Preventive Maintenance Optimization of Top Drives in Smart Rotary Drilling Systems

Idir Kessai[1](✉), Samir Benammar[1], Mohamed Z. Doghmane[2], and Sadek Khelifa[1]

[1] Laboratoire Energétique- Mécanique & Ingénieries (LEMI), Université M'Hamed Bougara de Boumerdes, 35000, Boumerdes, Algeria
ikessai8@gmail.com, s.benammar@univ-boumerdes.dz
[2] Laboratory of Applied Automatic, Faculty of Hydrocarbons and Chemistry, M'hamed Bougara University Boumerdes, Boumerdes, Algeria
m.doghmene@univ-boumerdes.dz

Abstract. The increased competition in petroleum industry has pushed many companies to revise the preventive maintenance schedules in a way that allows them to use effectively the drilling equipments, and improve the availability of backup equipments while ensuring a continuous production for the hydrocarbons markets. This paper treated the optimization of equipments availability as an objective function, wherein, the manipulated parameters are failure rate, maintenance costs and production loss costs. The optimization algorithm has been transformed into Visual Basic Application (VBA), which provides optimum results in reasonable time. Moreover, the proposed approach has been applied to CANRIG 8050-AC 712 Top Drive used in smart rotary drilling systems; it is very expensive equipment and suffers a lot of failures due torsional vibrations. Furthermore, the effectiveness of the approach has been demonstrated through an application to field rotary drilling system belongs to the national drilling company ENAFOR.

Keywords: Preventive maintenance · Equipment availability · Objective function optimization · VBA · Rotary drilling systems · Top drive

1 Introduction

Oil and gas are considered as one of the most important energies of this century, they are used in many countries all over the world. This energy forms the basis of the world economy, so that industrialized countries as well as developing countries cannot progress without exploring this energy. Indeed, our dependence on this fossil energy is very strong, for that and to meet the needs of the market, oil companies around the world have decided to extract as much oil as possible by drilling wells using different methods [1]. Drilling of wells involves creating a connection between the surface and the deposit containing hydrocarbons by making holes in several phases [2]. This connection is carried out using a drilling rig fitted with a derrick, capable of supporting the weight caused by the drillstring and drill bit screwed at its end [3]. In the past, the rotational drilling process was achieved by the rotary table but in recent years, and with

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the increase in demand for oil, this device was not able to meet the growing requirements due to its low rate [4]. Therefore, companies have prompted a new drilling technology which is based on the introduction of a new equipment to speed up the drilling process; this equipment is called the Top Drive [1, 4]. The Top Drive is developed to improve the performance of a drilling rig, to save time, money and lower the burden on operators [5]. However, in Algeria this equipment has often problem of unavailability due to lack of a preventive maintenance schedule that has been recommended by the manufacturer, this creates an acceleration of Top Drive aging [2]. To remedy this problem, in this study an action schedule procedure has been carried out on a CANRIG 8050AC-712 Top Drive. Then, the most penalizing elements in terms of availability have been selected and formulated as an objective function, and optimal solution was calculated based on the VBA algorithm. The manuscript is organized as follows: in section two, a general description of the Top Drive and its parts has been given in order to construct an idea about the type of more penalizing elements ([6, 7]). The third section focuses on CANRIG 8050AC-712 Top Drive as a case study. In the fourth section, the optimization algorithm of preventive maintenance has been detailed with all calculations and objective function implementation for CANRIG Top Drive [8]. The obtained results have been demonstrated and discussed in section five; they allowed us to end this paper with conclusive remarks and recommendations for the national drilling company.

2 Top Drive Types

The Top Drive is a rotating device, held at the derrick by means of a slide and a movable muffle, it constitutes the connection between the movable block and the drill pipe and it makes a part of the lifting device of a drilling installation [2]. It is integrated into the structure of mast via a guide rail system and can be moved up and down the mast between the crown bearing and the working platform; it is carried out using a control console. The Top Drive can perform the functions of the hook, injection head, rotary table, Kelly, keys…etc. [6]. This allows the drillers to go faster during the drilling process, save time, reduce work effort, eliminate dangerous situations and improve control of unforeseen events [1]. Generally the Top Drive encompasses three main functions: the rotation of the drill string [9], the circulation of drilling fluid, and maneuvering operations (ascent and descent).There are many types of Top drives like BENTEC, VARCO, TESCO, and CANRIG (Fig. 1). The Top Drive system can be chosen according to the user's needs, i.e. dimensions, maximum loading capacity of the hook, Torque and speed needed [10], AC/DC electric motor…etc. [6].

