mineralized water), and temperatures up to 150 °C. The sealant is modeled using nonlinear contact mechanics, taking into account adhesion.

Limit conditions and loads

The following loads are applied to the connection:

- An axial load of 250,000 N (250 kN) simulating mechanical pressure on a column in a deep well.
- The internal pressure is 10 MPa, which corresponds to the operating conditions in a gas or condensate well.
- Fixed Support on the other side of the connection.

Such loads correspond to the conditions of work in an environment with increased mining and geological risks.

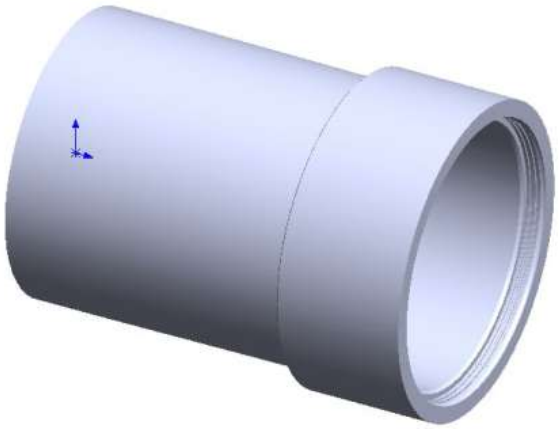


Fig. 4. Distribution of stresses in the threaded joint of the casing pipe under the action of axial load and internal pressure

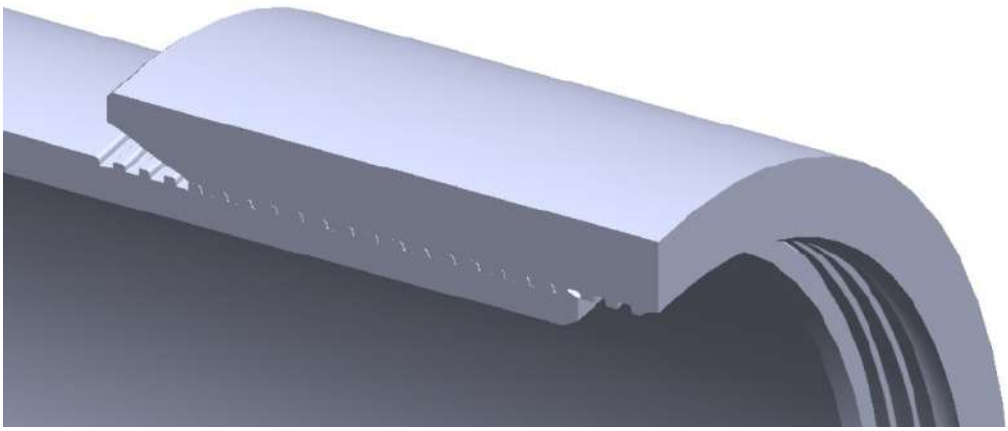


Fig. 5. Deformations in the area of the threaded joint according to the simulation results

