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MORPHOLOGICAL MATRIX APPLICATION IN THE DEVELOPMENT OF TECHNICAL SOLUTION FOR HYDRAULIC PUMPING UNIT USED OIL AND GAS EXPLOITATION

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Rezumat. *Matricele morfologice sunt considerate printre cele mai performante mijloace, instrumente, metode de structurare, sistematizare, clasificare, combinare, evaluare şi selecţie a informaţiilor utilizate în ştiinţă şi tehnică, cu aplicare în dezvoltarea de noi produse. În acest articol este prezentată o particularizare a acestei pentru obţinea mai multor soluţii tehnice pentru unităţi de pompare hidraulice utilizate în extracţia de petrol. Metodologia propusă şi utilizată presupune parcurgerea a trei etape: 1. Enumerarea şi codificarea elementelor ansamblelor formatoare, 2. Trasarea matricei morfologice; 3. Aplicarea unei metode de decizie şi stabilirea soluţiei optime. De o mare importanţă este analiza stadiului actual în cazul concepţiei unui nou produs, unde în cazul abordat, s-au utilizat cu precădere bazele de date de tip brevete. Prin abordarea morfologică de tip matrice se urmărește obținerea tuturor combinațiilor între elementele morfologiei, pentru a se descoperi noi produse, cu caracteristici tehnico-economice superioare.*

Abstract. *Morphological matrix are considered one of the most powerful, advanced, resources, tools, methods of structuring, classification, combination, evaluation and selection of information used in science and technology, with application in the development of new products. In this paper a particularisation of this method is presented for the development of technical solution for hydraulic pump unit used in oil extraction. The proposed methodology uses three stages: 1. listing and codification of elements forming assemblies, 2. listing of morphological matrix; 3. application of a decision method anddetermining theoptimal solution. Particularly important is the analysis of the current state of knowledge in the field, where in the case approached, patent databases were used extensively. By morphological matrix approach is desired to discover new products, superior technical and economic characteristics.*

Keywords: morphological matrix, hydraulic pump unit.

1. Introduction

In an competitive, system the intensity of an companies actions continuously evolve, manufactures don't remain content with the current achievements and introduce in to the market new super products. It requires, therefore, a continuous research on the value by product re-conception, material re-evaluation,

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introduction of new technologies that respond to the increasing requirements. This is the case of oil and gas industries were the amounts involved in research and development of new oil fields and methods and materials for exploitation.

Morphological matrix is established, as an intellectual work method, aimed at streamlining scientific research, scientific and technical, design, engineering etc. Morphological matrix method is method of creation found in the category of the combinatorial-logic-deductive, used methods in inventics [1].

Morphological matrix is a methodology for organizing alternative solutions for each function of a system and combining them to generate a large number of variants of solutions that can meet the imposed requirements [2], [3], [4].The base format of an morphological matrix is a grid of columns and rows. The first column lists the relevant functions, and the row adjacent to each function lists possible solutions to achieve that function. In developing the matrix, designers can use both text and drawings to represent possible solutions. Once the matrix has been developed, the designer can combine individual conceptual design effective solutions.

This methodology is a substitution of creative thinking but a structured means for developing and documenting design choices.

Also, the morphological matrixes have a character of maximum generality, which derives from the high degree of abstraction of the information presented. So, in essence, a morphological matrix allows the combination between codes, which designates certain data, information, ideas, images, items, sub-assemblies, etc.

This character of generality makes the morphological matrixes to be used in very different technical areas and beyond [1].

In the paper the subject of applying the morphological matrix method for the development of new technical solution for hydraulic pump unit that could replace the classic beam-balanced surface, crank-balanced pump unit.

2. Morphological research through matrixes in the field of hydraulic pump units

The wide uses of morphological matrix in creation, research, design etc. is due to the many advantages they present. First, morphological matrix method is an easy way to go for screening combinations (solutions, options) new and original, especially when the number of elements that combine reduced.

Also, morphological matrices are of the utmost generality, which comes from the high degree of abstraction of the information presented.

Based on the research of Fritz Zwicky and Abraham Moles, the morphological matrixes method involves three main stages [1], [4], [5]:

– identification and listing (listing the components of the basic product, attributes of the product that represent classification criteria, solutions for each attribute, function, and evaluation criteria);

– combinatorial analysis - the generation of various solution by combining the different attributes identified;

– evaluation of solutions (elimination of known or divergent-incompatible solutions, by using a decision technique the other solutions are considered, and the optimal combination is determined).

