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COMBINED TOOL FOR CUTTING INTERNAL THREADS OF TUBING

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Abstract. The oil and gas industry of the Republic of Kazakhstan, as one of the leading branches of industrial production, is the basis of economic development and largely determines the economic independence of the country.

In the oil and gas industry, a column of tubing is used to transport oil or gas and operates under extreme operating conditions.

Threaded connections play a crucial role in ensuring the service purpose of pipes. Threaded connections in the process of lifting and lowering operations and work in the well are exposed to various forces: stretching, compressing, bending, etc. In order to increase the service life of the tubing, the thread has to be re-threaded in the process. In order to improve the quality of the threaded connection, it is urgent and necessary to solve the problem.

In this article, a new combined two-stage metal cutting tool: a comb cutter and a method for cutting internal threads have been developed. By using this, two or three hole preparation operations can be integrated into one operation. The prediction of the operational properties of the threaded pipe-coupling connection, the distribution of the causes of destruction of oil grade pipes is given.

Keywords: tubing, threading, combined two-stage metal cutting tool, comb cutter, static calculation, quality.

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СОРҒЫ-КОМПРЕССОРЛЫҚ ҚҰБЫРЛАРДЫҢ ІШКІ БҰРАНДАЛАРЫН КЕСУГЕ АРНАЛҒАН ҚҰРАМА ҚҰРАЛ

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Аннотация. Қазақстан Республикасының мұнай-газ саласы өнеркәсіп өндірісінің жетекші салаларының бірі ретінде экономиканы дамытудың негізі болып табылады және елдің экономикалық тәуелсіздігін айқындайды. Мұнай-газ өндіру саласында сорғы-компрессорлық құбыр бағанасы мұнай немесе газ тасымалдау үшін пайдаланылады және экстремалды пайдалану жағдайында жұмыс істейді.

Құбырлардың қызметтік мақсатын қамтамасыз етудегі бірінші кезектегі мән бұрандалы қосылыстарға бөлінеді. Түсіру-көтеру операциялары мен ұңғымадағы жұмыс кезінде бұрандалы қосылыстар әртүрлі күштерге ұшырайды: созу, қысу, иілу және т.б. Сорғы-компрессорлық құбырлардың қызмет ету мерзімін ұзарту үшін бұрандаларды қайта кесу қажет. Мұның бәрі бұрандалы қосылыстың сапасын жақсартуды қамтамасыз ету үшін мәселені шешудің қажеттілігі мен өзектілігін тудырады.

Бұл мақалада екі сатылы металл кесетін жаңа құрал – тарақ кескіш және ішкі бұрандаларды кесу әдісі жасалды. Оның қолданылуы тесікті дайындаудың екі-үш операциясының бір операцияға бірігуін қамтамасыз етеді. "Құбыр-муфта" бұрандалы қосылысының пайдалану қасиеттерін болжау, мұнай құбырларының бұзылу себептерін бөлу келтірілген, мұнай құбырларының істен шығу себептерін бөлу.

Түйін сөздер: сорғы-компрессорлық құбырлар, бұранданы кесу, аралас екі сатылы металл кескіш құрал, тарақ кескіш, статикалық есептеу, сапа.

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КОМБИНИРОВАННЫЙ ИНСТРУМЕНТ ДЛЯ НАРЕЗАНИЯ ВНУТРЕННЕЙ РЕЗЬБЫ НАСОСНО-КОМПРЕССОРНЫХ ТРУБ

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Аннотация. Нефтегазовая отрасль Республики Казахстан, как одна из ведущих отраслей промышленного производства, является основой развития экономики и во многом определяет экономическую независимость страны. В нефтегазодобывающей отрасли колонна из насосно-компрессорных труб используется для транспортировки нефти или газа и работает в экстремальных условиях эксплуатации.