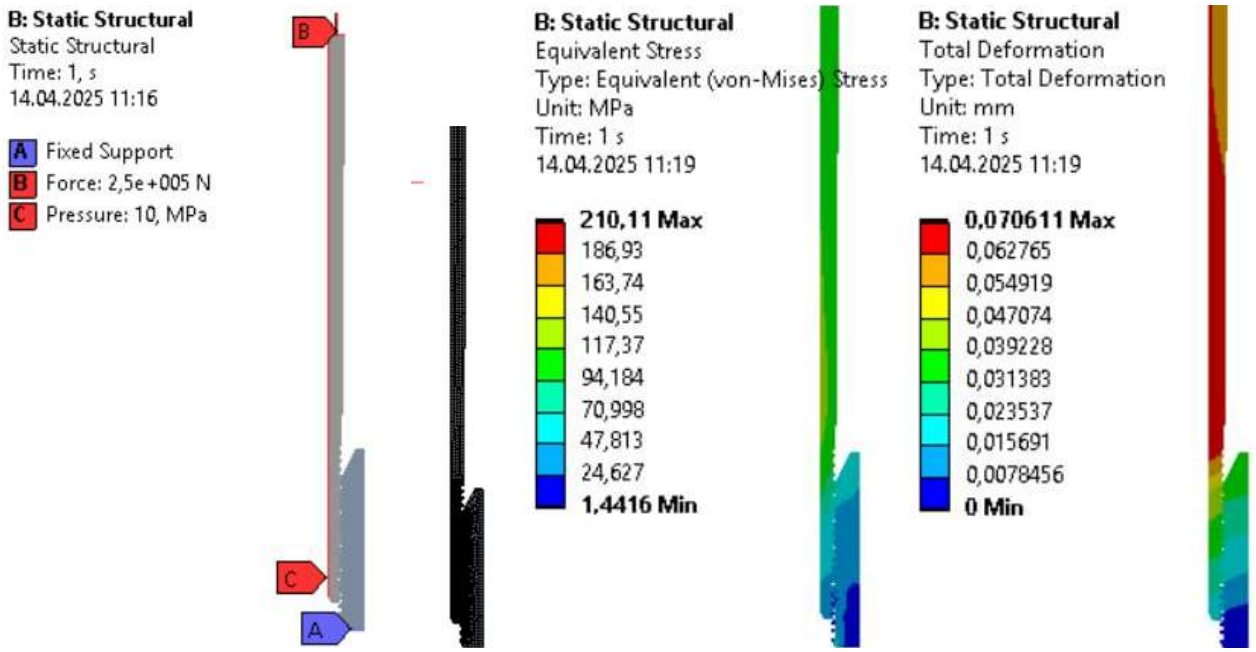


Fig. 6. Effect of anaerobic sealant on stress distribution in a threaded joint

Based on the calculation of stresses according to the von Mises stress criterion, it was found that the maximum stresses in the thread area reach 210.11 MPa (see Fig. 6). The highest values are focused on the first turns of the threaded joints, which is expected, given the concentration of forces at the local contact points.

This value is lower than the yield strength of the steel pipe; therefore, plastic deformations do not occur in the metal body, which confirms the operability of the structure in the elastic mode.

The maximum total movement in the joint area is 0.0706 mm (see Fig. 6), which indicates the rigidity of the assembly and its resistance to loss of tightness under mechanical stress. The largest movements are recorded in the coupling area, but they do not exceed the permissible values for pressure retention.

Anaerobic sealant, modeled as a contact intermediate layer, has demonstrated stability of shape and properties when interacting with metal, even at high pressure. Due to the adhesive interaction with the steel surface and high resistance to temperature and aggressive environments, it ensured the preservation of tightness under loads up to 10 MPa. The presence of a sealant also reduces local stress peaks in the thread area, working as a damper.

Numerical simulations confirmed that the threaded connection of the casing pipe with the applied anaerobic sealant successfully withstands an axial load of 250 kN and an internal pressure of 10 MPa without losing its tightness. The results obtained indicate:

- High reliability of connection with sealant;
- Absence of hazardous deformations under operational loads;
- The feasibility of using anaerobic sealants as an alternative to traditional sealing lubricants.

To study the stress-strain state of a threaded joint using an anaerobic sealant for its sealing, a three-dimensional model of this connection was built according to API Specification 5CT (Figure 7).

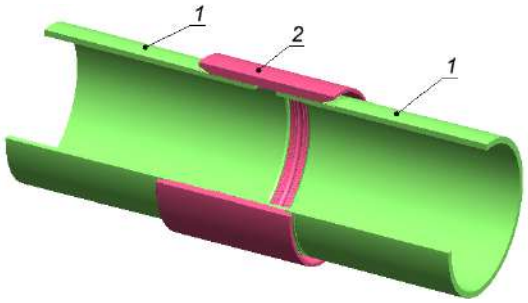


Fig. 7. Threaded casing joint: 1– nipple; 2 – coupling

The obtained simulation results were compared [24] with the requirements of international standards, in particular API Spec 5CT [25] and ISO/TS 14998, which determine the methods of testing the tightness of threaded joints. The analysis confirmed that the approaches that were used correlate with the practices of leading pipe manufacturers such as Tenaris, NOV, as well as developers of premium VAM ® and VAGT® systems. This allows us to assert that the model reflects the actual operating conditions of the casing strings.