The importance of the proposed theme arises from the problem of diminishing resources of oil and the growing share of the costs (energy, labor) for pumping oil and technological limitations of the pumping units classic (higher energy, high operational, maintenance costs, major risks in terms of operator protection, environment clogging, high production losses.

2.1. Identification and listing of classification criteria

In solving this stage, of great importance is the documentation of the actual state of knowledge in the researched field. The documentation can be made through the use of many information sources specific to the contemporary world. The question is what kind of information can be considered viable in documentary information. In the nomenclature of terms of the European Patent Office, information that should be considered in a documentary study can have any shape. Any type of information that relates to the subject in question treated as such. Thus, the information can be written on paper, electronically can be virtual, or may be oral. [3]. For information in the field of inventions specialized databases can be used such as Espacenet - with free access to over 90 million patents, Google Patent, FreePatentsOnline.com.

In general technical products can be characterized, on one hand, by a set of technical or technical-economic parameters and, on the other hand, are characterized by cost

Beam pumping, or the sucker-rod lift method, is the most used type of artificial lift for most wells, and also the oldest. A sucker-rod pumping system is made up of several components, some of which operate aboveground and other parts of which operate underground, down in the well. The surface-pumping unit, which drives the underground pump, consists of a prime mover (usually an electric motor) and, normally, a beam fixed to a pivotal post. The post is called a Sampson post, and the beam is normally called a walking beam [6].

The hydraulic pump unit uses a hydraulic piston to raise the fluid from the well. The hydraulic cylinder may be installed on the blowout preventer. The polished rod of the well and the hydraulic cylinder rod is connected directly to the pipe

coupon by a conventional coupling (flanges, etc.) or by means of a coupon intermediate (intermediate pipe).

Figure 1 presents the two pump unit's solutions (conventional pump jack and hydraulic pump unit) side by side.

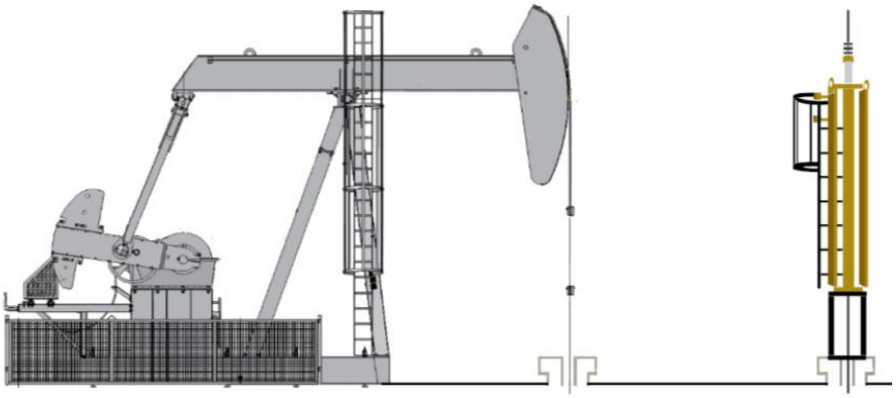


Fig. 1. Conventional pump jack and hydraulic pump unit [8].

Fig. 2. present the general structure of the hydraulic pump units [9].