Первостепенное значение в обеспечении служебного назначения труб причисляется резьбовым соединениям. Резьбовые соединения в процессе спускоподъёмных операций и работы в скважине подвергаются воздействию различных усилий: растягивающих, сжимающих, изгибающих и др. С целью увеличения срока работы насосно-компрессорных труб в процессе приходится заново нарезать резьбу. Все это вызывает необходимость и актуальность решения задачи, для обеспечения повышения качества резьбового соединения.

В данной статье разработан новый комбинированный двухступенчатый металлорежущий инструмент – резец-гребёнка и способ нарезания внутренней резьбы. Применение которого обеспечивает объединение в одну операцию двух-трёх операций подготовки отверстия. Приведено прогнозирование эксплуатационных свойств резьбового соединение «труба-муфта», распределение причин разрушения труб нефтяного сортамента.

Ключевые слова: насосно-компрессорные трубы, нарезание резьбы, комбинированный двухступенчатый металлорежущий инструмент, резец-гребенка, статический расчет, качество.

Introduction

With the growth of global energy demand, oil and gas companies face a wide range of opportunities and, at the same time, risks in the segments of oil and gas exploration and production, refining, transportation and marketing of products. The main component of any mining equipment for oil wells, gas pipelines, as well as for repair and lifting operations are tubes that connects into a column and descend into the well, therefore, the quality of the threaded connection is critically important to ensure tightness and reliability of operation (Tsybri, et al., 2022: 242-251). The considerable length of oil pipelines implies ensuring reliable pipe connections (Huifeng, et al., 2020: 022017). The problem of tightness and strength of threaded connections of oil grade pipes is very relevant, because it is inextricably linked with trouble-free wiring and fastening, durability and safety of oil well operation. The best specialists in the industry are working on the problem of increasing technical and economic efficiency and improving the designs of threaded connections. Global pipe companies are investing heavily in improving and developing new thread designs.

First of all, the permeability of threaded connections is influenced by the design features of the thread. Screw channels are created by gaps in the thread and are referred to as constructive. The main purpose of structural gaps is to ensure satisfactory screwing of threaded connections. In addition to structural gaps, any thread also has gaps of a technological nature, which are determined by the deviation of the profile elements from the theoretical (nominal) dimensions. Structural and technological gaps in the thread lead to the fact that the contact of the pipe with the coupling in the threaded connections turns out to be permeable, i.e. the connection itself is leaky (Dubinov, et al., 2022: 107-119; Ma, et al., 2019: 34-47). The complexity of the geometry of threaded connections implies increased attention to the conditions of quality formation in the threading process. Threading is the most crucial operation when making pipes and couplings for oil operations. The quality of the threaded connection is determined, first of all, by the condition of the machine tool - tool - part system. Errors in the course of the kinematic threading process can be combined with errors in the tool and its installation, geometric errors of the machine and the installation of the workpiece (Uzun, et al., 2016: 275-280).

For threading, a carbide threading tool is used, both domestic and imported, as well as combined threading tools of various designs (Mustafayev, et al., 2024: 19-29; Wu, et al., 2023: 4073-4081; Toshov, et al., 2023: 225-235; Kochergin, et al., 2017: 87-91).

Materials and research methods. The analysis of designs and methods of threading led to the development of a new combined two–stage metal cutting tool - cutter-comb. The combined two-stage metal cutting tool (Figure 1) is designed according to the principle of combining the parameters of a boring cutter (first stage) and a threading comb (second stage).

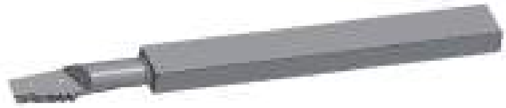


Figure 1 – The design of the comb cutter

A special feature of the design is that on the tool after the tip of the cutter there is a stripping section with a width of $\boldsymbol{b}$ = 0.5 steps of the thread being cut or slightly larger, $\boldsymbol{\alpha}$ = 0 (the main angle in the plan). All this leads to the work of the axial feed boring cutter to obtain a high-quality cylindrical hole.