Due to the fact that the research of this compound will be carried out only under the action of loads acting in the axial and radial directions, its model has been simplified in order to speed up the process of simulation modeling. In this case, the axisymmetric model is applied, which is shown in Figure 8.

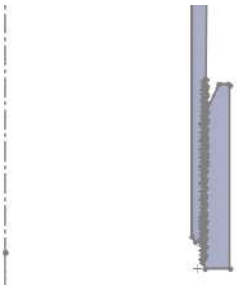


Fig. 8. Axisymmetric model of threaded joint of casing pipes

The properties of the materials used for the elements of the threaded joint of the casing pipes are given in Table 5

Table 5

Properties of materials

No.	Material	Young's modulus, 10^6 Pa	Poisson's ratio
1	Steel	200000	0.26
2	Anaerobic sealant (option 1)	3	0.4
3	Anaerobic sealant (option 2)	5	0.45

The threaded connection was modelled as an axisymmetric contact problem because the investigated loading was applied predominantly in the axial and radial

directions. The interaction between the nipple and coupling thread surfaces was represented using nonlinear contact mechanics. The anaerobic sealant was introduced into the model as a deformable intermediate layer located between the mating threaded surfaces, with its mechanical properties specified according to the considered calculation case.

The finite-element mesh was refined locally in the thread engagement zone, where the highest stress gradients and contact pressure variations were expected. A coarser mesh was used in regions located farther from the threaded contact zone in order to reduce the computational cost while preserving sufficient resolution in the critical areas of the model. The resulting finite-element discretization is shown in Figure 10.

The numerical model was validated by comparing its geometry, loading conditions, and evaluation criteria with relevant standards [7, 15, 31, 32]. The highest equivalent stresses were concentrated in the first engaged thread turns, where axial load transfer between the nipple and coupling is greatest, confirming the expected mechanical behaviour of the connection.

A separate mesh-independence study was not performed; therefore, the finite-element mesh was locally refined in the threaded engagement zone, where the highest stress gradients were expected, and this limitation was taken into account when interpreting the numerical results.

To evaluate the work of anaerobic sealant, the following characteristics are required: compressive strength - up to 100 MPa; tensile strength – up to 25–30 MPa; adhesive strength – up to 20 MPa; temperature range – from -55°C to +200°C.

Figure 9 shows the computational scheme used for simulation. According to this scheme, a tensile load (A) is applied to the end of the pipe, and the end of the coupling half is secured (B). It should be noted that the movement of the coupling end is prohibited in the axial direction (Y) and allowed in the radial direction (X) (according to the coordinate system, Fig. 9). The model of the threaded joint is divided into a grid of finite elements (Fig. 10).

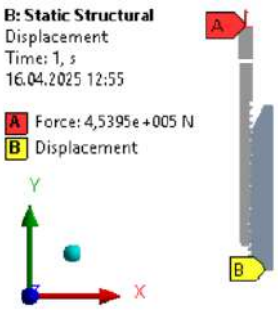


Fig. 9. Design model



Fig. 10. Finite element grid

In order to improve the accuracy of the simulation results, the finite element grid is made denser in the area of thread turns.