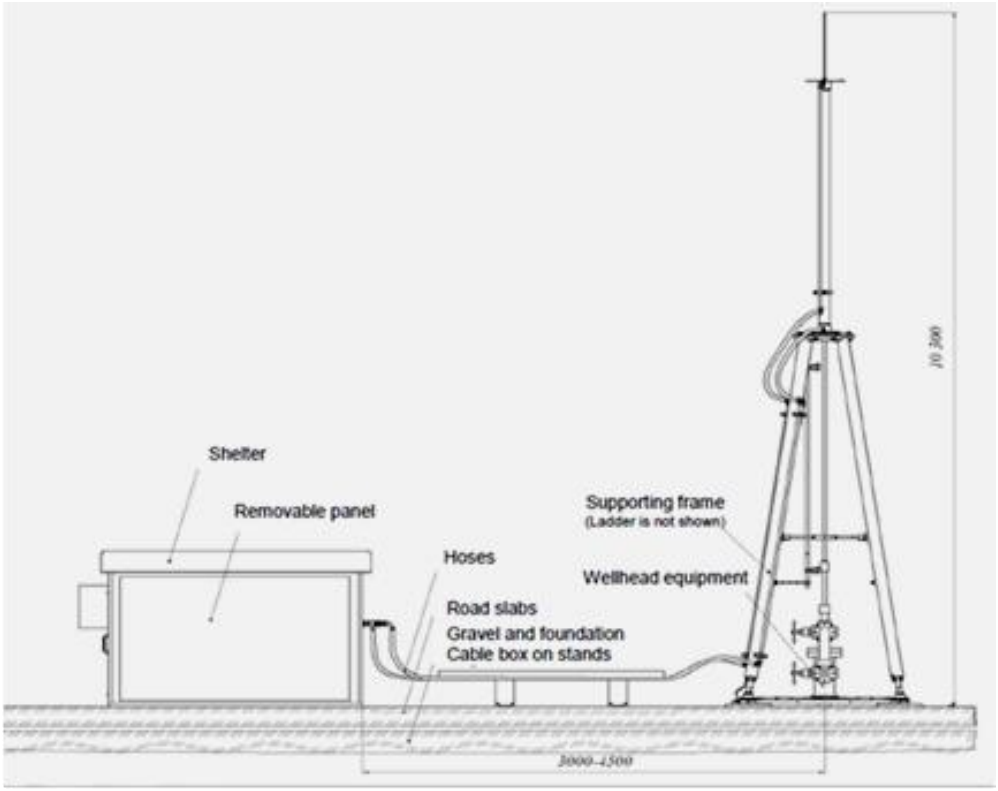


Fig. 2. General structure of the hydraulic pump units [9].

Advantages of sucker rod pumping installations (classical) are: known design relatively simple, common; possibility of reconditioning components.

Disadvantages of sucker rod pumping installations (classical) are: cumbersome control and optimization, stroke and forces adjustments is mechanical, cumbersome automation; large footprint, high maintenance cost; reduced possibilities to control blood of rod/pole extraction; large number of moving parts resulting in a lower reliability; laborious preparation of the site.

The advantages of hydraulic pumping units compared to conventional pump jack are:

·longer stroke length, instant adjustment of lifting speed and cadence/pace;

·the possibility of active control of force and up-stroke and down stroke;
·minimum number of pieces in motion resulting increased reliability;

·reduced wear of polished rod and sucker rod; tension control in polished rod;

·easy automation, telemetry and remote control, minimal footprint, quick installation.

From the presented advantages-disadvantages analysis results that the hydraulic pump unit can be a promising solution.

One of the most important objectives of the analysis in technical creativity, in design and creative conception, is the establishment, evaluation, assessment, performance analysis/advantages/disadvantages technical and economic ideas, solutions, known variants and/or proposed.

This involves establishing, developing, identifying the criteria for analysis - evaluation - hierarchy - ordering value/performance ideas, solutions, respective variants.

Also, know and apply several methods of decision, choice/selection of solutions/alternatives) optimal, rational [10].

However, the effectiveness of methods of analysis - evaluation - decision is directly conditioned by:

1. criteria used;
2. grading, sorting, weighting criteria;
3. hierarchy, ordering of ideas, solutions, alternatives after the degree of satisfaction of criteria.

In table 1 there are presented the main criteria's identified in the available literature that cover the function of hydraulic pump units [6], [7], [8], [9], [10], [11], [12].

Table 1. Main criteria's that describe the functionality of hydraulic pump units [7]

Criteria	**Possible variants**
Cinematics	Electro-hydraulic
	Electro-hydraulic
	Electro-mechanic
Flexibility	Modular
	Compact
Pumping capacity	Maximum pulling power
	Maximum stoke
	Usable stroke
	Pumping speed,
Adjustment capability	Load on hydraulic cylinder rod,
	Stroke adjustment
	Pumping cycle adjustment
Energy recovery	Flywheel attached to motor
	Hydraulic accumulator
	Pneumatic accumulator
Monitoring system	With locally up-date
	Remote monitoring
	With dynagraph plotting
	Telemetry data transfer
Work security system	Data transfer
	Mechanical
	Electrical
	Hydraulic
Anti-explosion system	Mechanical
	Electrical
Overload system	Mechanical
	Electrical
	Hydraulic

2.2 Combinatorial analysis

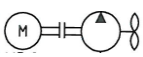
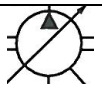
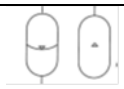
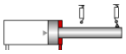
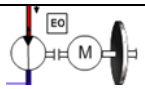
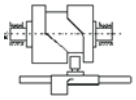
In this stage the generation of various solutions by combining the different attributes identified; this, also, can be accomplished by using software [1]. Thus, in this stage the possible mathematical solutions are obtained.

Simplified graphical representations of forming assemblies can be used in order to increase the visual impact of the solutions and speed up the analysis and decision process. Forming assemblies are the multitude of elements that combine, that can be objects of thought, attributes of creation object, solution for achieving a particular attribute, classified constructive-functional solutions in terms of a

particular attribute, object components, etc. All forming assemblies are called general morphology or morphology. All combinations between the elements of the forming assemblies are called morphological products forming and its research is called morphological research [1], [5].