Fig. 1. Types of top drive used in petroleum industry

3 Canrig 8050ac-712 Top Drive

CANRIG is one of the world's leading suppliers of drilling systems in the oil and gas industry [1]. The company manufactures markets and maintains a full range of superior, mobile and stationary drive systems, critically designed for most land and offshore platforms. This includes superior motors in all sizes and configurations to meet all drilling applications [11]. CANRIG superior drives are designed and manufactured according to API standards including the standard for safety and reliability [12]. The CANRIG Top Drive Type 8050AC-712 is powered by an AC asynchronous electric motor; it is used to transform electric energy into mechanical energy to ensure the rotation of the drill string [4]. These types of Top Drive are equipped by intelligent accessories in order to improve the efficiency of drilling [2]. Among these accessories we can find the following:

A. Advanced Diagnostic System

The advanced diagnostic system (ADS) monitors the strategic points of the upper unit and its associated control and power system which allow intelligent evaluation of defaults and report the possible causes.

B. Anti-collision System

CANRIG developed an anti-collision system (TAC) which triggers an alarm when contact between certain components is on point to happen [13]. If the alarm is activated and the problem is not corrected, the equipment will be stopped by an automatic shutdown device.

C. Equipment Condition Monitoring System

Using sophisticated sensors, specially designed software and the collection of data, CANRIG can offer an even higher level of reliability and higher performance by using equipment conditions monitoring system (ECM).

4 Preventive Maintenance Optimization Algorithm

All activities in the oil drilling companies have undergone considerable changes since 1980. These changes have only been possible through the development of new application, organization and management, which have made it possible to develop new work forms. Nowadays, most companies have become digitalized, which requires to have, in our time, the computation tools to manage them. Currently we do not choose the software applications only for their ability to perform an IT function but also for their roles in the company's production chain [1]. In this section, we will present an algorithm of optimization used for preventive maintenance operation of the Top drive, the algorithm is developed in VBA environment with graphical interface to simplify its use for drillers ([8, 14]). All the following mathematical equations have been integrated in the algorithm code [15].

A. The Objective Funtions

In order to estimate the number of interventions during the time interval $[0, T]$, and according to the Poisson distribution taking the random variable h as the number of failures in that interval [16], we present the probability of having h failures by

$$P(T, h) = \frac{a^h}{h!} e^{-a} \tag{1}$$

a: Mathematical expectation of the number of failures in the interval $[0, T]$, it is calculated as follows

$$a = \int_0^T \lambda(t) dt \tag{2}$$

With $\lambda(t)$: Instant failure rate.

For a material mainly composed of m components whose failure rates progress linearly, we have

$$\lambda_i(t) = \lambda_i + k_i t; i = 1, \cdots, m \tag{3}$$

λ_i: is the initial failure rate of the i^{th} hardware component, and k_i : is the coefficient of proportionality [16]. The overall failure rate, considering the serial components from the reliability point of view is determined by the following expression

$$\lambda(t) = \lambda_0 + \sum\nolimits_1^m k_i t \tag{4}$$

With $\lambda_0 = \sum_1^m \lambda_i$.

It is considered that after each planned repair at the subset level ensemble i its rate of default takes the initial value λ_i, the mathematical expectation of the number of failures in the interval $[0, T]$ is written as follows

$$a = \lambda_0 T + \sum\nolimits_1^m \frac{k_i T^2}{2} \tag{5}$$

B. Optimal Cost Estimation

We consider the frequency and structure of planned maintenance interventions over a time interval $[0, T]$. The planned periods are designated by $\Delta_1, \Delta_2, \Delta_3 \ldots \Delta_{m-1}$ for equipment of which m components require systematic maintenance beforehand planned one at times $t_1, t_2, t_3, \ldots . t_{m-1}$[13], we can formulate this by the following relationships

$$t_2 = t_1 + i\Delta_{1,t} t_3 = t_1 + i\Delta_1 + j\Delta_2, t_m = t_1 + i\Delta_1 + j\Delta_2 + \cdots + p\Delta_{m-1} \tag{6}$$