An internal thread cutting scheme with a combined two-stage tool has also been developed, shown in Figure 2 (Kassenov et al., 2024: 42-50).

In Figure 2: ***1*** – the workpiece; ***2*** – a metal–cutting tool; $\boldsymbol{\omega_0}$ – the rotational movement of the workpiece or tool; $\boldsymbol{\varepsilon_{pt}}$ – the angle of the profile of the thread being cut, equal to 60°; $\boldsymbol{S_0}$ – axial feed per revolution, equal to the pitch of the thread being cut; $\boldsymbol{D_t}$ – the outer diameter of the thread being cut, mm; ***Lw*** - the length of the workpiece, $\boldsymbol{b}$ – the length of the stripping section of the cutting edge of the boring cutter with the main angle in the plan equal to zero; $\boldsymbol{\varphi_t}$ – the main angle in the plan of the boring mill; $\boldsymbol{\varphi^1_t}$ – the auxiliary angle in the plan of the cutter; $\boldsymbol{H_t}$ – the height of the profile of the thread being cut.

Modern CAD systems can be utilized to increase forecasting productivity and quality by providing tools that significantly facilitate work (Tuncer et al., 2023).

The prediction of the operational properties of the threaded pipe-coupling connection was performed using the FEM automated control system, developed for strength finite element express analysis in KOMPAS-3D.

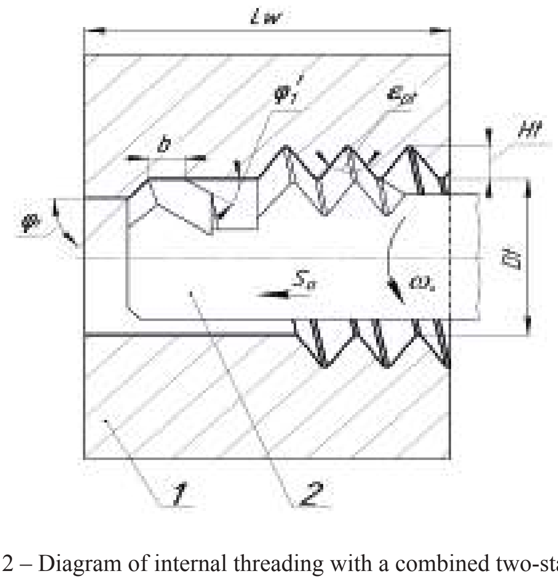


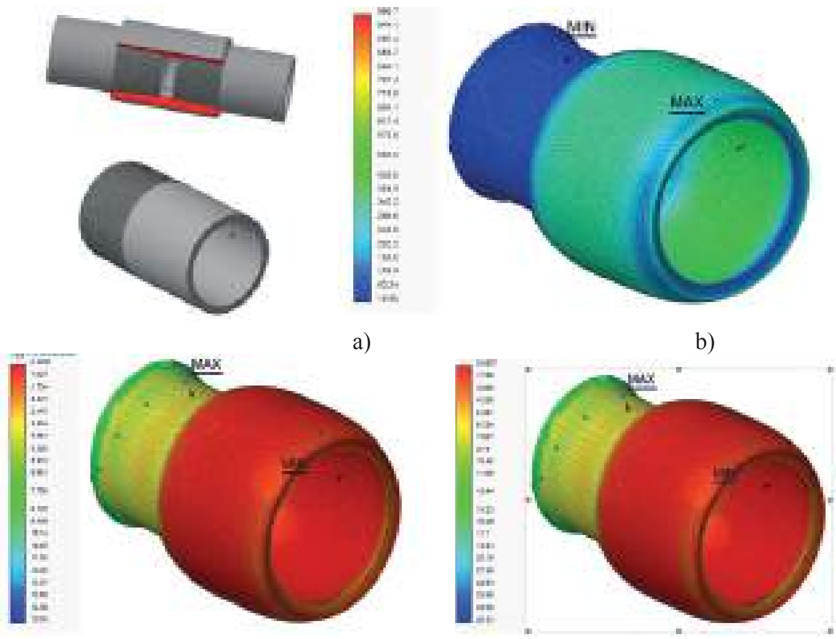
Figure 2 – Diagram of internal threading with a combined two-stage tool

Table 1 shows the inertial characteristics of the pump and compressor tube model.