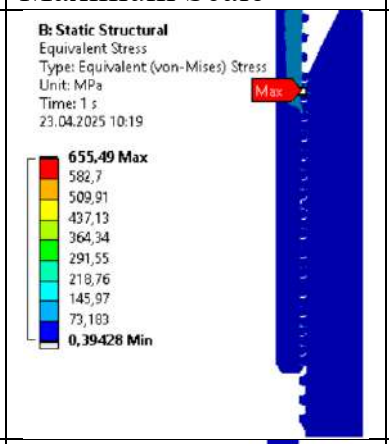
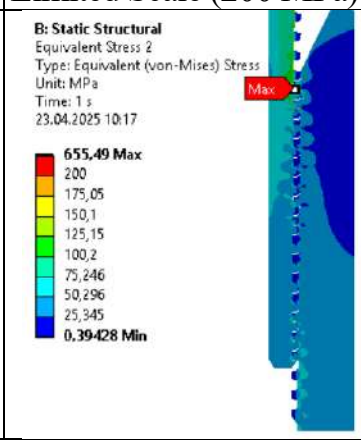
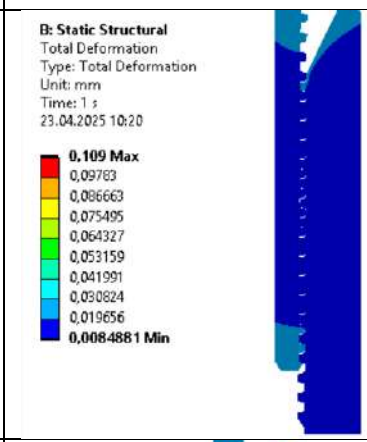
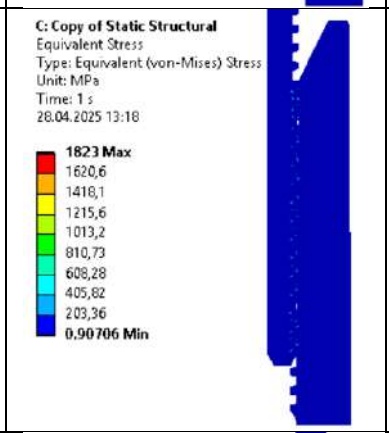
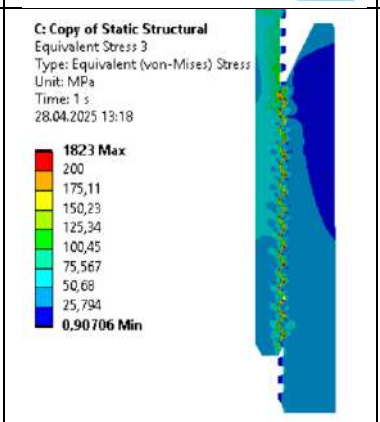
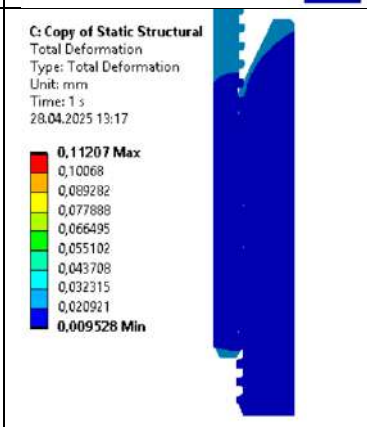
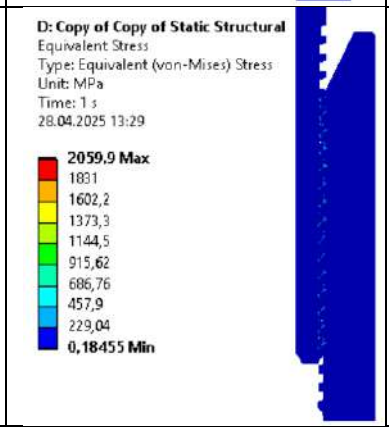
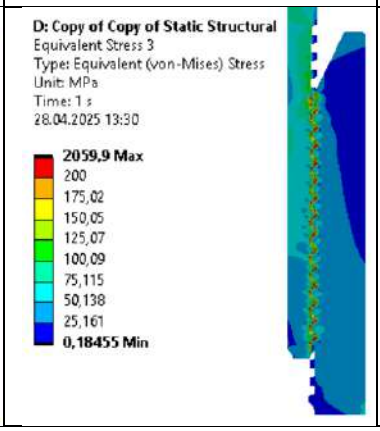
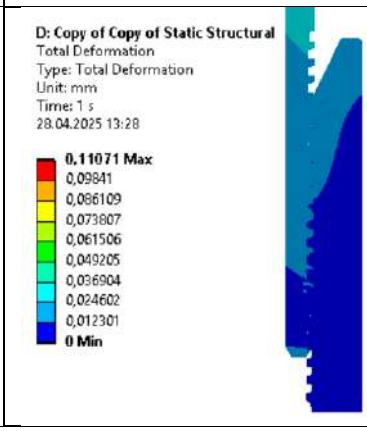
The stress–strain state of the threaded casing joint was investigated using three numerical calculation cases in ANSYS Mechanical. In Case 1, the threaded joint was analysed without anaerobic sealant under the action of axial load and make-up torque. In Case 2, an anaerobic sealant layer was introduced into the contact zone between the nipple and coupling threads; the sealant was characterized by Young's modulus of