Let us denote by $n_1, n_2, n_3, \ldots . n_m$ the quantities of periods of time whose durations are respectively $\Delta_1, \Delta_2, \Delta_3, \ldots, \Delta_m$ spread over the period $[0, T]$ such that

$$n_1 = \frac{\Delta_2}{\Delta_1}, n_2 = \frac{\Delta_3}{\Delta_2}, n_3 = \frac{\Delta_4}{\Delta_2^n}, n_m = \frac{T}{\Delta_{m-1}} \tag{7}$$

The relationships between the quantity of time period of duration $\Delta_1, \Delta_2, \Delta_3 \ldots$ *and* Δ_n and the quantity of interventions planned over the period $[0, T]$ are given by the following expressions

$$n_{p1} = (n_1 - 1)\prod\nolimits_2^m n_{i,} \, n_{p2} = (n_2 - 1)\prod\nolimits_3^m n_i, \, n_{p3} = (n_3 - 1)\prod\nolimits_3^m n_i, \, n_{pm} = (n_m - 1) \tag{8}$$

Taking into account the expressions (6), (7) and (8), relation (5) can be written in the following form

$$a = (t_1, n_1, n_2, \cdots n_m) = n_m \sum\nolimits_{p=0}^{n_m - 1} \sum\nolimits_{j=0}^{n_2 - 1} \sum\nolimits_{i=0}^{n_1 - 1} \int_0^{\Delta_1} [\lambda_0 + k_1 t_1 + k_2(i\Delta_1 + t_1) + k_3(i\Delta_1 + j\Delta_2 + t_1) + \cdots + k_m(i\Delta_1 + j\Delta_2 + \cdots + t_1)] dt_1 \tag{9}$$

The timing of the planned interventions (i) corresponds to drops in failure rate corresponding to their initial values λ_i and the failure rate is reduced up to the value λ_0 only when carrying out the general overhaul [16].

The structure and frequency of the planning of preventive interventions are determined using as an optimization criterion, the expenses of planned repairs and not planned during the calculation period of duration T [8]. By taking into account the relation (9), the function of the costs to be optimized (objective function) has the following form:

$$S = \Big(C_A \lambda_0 T + C_{A1} \tfrac{k_1 T^2}{2n_, n_2 n_k \cdots n_m} + C_{A2} \tfrac{k_2 T^2}{2n_n n_x \cdots n_m} + C_{A3} \tfrac{k_3 T^2}{2n_2 \cdots n_m} + \cdots +$$

$$C_{Am} \frac{k_m T^2}{2n_m} + C_1(n_1 - 1) n_2 n_3 \cdots n_m + C_2(n_2 - 1) n_3 \cdots n_m + .C_3(n_3 - 1) n_4 \cdots n_m) + \cdots +$$

$$C_m(n_m - 1) \tag{10}$$

S : is the summation maintenance cost. C_{Ai}: is the cost of an unplanned repair of the i^{th} component [13]. C_i: is the cost of a planned repair of the i^{th} component. So, in this study the optimization of maintenance based on equipment reliability, consists in optimizing the objective function; that is to say determine the combination $(n_1, n_2, n_3, \ldots, n_m)$ which gives the following minimum maintenance cost

$$\min S = C_A \lambda_0 T + \sum\nolimits_{i=1}^{m} \left[C_{Ai} \frac{k_i T^2}{2 \prod_{j=1}^{m} n_j} + C_i(n_i - 1) \prod\nolimits_{j=i+1}^{m} n_j \right] \tag{11}$$

Therefore, this equation was integrated into the calculation code algorithm in order to give it a mechanical aspect (i.e. making the program more user-friendly).

5 Results and Discussion

Avoiding failures of critical data is always a top priority [17], when a few minutes of service disruption can compromise the value of a company on the market, the reliability of the elements and their availability become importantly crucial [16]. In ENAFOR (Algerian Drilling company), we noticed that equipment that causes a lot of problems in a drilling site and that often falls broken down is the Top Drive system, which causes a lot of losses for the company since it is a strategic piece of equipment [4]. In order to master these failures and break the cycle of breakdowns, we decided to conduct a study based on the ABC method (PARETO analysis), to select the most more penalizing in terms of availability, then we will perform preventive maintenance according to a predetermined schedule to increase performance ([8, 18]). To develop a plan for preventive maintenance actions for essential components constituting an equipment from their direct costs (maintenance costs) and indirect (production loss costs) by knowing their survival models (Weibull), we developed a calculation code in Visual Basic

Application (VBA) which is based essentially on the objective mathematical functions given by Eqs. (10) and (11).