Figure 3 presents the proposed graphical representation for each forming assemblies/attribute/ feature/ mechanism that can describe and the hydraulic pump unit.

Table 2. Proposed graphical representation for hydraulic pump unit attributes/ forming assemblies

Criteria/ function/	Electro-hydraulic	Compact	Modular	Fixed	Adjustable	Pneumatic
Symbol						
Criteria/ function/	Data transfer	Stroke sensor	Flywheel	Manual operation	Electrical seonsor overload	Mechnical overload
Symbol						

2.3. Listing of the morphological matrix

In this stage the morphological products – combinations of forming assembling, from the structure of the morphological matrix are listed, and can be evaluated.

In case, there are more than two forming assemblies, then the space matrix/ matrices generated can be «broke down», in order to obtain a flat matrix for viewing all possible combinations [1].

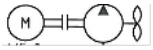
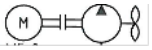
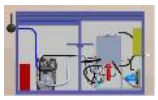
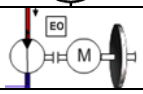
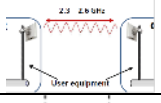
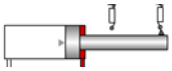
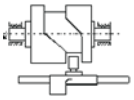
In his stage the issue of establishing, developing, identifying evaluation, criteria-ranking arises. On the analysis performed based on the requirements expressed by users.

The issue of establishing, developing, identifying evaluation criteria, ranking, of an optimal (rational) solution from the listed morphological products/solutions/ variants/known ideas and new ideas.

In figure 4 is presented the plane matrix associated to studies morphology and allows the visualization of all possible combinations, whatever the number of forming assemblies.

The presented solutions must be analysed in order to eliminate the known and the divergent-incompatible solutions.

Table 2. Matrix display for two hydraulic pump unit solutions

No.	Criteria	Solution 7	Solution 8
1	Cinematics		
2	Flexibility		
3	Pumping capacity	3t	5t
4	Maximum stoke	2000 mm	2000 mm
5	Usable stroke	1800 mm	1800 mm
6	Pumping speed,	5 stroke/min	5 stroke/min
7	Adjustment capability		
8	Energy recovery		
9	Monitoring system		
10	Work security system		
11	Overload system		

Establishing the analysis criteria, evaluation of technical systems (objects, products, technologies) is a creative act of great depth and subtlety and is a research topic in itself that must stay permanently in the attention of specialists in the field.

Establishing the criteria analysis employs a series of steps, procedures, rules, such as: analogy, synthesis, combination, generalization, extension, essentialization, redrafting [13].

Based on the values analysis of the returned morphological products/ solutions the following two variants were selected for further development, presented in table 3. The proposed hydraulic pump units are considered in minimal and maximal variant, considered the functions accomplished.

The maximal variant that contains a series of supplementary functions that are related to the automatization components.

The functions selected for the minimal and maximal variant are presented in table 3.

Table 3. Functions selected for the minimal and maximal variant

Nr. Crt.	*Function*	*Minimal hydraulic pump unit*	*Maximal hydraulic pump unit*
1	Cinematics	Electro-mechanical	Electro-mechanical
2	Energy recovery	Not available	Pneumatic
3	Speed and stroke adjustment capability	Available	Available
4	Automatic stop on failure	Available	Available
5	Automatic function restart	Available	Available
6	Automation of work cycle for production optimization	Not available	Available
7	Remote control	Not available	Available
8	Parameter display on site	Not available	Available
9	Data transmission	Not available	Available
10	Data storage	Not available	Available
11	Dynagraph data display	Not available	Available

The hydraulic pump unit with maximal features uses automation components that allow visualisation of a series of information on the screen of the programmable logic controller P.L.C. regarding the pumping parameters (stroke, stroke rate, stroke lengths, up-stroke speed, and down-stroke speed). Also the unit can receive and transmit data to a central server.

The proposed hydraulic pump unit, from fig. 3, contains several subsystem that cover a series of functions as presented.

Mechanical subsystem composed of frame and an optional container.

This subsystem realizes the function of support for the cylinder and protection for the hydraulic equipment.