$3x10^6$ Pa and Poisson's ratio of 0.40. In Case 3, the same threaded connection and loading conditions were considered, while the mechanical properties of the anaerobic sealant were changed to Young's modulus of 5×10^6 Pa and Poisson's ratio of 0.45.

So, after the calculation, the following results were obtained: equivalent stresses, displacements (Table 6). For the convenience of the analysis of the obtained results, graphical dependencies of the change in the value of equivalent stresses on the threaded joints' turns have been constructed.

Table 6

Simulation results

Research	Equivalent stresses, MPa		Displacement, mm
	Maximum Scale	Limited Scale (200 MPa)	
1 without anaerobic sealant			
2 with anaerobic sealant (option 1)			
3 with anaerobic sealant (option 2)			

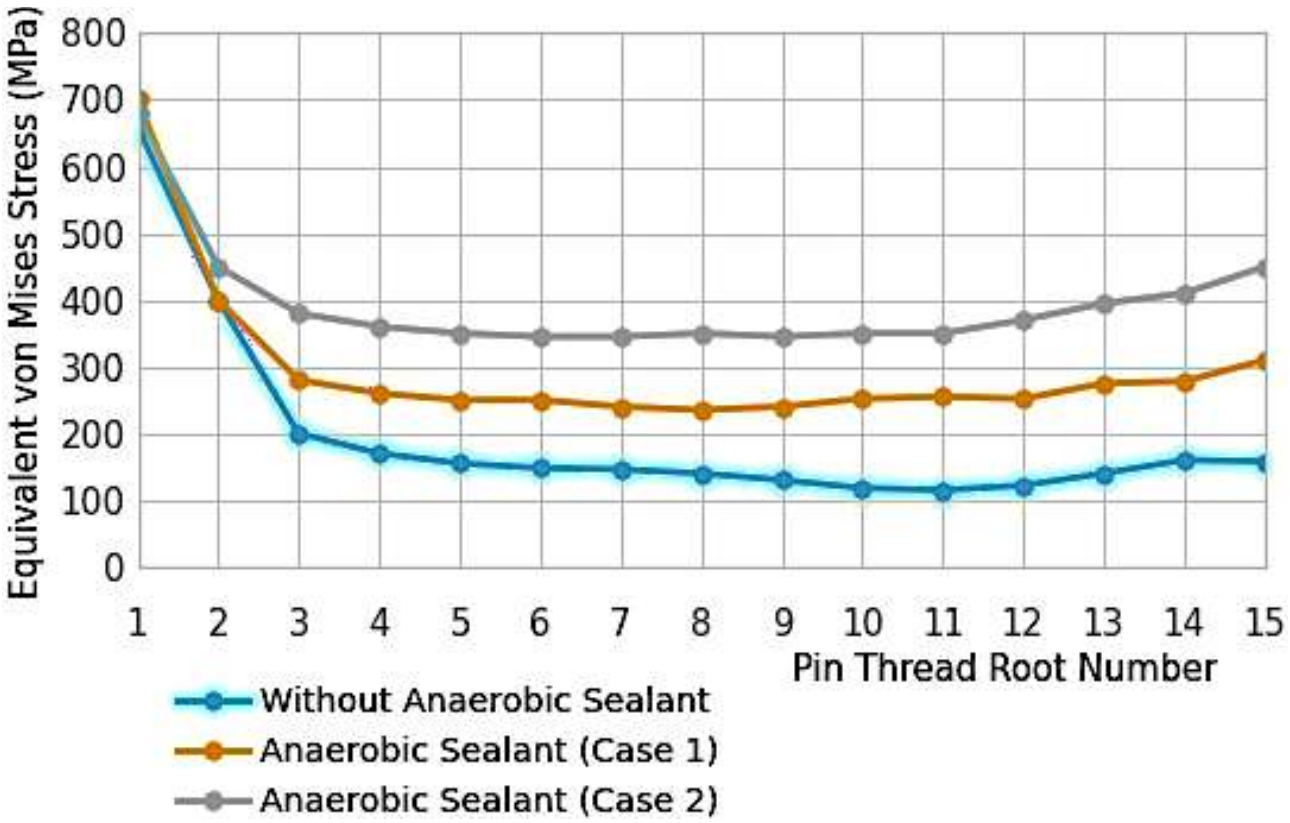


Fig. 11. Distribution of equivalent stresses in the nipple thread cavities

Thus, according to the results obtained, which are shown in Figure 11, the use of anaerobic sealant increases the magnitude of stresses in the cavities of the nipple thread turns . It should be noted that there is no significant increase in stress in the first nipple thread cavity. The increase in stresses to such values will not reduce the strength of the threaded joint.

As for the stress distribution in the anaerobic sealant, Figure 12 shows for option 1, and Figure 13 shows for option 2.

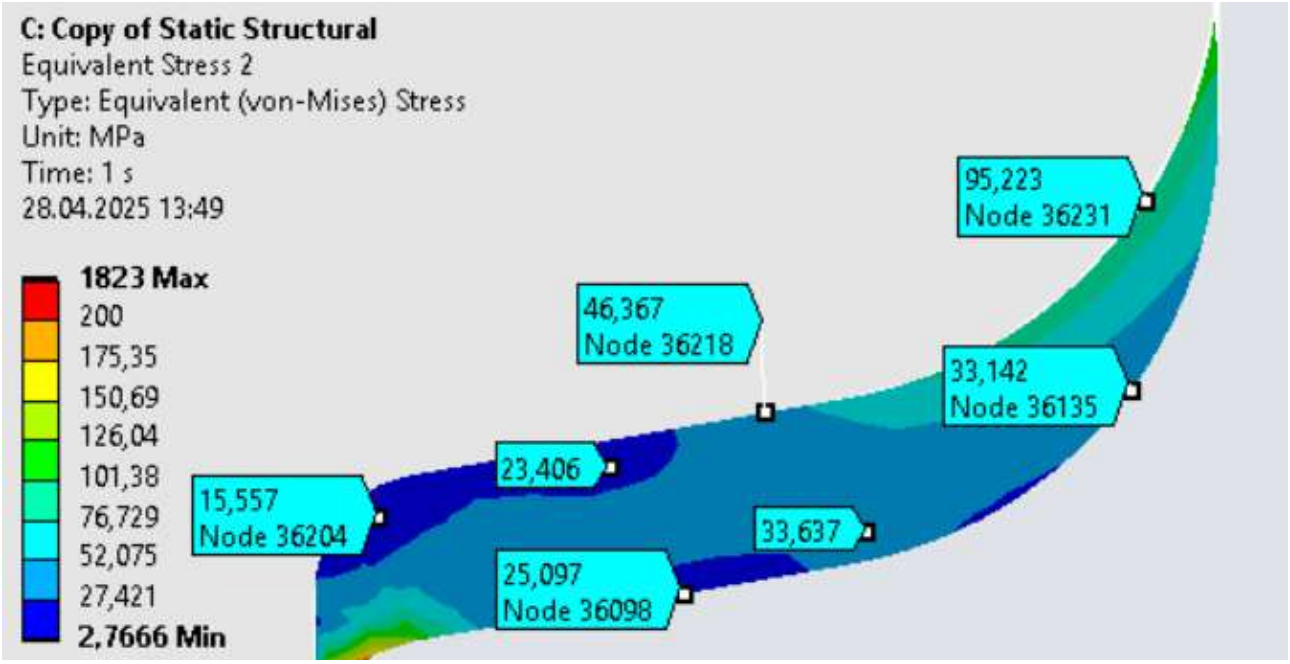


Fig. 12. Stress distribution in anaerobic sealant (option 1)