A. Pareto Method

This method necessarily assumes that you have a history of a previous period or forecast. To apply this method, we have followed the chronological steps:

1) Definition of the objective of the study and its limits (materials, causes of breakdowns…).
2) Choose of the classification criteria.
3) Building a Pareto graph.
4) Determination of the ABC zones (in general the curve has three paces).
5) Interpretation of the curve.

In the diagram of Fig. (2), there are three zones

- Zone A: 20% of breakdowns are responsible of 80% of the costs.
- Zone B: the 30% additional breakdowns cost only additional 15%.
- Zone C: the remaining 50% of failures concern only 5% of the total cost.

The graph in Fig. 2 illustrates that 80% of the cumulative costs are consumed by only 20% of failure; this will allow us to classify failures according to their order of importance based on their cost.

B. Essential Subsets Equipment

Based on the available technical data, we have considered certain elements as being essential for the operation of the Top Drive. The subsets on which the study was carried out are: Washpipe, Upper Kelly valve, Torque Boost [10], Stabing bell, Hpu (Hp Pump), Link Tilt, Back up wrench, Guide gear case, Rotary manifold, Gage-bearing [19].

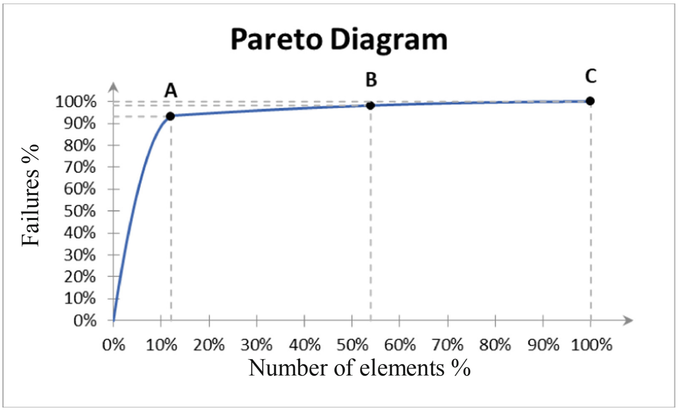


Fig. 2. General PARETO diagram of the top drive failures [17]

C. Elements with High Unavailability Rate

On the basis of the availability criterion, the data collected in the history files of a top drives set have been analyzed by using the PARETO method [19]; the obtained results are summarized in Table 1.

Table 1. History of the elements with high unavailability rate for top drive equipments

Order	Equipment	Number of interventions (n)	Technical time for reparation (T)	**n × T**
1	Back up wrench	3	90	270
2	Torque Boost	3	43	129
3	Rotary Manifold	2	45	90
4	Hpu (Hp Pump)	2	30	60
5	Guide gear case	3	19	57
6	Link Tilt	2	21	42
7	Gage bearing	2	21	42
8	Washpipe	6	4	24
9	Upper Kelly Valve	2	6	12
10	Stabing Bell	2	1	2

Table 2 shows for this case that the penalizing elements in terms of availability are also the most penalizing elements in terms of maintainability (level maintenance is greater than or equal to 3), which shows that these elements can be repaired at workshop level, the results found are listed in the Table 2.

Table 2. Ranking of the elements based on their importance

Order	Element	Elements %	Days of stop	Cumulated	Stop %
1	Back up wrench	10	90	90	31.80
2	Rotary manifold	20	45	135	47.70
3	Torque Boost	30	43	178	62.89
4	Hpu (Hp pump)	40	30	208	73.49
5	Guide gear case	50	22	230	81.26
6	Link Tilt	60	21	251	88.68
7	Gage bearing	70	21	272	96.10
8	Upper Kelly Valve	80	6	278	98.22
9	Washpipe	90	4	282	99.63
10	Stabing Bell	100	1	283	100

D. Graphic Representation

From the data in Table 2, the Pareto curve has been drawn as given in Fig. 4; this curve represents the unavailability rate as a function of the element rate. It contains three zones determined by the change in the shape of the curve ([20, 21]).