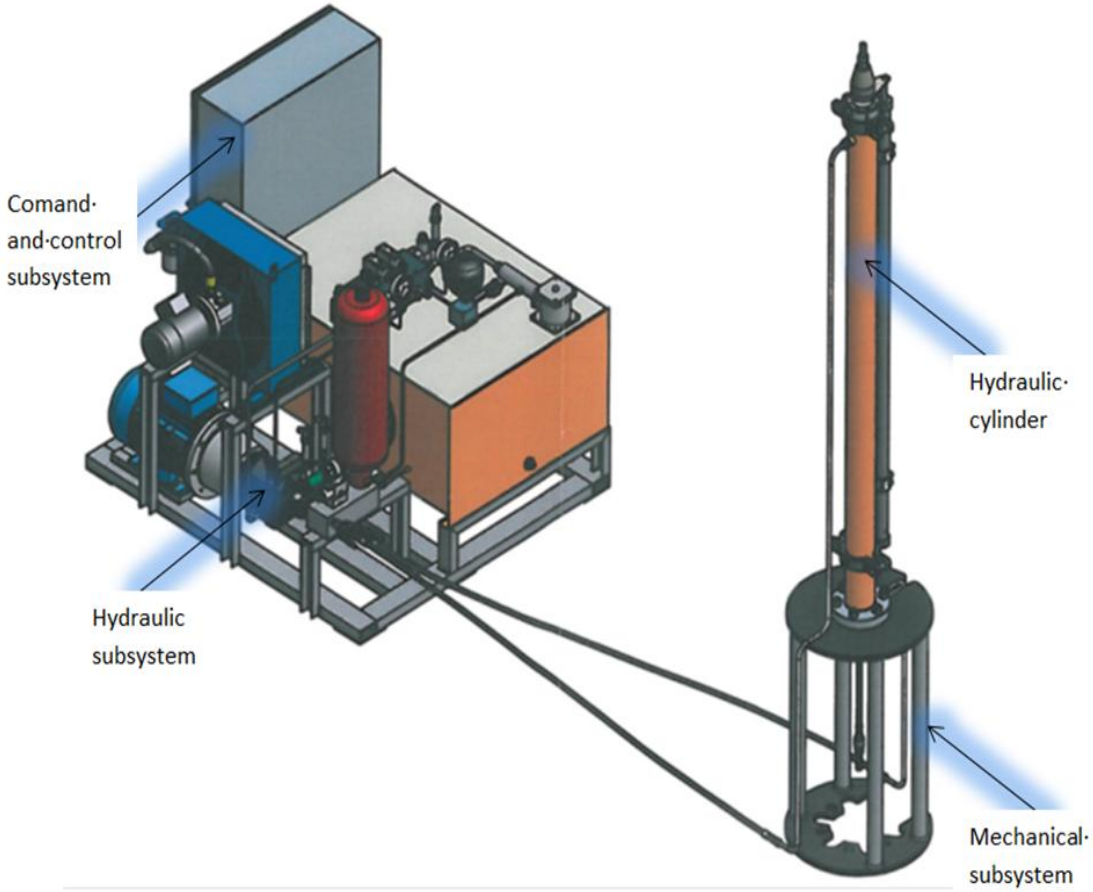


Fig. 3. Proposed hydraulic pump unit [7].

The mechanical subsystem assures the linkage between the cylinder and the polished rod and allows adjustment and correction of the coupling lengths thus facilitating the fitting operation.

The hydraulic subsystem consists of hydraulic panel, hoses, and cylinder.

The hydraulic panel contains the hydraulic pump and valves and transform the mechanical energy from the electrical motor to hydraulic energy.

The hoses transfer the hydraulic energy and the cylinder transforms the hydraulic energy in mechanical energy and assures the upstroke and down-stroke.

The command and control subsystem control the operation of the valves from the hydraulic panel thus modifying the hydraulic parameters in order to modify the stroke, stroke rate, stroke lengths, upstroke speed, down-stroke speed.

The command and control uses sensors and transducers to measure and control various parameters.

The command and control subsystem contains the P.L.C. that analyses the data from the various sensors and sends commands to the hydraulic panel and allows the commands of automatic stop on failure; automatic function restart; automation of work cycle for production optimization; remote control; parameter display on site; data transmission; data storage; dynagraph data display.

The system displays the total power output, instant flow, number of strokes, total number of strokes, stroke length.

Conclusion

The morphological matrix is a technique of creation and intellectual work.

The application of the morphological matrix technique generated a series of solutions based on the attributes identified in the field of hydraulic pump units.

In order to identify the identity these attributes that describe the functions and functionality of the hydraulic pump units specialized databases from the field of inventions were interrogated.

Based on the listed morphological matrix two solutions were outlined and described in the paper, a maximal variant from the features point of view and a minimal/ basic variant.

Also, the equipment required for the performing the functions is presented.

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