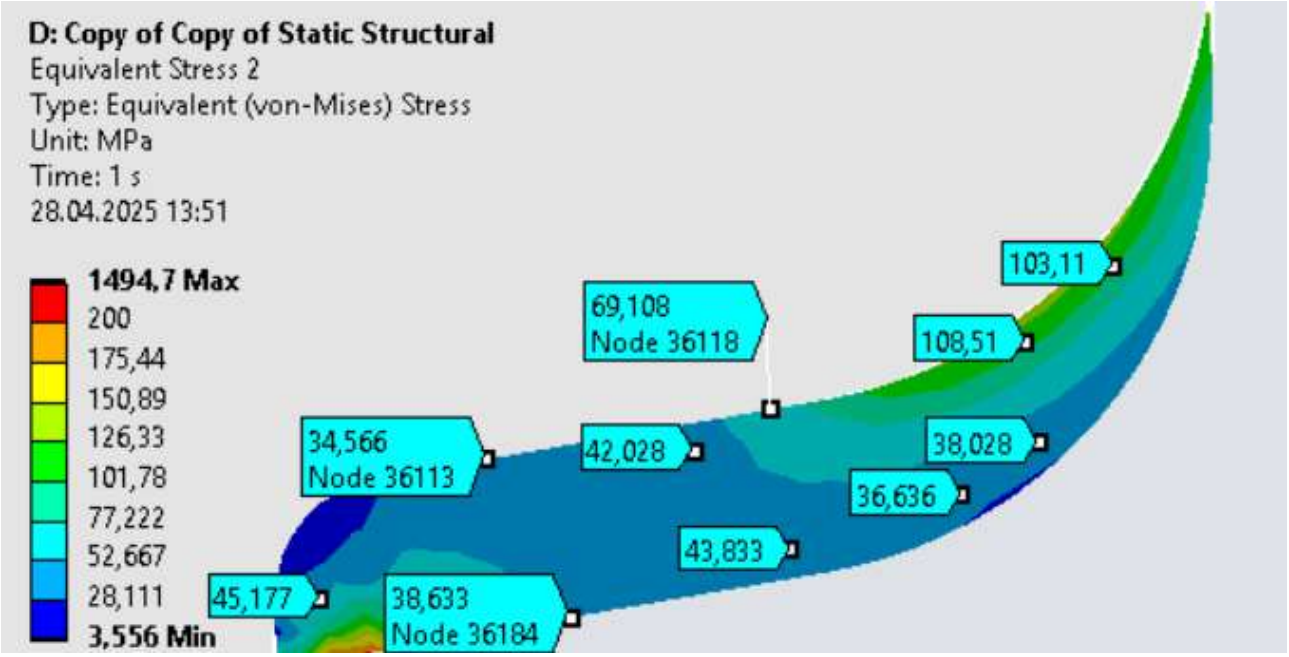


Fig. 13. Stress distribution in anaerobic sealant (option 2)

According to Figures 12 and 13, stresses in some areas of the anaerobic sealant exceed its tensile strength (25–30 MPa) and adhesion strength (up to 20 MPa).

Conclusions. Therefore, it should be noted that it is advisable to apply anaerobic sealant to threaded joints immediately before screwing them and lowering the column into the well. This can be explained by the fact that before solidification of the sealant, a deformation of the threaded joint will occur, which, in the future, during its solidification, will reduce the deformation and, as a result, prevent the occurrence of significant equivalent stresses in it. This will also prevent the sealant from peeling off the thread.