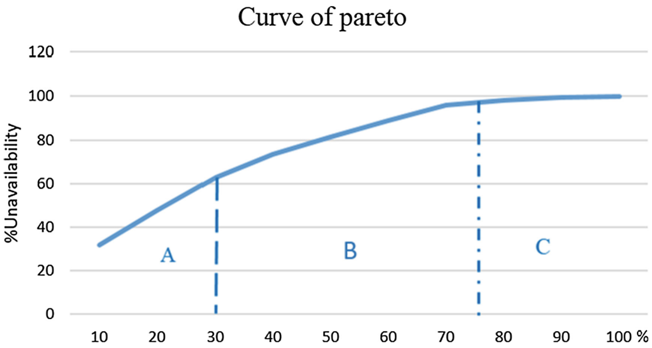


Fig. 3. Pareto curve of the Top drive data: Unavailability rate as a function of the element rate

From Fig. 3, we can clearly see that 40% of the considered elements are responsible for 73.49% of the overall unavailability of CARNIG Top drives. We note that our study is extended to the second zone to draw the elements concerned by the study. In the graph of the figure, we see that the elements that are in the area A and B are those on which priority should be given. The elements that causes the unavailability of the CARNIG Top Drive with a rate of 73.5% are:S_1: Back up wrench, S_2: Rotary Manifold, S_3: Torque Boost, S_4: Hpu [19]. Thus, in order to improve the performance and optimize (minimize) this rate, we proposed a preventive planning maintenance for these equipments as described in the next subsection.

E. Development of the Calculation Algorithm in VBA

The code is created as a programming language in Visual Basic for Application. It should be noted that this code is based on an objective function given by (11). This function is used to manipulate technical and economic parameters of the given sub-assemblies, with: S: Maintenance summary cost, C_{Ai} : Cost of an unplanned repair, C_i : Cost of a planned repair, n_j: Quantity of time periods. The introduction of data in the VBA algorithm is done through a dialog box shown in Fig. 4.

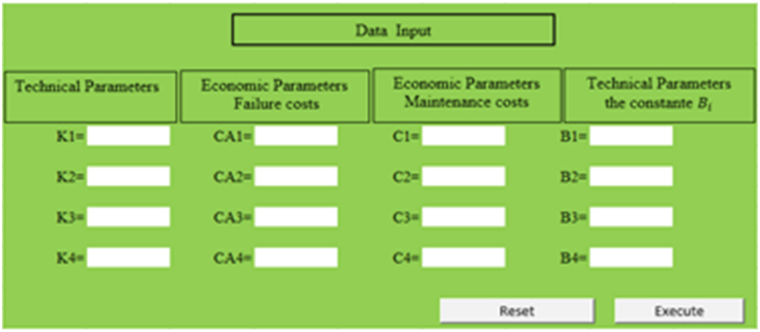
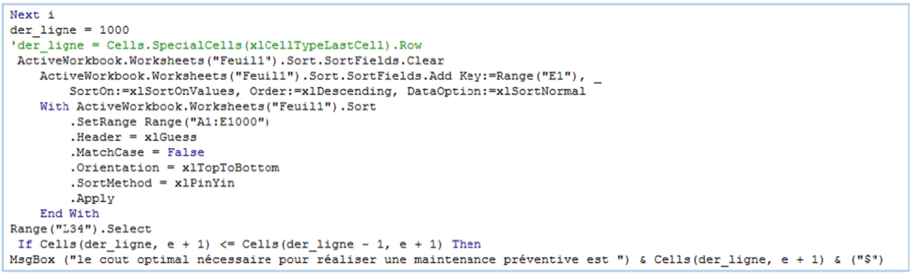


Fig. 4. Data input for program execution

The objective function is then written in the form of a loop going from zero to 1000. Figure 5 shows brief instructions used in our paper, in order to find the optimal cost S_{min} [7].



```
Next i
der_ligne = 1000
'der_ligne = Cells.SpecialCells(xlCellTypeLastCell).Row
 ActiveWorkbook.Worksheets("Feuil1").Sort.SortFields.Clear
    ActiveWorkbook.Worksheets("Feuil1").Sort.SortFields.Add Key:=Range("E1"), _
        SortOn:=xlSortOnValues, Order:=xlDescending, DataOption:=xlSortNormal
    With ActiveWorkbook.Worksheets("Feuil1").Sort
        .SetRange Range("A1:E1000")
        .Header = xlGuess
        .MatchCase = False
        .Orientation = xlTopToBottom
        .SortMethod = xlPinYin
        .Apply
    End With
Range("L34").Select
 If Cells(der_ligne, e + 1) <= Cells(der_ligne - 1, e + 1) Then
MsgBox ("le cout optimal nécessaire pour réaliser une maintenance préventive est ") & Cells(der_ligne, e + 1) & ("$")
```