Table 1 – Inertial characteristics of the model

Parameters	Values
Mass of model [kg]	3.076002
The center of gravity of the model [m]	(0.068397; 0.00001; 0.000006)
The moments of inertia of the model relative to the center of mass [kg·m^2]	(0.007363; 0.000109; 0.000138)
The reactive moment relative to the center of mass [N·m]	(-385.225233; 110.723886; -61.032872)
The total reaction of the supports [N]	(-3624093.632322; -1915.147431; -5842.068534)
The absolute value of the reaction [N]	3624098.847078
The absolute value of the moment [N·m]	405.442068

The results of the static calculation are shown in Figure 3 and in Table 2.



a) b)

c) d)

Figure 3 – Results of static calculation (a – calculation model; b – equivalent stress by Mises; c – coefficient of yield strength; d – coefficient of safety margin)

Table 2 – Results of static calculation

Parameter	Minimum value	Maximum value
Mises equivalent voltage, MPa	15.578405	990.72787
Turnover margin ratio	0.32024	15.090012
Safety margin factor	0.558717	26.327256

Results and discussion. The analysis of literature sources and studies (Liu, et al., 2024: 271-287; Zeng, et al., 2020: 634–644; Mukhametshin, et al., 2016: 19-24; Nabiullin et al., 2023: 88-93] showed that the upper zones of tubing in columns and especially threaded connections (up to 50%) are most susceptible to damage, which leads to their breakage and emergency situations (Figure 4).

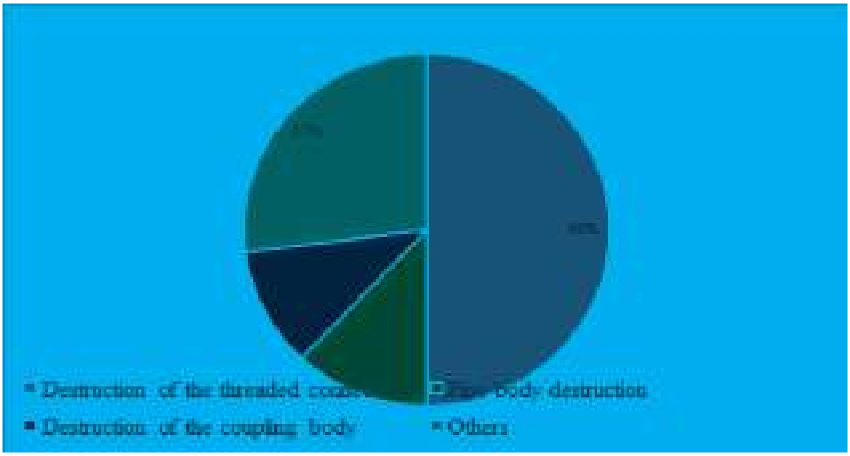


Figure 4 – Distribution of causes of destruction of oil grade pipes

The use of threads obtained by cutting, combined two-stage metal cutting tools compared with threads, by traditional methods (Kirichek et al., 2016), better operational properties, and, consequently, increased durability and strength during operation of the tubing. Thus, based on the calculation results for predicting the operational properties of the tubing, it led to a reduction in time costs.

The execution time of the full threading cycle and additional operations was reduced by an average of 20-30%, due to the cancellation of additional tool replacement and reconfiguration of equipment.

Conclusions. As a result of the conducted research, proposals have been developed to ensure and create favorable conditions for threading with a comb cutter, which increase the accuracy and quality of processing. The combined two-stage metal cutting tool reduces the number of transitions during manufacture, reduces technological time, and therefore increases productivity.

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