The research demonstrates the significant advantages of using anaerobic sealant for threaded joints in casing strings. In particular, it was established:

1. The use of this sealant increases the reliability and durability of the joints, which directly affects the performance of the casing. This, in turn, contributes to a reduction in costs and time required for maintenance and repair, due to a longer service life of joints and a decrease in the frequency of maintenance.

2. In addition, the use of anaerobic sealant significantly increases the safety of casing operation. By preventing leaks, the risk of accidents is reduced, and environmental protection is improved. This is important to ensure the safe and environmentally responsible operation of the enterprise.

3. Also, improving the efficiency and reliability of joints has a positive effect on the productivity of work at the facility, as the time spent on repairs and maintenance is reduced. As a result, the overall productivity and efficiency of workflows increase.

4. The introduction of research results into production processes allows the company to significantly increase its competitiveness in the market. The use of new technologies and methods that improve the quality, efficiency, and reliability of products and services strengthens the company's position and opens up new opportunities for development.

The results confirm that anaerobic sealants can improve the sealing performance and operational reliability of threaded casing joints. Numerical analysis showed a maximum equivalent stress of 210.11 MPa and a maximum total displacement of 0.0706 mm. Comparison of three calculation cases demonstrated that the anaerobic sealing layer and its mechanical properties affect stress distribution in the thread engagement zone. Local stresses in some sealant regions exceeded its tensile strength of 25–30 MPa and adhesive strength of up to 20 MPa, highlighting the importance of appropriate material properties and application conditions. The proposed solutions [27] can be applied in accordance with API Spec 5CT and SOU 09.1-30019775-258:2018 and used with premium threaded joints such as VAM®, VAGT®, and Schlumberger developments to improve casing reliability under high pressure, aggressive environments, and complex well profiles.

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АНОТАЦІЯ

Мета. Метою роботи є вдосконалення способу герметизації різьбових з'єднань обсадних колон шляхом застосування анаеробних герметиків та оцінка їх ефективності в умовах експлуатації нафтових і газових свердловин із використанням чисельного моделювання та порівняльного аналізу.

Методика. Дослідження виконано із застосуванням аналітичного огляду, порівняльного аналізу сучасних герметизувальних матеріалів та чисельного моделювання різьбового з'єднання обсадної колони у програмному комплексі ANSYS Mechanical.

Результати. Встановлено, що застосування анаеробного герметика забезпечує стабільну герметичність різьбового з'єднання за осьового навантаження 250 кН та внутрішнього тиску 10 МПа. Максимальні еквівалентні напруження становили 210,11 МПа, а максимальна сумарна деформація – 0,0706 мм, що підтверджує працездатність конструкції в межах пружної деформації.

Наукова новизна. Проведено чисельну оцінку впливу полімеризованого шару анаеробного герметика на напружено-деформований стан різьбового з'єднання обсадної колони. В моделі герметик представлено як деформівний проміжний шар, що взаємодіє зі спряженими поверхнями різьби. Порівняно три розрахункові випадки: без герметика та з герметиком із модулем Юнга $3 \cdot 10^6$ і $5 \cdot 10^6$ Па та коефіцієнтом Пуассона 0,40 і 0,45 відповідно. Встановлено залежність

між механічними характеристиками герметика та напружено-деформованим станом з'єднання. Максимальне еквівалентне напруження становить 210,11 МПа, сумарне переміщення – 0,0706 мм. Локальні напруження в герметику можуть перевищувати його міцність при розтягу 25–30 МПа та адгезійну міцність до 20 МПа, що вказує на можливість локального пошкодження шару.

Практична значущість. Запропонований підхід може бути використаний під час будівництва, ремонту та експлуатації нафтових і газових свердловин для підвищення герметичності різьбових обсадних з'єднань, зменшення ризику виникнення витоків і порушення цілісності свердловини, скорочення витрат на технічне обслуговування та збільшення строку експлуатації обсадних колон в умовах високого тиску й агресивних середовищ.

Ключові слова: *обсадна колона, різьбове з'єднання, анаеробний герметик, герметичність, метод скінченних елементів, ANSYS.*

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