Fig. 5. Source code of the optimization algorithm

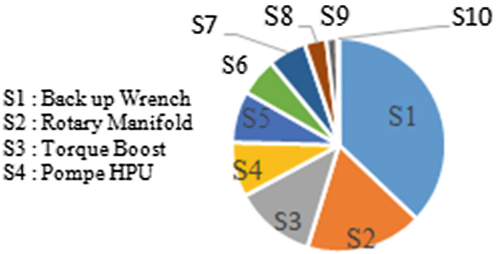


Fig. 6. Element unavailability rates

In order to use this algorithm, we have to:

- Select the most penalizing elements in terms of availability from Fig. 6;
- Linearize failure rates to get technical parameters K_i & B_i;
- Calculate failure costs C_{Ai} and maintenance costs C_i(on the basis of the documentation provided by ENAFOR);
- Fill in the dialog box with the necessary data;
- Run the VBA algorithm.

After running the program, we will obtain optimal results for our study:
a) The cost necessary S_{min} to carry out maintenance interventions is 363843,293 $.
b) Intervention periods are: $T_1 = 180$ D; $T_2 = T_3 = T_4 = 500$ D.

F. Proposed Preventive Maintainance Planning

The proposed preventive action schedule is illustrated in Fig. (7)

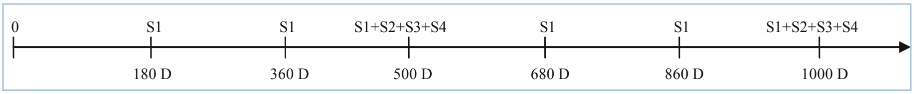


Fig. 7. Structure of the proposed intervention schedule

This result constitutes the first planning of systematic optimal preventive actions to offer top drives after several years of applying a practically corrective strategy, including default expenditure greater than $ 670000 (for a defined number of top drives). The implementation of this new strategy requires a preliminary investment which will allow us to lower the financial effects caused by production losses; and will allow the company to earn up to 46% of the expenses of the previous strategy. To implement this planning, the preparation department must carry out modes of the concerned sub-assemblies $(S_1, S_2, S_3 \text{ and } S_4)$. These operating modes (preparation) must contain the chronological order of operations, the necessary tools and the time allocated to the operation. This information is necessary for the scheduling department to plan the proposed schedule over time. This planning is essential for spare parts supply managers. This schedule requires the support of drilling companies.

6 Conclusion

In this study, we were able to distinguish the elements responsible for the unavailability of the Top drive in the field, the method used to find these elements is the Pareto technique. The main objective was mainly focused on the availability of sub-assemblies making up the Top Drive, we found that the elements penalizing in terms of availability are also penalizing in terms of maintainability. Therefore, we can say that the mastery of these elements allows us to control the availability and maintainability of the equipment and decrease the technical repair time. The objective function provided the possibility to apply a maintenance policy based on preventive actions planned with optimal cost, this approach requires that the elements concerned by the study follow the Weibull model and their failure rates are linearized. Moreover, it is automatically calculated the optimal cost necessary to carry out preventive actions as well as their corresponding periods (T_1, T_2, T_3 and T_4). The results of this study can be considered as a technical and industrial manual that will be used in the future as maintenance reference. It is highly recommended to implement the proposed preventive schedule, which can recover up to 70% of rig availability and save up to 46% of costs.

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References

1. Richarson, A.S., Kuttel, B.: Canrig Drilling Technology Ltd, 2000. *Drilling method and apparatus*. U.S. Patent 6,050,348 (1997)
2. Boone, S.G., Ellis, B., Gillan, C.J., Kuttel, B.: Canrig Drilling Technology Ltd, 2014. *Automated directional drilling apparatus and methods*. U.S. Patent 8,672,055 (2008)
3. De Mul, A.A., Roodenburg, J.: ITREC BV, 2018. *A drilling rig with a top drive system operable in a drilling mode and a tripping mode*. U.S. Patent Application 15/737,068 (2015)
4. Scott, G.B.: Drilling scorecard, US Patent US8510081B2. Nabors Drilling Technologies USA Inc (2009)
5. Doghmane, M.Z., Kidouche, M.: Decentralized controller Robustness improvement using longitudinal overlapping decomposition- Application to web winding system. Elektronika ir Elektronika **24**(5), 10–18 (2018). https://doi.org/10.5755/j01.eie.24.5.21837
6. Heidecke, K., Rials, J.R., Fisher, R., Olstad, D.M.: Weatherford Technology Holdings LLC, 2016. *Method of using a top drive system*. U.S. Patent 9,528,326 (2012)
7. Doghmane, M.Z.: "Optimal decentralized control design with overlapping structure", Magister Thesis. University M'hamed Bougara of Boumerdes, Algeria (2011)
8. Javanmard, H., Koraeizadeh, A.: Optimizing the preventive maintenance scheduling by genetic algorithm based on cost and reliability in National Iranian Drilling Company. J. Ind. Eng. Int. **12**(4), 509–516 (2016). https://doi.org/10.1007/s40092-016-0155-9
9. Riane, R., Kidouche, M., Doghmane, M.Z., Illoul, R.: Modeling of torsional vibrations dynamic in drill-string by using PI-observer. In: Bououden, S., Chadli, M., Ziani, S., Zelinka, I. (eds.) Proceedings of the 4th International Conference on Electrical Engineering and Control Applications, ICEECA 2019. Lecture Notes in Electrical Engineering, vol. 682. Springer, Singapore (2021). https://doi.org/10.1007/978-981-15-6403-1_12
10. Riane, R., Kidouche, M., Illoul, R., Doghmane, M.Z.: Unknown resistive torque estimation of a rotary drilling system based on kalman filter. IETE J. Res. 27 Feb 2020. https://doi.org/10.1080/03772063.2020.1724834
11. John, P., Schroeder, E.M.: Industrial plant equipment, process and maintenance optimization. US Patent US9626634B2. ABB Schweiz AG (2012)
12. Wan, J., Tang, S., Li, D., et al.: A manufacturing big data solution for active preventive maintenance. IEEE Trans. Ind. Inform. **13**(4), 2039–2047 (2017). https://doi.org/10.1109/TII.2017.2670505
13. Zhicheng, Z., Yisha, X., Bo, Z.: Multi-component maintenance optimization: a stochastic programming approach. under 2nd round revision at INFORMS J. Comput. arXiv:1907.00902v2 (2020)

14. Doghmane, M. Z., Kidouche, M., Habbi, H., et al.: A new decomposition strategy approach applied for a multi-stage printing system control optimization. In: 4thInternation Conference on Electrical Engineering (ICEE), Boumerdes, Algeria (2015)
15. David, E., Johnson, S., Gray, K., Uppuluri, B.: Maintenance optimization system through predictive analysis and usage intensity. US Patent US20190147413A1. GE Energy Power Conversion Technology Ltd (2017)
16. Zhang, C., Qian, Y., Dui, H., Wang, S., Shi, J.: Component failure recognition and maintenance optimization for offshore heave compensation systems based on importance measures. J. Loss Prevent. Process Ind. **63**, 103996 (2020). https://doi.org/10.1016/j.jlp.2019.103996
17. Kessai, I., Benammar, S., Doghmane, M.Z., Tee, K.F.: Drill bit deformations in rotary drilling systems under large-amplitude stick-slip vibrations. Appl. Sci. **10**, 6523 (2020)
18. Fadeji, J.A., Okuwa, M.O., Mgbennena, C.O., Ezekiel, K.C.: The Pareto principle and a hazard model as tools for appropriate scheduled maintenance in a manufacturing firm. African J. Sci. Technol. Innov. Develop. **8**(2), 173–177 (2016). https://doi.org/10.1080/20421338.2016.1147203
19. Faisal, Y., Tommy, V.: Top drive back-up wrench with thread compensation. US Patent US20190203546A1. Nabors Drilling Technologies USA Inc (2017)
20. Noghin, V.D.: Edgeworth-pareto principle. In: Reduction of the Pareto Set". Studies in Systems, Decision and Control. vol 126. Springer, Cham (2018). https://doi.org/10.1007/978–3-319-67873-3_1
21. Beata, N.: Preventive services of residential buildings according to the pareto principle. In: IOP Conference Series: Materials Science and Engineering. vol. 471(11), p. 112034 (2019)